European Commission

# Challenges and opportunities of broadcast-broadband convergence and its impact on spectrum and network use

**FINAL REPORT**

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*Digital Agenda for Europe*

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# Abstract

This report considers three questions:

- How will audio-visual (AV) consumption in the European Union change over the next 15 years?
- How will broadcast-broadband services develop in that period?
- Is there merit in moving to a converged platform in which mobile and terrestrial TV broadcast services share common infrastructure and UHF spectrum?

Traditional linear TV over broadcast networks dominates AV consumption today. This could change substantially by 2030 with fixed broadband and Wi-Fi playing a growing role in delivering and distributing video content – both as a substitute for, and a complement to, traditional broadcast networks. But there is considerable uncertainty over the scale of these effects, which require the construction of scenarios for AV consumption against which to assess the merits of a converged platform.

At the moment the development of broadcast-broadband converged services is focused on combining fixed broadband and broadcast services. Most of these developments will succeed or fail through market mechanisms. But the development of a converged platform will require policy interventions.

The best option for such a converged platform involves moving the DTT network from its current high-power high-tower topology to the low-power low-tower (LPLT) topology of the mobile networks. Making such a move requires substantial amounts of spectrum below 700 MHz for simulcasting and relies heavily on the use of co-channel single frequency networks (SFNs). Assuming these challenges are met, the main incremental benefit comes from the release of between 110 and 175 MHz of UHF spectrum.

The case from moving to a converged platform is not yet made. The incremental benefits of a converged platform are uncertain when compared to the incremental costs of transition. At the top end of the range of likely benefit values there is a clear case for a converged platform; at the bottom end of the range there is no such case. Therefore, committing to a converged platform at this stage would mean incurring substantial costs with no guarantee of future net benefits.  Much of this market uncertainty should disappear in the next 3 to 5 years.

We therefore recommend a review of the case for a converged platform, when market uncertainty is reduced in three to five years' time. In such a review a converged platform should be assessed alongside other options for use of sub-700 MHz spectrum. We also recommend, in advance of this review:

- The development of new, EU-wide, measures of AV consumption which include both linear and non-linear video
- That the broadcast community provides relevant guidance to 5G research programmes
- That spectrum authorities find a long-term spectrum home for PMSE audio
- That further work is done to investigate the feasibility of co-channel SFNs on an LPLT network.

It is not yet possible to specify any kind of EU-wide commitment to a converged platform. There are benefits to such a commitment. But the case for a converged platform has yet to be made.

# Résumé

Ce rapport cherche à répondre à trois questions :

- Comment la consommation audiovisuelle (AV) va-t-elle évoluer dans l'Union européenne au cours des 15 années à venir?
- Comment les services de diffusion-haut débit vont-ils se développer au cours de cette même période?
- Y aurait-il un avantage à évoluer vers une plateforme convergente à travers laquelle les services mobiles et de diffusion de télévision terrestre partageraient une infrastructure et un spectre UHF communs?

La télévision linéaire traditionnelle diffusée via des réseaux de diffusion domine actuellement la consommation AV. Cette situation pourrait changer considérablement d'ici 2030, avec le rôle croissant du haut débit fixe et du Wi-Fi dans la livraison et la distribution de contenus audiovisuels, à la fois en remplacement et en complément des réseaux de diffusion traditionnels. Mais il est assez difficile d'évaluer quelle sera l'étendue de ces effets, qui nécessitent la construction de scénarios pour la consommation AV grâce auxquels on peut ensuite évaluer les avantages d'une plateforme convergente.

Actuellement, le développement de services convergents de diffusion-haut débit se concentre sur l'association des services de haut débit fixe et de diffusion. La plupart de ces développements connaîtront soit un succès soit un échec en passant à travers les mécanismes de marché. Mais le développement d'une plateforme convergente nécessitera des interventions politiques.

La meilleure option pour une telle plateforme convergente consisterait à faire évoluer le réseau TNT pour l'éloigner de sa topologie actuelle, de grandes tours très puissantes, vers la topologie de petites tours basses peu puissantes (LPLT) typique des réseaux de mobiles. Une telle transition nécessiterait de larges parts du spectre en-dessous de 700 MHz pour la diffusion simultanée et dépendrait beaucoup de l'utilisation de réseaux isofréquence sur canal commun. En partant du principe que ces défis pourraient être relevés, le principal avantage supplémentaire viendrait de la libération d'entre 110 et 175 MHz du spectre UHF.

L'argument en faveur de la transition vers une plateforme convergente n'est pas encore convaincant. Les avantages supplémentaires d'une plateforme convergente sont incertains lorsqu'on les compare aux coûts supplémentaires engendrés par la transition. Tout en haut de la gamme de valeurs d'avantages probables, il y a un argument clair en faveur d'une plateforme convergente ; tout en bas de la gamme, cet argument n'est plus valable. Un engagement en faveur d'une plateforme convergente impliquerait donc actuellement de s'exposer à des coûts considérables, sans garantie sur ce que seraient les avantages futurs nets. Une grande partie de cette incertitude du marché devrait disparaître au cours des 3 à 5 prochaines années.

Nous conseillons donc de réévaluer l'argument en faveur d'une plateforme convergente une fois que l'incertitude du marché aura été réduite dans trois à cinq ans. Une telle réévaluation devrait examiner l'option d'une plateforme convergente en parallèle à d'autres options pour l'utilisation du spectre en-dessous de 700 MHz. Nous conseillons aussi, avant cette réévaluation :

- Le développement de nouvelles mesures, à l'échelle européenne, pour la consommation AV, comprenant à la fois la vidéo linéaire et non-linéaire
- Que l'industrie audiovisuelle fournisse des conseils appropriés aux programmes de recherche 5G

- Que les autorités gouvernant les spectres trouvent un spectre pouvant abriter le PMSE audio sur le long terme
- Que la faisabilité de réseaux isofréquence sur canal commun sur un réseau LPLT soit évaluée d'une manière plus approfondie.

Il n'est pas encore possible de préciser quelle forme pourrait prendre un engagement à l'échelle européenne en faveur d'une plateforme convergente. Un tel engagement aurait certains avantages. Mais il n'existe pas encore d'argument convaincant en faveur d'une telle plateforme convergente.

# Zusammenfassung

Dieser Bericht behandelt drei Fragen:

- Wie wird sich der audiovisuelle Konsum (AV-Konsum) in der europäischen Union in den kommenden 15 Jahren ändern?
- Wie werden sich Rundfunk- und Breitbanddienstleistungen in diesem Zeitraum entwickeln?
- Gibt es Vorteile durch die Schaffung einer konvergenten Plattform, auf der sich mobile und terrestrische Fernsehdienste eine Infrastruktur und ein UHF-Spektrum teilen?

Traditionelles lineares Fernsehen über Rundfunknetze dominiert heute den AV-Konsum. Dies könnte sich bis 2030 deutlich ändern, da festes Breitband und WLAN eine immer stärkere Rolle im Angebot und der Verteilung von Videoinhalten spielen - sowohl als Ersatz für als auch als Ergänzung von traditionellen Rundfunksendern. Aber es herrscht große Unsicherheit über die Tragweite dieser Effekte, die die Schaffung von Szenarien für den AV-Konsum erfordern, an dem die Vorteile einer gemeinsamen Plattform gemessen werden können.

Zurzeit konzentriert sich die Entwicklung von konvergenten Rundfunk-Breitband-Diensten auf die Kombination von festen Breitband- und Rundfunkdiensten. Die meisten dieser Entwicklungen werden aufgrund von Marktmechanismen entweder erfolgreich sein oder fehlschlagen. Doch die Entwicklung einer konvergenten Plattform erfordert politische Interventionen.

Die beste Option für eine solche konvergente Plattform umfasst die Umwandlung des DTT-Netzwerks von der derzeitigen Topologie mit hohen Masten und hoher Leistung (“high-power high-tower“ - HPHT) zu der Topologie der mobilen Netze mit niedrigen Masten und niedriger Leistung (“low-power low-tower“ - LPLT). Eine derartige Maßnahme erfordert, dass sich für die Simultanübertragung große Anteile des Spektrums unter 700 MHz befinden und ist stark von der Nutzung von Zweikanal-Gleichwellennetzen (“Single Frequency Networks“ - SFN) abhängig. Vorausgesetzt diese Herausforderungen werden erfüllt, dann wäre der wichtigste inkrementelle Vorteil die Freigabe von 110 bis 175 MHz UHF-Spektrum.

Der Wechsel zu einer konvergenten Plattform ist noch nicht vollzogen. Die inkrementellen Vorteile einer konvergenten Plattform sind im Vergleich zu den inkrementellen Kosten des Wechsels unklar. Der wichtigste der wahrscheinlichen Vorteile ist die klare Notwendigkeit einer konvergenten Plattform. Im anderen Extrem gibt es diese Notwendigkeit nicht. Daher bedeutet die Umsetzung einer konvergenten Plattform in dieser Phase die Entstehung von hohen Kosten ohne garantierte Nettovorteile in der Zukunft. Der größte Teil dieser Marktunsicherheit dürfte in den nächsten drei bis fünf Jahren verschwinden.

Daher empfehlen wir eine Prüfung der Notwendigkeit einer konvergenten Plattform, wenn die Marktunsicherheit in drei bis fünf Jahren zurückgegangen ist. In einer solchen Prüfung muss die konvergente Plattform neben anderen Optionen für die Nutzung des Spektrums unter 700 MHz bewertet werden. Auch empfehlen wir vor dieser Prüfung:

- Die Entwicklung neuer EU-weiter Messungen des AV-Konsums, die linearen und nicht-linearen Videoinhalt umfassen
- Dass die Rundfunkgemeinschaft relevante Beratung für 5G-Forschungsprojekte anbietet
- Dass Frequenzbehörden ein langfristig nutzbares Spektrum für PSME-Audio finden

- Dass weitere Untersuchungen zur Machbarkeit von Zweikanal-SFNs in einem LPLT-Netz durchgeführt werden

Noch ist es nicht möglich, eine EU-weite Arbeit an einer konvergenten Plattform zu spezifizieren. Eine solche Arbeit hat Vorteile, doch die Notwendigkeit einer konvergenten Plattform muss erst noch geschaffen werden.

# Executive Summary

## S1 The purpose of the study

In January 2014 the European Commission initiated a study in which it asked a team from Plum and Farncombe to consider three main issues:

- To explore future developments in the delivery of audio-visual and Internet services over the next 15 years
- To explore how these developments will impact on evolution of terrestrial wireless access networks and especially digital terrestrial television (DTT) and mobile (broadband) networks
- To assess the social and economic merit in moving to a converged platform. A converged platform is defined as a common infrastructure (such as towers and backhaul) which delivers terrestrial broadcast services, mobile broadband services and converged broadcast-broadband services using UHF spectrum.

## S2 Audio visual (AV) consumption now

Traditional linear TV, viewed over a mix of DTT, satellite, and cable networks, currently dominates AV consumption. The average EU citizen watches around four hours of content in this way each day and there is little sign of change. But there are trends which might alter the situation. For example we are seeing:

- Rapid take-up of portable devices with good video-viewing capability, such as smartphones and tablets
- Growing consumption of video content on these devices out of the home and on the move
- Significant growth, albeit from a small base, of non-linear viewing over these devices via over-the-top (OTT) and catch-up services
- Significant growth in take-up of IPTV services, both as a complement and an alternative to traditional TV broadcast networks
- A move towards higher resolution formats for AV content, such as high definition (HD) and ultra-high definition (UHD), for AV content.

AV consumption varies considerably between EU member states in terms of the mix of platforms used, the structure of the value chain which delivers content and the rate of change within the market. For example the proportion of households where DTT is a primary delivery platform varies from 4% in Belgium to 80% in Greece.

We have found it difficult to quantify the current level of non-linear AV consumption and the rate at which it is growing. The information available does not measure consumption in a consistent way across different devices and delivery networks, it is readily available in only a few member states, and it is sometimes contradictory. This lack of consistent data makes it difficult to monitor trends accurately and to support well-founded policy decisions on AV markets.

## S3 Technology trends

The price/performance of the networks which deliver AV content to end-users - both broadcast and broadband - will change significantly over the next decade. We expect to see:

- Big improvements in the price/performance of **fixed** broadband networks when compared with the spectrum-based broadcast networks, given historic trends and anticipated future performance gains
- Continuing limitations on the role of unicast **mobile** services relative to fixed broadband. The incremental cost per gigabyte for mobile services is one to two orders of magnitude greater than for fixed broadband. There is clearly strong and growing demand for unicast, personalised video delivery to mobile devices. But that demand will be constrained by the higher unit costs of mobile broadband delivery
- Multicast mobile services (for example based on the eMBMS standard) may also become important as a way of meeting high demand for the same video content in an individual cell or cluster of cells
- A substantial growth in the capacity, speed and reach of Wi-Fi services - both in the home and via public hotspots - as new technology Wi-Fi routers replace legacy routers in the installed base.

## S4 AV consumption in 2030

Given these technology trends we expect to see:

- Fixed broadband playing a central role in the delivery of TV content by 2030. Fixed broadband will both **complement** traditional TV broadcast networks[1] and **substitute** for traditional platforms
- Wi-Fi playing a growing role in AV distribution over the rapidly growing population of tablets and smart phones – both around and out of the home. For example Wi-Fi has the potential to act as a cheap substitute for unicast mobile video in many situations – both in and out of the home.

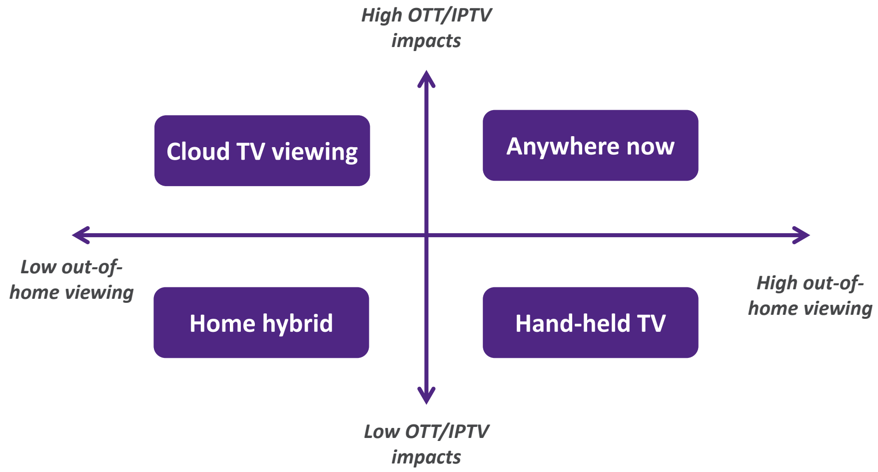
However there are big uncertainties over how AV consumption might change by 2030. For example, there are divergent views amongst stakeholders on:

- How quickly and to what extent will consumers switch from linear to on-demand viewing
- Whether DTT will retain its current position or be displaced to a substantial degree by pure OTT services or IPTV services in the average household
- The extent to which tablets will replace traditional TV sets for secondary viewing in the home
- How the balance between in-home and out-of-home viewing will change over the next 10 years.

To deal with these uncertainties we have constructed the four scenarios shown in Figure S1 for the possible states of AV consumption in 2030 in a typical member state. We consider the merits of a converged platform under each of these scenarios.

[1] To deliver hybrid services with mixed linear and non-linear TV consumption

Figure S1: Scenarios for AV consumption on 2030[2]




## S5 The development of broadcast-broadband converged services

As well as substitution effects, the growing role of broadband in AV consumption is leading to convergence effects - in which complimentary combinations of broadcast and broadband services create new opportunities for value added services. We have identified four types of broadcast-broadband convergence:

- Content convergence at the device level which allows users to view broadcast and broadband AV content on the same device
- Application convergence at the device level which allows users to view broadcast and broadband AV content over the same user interface on the same device
- Service level convergence which allows end users to access the same linear and non-linear AV content seamlessly on multiple devices
- Infrastructure level convergence which uses the same infrastructure to deliver broadcast and broadband services to end users

Convergence activities are currently focused on combining broadcast and **fixed** broadband through the development of connected TVs and hybrid services like HbbTV-based services. But what is the potential to extend such convergence to combinations of mobile broadband and broadcast platforms as well?

At the content, application or service level such convergence will probably succeed or fail through normal market mechanisms. But infrastructure level convergence will need public policy interventions given current regulatory constraints[3]. So, before committing to any such initiatives, there is a need to consider the economic and social merits of a converged platform. In making that assessment we need to take account of the fact that convergence at the device and service levels is possible without a

[2] High OTT/IPTV impact – 70% reduction in DTT HH by 2030; Low OTT/IPTV impact – 10% reduction in DTT HH by 2030; High OOH viewing – 40 minutes/day/person OOH viewing on portable devices; Low OOH viewing – 20 minutes/day/person OOH viewing on portable devices

[3] For example on use of relevant spectrum and rules for DTT platforms

converged platform and that a significant proportion of the benefits of converged services can be captured without implementing a converged platform.

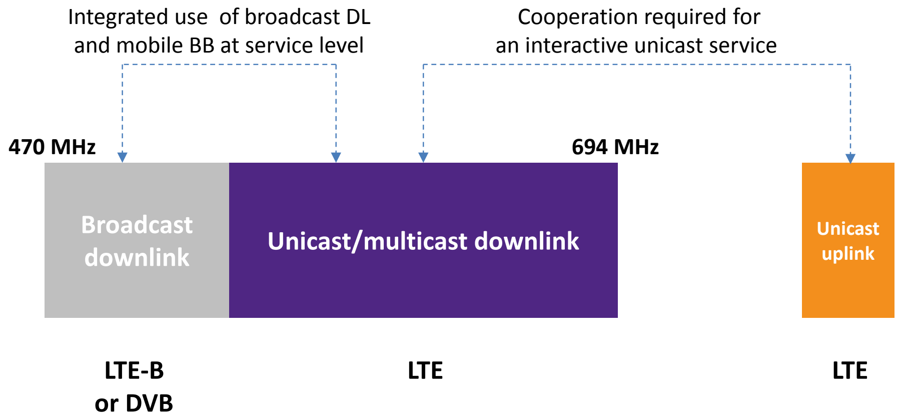
## S6 Options for a converged platform

Any option for a converged platform will need to meet a number of requirements:

- To provide near universal free-to-air coverage so as to preserve the current European AV model
- To use sub-700 MHz UHF spectrum if it is to meet this requirement in a cost-effective way
- To deliver an adequate number of TV channels. The TV payload varies by member state. We have considered payloads from 60 to 180 Mbps
- To provide two-way mobile broadband services
- To free-up substantial amounts of sub-700 MHz spectrum so as to create incremental benefits which might justify the cost of transition.

After considering a number of options we selected two for detailed examination. Both involve moving from the existing high-power high tower (HPHT) DTT platform to the low-power low tower (LPLT) infrastructure of the mobile networks. Figure S2 shows how the spectrum might be used.

Figure S2: The LTE and DVB options for a LPLT converged platform




Both options involve dividing the spectrum between 470 and 694 MHz into two downlinks:

- A broadcast downlink. This might use existing DVB standards (the DVB option) or a new LTE broadcast standard (the LTE option)[4] for linear TV broadcasts
- A unicast downlink using LTE standards.

The unicast uplink which is needed to complement these downlinks might use spectrum at the top end of the sub-700 MHz band or higher frequencies (e.g. in the 900 MHz frequency range), depending on the business models which are developed for the licensing and use of the converged platform.

[4] 3GPP would need to develop existing the LTE standards to enable broadcast coverage in rural areas through longer cyclic prefixes, carrier frequencies to be used exclusively for a downlink, and free-to-air access for all

The DVB option has two main advantages over the LTE broadcast option:

- There are no upgrade costs for TV receivers
- DVB offers potentially higher spectrum efficiency (in excess of 3.5 bps/Hz compared to in excess of 2 bps/Hz for LTE). This makes migration easier and increases spectrum release

The LTE broadcast option has three main advantages over the DVB option:

- A single technology means lower cost networks and end user equipment
- A single technology means less processing required for broadcast-broadband integration of services
- It may be easier to reassign spectrum between broadcast and broadband use as market demand changes.

## S7 Making the transition to an LPLT converged platform

There are a number of challenges in moving to an LPLT converged platform:

- Implementation of a converged platform is unlikely to be practicable before 2025 in many member states given:
  - The need to clear the 700 MHz band for mobile use
  - The need to migrate the HPHT network from DVB-T to DVB-T2 technology in a significant number of member states
  - The need to find a permanent spectrum home for PMSE audio use before implementing a converged platform
- There is a need to determine whether co-channel regional SFNs[5] will work satisfactorily on an LPLT network
- Simulcast spectrum will be required in the transition period so that the (old) HPHT DTT network and the new LPLT network can broadcast in parallel. It may be impossible to find the required simulcast spectrum for a member state with a high TV traffic load without a substantial temporary reduction in the TV payload
- Significant effort is also required to mitigate cross-border interference – especially in the member states which move first to a converged platform.

We have assumed in our cost benefit analysis that co-channel regional SFNs are viable with an LPLT network and that its spectral efficiency ranges from 2 bps/Hz (LTE option) to 3.5 bps/Hz (DVB option). With these assumptions the converged platform might free up between 110 and 170 MHz in the 470-694 MHz frequency range.

[5] In which adjacent regions use the same frequency to broadcast different content

## S8 The costs and benefits of a converged platform

To assess whether there is an economic case for an LPLT converged platform we have compared the net present value of the incremental costs and benefits of a converged platform relative to a counterfactual in which:

- Sub-700 MHz spectrum is exclusively used by HPHT DTT network for DVB TV broadcast
- There is commercial cooperation between TV broadcasters and mobile operators to develop broadcast-broadband converged services, with each type of supplier using its own existing network infrastructure.

Many of the benefits of a converged platform are also captured by the counterfactual (as discussed in Section S5). As such they are not incremental benefits. The main incremental benefit of an LPLT converged platform is that it frees up sub-700 MHz spectrum to use as a unicast mobile downlink. The value of this spectrum release is currently uncertain. We consider a range of values between €0.1 and €0.4 per MHz pop. In a hypothetical member state, with a population of 20 million and a population density of 250 per square kilometres, these assumptions lead to a net present value (NPV) of incremental benefits of between €265 million and €885 million. There may be additional incremental benefits from easier integration of broadband and broadcast functions on a converged platform. But there is as yet little evidence that these additional benefits would be substantial.

There are three main incremental costs for a converged platform:

- The cost of building and operating the LPLT network (less the cost of operating the HPHT network)
- The transition cost of ensuring end-users can use new platform - converting TV receivers (LTE option) and re-orienting TV aerials (both options)
- The transition costs of freeing simulcast spectrum and dealing with cross-border interference.

Figure S3 indicates under what circumstances the incremental benefits exceed the incremental costs.

**Figure S3: Where do the benefits exceed the costs?**

| Benefits assumed at | Lower limit | | Mid-point value | | Upper limit | |
|---|---|---|---|---|---|---|
| OTT/IPTV impacts | Low | High | Low | High | Low | High |
| Central case (LTE option) [6] | No | No | No | Yes | Yes | Yes |
| DVB rather than LTE option | No | No | Yes | Yes | Yes | Yes |
| Low TV payload (60 Mbps) | No | No | Yes | Yes | Yes | Yes |
| High TV payload (180 Mbps) | No | No | No | Yes | Yes | Yes |
| 10% DTT HH in 2014 | No | No | Yes | Yes | Yes | Yes |
| 70% DTT HH in 2014 | No | No | No | Yes | Yes | Yes |

*Note: More heavily shaded cells indicate where benefits exceed costs*

We can see that:

[6] In which we assume LTE broadcast, support for primary TV sets only, 40% DTT households in 2014, 120 Mbps TV payload

- There is no economic case for a converged platform if the incremental benefits are at the bottom end of our benefits range
- There is a good economic case for a converged platform if benefits are at the top end of the likely range
- If benefits are at the midpoint value then the case is ambiguous:
  - If OTT/IPTV reduces DTT demand by 70% by 2030 (high impact) then there are net incremental benefits in our hypothetical member state in all cases.
  - But if the impact of OTT/IPTV services on DTT is low, with only a 10% reduction in DTT demand, then there are net benefits only in member states where DTT currently has a low market share or where the DTT TV payload is small.

Of course not all member states are like our hypothetical member state. Our sensitivity analysis indicates that the case for a converged platform weakens considerably in small member states[7] but otherwise is similar to that for the hypothetical member state.

There are a number of qualitative issues which also need to be taken into account in considering the case for a converged platform:

- How easily could an LPLT converged platform meet the ICNIRP's RF emission limits? Adding substantial new carriers to a mast, especially at frequencies below 1 GHz, could significantly increase the size of the exclusion zone around the mast and so raise the costs of constructing an LPLT converged platform in urban areas
- Would network reliability (measured in terms of network uptime) be good enough? Our analysis of the limited information which is in the public domain is inconclusive, although there is anecdotal evidence to suggest that the LPLT network might be less reliable
- Would a move to an LPLT converged platform lead to higher transmission charges for radio broadcasters using the HPHT network? This is possible but the effects are uncertain and would vary by member state
- Would a move to an LPLT network make the DTT network more flexible? Our analysis suggests that it would:
  - When compared with an HPHT network, an LPLT network could change at relatively low cost to meet evolving market requirements for delivery of TV content
  - A move to an LPLT network might make it easier to release UHF spectrum for mobile services in the middle of the day when TV payloads are (sometimes) significantly lower than in the evening.

## S9 Conclusions from our economic assessment

The economic case for a converged platform is not yet made. As Figure S3 shows, net benefits might be positive or negative. Committing now to an LPLT converged platform would mean committing to substantial costs without any guarantee of net benefits in the long term. In any case it is unlikely to be feasible to implement a converged platform before 2025. This means that a decision by policy makers is not necessary now and there is value in preserving options by postponing a decision.

[7] For example those with a population of less than 2 million

The fact that the economic case for a converged platform is ambiguous reflects two major market uncertainties:

- There is currently substantial uncertainty over the incremental value of releasing sub-700 MHz spectrum for mobile use. We would expect this uncertainty to reduce substantially over the next five years as the 700 MHz band is auctioned
- The extent to which take-up of IPTV and OTT services might reduce demand for HPHT DTT networks. Again the position here should be clearer by 2020.

There are also several other unresolved issues - on RF emissions, the viability of co-channel SFNs, network reliability, creating simulcast spectrum, and the costs of upgrading the macro-cells of a mobile network - which add to this market uncertainty.

This analysis points to the need for a further review of the merits of a converged platform (perhaps three to five years from now) when the market uncertainties listed above should be much reduced.

## S10 Recommendations

***Recommendation 1****: The Commission and industry should consider how best to develop and implement comprehensive measures of video consumption, which are consistent across EU member states over time.*

The lack of consistent measurement of traditional linear TV and non-linear AV consumption needs to be remedied if important policy (and commercial) decisions about the future of AV services in the EU are to be soundly based.

***Recommendation 2****: The broadcast community should provide relevant guidance to 5G research programmes.*

5G research programmes are starting now and there is as yet little focus on broadcasting capability. To fill this gap 5G research programmes might research the viability of a broadcast capability in 5G networks at low incremental costs and/or ways of integrating existing HPHT broadcast networks into 5G heterogeneous networks[8]

***Recommendation 3****: The relevant spectrum authorities should specify a long-term spectrum home for PMSE audio services, including whether to reserve part of the UHF band for PMSE.*

A move to a converged platform would lead to loss of access by PMSE audio services to most, or possibly all the entire sub-700 MHz spectrum. There are European Commission decisions which identify spectrum in the 800 MHz and 1800 MHz bands which might deal with loss of 800 MHz spectrum by PMSE audio. There are also initiatives in the 1 to 2 GHz range under consideration to compensate for loss of 700 MHz spectrum. But there is as yet no agreed way forward.

***Recommendation 4****: The broadcast and mobile communities should investigate further the feasibility and cost of implementing co-channel SFNs.*

[8] Which may include LTE, WiFi and other networks

The case for a converged platform is highly dependent on the viability of such SFNs. Yet studies by the BBC and ATDI (for Qualcomm) give very different results in terms of costs and coverage. These differences need to be resolved before the case for a converged platform is clear.

***Recommendation 5****: The European Commission should initiate another review of the case for a converged platform once the market uncertainties identified in Section S9 are substantially reduced.*

Market uncertainties mean that it is not yet possible to make a firm decision about a converged platform. We expect that these uncertainties will reduce substantially over the next 3 to 5 years. In particular 700 MHz auctions in next three to five years will give information about value of sub-700 MHz spectrum and the impacts of convergence in fixed environment should be much clearer.

Any future review should assess other options as well as a converged platform. This might include:

- The flexibility option proposed in the Lamy report.  This would involve the implementation of unicast/multicast LTE downlinks in sub-700 MHz spectrum provided that they do not affect the existing HPHT DTT networks or their development
- A move to a single HPHT DTT network based on SFNs so as to release sub-700 MHz spectrum for mobile use
- Complete closure of the DTT network - which is replaced by a mix of free-to-air satellite DTH and IPTV broadcast.

In making Recommendation 5, we do not intend to inhibit market or technology developments in broadcast-broadband convergence services prior to the review. Specifically we propose that work on Recommendations 1 to 4 and Recommendation 7 takes place in advance of action related to Recommendation 5.

***Recommendation 6****: Those carrying out such a future review should resolve uncertainties in CBA parameters and technical assumptions.*

Such work might include assessment of the reliability of an LPLT network; safe emission limits; finding spectrum for simulcasting; and the costs of upgrading macro-sites to provide a LPLT converged network.

***Recommendation 7****: Between now and the next review, the broadcast and mobile communities should seek ways of working together to produce innovative broadcast-broadband converged services which are commercially viable and deliver added value to end users.*

Our research suggests that there is relatively little activity of this kind as yet but that there are opportunities for commercially viable broadcast–mobile broadband services which use the existing infrastructure of the broadcasters and the mobile operators.  Any development of such services would change the counterfactual against which a converged platform is re-evaluated in future and might materially alter the findings of a future review.

If the review proposed in Recommendation 5 leads to a decision to implement a converged platform, then further work would be required. This includes:

- The development of the LTE broadcast standard

- A review of national regulations governing DTT platforms – for example those imposing technical, coverage and other restrictions on UHF spectrum use and requiring broadcasters to use the DTT platform
- The development of commercial and licensing models to consider who might run a converged network with what spectrum, and what role governments might play in enabling commercial models
- The development of the necessary spectrum management and frequency coordination arrangements such as a band plan, arrangements for incumbents, and bi-lateral/multi-lateral spectrum co-ordination arrangements.

## S11 EU level commitment

Assuming the next review concludes that a converged platform is the best option for use of sub-700 MHz spectrum, then the Commission would need to consider what role it, and other EU level institutions and relevant bodies, should play in facilitating the transition to a converged platform. In defining this role there are a number of factors which need to be taken into account.

- There would be significant benefits from an EU-wide commitment to a move to a converged platform in terms of spectrum co-ordination and release, equipment production and EU-wide service provision
- There is currently a wide variety of audio-visual market conditions in different member states. Such variation would mean that an EU-wide move to a converged platform is likely to create winners and losers amongst member states, even if the move creates net benefits overall
- It is not clear to what extent a coordinated EU-wide move to a converged platform would help complete *the single market* in consumption of AV services. An EU-wide commitment would allow EU citizens to use portable devices across the EU to consume converged AV services. But the problem of national content rights would remain and citizens roaming in another member state may still be prohibited from viewing content originated in the home member states using (say) OTT catch-up services
- There is, as yet, no evidence that an EU wide commitment to a converged platform would give the *EU industrial policy leadership* on a global basis. There is as yet little evidence that other world regions would be interested in implementing a converged platform.

# Note de synthèse

## S1 But de l'étude

En janvier 2014, la Commission européenne a lancé une étude dans laquelle elle demandait à une équipe de Plum and Farncombe de se pencher sur trois problématiques principales :

- Explorer les évolutions à venir dans la livraison de services audiovisuels et Internet au cours des 15 prochaines années
- Explorer comment ces évolutions influeront sur l'évolution des réseaux d'accès sans fil terrestres et surtout de la télévision numérique terrestre (TNT) et des réseaux (haut débit) mobiles
- Évaluer l'avantage social et économique de la transition vers une plateforme convergente. Une plateforme convergente est définie comme étant une infrastructure commune (telle que les tours et éléments de relais) qui délivre des services de diffusion terrestre, des services mobiles à haut débit et des services de diffusion-haut débit convergents à l'aide du spectre UHF.

## S2 La consommation audiovisuelle (AV) actuelle

La télévision linéaire traditionnelle, visionnée à travers un mix de réseaux TNT, satellite et câblé, domine actuellement la consommation AV. Le citoyen de l'UE moyen regarde environ quatre heures de contenu par jour de cette manière, et peu de choses indiquent que cette situation est en train de changer. Mais il existe des tendances qui pourraient changer la situation. Par exemple, nous observons :

- Une adoption rapide des appareils portables présentant de bonnes capacités de visionnage de vidéos, tels que les smartphones et tablettes
- Une consommation croissante du contenu vidéo sur ces appareils hors domicile et en déplacement
- Une croissance considérable, même si la part est très réduite, du visionnage non-linéaire sur ces appareils via des services "over-the-top" (OTT) et de rattrapage
- Une croissance considérable de l'adoption de services IPTV, à la fois en complément et en remplacement des réseaux de télédiffusion traditionnels
- Une évolution vers des formats à plus haute résolution pour les contenus AV, tels que la haute définition (HD) et l'ultra haute définition (UHD), pour les contenus AV.

La consommation AV diffère considérablement d'un État membre de l'UE à l'autre en ce qui concerne la combinaison des plateformes utilisées, la structure de la chaîne de valeur livrant le contenu et le taux d'évolution sur le marché. Par exemple, la proportion de ménages pour lesquels la TNT est une plateforme de livraison principale varie de 4 % en Belgique à 80 % en Grèce.

Nous avons eu des difficultés à quantifier le niveau actuel de consommation AV non-linéaire et son taux de croissance. Les données disponibles ne mesurent pas la consommation de manière cohérente entre les différents appareils et réseaux de livraison ; elles ne sont facilement disponibles que dans quelques États membres, et elles sont parfois contradictoires. Ce manque de données cohérentes fait qu'il est difficile de surveiller les tendances avec exactitude et de soutenir des décisions politiques bien-fondées sur les marchés AV.

## S3 Tendances technologiques

Le rapport prix/performance des réseaux qui livrent des contenus AV aux utilisateurs finaux - à la fois de diffusion et de haut débit - va considérablement évoluer au cours de la décennie à venir. Nous nous attendons à voir :

- De gros progrès dans le rapport prix/performance des réseaux de haut débit **fixes** par rapport aux réseaux de diffusion basés sur le spectre des radiofréquences, étant donné les tendances historiques et les gains de performance futurs attendus
- Des limitations continues sur le rôle des services **mobiles** à diffusion individuelle par rapport au haut débit fixe. Le coût supplémentaire par gigaoctet pour les services mobiles est d'une à deux fois plus élevé que pour le haut débit fixe. Il y a clairement une demande forte et croissante pour une livraison de vidéos personnalisée, par diffusion individuelle, vers les appareils mobiles. Mais cette demande sera limitée par les coûts unitaires plus élevés de la livraison haut débit mobile
- Des services mobiles à diffusion groupée (par exemple basés sur la norme eMBMS) pourraient aussi devenir importants en offrant un moyen de répondre à la demande élevée pour le même contenu vidéo dans une cellule individuelle ou un groupe de cellules
- Une croissance considérable dans la capacité, vitesse et étendue des services Wi-Fi - à la fois au domicile et via des points d'accès publics, au fur et à mesure que des routeurs Wi-Fi nouvelle génération remplacent les anciens routeurs dans la base installée.

## S4 Consommation AV en 2030

Étant donné ces tendances technologiques, nous nous attendons à voir :

- Le haut débit fixe jouer un rôle central dans la livraison de contenus télévisuels d'ici 2030. Le haut débit fixe va devenir à la fois un **complément** pour les réseaux de télédiffusion traditionnels[9] et une **alternative** aux plateformes traditionnelles
- Le Wi-Fi jouer un rôle croissant dans la distribution AV dans la population à croissance rapide des tablettes et smartphones, à la fois à et hors domicile. Par exemple, le Wi-Fi pourrait potentiellement constituer une alternative bon marché pour la vidéo mobile à diffusion individuelle dans de nombreuses situations, à la fois à et hors domicile.

Toutefois, de grandes incertitudes planent sur la façon dont la consommation AV pourrait évoluer d'ici 2030. Par exemple, les parties prenantes ont des avis divergents sur :

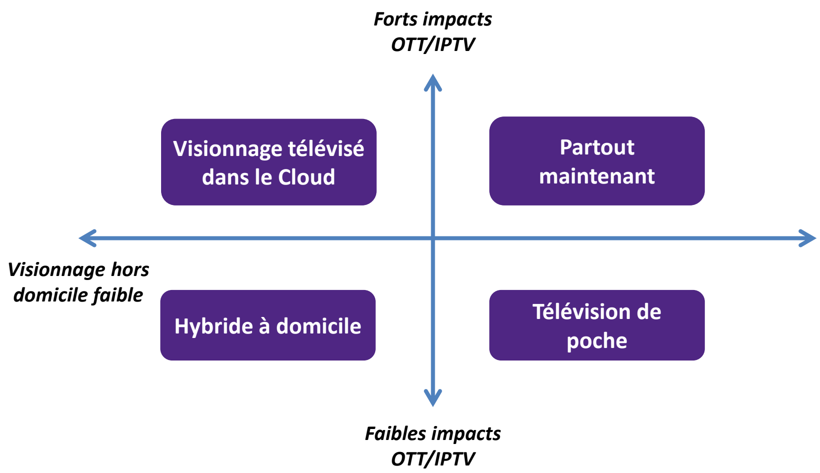
- La rapidité avec laquelle et la mesure dans laquelle les consommateurs sont susceptibles de passer d'un visionnage linéaire à un visionnage à la demande
- Si la TNT conservera sa position actuelle, ou si elle sera largement supplantée par des services OTT purs ou des services IPTV dans le ménage moyen

[9] Pour fournir des services hybrides avec une consommation télévisuelle à la fois linéaire et non-linéaire

- La mesure dans laquelle les tablettes remplaceront les postes de télévision traditionnels pour le visionnage secondaire à domicile
- La façon dont l'équilibre entre le visionnage à domicile et hors domicile est susceptible d'évoluer au cours des 10 années à venir.

Pour faire face à ces incertitudes, nous avons élaboré les quatre scénarios présentés dans le Schéma S1 pour les états possibles de la consommation AV en 2030 dans un État membre type. Nous examinons les avantages d'une plateforme convergente dans chacun de ces scénarios.

**Schéma S1 : Scénarios pour la consommation AV en 2030**[10]




## S5 Le Développement des services convergents de diffusion-haut débit

En plus des effets de substitution, le rôle croissant du haut débit dans la consommation AV donne lieu à des effets de convergence, dans lesquels les combinaisons gratuites de services de diffusion et de haut débit créent de nouvelles opportunités pour des services à valeur ajoutée. Nous avons identifié quatre types de convergence diffusion-haut débit :

- Convergence de contenus à l'échelle de l'appareil, permettant aux utilisateurs de visionner du contenu AV de diffusion et de haut débit sur le même appareil
- Convergence d'applications à l'échelle de l'appareil, permettant aux utilisateurs de visionner du contenu AV de diffusion et de haut débit sur la même interface utilisateur sur le même appareil
- Convergence de niveau de service, permettant aux utilisateurs finaux d'accéder au même contenu AV linéaire et non-linéaire sans accroches sur plusieurs appareils
- Convergence de niveau d'Infrastructure utilisant la même infrastructure pour fournir des services de diffusion et de haut débit aux utilisateurs finaux

[10] Fort impact de l'OTT/IPTV – réduction de 70 % de la TNT par ménage d'ici 2030 ; Faible impact de l'OTT/IPTV – réduction de 10 % de la TNT par ménage d'ici 2030 ; Fort visionnage hors domicile – visionnage hors domicile sur des appareils portables = 40 minutes/jour/personne ; Faible visionnage hors domicile – visionnage hors domicile sur des appareils portables = 20 minutes/jour/personne

Les activités de convergence se concentrent actuellement sur la combinaison de la diffusion et le haut débit **fixe** à travers le développement des télévisions connectées et de services hybrides tels que les services basés sur le HbbTV. Mais quel est le potentiel pour aussi étendre une telle convergence à des combinaisons de plateformes de haut débit mobile et de diffusion ?

Au niveau du contenu, de l'application ou du service, une telle convergence connaîtra probablement soit un succès soit un échec en passant à travers les mécanismes normaux du marché. Mais une convergence au niveau de l'infrastructure nécessitera des interventions de politique publique étant donné les contraintes réglementaires actuelles[11]. Il faut donc, avant de s'engager sur de telles initiatives, prendre en compte les avantages économiques et sociaux d'une plateforme convergente. En effectuant cette évaluation, il nous faut prendre en compte le fait que la convergence au niveau de l'appareil et du service est possible sans plateforme convergente, et qu'une grande partie des avantages des services convergents peut être obtenue sans mettre en place une plateforme convergente.

## S6 Options pour une plateforme convergente

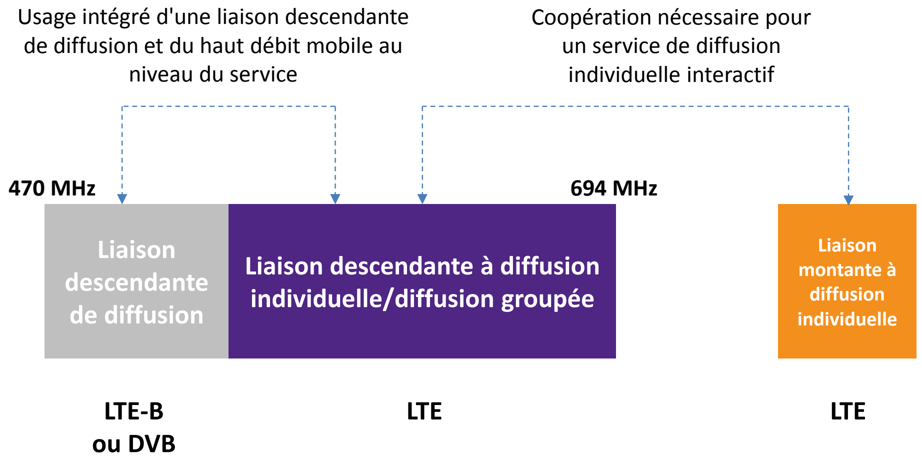
Toute option pour une plateforme convergente devra remplir un certain nombre de critères :

- Fournir une couverture en clair presque universelle pour préserver le modèle AV européen actuel
- Utiliser le spectre UHF en-dessous de 700 MHz de façon à remplir ce critère d'une façon rentable
- Fournir un nombre adéquat de chaînes de télévision. La charge utile TV varie en fonction de l'État membre. Nous avons pris en compte des charges utiles allant de 60 à 180 Mbps
- Fournir des services de haut débit mobiles bidirectionnels
- Libérer de grandes parties du spectre en-dessous de 700 MHz de façon à créer des avantages supplémentaires qui pourraient justifier le coût de la transition.

Après avoir envisagé un certain nombre d'options, nous en avons sélectionné deux à examiner en détail. Toutes deux impliquent de s'éloigner des plateformes existantes de TNT via des tours émettrices hautes et puissantes (HPHT) pour aller vers l'infrastructure de tours émettrices basses à faible puissance (LPLT) des réseaux mobiles. Le Schéma S2 montre comment l'on pourrait utiliser le spectre.

[11] Par exemple, au sujet de l'utilisation du spectre pertinent et des règles pour les plateformes TNT

Schéma S2 : Les Options LTE et DVB pour une plateforme convergente LPLT




Les deux options impliquent de diviser le spectre entre 470 et 694 MHz en deux liaisons descendantes :

- Une liaison descendante de diffusion Celle-ci pourrait utiliser les normes DVB existantes (l'option DVB) ou une nouvelle norme de diffusion LTE (l'option LTE)[12] pour les diffusions télévisuelles linéaires
- Une liaison descendante à diffusion individuelle utilisant les normes LTE.

La liaison montante à diffusion individuelle qui serait nécessaire pour compléter ces liaisons descendantes pourrait utiliser un spectre situé tout en haut de la gamme de fréquences en-dessous de 700 MHz, ou des fréquences plus élevées (par ex. dans la gamme de fréquences autour de 900 MHz), en fonction des modèles commerciaux qui seront développés pour l'octroi de licences et l'utilisation de la plateforme convergente.

L'option DVB a deux principaux avantages par rapport à l'option de diffusion LTE :

- Elle n'implique pas de coûts de mise à jour des récepteurs TV
- Le DVB offre potentiellement une efficacité de spectre plus élevée (plus de 3,5 bps/Hz contre plus de 2 bps/Hz pour le LTE). Cela rend la migration plus facile et augmente la libération de spectre

L'option DVB a trois principaux avantages par rapport à l'option de diffusion LTE :

- Une seule technologie signifie des réseaux et équipements pour utilisateurs finaux à moindre coût
- Une seule technologie signifie qu'il faut moins de traitement pour une intégration des services de diffusion-haut débit
- Il sera peut-être plus facile de réassigner le spectre entre l'utilisation de la diffusion et du haut débit au gré des évolutions dans la demande du marché.

[12] Il faudrait que 3GPP développe les normes LTE existantes pour permettre une couverture de diffusion dans les zones rurales à travers des préfixes cycliques plus longs, que les fréquences porteuses soient utilisées exclusivement pour une liaison descendante, et un accès en clair pour tous

## S7 Effectuer la transition vers une plateforme convergente LPLT

La transition vers une plateforme convergente LPLT impliquerait un certain nombre de défis :

- Il est peu probable que la mise en place d'une plateforme convergente soit réalisable avant 2025 dans de nombreux États membres étant donné :
  - La nécessité de libérer la bande des 700 MHz pour une utilisation mobile
  - La nécessité de faire migrer le réseau HPHT d'une technologie DVB-T vers une technologie DVB-T2 dans un grand nombre d'États membres
  - La nécessité de trouver un spectre pouvant héberger de façon permanente l'audio PMSE avant de mettre en place une plateforme convergente
- La nécessité de déterminer si les réseaux isofréquence régionaux sur canal commun [13] fonctionneront de manière adéquate sur un réseau LPLT
- Le spectre de diffusion simultanée sera nécessaire pendant la période de transition, de façon à assurer que le (vieux) réseau TNT HPHT et le nouveau réseau LPLT puissent être diffusés en parallèle. Il pourrait se révéler impossible de trouver le spectre de diffusion simultanée nécessaire pour un État membre ayant une importante charge de trafic TV sans une réduction temporaire considérable de la charge utile TV
- Il faudra aussi faire d'importants efforts pour atténuer l'interférence transfrontalière, surtout dans les États membres qui seront les premiers à évoluer vers une plateforme convergente.

Nous sommes partis du principe, dans notre analyse coûts-avantages, que les réseaux isofréquence régionaux sur canal commun sont viables avec le réseau LPLT et que son efficacité spectrale varie entre 2 bps/Hz (option LTE) et 3,5 bps/Hz (option DVB). Sur la base de ces hypothèses, la plateforme convergente pourrait libérer entre 110 et 170 MHz dans la gamme de fréquences de 470-694 MHz.

## S8 Les Coûts et avantages d'une plateforme convergente

Pour évaluer s'il existe un argument économique valable en faveur d'une plateforme convergente LPLT, nous avons comparé la valeur nette actuelle des coûts et avantages supplémentaires d'une plateforme convergente par rapport à une hypothèse contrefactuelle selon laquelle :

- Le spectre en-dessous de 700 MHz est utilisé exclusivement par le réseau TNT HPHT pour une télédiffusion DVB
- Il existe une coopération commerciale entre les télédiffuseurs et les opérateurs de téléphonie mobile pour développer des services convergents de diffusion-haut débit, où chaque type de fournisseur utilise sa propre infrastructure de réseau existante.

Un grand nombre des avantages d'une plateforme convergente sont aussi capturés par l'hypothèse contrefactuelle (comme évoqué dans la Section S5). Il n'y a donc pas d'avantages supplémentaires. L'avantage supplémentaire principal d'une plateforme convergente LPLT est qu'elle libérerait le spectre en-dessous de 700 MHz pour une utilisation comme liaison descendante mobile à diffusion individuelle. La valeur de cette libération de spectre est actuellement incertaine. Nous avons pris en compte une gamme de valeurs entre 0,1 € et 0,4 € par MHz pop. Dans un État membre hypothétique,

[13] Dans lesquels les régions adjacentes utilisent la même fréquence pour diffuser des contenus différents

avec une population de 20 millions d'habitants et une densité démographique de 250 habitants au kilomètre carré, ces hypothèses donnent une valeur actuelle nette (VAN) des avantages supplémentaires qui se situent entre 265 millions d'euros et 885 millions d'euros. Il pourrait y avoir d'autres avantages supplémentaires créés par l'intégration plus aisée des fonctions de diffusion et de haut débit sur une plateforme convergente. Mais il existe actuellement peu de signes indiquant que ces avantages supplémentaires seraient conséquents.

Une plateforme convergente implique trois principaux coûts supplémentaires :

- Le coût de la construction et de l'exploitation du réseau LPLT (moindre que le coût de l'exploitation du réseau HPHT)
- Le coût transitionnel pour garantir que les utilisateurs finaux peuvent utiliser la nouvelle plateforme, conversion des récepteurs TV (option LTE) et réorientation des antennes télé (pour les deux options)
- Les coûts transitionnels de l'utilisation du spectre de diffusion simultanée et de la gestion des interférences transfrontalières.

Le Schéma S3 montre dans quelles circonstances les avantages supplémentaires sont supérieurs aux coûts supplémentaires.

**Schéma S3 : Dans quels cas les avantages sont-ils supérieurs aux coûts ?**

| Avantages supposés à | Limite inférieure | | Valeur médiane | | Limite supérieure | |
|---|---|---|---|---|---|---|
| Impacts OTT/IPTV | Faibles | Forts | Faibles | Forts | Faibles | Forts |
| Cas central (option LTE) [14] | Non | Non | Non | Oui | Oui | Oui |
| Option DVB plutôt que LTE | Non | Non | Oui | Oui | Oui | Oui |
| Faible charge utile TV (60 Mbps) | Non | Non | Oui | Oui | Oui | Oui |
| Forte charge utile TV (180 Mbps) | Non | Non | Non | Oui | Oui | Oui |
| 10 % de ménages TNT en 2014 | Non | Non | Oui | Oui | Oui | Oui |
| 70 % de ménages TNT en 2014 | Non | Non | Non | Oui | Oui | Oui |

*Remarque : Les cellules aux trames de fond plus foncées indiquent les catégories où les avantages sont supérieurs aux coûts*

Nous voyons que :

- Il n'y a pas d'argument économique en faveur d'une plateforme convergente si les avantages supplémentaires sont relativement bas dans notre gamme d'avantages
- Il y a un bon argument économique en faveur d'une plateforme convergente si les avantages se situent en haut de la gamme probable
- Si les avantages sont à un niveau moyen, alors le cas est ambigu :
  - Si l'OTT/IPTV réduit la demande pour la TNT de 70 % d'ici 2030 (fort impact), il y a alors des avantages supplémentaires nets dans notre État membre hypothétique dans tous les cas.

[14] Dans lequel nous supposons une diffusion LTE, un soutien uniquement pour les postes télé principaux, 40 % de ménages TNT en 2014, une charge utile TV de 120 Mbps

- Mais si l'impact des services OTT/IPTV sur la TNT est faible, avec une réduction de demande pour la TNT de seulement 10 %, alors il n'y aura des avantages nets que dans les États membres où la TNT a actuellement une faible part de marché, ou là où la charge utile TV TNT est faible.

Bien sûr, tous les États membres ne sont pas comme notre État membre hypothétique. Notre analyse de sensibilité indique que l'argument en faveur d'une plateforme convergente est fortement affaibli pour les petits États membres[15] mais sinon est semblable à l'argument qui s'appliquerait à l'État membre hypothétique.

Il y a plusieurs problématiques qualitatives qui doivent aussi être prises en compte lorsque l'on considère l'argument en faveur d'une plateforme convergente :

- Serait-il aisé pour une plateforme convergente LPLT d'être conforme aux limites d'émission RF de l'ICNIRP ? Le fait d'ajouter des nouveaux opérateurs importants à un mât, surtout à des fréquences inférieures à 1 GHz, pourrait considérablement augmenter l'étendue de la zone d'exclusion autour du mât et donc augmenter les coûts de la construction d'une plateforme convergente LPLT dans les zones urbaines
- Est-ce que la fiabilité du réseau (mesurée en termes de disponibilité du réseau) serait suffisamment bonne ? Notre analyse des données limitées disponibles dans le domaine public est peu concluante, même s'il existe des indications anecdotiques qui suggèrent que le réseau LPLT serait moins fiable.
- Est-ce que la transition vers une plateforme convergente LPLT générerait des frais de transmission plus élevés pour les diffuseurs radio qui utiliseraient le réseau HPHT ? C'est possible, mais les effets sont incertains et varieraient d'un État membre à l'autre
- Est-ce que la transition vers un réseau LPLT rendrait le réseau TNT plus flexible ? Notre analyse suggère que ce serait bien le cas :
  - Par rapport au réseau HPHT, un réseau LPLT pourrait évoluer à un coût relativement bas pour s'adapter aux exigences changeantes du marché pour la livraison de contenus TV
  - Une transition vers un réseau LPLT pourrait faciliter la libération du spectre UHF pour les services mobiles en milieu de journée, quand les charges utiles TV sont (parfois) beaucoup plus basses qu'en soirée.

## S9 Conclusions de notre évaluation économique

L'argument économique en faveur d'une plateforme convergente n'est pas encore convaincant. Comme le montre le Schéma S3, les avantages nets pourraient être positifs ou négatifs. S'engager maintenant pour une plateforme convergente LPLT signifierait engager des coûts considérables sans avoir de garantie d'obtenir des avantages nets sur le long terme. De toute façon, il est peu probable qu'il soit possible de mettre en place une plateforme convergente avant 2025. Cela signifie qu'une décision de la part des décideurs politiques n'est pas encore nécessaire, et qu'il y a des avantages à préserver nos options en remettant une telle décision à plus tard.

Le fait que l'argument économique en faveur d'une plateforme convergente soit ambigu reflète deux grandes incertitudes du marché :

[15] Par exemple, pour les États dont la population est inférieure à 2 millions

- Il existe actuellement une grande incertitude concernant la valeur supplémentaire de la libération du spectre en-dessous de 700 MHz pour une utilisation mobile. Nous nous attendons à ce que cette incertitude diminue considérablement au cours des cinq années à venir, au fur et à mesure que la bande des 700 MHz est mise aux enchères
- La mesure dans laquelle l'adoption de services IPTV et OTT pourrait réduire la demande pour des réseaux TNT HPHT. Ici encore, la situation devrait s'éclaircir d'ici 2020.

Il existe aussi plusieurs autres problématiques qui restent ouvertes, sur les émissions RF, la viabilité des réseaux isofréquence sur canal commun, la fiabilité du réseau, la création d'un spectre de diffusion simultanée, et les coûts de la mise à jour des macro-cellules du réseau mobile, ce qui ajoute à cette incertitude du marché.

Cette analyse suggère qu'il faudrait une nouvelle évaluation des avantages d'une plateforme convergente (dans trois à cinq ans, par exemple), à un moment où les incertitudes du marché décrites ci-dessus devraient être considérablement réduites.

## S10 Recommandations

***Recommandation 1** : La Commission et l'industrie devraient réfléchir à la façon de développer et de mettre en place au mieux des mesures globales de consommation vidéo qui soient concordantes dans tous les États membres de l'UE au fil du temps.*

Ce manque de mesures concordantes de consommations de TV linéaire traditionnelle et d'AV non-linéaire doit être corrigé si l'on veut pouvoir prendre d'importantes décisions politiques (et commerciales) sur l'avenir des services AV dans l'UE sur la base d'un raisonnement fiable.

***Recommandation 2** : L'industrie audiovisuelle devrait fournir des conseils appropriés aux programmes de recherche 5G.*

Les programmes de recherche 5G sont actuellement en train d'être lancés, et ils ne s'intéressent pour l'instant que très peu aux capacités de diffusion. Pour combler cette lacune, les programmes de recherche 5G pourraient examiner la viabilité d'une capacité de diffusion dans les réseaux 5G à des coûts supplémentaires bas et/ou des moyens d'intégrer les réseaux de diffusion HPHT existants dans les réseaux 5G hétérogènes[16]

***Recommandation 3** : Les autorités responsables pour le spectre devraient définir un spectre pouvant héberger sur le long terme les services audio PMSE, et s'il faut réserver une partie de la bande UHF pour les PMSE.*

La transition vers une plateforme convergente mènerait à une perte d'accès pour les services audio PMSE à la plupart, ou même la totalité du spectre en-dessous de 700 MHz. Il existe des décisions de la Commission européenne identifiant des spectres dans les bandes 800 MHz et 1 800 MHz qui pourraient offrir une solution à cette perte du spectre des 800 MHz par l'audio PMSE. Il existe aussi des initiatives dans les gammes de 1 à 2 GHz qui sont actuellement envisagées pour compenser la perte du spectre des 700 MHz. Mais il n'y a pour l'instant pas d'accord sur la façon de procéder.

[16] Cela pourrait inclure les réseaux LTE, Wi-Fi et d'autres.

***Recommandation 4** : Les industries de la diffusion et du mobile devraient examiner plus en détail la faisabilité et le coût d'une mise en place de réseaux isofréquence sur canal commun.*

L'argument en faveur d'une plateforme convergente dépend largement de la viabilité de tels réseaux isofréquence. Cependant, des études menées par la BBC et par ATDI (pour Qualcomm) ont donné des résultats très différents en termes de coûts et de couverture. Il faudra résoudre ces différences avant de pouvoir clarifier l'argument en faveur d'une plateforme convergente.

***Recommandation 5** : La Commission européenne devrait lancer une autre évaluation de l'argument en faveur d'une plateforme convergente une fois que les incertitudes de marché identifiées dans la Section S9 auront été réduites de manière conséquente.*

Les incertitudes du marché signifient qu'il n'est pas encore possible de prendre une décision ferme sur une plateforme convergente. Nous nous attendons à ce que ces incertitudes se réduisent considérablement au cours des 3 à 5 années à venir. En particulier, les mises aux enchères du spectre des 700 MHz dans les trois à cinq années à venir nous donneront des informations sur la valeur du spectre en-dessous de 700 MHz et les impacts de la convergence dans un environnement fixe devraient devenir beaucoup plus clairs.

Toute évaluation future devra étudier d'autres options en parallèle de celle qui propose une plateforme convergente. Celles-ci pourraient inclure :

- L'option de flexibilité proposée dans le rapport Lamy. Celle-ci impliquerait la mise en place de liaisons descendantes LTE à diffusion individuelle/à diffusion groupée dans le spectre en-dessous de 700 MHz, tant que celles-ci n'impactent pas sur les réseaux TNT HPHT existants ou leur développement
- Une transition vers un réseau TNT HPHT unique basé sur des réseaux isofréquence de façon à libérer le spectre en-dessous de 700 MHz pour une utilisation pour le mobile
- La clôture complète du réseau TNT, qui serait remplacé par un mélange de diffusion en clair par satellite DTH et par IPTV.

En formulant la Recommandation 5, notre intention n'est pas d'inhiber les évolutions du marché ou technologiques dans les services de convergence de diffusion-haut débit en amont de la réévaluation. Spécifiquement, nous suggérons que le travail sur les Recommandations 1 à 4 et sur la Recommandation 7 soit effectué en amont de toute action liée à la Recommandation 5.

***Recommandation 6** : Ceux qui effectueront une telle réévaluation future devront résoudre certaines incertitudes dans les paramètres de l'ACA et dans les hypothèses techniques.*

Un tel travail pourrait comprendre l'évaluation de la fiabilité d'un réseau LPLT ; les limites des émissions sûres ; la détermination d'un spectre pour la diffusion simultanée ; et les coûts de la mise à jour des macro-sites pour fournir un réseau convergent LPLT.

***Recommandation 7** : Entre la date présente et la prochaine évaluation, les industries de la diffusion et du mobile devraient chercher à développer des façons de travailler ensemble pour produire des services convergents de diffusion-haut débit qui soient viables d'un point de vue commercial et qui produisent de la valeur ajoutée pour les utilisateurs finaux.*

Nos recherches indiquent qu'il n'y a pour l'instant que peu d'activité de ce type, mais qu'il existe des opportunités pour créer des services de diffusion-haut débit mobile qui soient viables d'un point de vue commercial et qui utilisent l'infrastructure existante des diffuseurs et des opérateurs mobiles. Tout développement de tels services changerait l'hypothèse contrefactuelle selon laquelle la plateforme convergente serait réévaluée, et pourrait changer matériellement les conclusions d'une réévaluation future.

Si la réévaluation suggérée à la Recommandation 5 aboutit à la décision de mettre en place une plateforme convergente, un travail supplémentaire sera alors nécessaire. Celui-ci comprendra :

- Le développement de la norme de diffusion LTE
- Une analyse des réglementations nationales gouvernant les plateformes TNT, par exemple, celles qui imposent des restrictions techniques, de couverture et autres sur le spectre UHF et qui imposent aux diffuseurs d'utiliser la plateforme TNT
- Le développement de modèles commerciaux et d'octroi de licences pour envisager qui pourrait gérer un réseau convergent avec quel spectre, et quel rôle pourraient jouer les gouvernements dans l'activation des modèles commerciaux
- Le développement de la gestion du spectre nécessaire et des mesures de coordination des fréquences tels qu'un plan de bande, des mesures pour les organisations déjà en place, et des mesures de coordination de spectre bilatérales/multilatérales.

## S11 Engagement au niveau de l'UE

En partant du principe que la prochaine réévaluation aboutira à la conclusion qu'une plateforme convergente est la meilleure option pour l'utilisation du spectre en-dessous de 700 MHz, alors la Commission devra envisager quel rôle elle, et les autres institutions de l'UE et les autorités compétentes, devraient jouer afin de favoriser la transition vers une plateforme convergente. Pour définir ce rôle, il y a un certain nombre de facteurs qui doivent être pris en compte.

- Un engagement de la totalité de l'UE pour une transition vers une plateforme convergente aurait des avantages considérables en termes de coordination et de libération de spectres, de production de matériel et de fourniture de services à l'échelle européenne
- Les conditions du marché de l'audiovisuel dans les différents États membres sont actuellement très variables. Cette variation signifie qu'une transition à l'échelle européenne établirait probablement des vainqueurs et des perdants parmi les États membres, même si cette transition produisait globalement des avantages nets
- Il n'est pas clair à quel point une transition coordonnée à l'échelle européenne pourrait aider à compléter *le marché unique* dans la consommation de services AV. Un engagement à l'échelle de l'UE permettrait aux citoyens de l'UE d'utiliser leurs appareils portables partout en Europe pour consommer des services AV convergents. Mais il resterait le problème des droits nationaux sur le contenu, et les citoyens se déplaçant dans un autre État-membre pourraient encore se voir interdire le visionnage de contenus créés dans les États membres d'origine à l'aide (par exemple) de services de rattrapage OTT
- Pour l'instant, il n'existe pas d'indications qu'un engagement à l'échelle de l'UE en faveur d'une plateforme convergente placerait l'*UE en position de leader en termes de politique pour l'industrie* à l'échelle mondiale. Pour l'instant, peu de choses indiquent que d'autres régions du monde seraient intéressées par la mise en place d'une plateforme convergente.

# Zusammenfassung

## S1 Der Zweck der Studie

Im Januar 2014 startete die Europäische Kommission eine Studie, in der ein Team von Plum und Farncombe gebeten wurden, drei Hauptangelegenheiten zu untersuchen:

- Die zukünftigen Entwicklungen im Angebot audiovisueller und internetbasierter Dienstleistungen in den kommenden 15 Jahren
- Welchen Einfluss diese Entwicklungen auf die Veränderungen bei terrestrischen Drahtlosnetzwerken und insbesondere auf das digitale terrestrische Fernsehen (“Digital Terrestrial Television“ - DTT) und mobile (Breitband-) Netze haben
- Die Bewertung der sozialen und wirtschaftlichen Vorteile durch die Bewegung hin zu einer konvergenten Plattform Eine konvergente Plattform wird als gemeinsame Infrastruktur (wie Masten und Backhaul) definiert, die terrestrische Rundfunkdienste, mobile Breitbanddienste und konvergente Rundfunk-Breitband-Dienste über ein UHF-Spektrum verbreitet.

## S2 Audiovisueller (AV) Konsum heute

Traditionelles lineares Fernsehen, das über eine Mischung von DTT, Satellit und Kabelnetze gesehen wird, dominiert zurzeit den AV-Konsum. Der durchschnittliche EU-Bürger sieht pro Tag etwa vier Stunden auf diese Weise fern, und es gibt kaum Anzeichen für eine Veränderung. Doch es gibt Trends, die die Situation ändern könnten. Zum Beispiel:

- Rasche Verbreitung von tragbaren Geräten mit guten Voraussetzungen zum Ansehen von Videos, wie Smartphones und Tablet-PCs
- Steigender Konsum von Videoinhalten auf diesen Geräten außerhalb von Zuhause und unterwegs
- Signifikantes Wachstum, wenn auch von einer kleinen Grundlage aus, im nicht linearen Ansehen auf diesen Geräten über Over-the-Top- (OTT) und Catch-Up-Dienste
- Signifikantes Wachstum in der Nutzung von IPTV-Diensten als Ergänzung und Alternative zu traditionellen Rundfunk-Fernsehsendern
- Verlagerung hin zu höher auflösenden Formaten für AV-Inhalt, etwa High Definition (HD) und Ultra High Definition (UHD) für AV-Inhalte

Der AV-Konsum weist bei der Mischung der genutzten Plattformen deutliche Unterschiede zwischen den EU-Mitgliedsstaaten, der Struktur der Inhalte liefernden Wertschöpfungskette und der Veränderungsrate innerhalb des Marktes auf. Zum Beispiel reicht der Anteil der Haushalte, in denen DTT die Hauptplattform ist, von 4 % in Belgien bis zu 80 % in Griechenland.

Es war schwierig, das derzeitige Niveau des nicht-linearen AV-Konsums und die Geschwindigkeit, mit der dieser wächst, zu quantifizieren. Die verfügbaren Informationen messen den Konsum nicht gleichmäßig über verschiedene Geräte und Netzwerke hinweg - diese Daten sind nur in wenigen Mitgliedsstaaten verfügbar und manchmal sind diese auch widersprüchlich. Dieses Fehlen von konsistenten Daten erschwert die Überwachung von Trends und die Unterstützung fundierter politischer Entscheidungen auf AV-Märkten.

## S3 Technologietrends

Der Preis/die Leistung der Netzwerke, die AV-Inhalte an Endkunden liefern - nämlich Rundfunk und Breitband - werden sich in den kommenden zehn Jahren deutlich verändern. Wir erwarten:

- Angesichts historischer Trends und erwarteter zukünftiger Leistungsgewinne große Verbesserungen im Preis/in der Leistung von **festen** Breitbandnetzen im Vergleich zu spektrumbasierten Rundfunknetzen.
- Weitere Einschränkungen in der Rolle von Unicast-**Mobildiensten** relativ zum festen Breitband. Die inkrementellen Kosten pro Gigabyte für mobile Dienste sind ein bis zwei Größenordnungen höher als bei festem Breitband. Es gibt eine klare und wachsende Nachfrage nach personalisierten Unicast-Videoangeboten auf mobilen Geräten. Aber diese Nachfrage wird von den höheren Stückkosten des mobilen Breitbands eingeschränkt.
- Multicast-Mobildienste (zum Beispiel basierend auf dem eMBMS-Standard) könnten ebenfalls als Weg zur Befriedigung der hohen Nachfrage nach dem gleichen Videoinhalt in einer individuellen Zelle oder einem Cluster von Zellen wichtig werden.
- Ein deutliches Wachstum in der Kapazität, Geschwindigkeit und Reichweite von WLAN-Diensten, sowohl zu Hause als auch in öffentlichen Hotspots. WLAN-Router als neue Technologie ersetzen alte Router in der installierten Basis.

## S4 AV-Konsum im Jahr 2030

Angesichts dieser Technologietrends erwarten wir:

- Dass festes Breitband bis 2030 eine zentrale Rolle in der Lieferung von Fernsehinhalten spielt Dass festes Breitband traditionelle Rundfunk-Fernsehsender[17] **ergänzt** und traditionelle Plattformen **ersetzt**
- WLAN eine immer stärkere Rolle in der rasch wachsenden Population von Tablet-PCs und Smartphones spielt - und das sowohl zu Hause als auch unterwegs Zum Beispiel hat WLAN das Potenzial, in vielen Situationen als günstiger Ersatz für mobile Unicast-Videos zu fungieren - zu Hause und unterwegs.

Jedoch gibt es große Unsicherheit darüber, wie sich der AV-Konsum bis 2030 verändern könnte. Zum Beispiel gehen die Meinungen der Interessenvertreter in einigen Punkten auseinander:

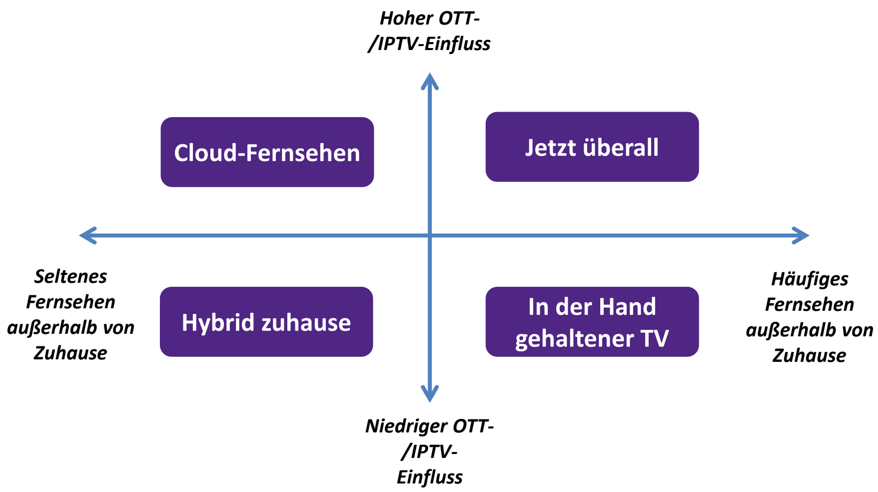
- Wie schnell und inwieweit Verbraucher von linearem zu On-Demand-Sehen wechseln
- Ob DTT seine derzeitige Position behält oder im Durchschnittshaushalt von reinen OTT-Diensten oder IPTV-Diensten weitestgehend verdrängt wird
- Inwieweit Tablet-PCs traditionelle Fernsehgeräte als Zweitbildschirme zu Hause ersetzen

[17] Dass Hybriddienste mit gemischtem linearem und nicht linearem Fernsehkonsum angeboten werden

- Wie sich die Balance zwischen dem Sehen zu Hause und außerhalb des Heims in den kommenden zehn Jahren verändern wird

Für diese Unsicherheiten haben wir die vier in Abbildung S1 gezeigten Szenarien entwickelt, die die möglichen Zustände des AV-Konsums in einem typischen Mitgliedsstaat im Jahr 2030 zeigen. Wir berücksichtigen in jedem dieser Szenarien die Vorteile einer konvergenten Plattform.

Abbildung S1: Szenarien für den AV-Konsum im Jahr 2030[18]




## S5 Die Entwicklung von konvergenten Rundfunk-Breitband-Diensten

Neben Ersetzungseffekten führt die wachsende Rolle des Breitbands im AV-Konsum auch zu Konvergenzeffekten, in denen sich ergänzende Kombinationen aus Rundfunk- und Breitbanddiensten neue Möglichkeiten für Dienstleistungen mit zusätzlichem Mehrwert schaffen. Wir haben vier Typen der Rundfunk-Breitband-Konvergenz ausgemacht:

- Inhaltskonvergenz auf Geräteniveau, wodurch Nutzer Rundfunk- und Breitband-AV-Inhalte auf demselben Gerät ansehen können
- Anwendungskonvergenz auf Geräteniveau, wodurch Nutzer Rundfunk- und Breitband-AV-Inhalte auf demselben Gerät und über dieselbe Benutzeroberfläche ansehen können
- Konvergenz auf Dienstleistungsebene, wodurch Nutzer nahtlos über verschiedene Geräte auf linearen und nicht linearen AV-Inhalt zugreifen können
- Konvergenz auf Infrastrukturebene, wo die selbe Infrastruktur für die Lieferung von Rundfunk- und Breitbanddiensten an die Endnutzer verwendet wird

Konvergenzaktivitäten konzentrieren sich zurzeit auf die Kombination von Rundfunk und **festem** Breitband durch die Entwicklung von verbundenen Fernsehgeräten und Hybriddiensten wie HbbTV-

[18] Hoher OTT/IPTV-Einfluss – 70 % Rückgang bei DTT-HH bis 2030; Niedriger OTT/IPTV-Einfluss – 10 % Rückgang bei DTT-HH bis 2030; Hohes OOH-Ansehen – 40 Minuten OOH-Ansehen auf tragbaren Geräten pro Tag und Person; Niedriges OOH-Ansehen – 20 Minuten OOH-Ansehen auf tragbaren Geräten pro Tag und Person

basierten Diensten. Aber was ist das Potenzial der Erweiterung solcher Konvergenzen auf Kombinationen von mobilem Breitband und Rundfunkplattformen?

Auf Inhalts-, Anwendungs- oder Dienstleistungsebene wird eine solche Konvergenz wahrscheinlich aufgrund normaler Marktmechanismen entweder erfolgreich sein oder fehlschlagen. Doch angesichts der derzeitigen gesetzlichen Einschränkungen erfordert die Konvergenz auf Infrastrukturebene Interventionen durch die Politik.[19] Bevor also solche Initiativen gestartet werden, müssen die wirtschaftlichen und sozialen Vorteile einer konvergenten Plattform ermittelt werden. Bei dieser Bewertung müssen wir berücksichtigen, dass Konvergenz auf Geräte- und Dienstleistungsebene ohne eine konvergente Plattform möglich ist und dass ein signifikanter Anteil der Vorteile von konvergenten Diensten ohne die Einrichtung einer konvergenten Plattform erreicht werden kann.

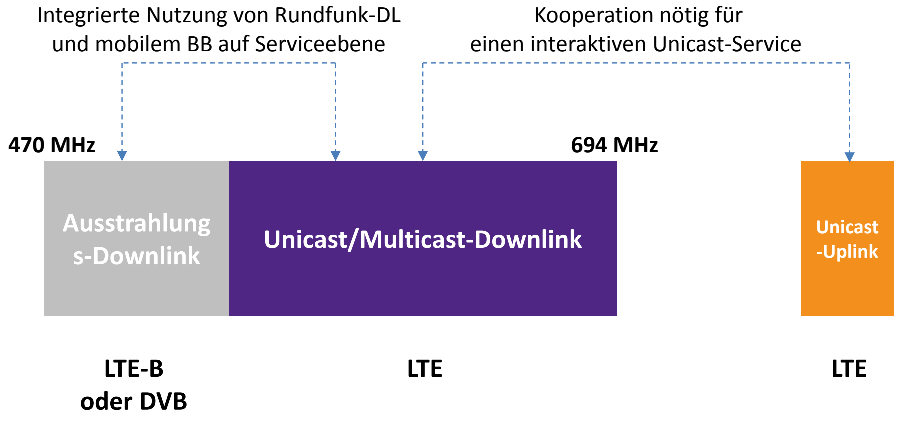
## S6 Optionen für eine konvergente Plattform

Jede Option für eine konvergente Plattform muss mehrere Anforderungen erfüllen:

- Fast universelle, frei empfangbare Abdeckung, um das derzeitige europäische AV-Modell zu erhalten
- Nutzung des UHF-Spektrums unter 700 MHz, wenn diese Anforderung kostengünstig erfüllt werden soll
- Angebot einer ausreichenden Zahl an Fernsehsendern Die Auslastung durch das Fernsehen variiert je nach Mitgliedsstaat. Wir haben mit Auslastungen von 60 bis 180 Mbit/s gerechnet
- Mobile Zwei-Wege-Breitbanddienste
- Freistellung eines nicht unerheblichen Bereichs des Spektrums unter 700 MHz, damit inkrementelle Vorteile geschaffen werden, die die Kosten der Umstellung rechtfertigen könnten.

Nach der Betrachtung einiger Optionen haben wir zwei für die genauere Untersuchung ausgewählt. Beide umfassen die Umstellung von der bestehenden “high-power high-tower“ (HPHT) DTT-Plattform zur “low-power low-tower“ (LPLT) Infrastruktur der mobilen Netzwerke. Abbildung S2 zeigt, wie das Spektrum verwendet werden kann.

**Abbildung S2: Die LTE- und DVB-Optionen für eine konvergente LPLT-Plattform**




[19] Ein Beispiel dafür ist die Nutzung der für DTT-Plattformen relevanten Spektren und Regeln.

Beide Optionen umfassen die Teilung des Spektrums zwischen 470 und 694 MHz in zwei Downlinks:

- Einen Rundfunk-Downlink. Dieser könnte die bestehenden DVB-Standards (die DVB-Option) oder einen neuen LTE-Rundfunkstandard (die LTE-Option)[20] für linearen Fernsehrundfunk nutzen
- Ein Unicast-Downlink unter Verwendung von LTE-Standards.

Der Unicast-Uplink, der für die Ergänzung dieser Downlinks nötig ist, könnte das Spektrum am oberen Ende des Bereichs unter 700 MHz oder höhere Frequenzen verwenden (z. B. im 900 MHz-Frequenzbereich), je nach den Geschäftsmodellen, die für die Lizenzierung und Verwendung der konvergenten Plattform entwickelt werden.

Die DVB-Option hat zwei Hauptvorteile gegenüber der LTE-Rundfunk-Option:

- Es entstehen keine Kosten für das Upgrade von Fernsehreceivern
- DVB bietet eine potenziell höhere Spektrumseffizienz (mehr als 3,5 Bit/s/Hz im Vergleich zu mehr als 2 Bit/s/Hz bei LTE). Dies erleichtert die Migration und erhöht das nutzbare Spektrum

Die LTE-Rundfunk-Option hat drei Hauptvorteile gegenüber der DVB-Option:

- Eine einzelne Technologie bedeutet niedrigere Kosten für Netzwerke und Endnutzer-Ausrüstung
- Eine einzelne Technologie bedeutet, dass weniger Verarbeitungskapazität für die Rundfunk-Breitband-Integration von Diensten erforderlich ist
- Es könnte einfacher sein, Spektrumsbereiche unter der Rundfunk- und Breitbandnutzung umzuverteilen, wenn sich die Nachfrage auf dem Markt ändert.

## S7 Übergang zu einer konvergenten LPLT-Plattform

Es gibt mehrere Herausforderungen beim Übergang zu einer konvergenten LPLT-Plattform:

- In vielen Mitgliedsstaaten ist die Umsetzung einer konvergenten Plattform vor 2025 wahrscheinlich nicht durchführbar:
  - Das 700 MHz-Band muss für die mobile Nutzung freigegeben werden
  - Das HPHT-Netz muss in zahlreichen Mitgliedsstaaten von der DVB-T zur DVB-T2-Technologie migriert werden
  - Es muss ein dauerhaftes Spektrum für die PMSE-Audio-Verwendung gefunden werden, bevor eine konvergente Plattform umgesetzt werden kann
- Es muss ermittelt werden, ob regionale Zweikanal-SFNs[21] in einem LPLT-Netz zufriedenstellend arbeiten
- In der Übergangsphase ist das Simulcast-Spektrum erforderlich, sodass das (alte) HPHT DTT-Netz und das neue LPLT-Netz parallel ausstrahlen können. In einem Mitgliedsstaat mit hohem Fernsehaufkommen könnte es unmöglich sein, das erforderliche Simulcast-Spektrum zu finden, ohne die Fernsehausstrahlung vorübergehend deutlich zu reduzieren

[20] 3GPP müsste die bestehenden LTE-Standards entwickeln, um durch längeres Cycling-Prefix die Rundfunkabdeckung in ländlichen Gebieten zu ermöglichen; Trägerfrequenzen werden ausschließlich für einen Downlink und einen für alle kostenlosen Empfang verwendet

[21] Benachbarte Regionen nutzen möglicherweise die gleiche Frequenz für die Ausstrahlung verschiedener Inhalte

- Außerdem sind weitreichende Maßnahmen erforderlich, um grenzübergreifende Interferenzen abzumildern - insbesondere in Mitgliedsstaaten, die zunächst eine konvergente Plattform einsetzen.

Wir haben in unserer Kosten-Nutzen-Analyse angenommen, dass regionale Zweikanal-SFNs in einem LPLT-Netz funktionsfähig sind und dass die spektrale Effizienz von 2 Bit/s/Hz (LTE-Option) bis 3,5 Bit/s/Hz (DVB-Option) reicht. Unter diesen Annahmen könnte die konvergente Plattform 110 bis 170 MHz im Frequenzbereich von 470 bis 694 MHz freigeben.

## S8 Die Kosten und Vorteile einer konvergenten Plattform

Um zu ermitteln, ob es einen wirtschaftlichen Bedarf nach einer konvergenten LPLT-Plattform gibt, haben wir den derzeitigen Nettowert der inkrementellen Kosten und die Vorteile einer konvergenten Plattform mit einer kontrafaktischen Annahme verglichen, in der:

- Das Spektrum unter 700 MHz ausschließlich vom HPHT DTT-Netz für die DVB-Fernsehausstrahlung verwendet wird
- Es wirtschaftliche Zusammenarbeit zwischen Fernsehsendern und mobilen Betreibern für die Entwicklung konvergenter Rundfunk-Breitband-Dienste gibt, wobei jeder Anbieter seine eigene bestehende Netz-Infrastruktur nutzt

Viele Vorteile einer konvergenten Plattform werden auch durch die kontrafaktische Annahme erfasst (wie beschrieben in Abschnitt S5). Somit handelt es sich dabei nicht um inkrementelle Vorteile. Der inkrementelle Hauptvorteil einer konvergenten LPLT-Plattform ist, dass sie das Spektrum unter 700 MHz freigibt und dessen Nutzung als mobilen Unicast-Downlink ermöglicht. Der Wert dieser Spektrumsfreigabe ist zurzeit unklar. Wir betrachten Werte zwischen 0,1 € und 0,4 € pro MHz/pop. In einem hypothetischen Mitgliedsstaat mit einer Bevölkerung von 20 Millionen und einer Bevölkerungsdichte von 250 Einwohnern pro Quadratkilometer führen diese Annahmen zu einem Kapitalwert zwischen 265 Mio. € und 885 Mio. €. Es könnte weitere inkrementelle Vorteile durch die einfachere Integration von Breitband und Breitbandfunktionen auf einer konvergenten Plattform geben. Bisher gibt es jedoch nur wenige Beweise, dass diese zusätzlichen Vorteile bedeutsam sind.

Bei einer konvergenten Plattform entstehen hauptsächlich drei inkrementelle Kosten:

- Die Kosten des Aufbaus und Betriebs des LPLT-Netzes (abzüglich der Kosten für den Betrieb des HPHT-Netzes)
- Die Übergangskosten bei der Sicherstellung, dass Endnutzer die neue Plattform verwenden können - Umwandlung von TV-Receivern (LTE-Option) und Neuausrichtung von TV-Antennen (beide Optionen)
- Die Übergangskosten bei der Freigabe von Simulcast-Spektrum und der Umgang mit grenzübergreifenden Interferenzen

Abbildung S3 zeigt, unter welchen Umständen die inkrementellen Vorteile die inkrementellen Kosten übersteigen.

**Abbildung S3: Wo übersteigen die Vorteile die Kosten?**

| Vorteile angenommen bei | Untere Grenze | | Mittelwert | | Obere Grenze | |
|---|---|---|---|---|---|---|
| OTT-/IPTV-Einfluss | Niedrig | Hoch | Niedrig | Hoch | Niedrig | Hoch |
| Zentraler Fall (LTE-Option) [22] | Nein | Nein | Nein | Ja | Ja | Ja |
| DVB-Option anstatt der LTE-Option | Nein | Nein | Ja | Ja | Ja | Ja |
| Niedriges Fernsehaufkommen (60 Mbit/s) | Nein | Nein | Ja | Ja | Ja | Ja |
| Hohes Fernsehaufkommen (180 Mbit/s) | Nein | Nein | Nein | Ja | Ja | Ja |
| 10 % DTT-HH im Jahr 2014 | Nein | Nein | Ja | Ja | Ja | Ja |
| 70 % DTT-HH im Jahr 2014 | Nein | Nein | Nein | Ja | Ja | Ja |

*Hinweis: Dunkler gefärbte Felder zeigen an, wo die Vorteile die Kosten übersteigen*

Wir sehen, dass:

- Es keine wirtschaftliche Notwendigkeit für eine konvergente Plattform gibt, wenn die inkrementellen Vorteile am unteren Ende unserer Vorteilsspanne liegen
- Es eine gute wirtschaftliche Notwendigkeit für eine konvergente Plattform gibt, wenn die Vorteile am oberen Ende der wahrscheinlichen Spanne liegen
- Wenn die Vorteile im mittleren Wert liegen, ist der Fall unklar:
  - Wenn OTT/IPTV bis 2030 die Nachfrage nach DTT um 70 % senkt (hoher Einfluss), gibt es in allen Fällen in unserem hypothetischen Mitgliedsstaat inkrementelle Nettovorteile.
  - Aber wenn der Einfluss von OTT/IPTV-Diensten auf DTT niedrig ist (nur eine Senkung um 10 % bei der DTT-Nachfrage), gibt es nur in den Mitgliedsstaaten Nettovorteile, in denen DTT zurzeit einen niedrigen Marktanteil hat oder wo das DTT-Fernsehaufkommen gering ist.

Natürlich sind nicht alle Mitgliedsstaaten mit unserem hypothetischen Beispiel identisch. Unsere Sensitivitätsanalyse zeigt, dass sich die Notwendigkeit einer konvergenten Plattform in kleinen Mitgliedsstaaten deutlich abschwächt[23], aber sonst ähnlich der des hypothetischen Mitgliedsstaats ist.

Es gibt einige qualitative Probleme, die bei der Ermittlung der Notwendigkeit einer konvergenten Plattform ebenfalls berücksichtigt werden müssen:

- Wie leicht könnte eine konvergente LPLT-Plattform die RF-Emissionsgrenzen der ICNIRP erfüllen? Die Hinzufügung von neuen Trägern zu einem Mast, insbesondere in Frequenzen unter einem 1 GHz, könnte die Sperrzone um den Mast deutlich vergrößern und so die Kosten für den Bau einer konvergenten LPLT-Plattform in städtischen Gebieten deutlich erhöhen
- Wäre die Zuverlässigkeit des Netzes (gemessen an der Betriebszeit des Netzwerks) gut genug? Unsere Analyse der begrenzten, öffentlich verfügbaren Informationen ist nicht beweiskräftig, auch wenn es einzelne Beweise dafür gibt, dass das LPLT-Netz weniger zuverlässig sein könnte

[22] Die Annahme ist LTE-Ausstrahlung, nur Unterstützung für Haupt-Fernsehgeräte, 40 % DTT-Haushalte im Jahr 2014 und 120 Mbit/s Fernsehaufkommen

[23] Zum Beispiel in Staaten mit einer Bevölkerung von weniger als 2 Millionen Menschen

- Würde der Wechsel zu einer konvergenten LPLT-Plattform zu höheren Übertragungsgebühren für Radiosender, die das HPHT-Netz nutzen, führen? Dies ist möglich, aber die Effekte sind unsicher und würden je nach Mitgliedsstaat unterschiedlich ausfallen
- Würde der Wechsel zu einem LPLT-Netz das DTT-Netz flexibler machen? Unsere Analyse weist darauf hin, dass dies der Fall wäre:
  - Im Vergleich zu einem HPHT-Netz könnte ein LPLT-Netz zu relativ geringen Kosten so umgeändert werden, dass es sich den veränderlichen Marktanforderungen hinsichtlich der Bereitstellung von Fernsehinhalten anpasst
  - Der Wechsel zu einem LPLT-Netz könnte es einfacher machen, tagsüber - da das Fernsehaufkommen (manchmal) deutlich niedriger ist als abends - UHF-Spektrum für mobile Dienste freizugeben.

## S9 Schlussfolgerungen unserer wirtschaftlichen Bewertung

Die wirtschaftliche Notwendigkeit für eine konvergente Plattform besteht noch nicht. Wie Abbildung S3 zeigt, können die Nettovorteile positiv oder negativ sein. Der jetzige Wechsel zu einer konvergenten LPLT-Plattform würde nicht unerhebliche Kosten ohne Garantie von langfristigen Nettovorteilen bedeuten. In jedem Fall ist es unwahrscheinlich, dass eine konvergente Plattform vor 2025 umgesetzt werden kann. Das bedeutet, dass eine politische Entscheidung noch nicht notwendig und es sinnvoll ist, sich durch die Vertagung einer Entscheidung die Optionen offen zu halten.

Die Tatsache, dass die wirtschaftliche Notwendigkeit einer konvergenten Plattform unklar ist, spiegelt zwei große Unsicherheiten auf dem Markt wider:

- Es besteht zurzeit große Unsicherheit über den inkrementellen Wert der Freigabe des Spektrums unter 700 MHz für die mobile Nutzung. Wir erwarten, dass diese Unsicherheit in den kommenden fünf Jahren, wenn das 700 MHz-Band versteigert wird, deutlich abnimmt
- Der Umfang, in dem die Nutzung von IPTV- und OTT-Diensten die Nachfrage nach HPHT DTT-Netzen reduzieren könnte. Auch hier sollte die Position bis 2020 klarer sein.

Außerdem gibt es noch weitere, ungelöste Probleme - bei RF-Emissionen, der Machbarkeit von Zweikanal-SFNs, der Zuverlässigkeit der Netzwerke, der Schaffung eines Simulcast-Spektrums und den Kosten für das Upgrade der Makrozellen eines mobilen Netzes - die zu dieser Marktunsicherheit beitragen.

Diese Analyse zeigt, dass die Vorteile einer konvergenten Plattform nochmals geprüft werden müssen (vielleicht in drei bis fünf Jahren), wenn die oben aufgeführten Marktunsicherheiten deutlich reduziert worden sein sollten.

## S10 Empfehlungen

***Empfehlung 1**: Die Kommission und die Industrie müssen ermitteln, wie umfassende Messungen des Videokonsums, die im Laufe der Zeit in allen EU-Mitgliedsstaaten vereinheitlicht werden, am besten entwickelt und umgesetzt werden können.*

Der Mangel an konsistenten Messungen von traditionellem linearem Fernsehen und nicht-linearem AV-Konsum muss behoben werden, wenn wichtige politische (und kommerzielle) Entscheidungen über die Zukunft von AV-Diensten in der EU eine solide Basis haben sollen.

***Empfehlung 2****: Die Rundfunkgemeinschaft muss relevante Beratung für 5G-Forschungsprojekte anbieten.*

5G-Forschungsprogramme beginnen jetzt und die Konzentration auf Rundfunkpotentiale ist bisher noch sehr gering. Um diese Lücke zu füllen, könnten in 5G-Forschungsprogrammen die Machbarkeit einer Rundfunkmöglichkeit in 5G-Netzen zu niedrigen inkrementellen Kosten und/oder Wege für die Integration bestehender HPHT-Rundfunknetze in heterogene 5G-Netze untersucht werden.[24]

***Empfehlung 3****: Die zuständigen Spektrumsbehörden müssen ein langfristig nutzbares Spektrum für PMSE-Audiodienste festlegen und entscheiden, ob ein Teil des UHF-Bands für PMSE reserviert werden soll.*

Der Wechsel zu einer konvergenten Plattform würde für PMSE-Audiodienste den Verlust des Zugangs zum größten Teil oder vielleicht sogar dem gesamten Spektrum unter 700 MHz bedeuten. Es gibt Entscheidungen der Europäischen Kommission, die Spektren in den 800 MHz- und 1.800 MHz-Bändern für den Ausgleich des Verlusts des 800 MHz-Spektrums für PMSE-Audio identifizieren. Weiterhin gibt es Überlegungen zu Initiativen in der Spanne von 1 bis 2 GHz zur Kompensation des Verlusts des 700 MHz-Spektrums. Es wurde jedoch noch keine Entscheidung über das weitere Vorgehen getroffen.

***Empfehlung 4****: Die Rundfunk- und mobile Gemeinschaft muss weiterhin die Machbarkeit und die Kosten der Umsetzung von Zweikanal-SFNs untersuchen.*

Die Notwendigkeit einer konvergenten Plattform ist sehr stark von der Machbarkeit solcher SFNs abhängig. Studien von BBC und ATDI (für Qualcomm) kommen bei den Kosten und der Abdeckung zu sehr unterschiedlichen Ergebnissen. Diese Unterschiede müssen aufgelöst werden, bevor die Notwendigkeit einer konvergenten Plattform eindeutig wird.

***Empfehlung 5****: Die Europäische Kommission muss eine weitere Prüfung der Notwendigkeit einer konvergenten Plattform einleiten, sobald die in Abschnitt S9 genannten Marktunsicherheiten deutlich reduziert wurden.*

Marktunsicherheiten bedeuten, dass es noch nicht möglich ist, eine endgültige Entscheidung über eine konvergente Plattform zu treffen. Wir erwarten, dass diese Unsicherheiten in den kommenden drei bis fünf Jahren deutlich reduziert werden. Insbesondere die 700 MHz-Auktionen in den nächsten drei bis fünf Jahren geben Informationen über den Wert des Spektrums unter 700 MHz, und auch der Einfluss der Konvergenz in einer festgelegten Umgebung dürfte viel klarer sein.

Alle zukünftigen Prüfungen müssen andere Optionen und die konvergente Plattform bewerten. Dies könnte folgendes umfassen:

- Die im Lamy-Bericht vorgeschlagene Flexibilitätsoption. Dies würde die Umsetzung von Unicast-/Multicast-LTE-Downlinks im Spektrum unter 700 MHz beinhalten, vorausgesetzt, dass dies die bestehenden HPHT DTT-Netze oder deren Entwicklung nicht beeinflusst

[24] Dies kann LTE, WLAN und andere Netze umfassen

- Die Hinwendung zu einem einzelnen HPHT DTT-Netz basierend auf SFNs zur Freigabe des Spektrums unter 700 MHz für die mobile Nutzung
- Völlige Schließung des DTT-Netzes, welches durch eine Mischung aus kostenloser Satelliten-DTH- und IPTV-Ausstrahlung ersetzt wird

Mit der Empfehlung Nummer 5 möchten wir keine Markt- oder Technologieentwicklungen in der Rundfunk-Breitband-Konvergenz hemmen, bevor diese überprüft wurden. Insbesondere schlagen wir vor, dass die Arbeit an den Empfehlungen 1 bis 4 und der Empfehlung 7 vor in Zusammenhang mit Empfehlung 5 stehenden Maßnahmen stattfindet.

***Empfehlung 6****: Die Personen, die mit einer solchen zukünftigen Bewertung betraut sind, müssen Unsicherheiten bei den CBA-Parametern und technische Annahmen auflösen.*

Diese Arbeit könnte die Bewertung der Zuverlässigkeit eines LPLT-Netzes, sichere Emissionsgrenzen und die Ermittlung eines Spektrums für die Simultanübertragung und der Kosten für das Upgrade von Makro-Standorten für ein konvergentes LPLT-Netz umfassen.

***Empfehlung 7****: Zwischen dem aktuellen Zeitpunkt und der nächsten Bewertung müssen die Rundfunk- und mobilen Gemeinschaften Wege zur Zusammenarbeit finden, sodass innovative, konvergente Rundfunk-Breitband-Dienstleistungen entwickelt werden können, die wirtschaftlich lebensfähig sind und den Endnutzern einen Zusatzwert bieten.*

Unsere Forschungsarbeit ergab, dass es bis jetzt zwar nur sehr wenige Aktivitäten dieser Art gibt, aber dass Möglichkeiten für wirtschaftlich lebensfähige Dienste in Rundfunk und mobilem Breitband bestehen, die die existierende Infrastruktur der Rundfunkanstalten und mobilen Anbieter nutzen. Jegliche Entwicklung solcher Dienste würde die kontrafaktische Annahme, gegen die eine konvergente Plattform in der Zukunft bewertet wird, verändern und die Ergebnisse einer zukünftigen Bewertung wesentlich beeinflussen.

Wenn die in Empfehlung 5 vorgeschlagene Bewertung zu der Entscheidung führt, eine konvergente Plattform einzurichten, wäre zukünftige Arbeit erforderlich. Diese umfasst:

- Die Entwicklung eines LTE-Rundfunk-Standards
- Eine Prüfung der nationalen Gesetze zur Regelung von DTT-Plattformen - zum Beispiel der Gesetze, die dem UHF-Spektrum unter anderem technische Einschränkungen und Einschränkungen bei der Abdeckung auferlegen und Rundfunkanstalten zwingen, die DTT-Plattform zu verwenden
- Die Entwicklung von kommerziellen und Lizenzierungsmodellen für die Überlegung, wer ein konvergentes Netz mit welchem Spektrum betreibt und welche Rolle Regierungen bei der Umsetzung von kommerziellen Modellen spielen könnten
- Die Entwicklung der notwendigen Maßnahmen zum Spektrumsmanagement und der Frequenzkoordination, wie zum Beispiel einen Frequenzplan, Vereinbarungen für Marktteilnehmer und bilaterale/multilaterale Spektrumskoordination.

## S11 Beteiligung auf EU-Niveau

Ausgehend von der Annahme, dass die nächste Bewertung zu dem Schluss kommt, dass eine konvergente Plattform die beste Option für die Nutzung des Spektrums unter 700 MHz ist, dann müsste die Kommission ermitteln, welche Rolle sie selbst, andere Institutionen auf EU-Niveau und andere relevante Stellen in der Erleichterung des Übergangs zu einer konvergenten Plattform spielen müssen. Bei der Definition dieser Rolle gibt es einige Faktoren, die berücksichtigt werden müssen.

- Ein EU-weites Engagement für den Wechsel zu einer konvergenten Plattform würde bedeutende Vorteile in Bezug auf die Spektrumskoordination und -freigabe, die Produktion von Ausrüstung und die EU-weite Dienstleistungsbereitstellung nach sich ziehen.
- Zurzeit besteht zwischen den verschiedenen Mitgliedsstaaten eine hohe Variabilität in den Bedingungen auf dem audiovisuellen Markt. Solche Variationen bedeuten, dass ein EU-weiter Wechsel zu einer konvergenten Plattform unter den Mitgliedsstaaten wahrscheinlich Sieger und Verlierer schafft, auch wenn insgesamt Nettovorteile entstehen.
- Es ist nicht klar, inwieweit ein koordinierter EU-weiter Wechsel zu einer konvergenten Plattform dazu beiträgt, den *Binnenmarkt* für den Konsum von AV-Diensten zu schaffen. Ein EU-weites Engagement würde EU-Bürgern ermöglichen, mobile Geräte in der gesamten EU für den Konsum von konvergenten AV-Diensten zu nutzen. Aber das Problem von nationalen Rechten am Inhalt würde bestehen bleiben, und Bürgern, die sich in anderen Mitgliedsstaaten aufhalten, könnte es weiterhin verboten sein, Inhalt aus dem Heimatstaat über (zum Beispiel) OTT-Catch-Up-Dienste anzusehen.
- Noch gibt es keine Beweise, dass ein EU-weites Engagement für eine konvergente Plattform der *EU industriepolitische Führung* auf globaler Basis verleiht. Auch gibt es noch sehr wenige Nachweise dafür, dass andere Regionen der Welt an der Umsetzung einer konvergenten Plattform interessiert wären.

# Abbreviations

The table below lists the abbreviations used in this report.

| Abbreviation | The full term |
|---|---|
| 3G | Third Generation |
| 3GPP | Third Generation Partnership Project |
| ABR | Adaptive Bitrate |
| ATSC | Advanced Television Systems Committee |
| AV | Audio-visual |
| BARB | Broadcasters Audience Research Board |
| CBA | Cost-Benefit Analysis |
| CDN | Content Distribution Network |
| CENELEC | European Committee for Electro-technical Standardization |
| CEPT | European Conference of Postal and Telecommunications Administrations |
| CMBB | China Mobile Multimedia Broadcasting |
| DAB | Digital Audio Broadcasting |
| DAE | Digital Agenda for Europe |
| DASH | Dynamic Adaptive Streaming over HTTP |
| DCF | Discounted Cash Flow |
| S/T-DMB | Satellite/Terrestrial Digital Multimedia Broadcasting |
| DL | Down-link |
| DOCSIS | Data Over Cable Service Interface Specification |
| DRM | Digital Rights Management |
| xDSL | Asymmetric/Symmetric/Very-high bit rate Digital Subscriber Line |
| DTH | Direct-to-Home |
| DTT | Digital Terrestrial Television |
| DTV | Digital Television |
| DVB-H | Digital Video Broadcasting - Handheld |
| DVB-NGH | Digital Video Broadcasting – Next Generation Handheld |
| DVB-T/S/C | Digital Video Broadcasting – Terrestrial/Satellite/Cable |
| DVB-T/S/C2 | Digital Video Broadcasting - 2nd Generation Terrestrial/Satellite/Cable |
| DVD | Digital Video Disc |
| EC | European Commission |
| ECC | Electronic Communications Committee |
| EDGE | Enhanced Data rates for GSM Evolution |
| eMBMS | evolved Multimedia Broadcast and Multicast Services |
| EPG | Electronic Programme Guide |
| ETSI | European Telecommunications Standards Institute |
| EU | European Union |

| Abbreviation | The full term |
|---|---|
| FDD | Frequency Division Duplex |
| FFT | Fast Fourier Transform |
| FoBTV | Future of Broadcast Television Initiative |
| FTA | Free-to-Air |
| FTTx | Fibre-to-the-(Building/Cabinet/Home/Premise) |
| FWA | Fixed Wireless Access |
| GDP | Gross Domestic Product |
| GE-06 | Geneva 2006 Agreement |
| GSM | Global System for Mobile communications |
| HbbTV | Hybrid Broadcast Broadband TV |
| HD | High Definition |
| HDTV | High Definition Television |
| HEVC | High Efficiency Video Coding |
| HF | High Frequency band |
| HPHT | High-power high-tower |
| HSPA | High Speed Packet data Access |
| HTTP | Hypertext Transfer Protocol |
| ICNIRP | International Commission on Non Ionising Radiation Protection |
| IEM | In-ear monitoring |
| IMT | International Mobile Telecommunications |
| IPTV | Internet Protocol Television |
| ISD | Inter-site distance |
| ISDB | Integrated Services Digital Broadcasting |
| ITU | International Telecommunication Union |
| ITU-R | ITU Radiocommunications Sector |
| LF | Low Frequency band |
| LPLT | Low-power low-tower |
| LTE | Long Term Evolution (A Third Generation Partnership Project) |
| LTE-A | Long Term Evolution-Advanced |
| MBB | Mobile broadband |
| MBSFN | Multicast Broadcast over Single Frequency Network |
| MF | Medium Frequency band |
| MFN | Multiple Frequency Network |
| MHEG | Multimedia Hypertext Experts Group |
| MHP | Multimedia Home Platform |
| MIMO | Multiple-Input Multiple-Output |
| MNO | Mobile Network Operator |
| MPEG | Moving Picture Experts Group |

| Abbreviation | The full term |
|---|---|
| MPEG-DASH | MPEG-Dynamic Adaptive Streaming over HTT |
| NPV | Net Present Value |
| OFDM | Orthogonal Frequency Division Multiplex |
| OTT | Over-the-top |
| PMSE | Program Making and Special Events |
| PPDR | Public Protection and Disaster Relief |
| PSB | Public Service Broadcasting/Broadcasters |
| PVR | Personal Video Recorder |
| QAM | Quadrature amplitude modulation |
| RAS | Radio astronomy service |
| RSPG | Radio Spectrum Policy Group |
| RSPP | Radio Spectrum Policy Programme |
| SD | Standard Definition |
| SDL | Supplemental Down Links |
| SDTV | Standard Definition Television |
| SFN | Single Frequency Network |
| SI | Service Information |
| SMS | Short Message Service |
| TCP | Transmission Control Protocol (IP) |
| TDD | Time Division Duplex |
| TG6 | Task Group 6 |
| UE | User equipment |
| UGC | User-Generated Content |
| UHD | Ultra-High Definition |
| UHF | Ultra High Frequency |
| UHDTV | Ultra High Definition Television |
| UMTS | Universal Mobile Telecommunications System |
| UTRAN | Universal Terrestrial Radio Access Network |
| VHF | Very High Frequency |
| VoD | Video on demand |
| WCDMA | Wideband Code Division Multiple Access |
| WRC | World Radiocommunications Conference |

# 1 Study objectives and approach

## 1.1 The study objectives

In January 2014 the European Commission asked Plum and Farncombe to carry out a study to explore opportunities for broadcast-broadband convergence and its possible impact on the use of sub-1 GHz spectrum. This report presents our findings.

The overall objectives of the study are:

- To explore likely future developments in the delivery of audio-visual (AV) services over the next 15 years
- To see how these developments impact on the evolution of terrestrial networks with a focus on DTT and mobile networks
- To assess the merits of a converged platform that uses UHF spectrum to deliver both terrestrial broadcasting and mobile broadband services over a common infrastructure.

This study should be seen in the context of a series of parallel EU-level initiatives[25] to develop a long-term strategy for use of UHF spectrum in the EU, and in particular the Lamy report[26]. The Lamy report is based on work by a high-level group of senior executives from the mobile and broadcast sectors under the chairmanship of Pascal Lamy. The high-level group was set up at the end of 2013 to consider future use of the UHF band (470 to 790 MHz) and the report was published in August 2014. It represents the personal views of Lamy while reflecting many common views of the high-level group. Key findings are set out in Figure 1-1.

In our work we look at the specific issue of whether UHF spectrum should primarily be used by a converged broadcast-broadband platform. We hope that, by answering this question, we can inform other studies on the broader issue of a long-term strategy for UHF spectrum. We have conducted our analysis with this context in mind.

[25] For example including work by the RSPG, the ECC, and the high level group led by Pascal Lamy

[26] *Results of the work of the high level group on the future use of the UHF band* (470-790 MHz), Pascal Lamy, Undated

**Figure 1-1: Key findings from the Lamy report**

Linear TV will remain the dominant form of video consumption for the foreseeable future.

The DTT platform will remain an important way of supporting the EU's audio-visual model - which promotes free to air viewing across a range of channels so as to reflect cultural objectives, content plurality and demographic diversity.

Portable devices will become increasingly important as a way of consuming both linear and non-linear video.

Terrestrial broadcasting and mobile platforms are likely to coexist for a long time to meet demand for AV services.

Convergence of the two platforms is not yet on the *"practical political agenda"*.

A predictable future for PMSE audio services is *"absolutely necessary"*.

DTT has a differing role in delivering broadcast TV across the EU. DTT market shares vary from 4% (Belgium) to 80% (Italy). This means UHF spectrum utilisation by DTT varies considerably across EU member states.

Future use of the 470 to 790 MHz band should:

- Enable sustainable development of the EU's digital economy and audio-visual model
- Be based on specific national solutions for use of UHF spectrum within an EU-wide framework
- Promote the EU's position in global markets for the future use of UHF spectrum.

Given these objectives:

- The 700 MHz band (694 to 790 MHz) should be released for mobile broadband use by **2020**
- The sub-700 MHz band should remain available for DTT use until at least **2030**
- The long-term position of the sub-700 MHz band should be reviewed before **2025**
- Wireless broadband services should be allowed to use the sub-700 MHz band for downlinks only in the meantime in cases where there is no or declining demand for DTT at the national level.

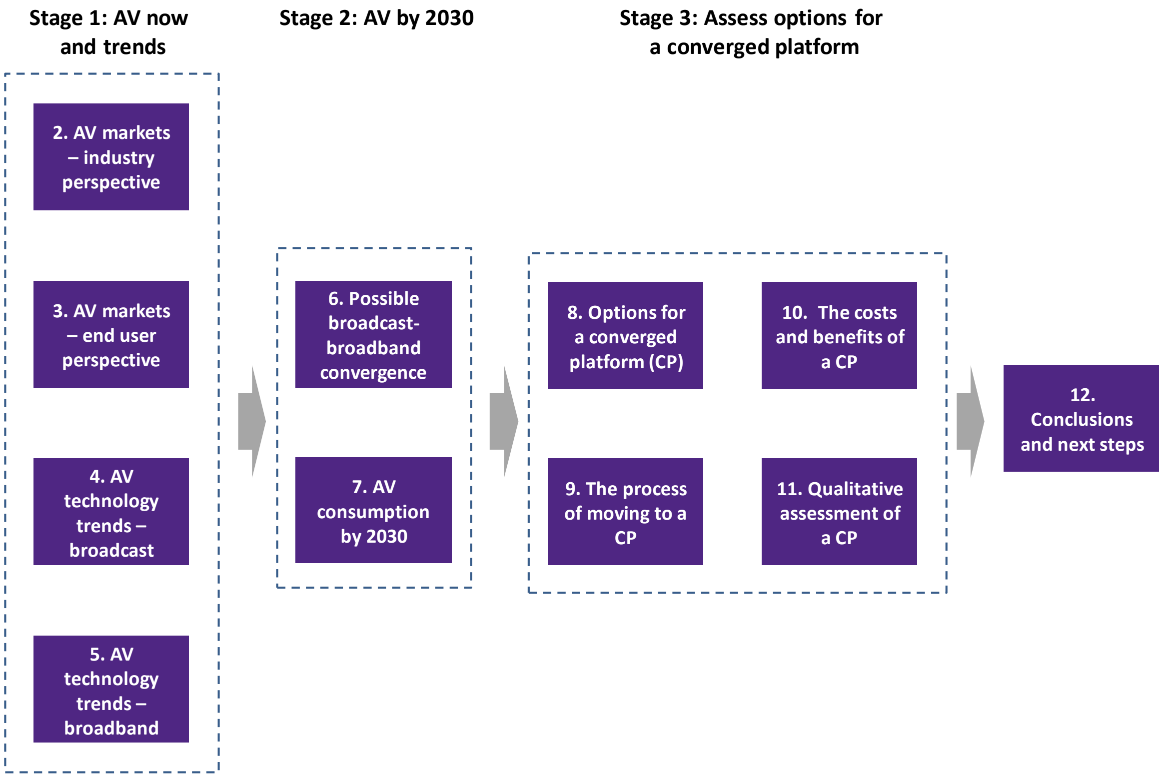
## 1.2 The structure of the report

Figure 1-2 shows the overall structure of the report in graphical form. There are three main stages to our work.

In **Stage 1** we assess the current way in which audio-visual (AV) services are delivered and consumed in the EU and the technology trends which are driving change in these patterns:

- Chapter 2 looks at the AV market from a supply perspective. It highlights key trends in EU AV service delivery and key differences between member states
- Chapter 3 then looks at the AV market from the end-user perspective. It looks in particular at how much AV viewing there is and how this is made up in terms of how, when and where AV content is viewed.
- Chapters 4 and 5 then look at technology trends which are driving changes in AV consumption. Chapter 4 focuses on broadcast technologies while Chapter 5 looks at broadband technologies and their suitability for AV service delivery.

Figure 1-2: The report structure




**Stage 2** draws together the findings of Chapters 2 to 5 to assess likely future patterns of AV consumption:

- Chapter 6 lists the various ways in which broadcast and broadband networks might combine to deliver converged AV services
- Chapter 7 then considers the future prospects for broadband, WiFi and DTT networks in delivering AV services in the period 2025 to 2030 and construct scenarios for the most likely outcomes.

These assessments then feed into the analysis of Stage 3.

In **Stage 3** we then examine the economic and social merit of options for moving AV services to a converged platform – a platform in which broadband and broadcast services use a common infrastructure to deliver AV services via UHF spectrum:

- In Chapter 8 we define what we mean by a converged platform, consider its potential advantages, list possible options, and identify those worthy of detailed evaluation
- Chapter 9 then considers the steps which would be required to make the transition to a converged platform. In particular we consider spectrum issues - including changes to the uses of UHF spectrum which are currently underway and other actual and potential uses of UHF spectrum (in addition to terrestrial broadcasting and mobile use)
- Chapter 10 then presents a cost benefit analysis (CBA) of the merits of a converged platform in which we:
  - Set out our basic approach to the CBA

- Assess the incremental costs and benefits of moving to a converged platform and make explicit the logic and assumptions which underlie our estimates
- Compare the incremental costs and benefits to see whether there is an economic case for a converged platform
- Carry out sensitivity analysis to evaluate the effects of varying those parameters in our analysis which are considered most uncertain

- Chapter 11 complements the CBA by considering qualitative factors which affect the merits of a converged platform. This includes network reliability, environmental factors and impacts on radio broadcasting.

Finally we set out our conclusions and make proposals on possible next steps in Chapter 12. This includes contingent proposals on regulatory changes, spectrum management and coordination arrangements, and the role of EU institutions if a converged platform were to be implemented.

## 1.3 The basis for our findings

Our findings are based upon:

- Consultation through face-to-face discussion, teleconferences and e-mail exchange with over 60 different organisations - drawn from the telecommunications and broadcasting sectors, from NRAs and other spectrum authorities, and from equipment vendors
- Two stakeholder workshops at which we presented our preliminary findings. This produced extensive feedback – both verbal and written – which we have taken into account in our final report
- A series of meetings and teleconferences with staff from the European Commission to provide feedback and guidance
- The findings of previous relevant Plum and Farncombe studies for a wide range of clients which include leading suppliers of mobile and broadcast services and their equipment suppliers as well as their regulators. Many of these studies are confidential. But we have indicated specific sources at the relevant points in the report where the findings are in the public domain
- Extensive desk research.

## 1.4 Definition of terms

There are a number of terms which we use in specific ways throughout this report. In particular we see the value chain for the delivery of AV services as made up of the following roles:

- **Content producers** develop original material for distribution across analogue, digital, or physical media
- **Distributors**/**Aggregators** license content and store, aggregate, package or manipulate it for availability to end-users
- **Networks** provide the communication links to carry content to end-users. These can be satellite, DTT or wired networks. A producer or a distributor may own a network (or vice versa), but the functions of moving bits and selling content are conceptually distinct

- **Hardware vendors** manufacture end-user devices to display, store, and manage content[27]. The hardware involved may be a general-purpose platform such as a personal computer or smartphone, or it may be a specialised device such as a television, video recorder or set-top box.
- **Supporting services** such as advertising, programme guides, search, analytics and tools facilitate revenue-generating business opportunities around digital content
- **Platform providers** integrate/coordinate the activities of content distributors, network providers and device suppliers to provide, for example, user interfaces to AV services such as EPGs. We note that several different **platforms** may use the same **network** by combining different AV content in different ways and offering different user interfaces to select between content.

In many cases organisations in the real world fulfil more than one of these roles. In particular a broadcaster fulfils at least the distribution/aggregator role. But it often also acts as a content producer, a network provider and a platform provider as well.

There are also a number of other terms used in the report which may be ambiguous to some readers and therefore require definition.

- **Linear AV services**: we follow the AVMS Directive and define linear AV services as services provided by a media service provider for simultaneous viewing on the basis of a programme schedule
- **Non-linear AV services** in contrast are defined as services provided by a media service provider for viewing at the moment chosen by the user and at the user's request on the basis of a catalogue of programmes selected by the media service provider
- **Non-linear viewing** of AV services. From an end-user perspective linear services might be viewed in either a linear or non-linear way. For example a linear service might be recorded onto a PVR for storage and then viewed later using pause and rewind functions (time-shifted). Non-linear viewing also includes video on demand, and catch-up TV services
- **Over-the-top (OTT)** AV services are services delivered using the best efforts broadband Internet whilst **IPTV** services are services delivered over a managed IP network so as to ensure a minimum quality of service. OTT services could include both linear and non-linear viewing
- **Hybrid services** combine linear AV and OTT AV services on a single device. They often deploy an integrated user interface such as an electronic programme guide
- **TV originated content** is content which was originally produced or commissioned by an AV content aggregator for broadcast as a linear AV service
- **Mobile TV services** involve the broadcast of linear TV services to mobile devices.

## 1.5 Meeting the Commission's technical specification

As our research on this study has progressed so our thinking on how to present the findings in a coherent and logical way has changed. As a result we do not precisely follow the structure of the report as laid down in of Section 4.1.4 of the Commission's technical specification. Figure 1-3 shows how the contents of the final report correspond to this specification

[27] They often also make AV network equipment

Figure 1-3: meeting the Commissions technical specification

| Technical Specification – Section 4.1.4 structure | Final report |
|---|---|
| 1. Executive summary | Executive summary |
| 2. Content, objectives, method | Sections 1.1 to 1.3 |
| 3. Potential of terrestrial wireless broadband platforms to provide linear AV services | Section 5 |
| 4. Potential of terrestrial broadcast platforms to provide non-linear AV and Internet services | Sections 2.9, 4 and Appendix E |
| 5. Market developments for the provision of AV services | Sections 2, 3 and 7 |
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# 2 AV market trends

## 2.1 Introduction

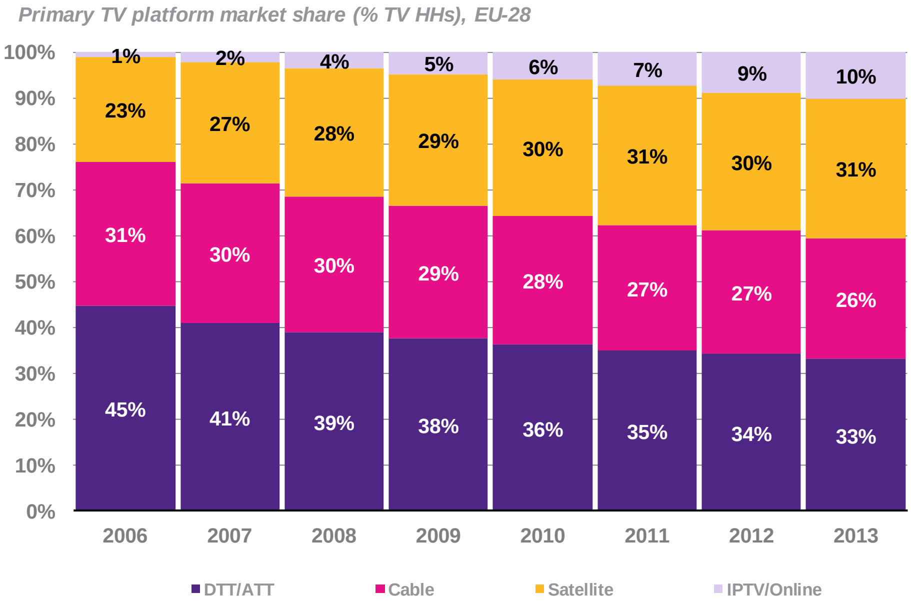
In this chapter we consider current AV market trends in the EU and the extent to which the AV market varies between member states. We start by considering the traditional TV platforms before considering the impact of Internet-based online services. This chapter focuses on market trends from an aggregated industry-based perspective. In Chapter 3 we then consider the market from the perspective of end-user consumption of AV services and consider trends in these consumption patterns.

## 2.2 Broadcast platforms used for TV distribution

Figure 2-1 shows how the mix of delivery platforms used by the main TV set in the households of the EU has changed over the past seven years. We can see that:

- The terrestrial platform remains the leading TV platform
- The market share for IPTV[28] and DTH satellite has grown
- The market share for terrestrial TV broadcast and, to a lesser extent, cable TV has shrunk.

Figure 2-1: TV platform distribution (% of TV households – main TV-set), EU-28

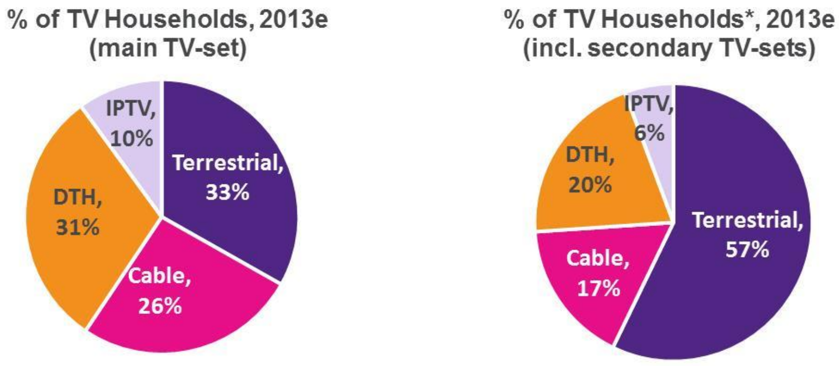



*Source: EAVO (2011, 2012), e-Communications Household Survey (2013), Yearly/Quarterly reports from National Regulatory Authorities, Digitalisierungsbericht 2013 (die medienanstalten), Farncombe analysis & research*

[28] TV services delivered over a managed IP network using fixed broadband

This raises the question of how the platform share of the terrestrial TV platform (now almost entirely DTT) will change over the next 15 years. Will it continue to shrink or will it stabilise? In answering this question we also need to consider the fate of TV sets used for secondary viewing, almost all of which use DTT. Figure 2-2 shows that the platform share of the DTT platform increases substantially if we include second sets. But there is now anecdotal evidence that tablets may replace secondary TV sets over the next decade. We consider this issue further in Chapter 7.

**Figure 2-2: TV platform distribution for main and secondary TV-sets, EU-28**[29]



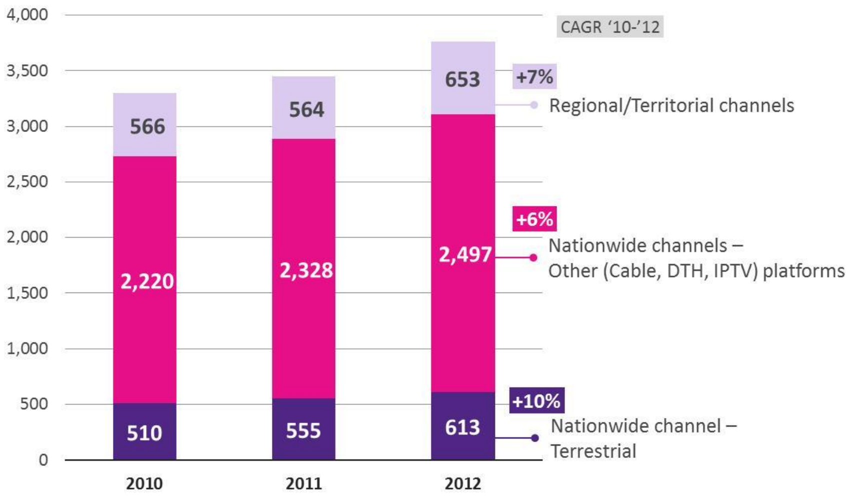

*Source: EAVO (2011, 2012), e-Communications Household Survey (2013), Yearly/Quarterly reports from National Regulatory Authorities, Digitalisierungsbericht 2013 (die medienanstalten), Farncombe analysis & research*

## 2.3 The number and nature of TV channels

The increased capacity of digital broadcast networks, created by the transition from analogue broadcasting, has facilitated the launch of new TV channels in the EU. Across all platforms the number of nationwide TV channels grew at 7% pa between 2010 and 2012. The number of regional/territorial channels also grew at 7% in the same period as Figure 2-3 shows.

[29] Assumes 1.8 TV-sets per EU TV household; Cable multiroom take-up: 15%; Satellite multiroom take-up: 20%; IPTV multiroom take-up: 2% (*second graph accounts for "dual" households for primary and secondary TV platforms)

**Figure 2-3: Number of nationwide and regional TV channels 2010 - 2012, EU[30]**



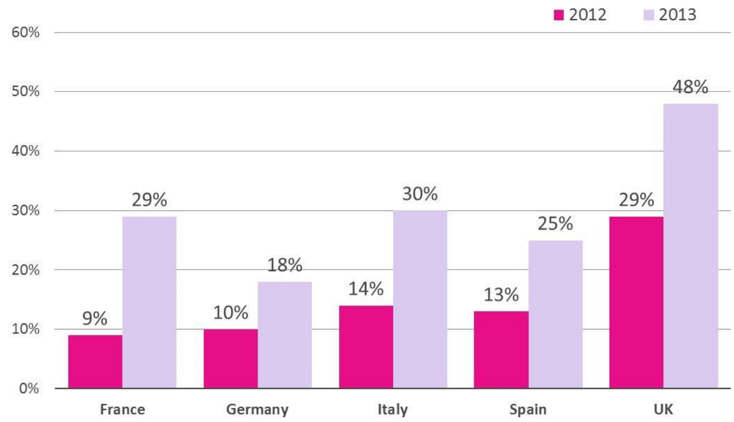

*Note: Local stations and windows channels are not included. Source: EAVO (2012)*

There is also a steady move towards the launch of HD format channels. These are virtually all simulcasts of SD channels. For example:

- There are an increasing percentage of households with access to HD services, for example households able to receive FTA HD services and/or households subscribing to Pay-TV HD packages. See Figure 2.4
- The total number of HD channels available in the EU grew from 274 in 2009 to over 1000 in 2012. See Figure 2-5. As transmission and encoding standards continue to improve and enhance distribution efficiencies, we can expect that the number of higher quality services will continue to grow.
- There is a move towards bigger screen TV sets. In the UK for example the proportion of TV sets sold with screens smaller the 19 inches fell from 40% in 2004 to 10% today. At the same time the percentage of TV sets sold with screens bigger than 33 inches increased from 40% to nearly 70%. See Figure 2-6. This trend is also a strong indication that we can expect that the TV set will remain the dominant viewing device.

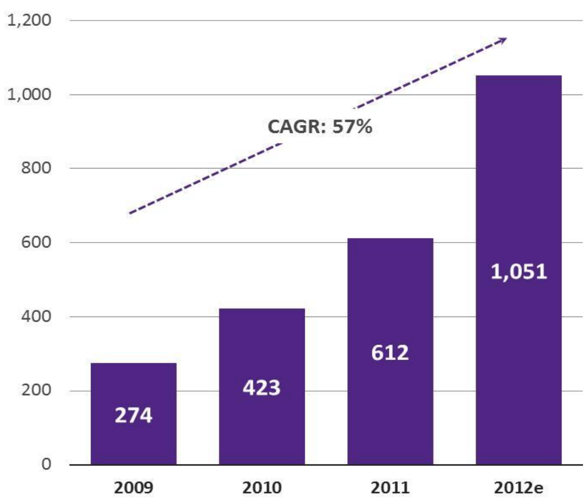
[30] Local stations and windows channels are not included

**Figure 2-4: Percentage of households with access to HD services**




*Source: Ofcom ICMR (2013)-Q3-data, Farncombe estimates*

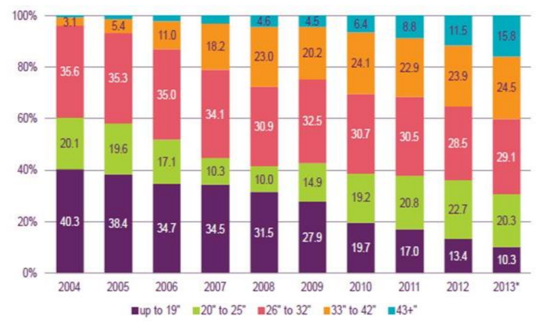
**Figure 2-5: Number of HD channels in the EU**



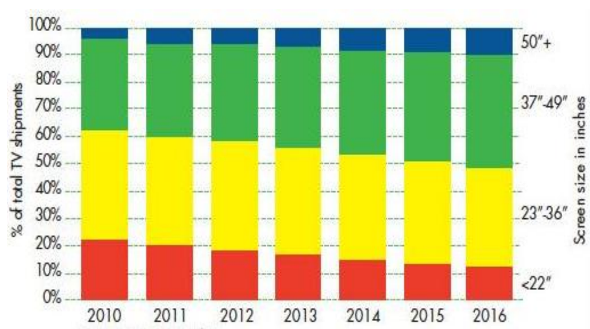

*Source: EAVO, Farncombe estimates for 2012*

**Figure 2-6: Screen size migration in Europe**

**Percentage of TV sales by screen size, UK**




**Percentage of TV shipments, Europe**




*Source: GfK sales data estimates. *2013 data represents Q1 only*

*Source: Futuresource Consulting*

## 2.4 The move to higher resolution screen formats

There is now a move to AV formats which offer higher screen resolution than HD (>HD). We are now seeing:

- Analysts predicting that the sales of >HD TV sets will have a growing trend
- Expectations that a significant proportion of smart phones will involve >HD screen resolution by 2017
- YouTube offering >HD formats for OTT viewing in future
- Pay-TV satellite providers trialling >HD sports content.

Appendix A provides a more detailed analysis of these trends in AV formats.

The key question is how quickly >HD formats will be deployed on mass media platforms. Our research and discussions with DTT network operators suggest that:

- Deployment of >HD will come first on satellite platforms, perhaps followed by cable and IPTV platforms
- Deployment of >HD on DTT platforms is likely to be limited to occasional events (such as key sporting events) - given that the DTT provider must meet end-user requirements for multiple channel choice over multiplexes with limited capacity.

## 2.5 Trends in sources of funds

We can identify four key sources of funding for the traditional AV platforms across the EU markets:

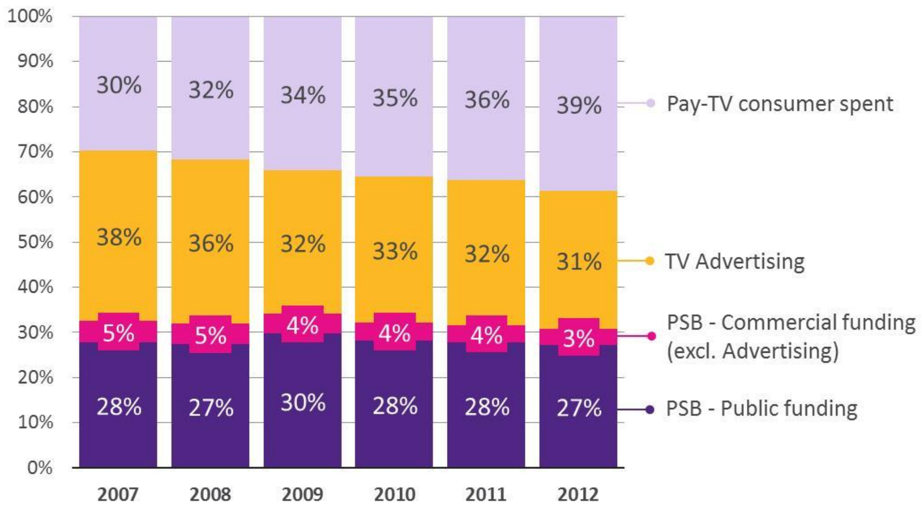
- PSB - Public funding, which includes public aids/grants and licence fees
- PSB - Commercial funding, which includes sponsoring, programme sales, merchandising and other commercial income[31]
- TV revenues from advertisers
- Consumer spending for Pay-TV services, which includes subscription, transactional, etc. revenues.

Figure 2-7 shows trends in the way the established AV platforms are funded. We can see that:

- The share of funding through government grants and licence fees has remained roughly constant
- The share of funding which comes from advertising has shrunk significantly while the share of funding which comes from pay-TV, mainly through subscription-based services, has grown significantly.

[31] Sponsoring, programme sales, etc. is also a funding source for commercial broadcasters. We expect these revenues to be negligible compared to TV advertising revenues.

**Figure 2-7: Funding/Revenues split, EU-28**[32]




*Source: EAVO (2012, 2013), Farncombe analysis*

In 2012, the total level of funding reached €92 billion compared to €85 billion in 2007, showing a below inflation CAGR of 1.6% during the period 2007 to 2012.

## 2.6 The rise in online services for AV consumption[33]

We have seen a big rise in the take-up of fixed broadband services in the EU over the past 10 years, driven largely by an end user desire to access Internet-based services and applications. Figure 2-8 illustrates.

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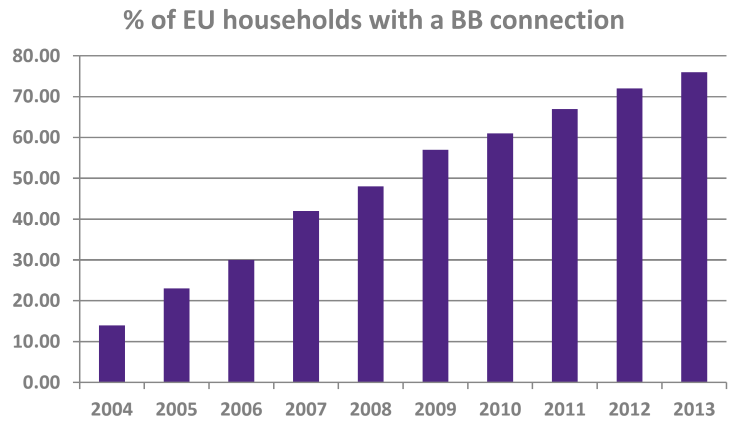
[32] We refer to Pay-TV when TV services require a monthly fee or subscription. Cable and IPTV may offer FTA channels, but they usually include a subscription fee even for the basic packages in order for the operator to recover the cost of the STB and/or customer support. In Germany, the cable market is more complicated than in other European markets. Cable operators may have billing relationship with housing associations or end-users. In general, a cable fee is charged - even for basic FTA packages. It might be paid by the end-user directly or by housing association (via the building owner).

[33] We consider the related growth in non-linear viewing of AV services in the next chapter

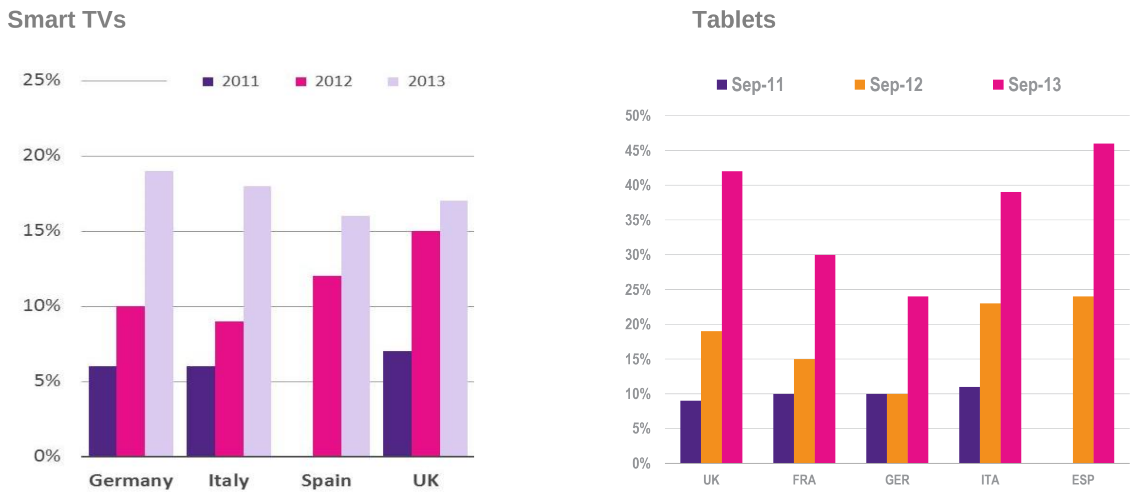
**Figure 2-8: Growth in broadband take-up in EU households**




*Source: DAE website See http://digital-agenda-data.eu/*

In parallel we are now seeing a big growth in the ownership of connected devices which allow end users to use the broadband network to view video content. This includes smart TVs, tablets, and smart phones as well as PCs. See Figure 2-9. While virtually all households in the EU are now TV households it took two decades to reach this position. By contrast it looks as if the penetration of tablets might reach near universal levels much more quickly.

**Figure 2-9: Growth in penetration of smart TVs and tablets in major EU member states**




*Source: Ofcom ICMR 2013*

According to Ofcom's ICMR 2013 report, the percentage of people connecting their smart TVs and using the TV set varies from 67% in France to 81% in Italy, although frequency of use was not reported. Statistics for Germany and Spain indicate that 76% of those with a smart TV connected use the internet connection on the TV-set. In the UK the proportion was 78%.

There are two main ways to use broadband for AV delivery:

- Over a managed IP network which offers good quality of service. This is the basis for the IPTV services of Figure 2-1
- Over the best efforts Internet as an IP stream. We refer to such services as online or OTT services in this report[34] and consider their nature below.

There is a range of different services which generate OTT AV content. The main ones are:

- User generated content (UGC) based services such as YouTube
- Catch-up services offered by the established TV broadcasters. These are now available in a wide variety of ways such as web access to the broadcaster's website; web-based access via third parties like YouTube; and portal access through connected TVs
- Subscriber video on demand (SVoD) services offered by pure SVoD players like Netflix and Amazon, by broadcasters (eg Hulu Plus) or by pay-TV operators (eg BSkyB's NowTV service). So far Netflix is the most successful of these players
- Pure OTT service providers like Magine (with offers in Sweden, Germany, and Spain), Aero (in the US) and TVcatchup.com (in the UK). These offer live streaming of broadcast TV channels. Often there are rights issues which restrict the availability of channels and, in the case of Aereo, there are disputes over the legality of the service offered.

In addition the established broadcasters themselves are beginning to generate significant OTT AV content through the provision of hybrid services. These combine broadcast and OTT content using standards such as HbbTV (e.g. in Germany, France, Spain), or through the development of dedicated hybrid platforms like YouView in the UK and Hibrida (in Spain). These hybrid services typically offer:

- Integrated search functions across TV schedule, recorded PVR content and catch up content.
- Online-only channels integrated into the linear EPG
- Live pay-TV and on-demand OTT services integrated into a single user interface
- Backwards EPG functionality which allows users to access on demand versions of previously aired shows from multiple channel providers

There are three main business models for online services:

- Free or advertising-funded. To date, free or advertising-funded catch-up TV services have proven the most popular form of online content. For on-demand content, adverts usually vary from 30 to 60 seconds for pre-roll and up to 1 minute for post-roll. Ad-funded video-on-demand deals are usually based on revenue share agreements between content producer/aggregators and platform providers.
- Subscription-based. Subscription models are offered either as a standalone package or as part of bundle
- Transaction based. This might involve Pay-Per-View (PPV) with a single payment per title or content viewing per event. This model may also include a Download-to-Rent (DtR) option allowing users to download content to their devices for later viewing, usually within a limited time window or a Download-to-Own (DtO) option which allows users to download content to their devices for later viewing at any time.

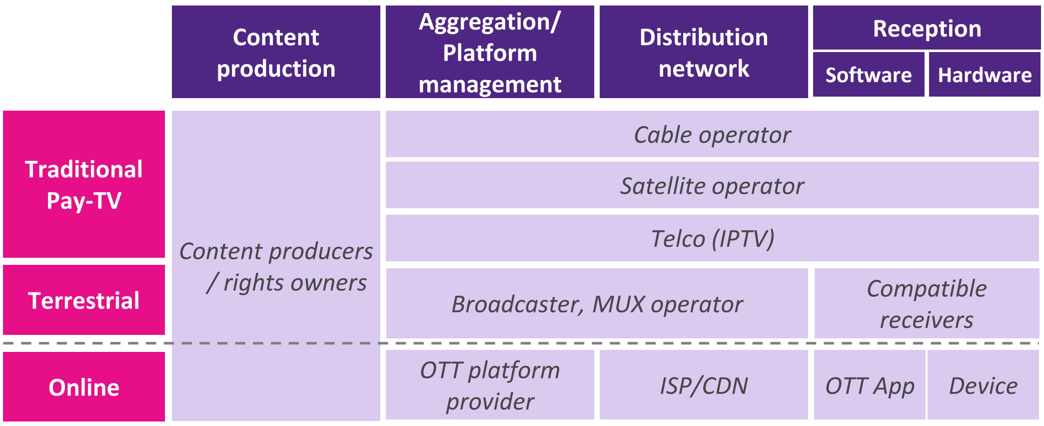
[34] This definition encompasses platforms providing linear and on-demand content, "free-to-view" and pay content. These services are usually offered for a range of connected devices, which may or may not be provided by the platform provider.

Appendix B offers a more detailed description of developments in OTT services.

## 2.7 The impact of online platforms on established business models

As Figure 2-10 shows, the business model of the online service provider is often very different from that of the established broadcaster. The latter often uses an integrated business model which allows it to exercise control over content aggregation, distribution and reception through a single platform. In contrast OTT content is often made available through a more disaggregated value chain in which the different functions are provided by different players.

**Figure 2-10: Online platforms impact on value chains (illustrative)**




AV services on OTT platforms have proliferated in the recent years. The main key drivers for this trend include:

- Greater broadband availability and take-up
- Higher broadband quality (speed)
- The growing availability of free-to-air content
- A big growth in the availability of connected/viewing devices with enhanced user interfaces which enable content aggregators to reach new audiences.

At the same time there are a number of barriers which stand in the way of a move to OTT services. These include:

- Existing broadband speeds which, for many people, are too low to deliver high resolution content and so currently limit the addressable market and audience reach of OTT services
- The variable quality of the end-user experience of OTT services
- The limited range of online content available through OTT services
- Competition from platforms, such as IPTV and cable, with similar bidirectional features.

Growth in consumption of OTT content threatens the business models of the established providers. Online platforms enable new players[35] to enter the market, changing the traditional distribution and business models and introducing fragmentation across platforms, devices and, to a certain extent, standards. But OTT also creates opportunities for established providers, who can enhance the value of their broadcast offerings by integrating them with OTT content through a hybrid model. As a result we see strong backing from broadcasters for hybrid services either through open standards such as HbbTV or manufacturer-centric platforms such as the ones developed by Samsung or the Smart TV Alliance.

Appendix C, which describes interactivity standards for DTT, provides a more detailed description of these developments.

## 2.8 Variations in market conditions by member state

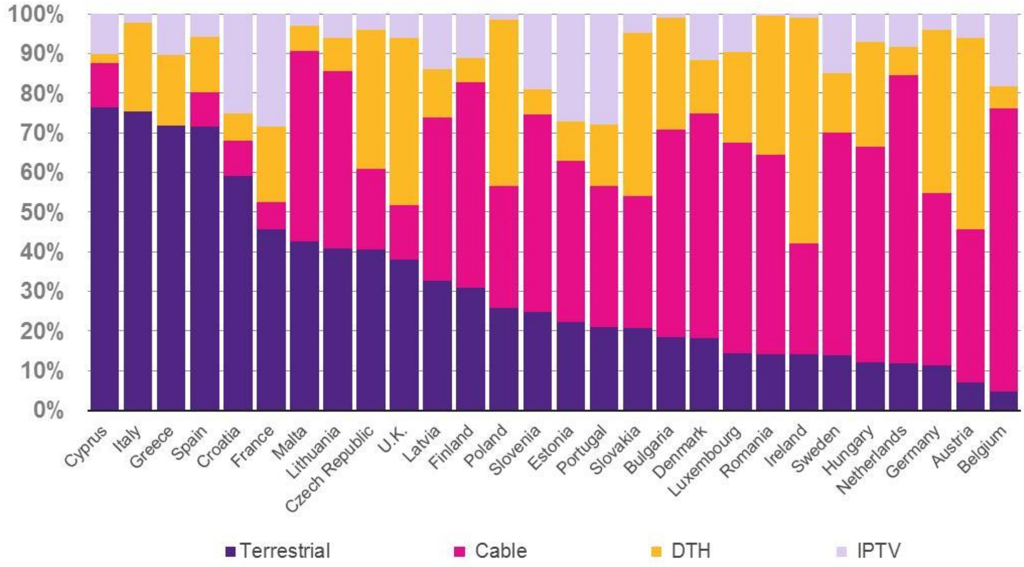
There is considerable variation in AV markets by member state on a number of dimensions. For example:

- The mix of platforms used to deliver AV services varies considerably. As Figure 2-11 shows, over 70% of households use DTT as the main platform in Italy, Greece and Spain whilst this figure drops below 10% in Austria, Belgium and Poland
- The total funding level per household per year for traditional TV platforms varies considerably – from nearly €900 per year in Denmark to less than €100 per year in Lithuania. See Figure 2-12. This figure also shows a big variation in the balance between advertising revenues, public funding and subscription revenues as a source of funding
- While virtually all member states have now completed digital switchover, by no means all have made a commitment to upgrade their DTT network to DVB-T2. Figure 2-13 illustrates
- The number of free-to-air channels in a member state varies between 5 and 34 with an average of 12 as shown in Figure 2-14. We can see, perhaps unsurprisingly, that the largest member states offer their residents the widest choice of free-to-air channels
- PSB requirements, whether measured in terms of free-to-air requirements, must carry obligations, population coverage, regional programming or the role of DTH satellite services, vary significantly. Appendix D provides detailed analysis on this variation.

These variations will impact on the case for a converged platform – with a stronger case in some member states than in others depending on current market conditions. We consider these variations again in Chapter 10 when we carry out a CBA on the case for a converged platform.

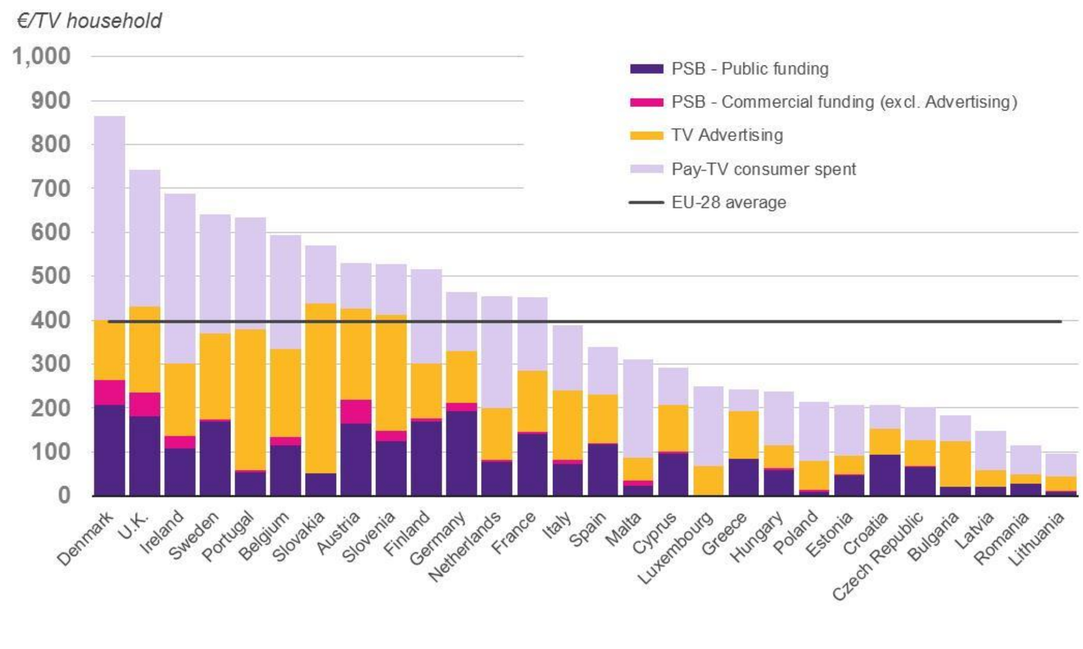
[35] Such as TV-set (e.g. Samsung Smart-TV, Panasonic Viera Connect, LG Netcast, Sony Smart, etc.) and STB manufacturers (e.g. Roku, AppleTV), gaming console providers (e.g. XBox, Playstation), VoD service providers (e.g. Netflix, Amazon instant, maxdome, etc.), and online aggregators (e.g. Hulu, YouTube)

**Figure 2-11: TV platform distribution (% of TV households – Main platform), EU-28**




*Source: EAVO (2011, 2012), e-Communications Household Survey (2013), Yearly/Quarterly reports from National Regulatory Authorities, Digitalisierungsbericht 2013 (die medienanstalten) Farncombe analysis and research.*

**Figure 2-12: Funding/Revenues (€ per TV HH in 2012) EU-28[36]**




*Source: EAVO (2012), Farncombe analysis & research*

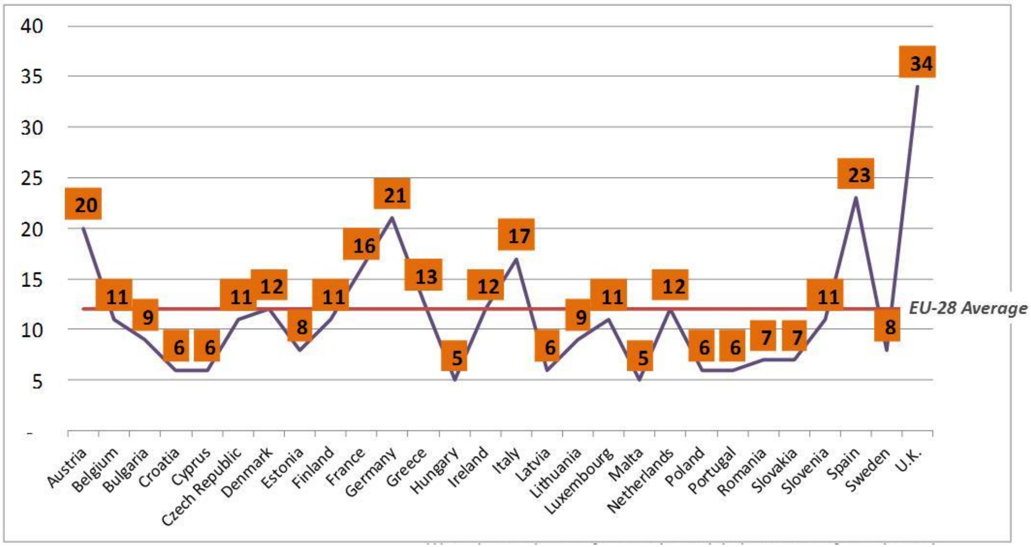
36 *EU average of PSB - Public funding per TV household: €89, EU average of PSB - Commercial funding (excl. Advertising) per TV household: €12, EU average of TV Advertising per TV household: €130, EU average of Pay-TV consumer spent: €166*

### Figure 2-13: EU-28 DTT evolution stage[37]

| Expanding DTT / No concrete plans for T2 (5) | Mature DTT / No current commitment for T2 (11) | Introduced / Planning for T2 (12) |
|---|---|---|
| Bulgaria | Croatia | Austria |
| Estonia | Cyprus | Belgium |
| Greece | Ireland | Czech Republic |
| Hungary | Latvia | Denmark |
| Slovakia | Lithuania | Finland |
| | Luxembourg | France |
| | Malta | Germany |
| | Netherlands | Italy |
| | Poland | Romania |
| | Portugal | Slovenia |
| | Spain | Sweden |
| | | UK |

*Source: Results from the questionnaire to member states on digital broadcasting, COCOM 13-11 FINAL, 8 January 2014, Farncombe analysis*

### Figure 2-14: Number of DTT FTA channels reaching 100% adjusted daily share[38]




*Source: EAVO (2012), Farncombe analysis & research*

[37] We have used COCOM's questionnaire as an input to this table. But the table also takes account of other DTT evolution plans which a member state may have (e.g. launch of new services, new MUXs, etc.). It is not solely related to DVB-T2 plans

[38] Daily share refers to average viewership of multiplatform channels adjusted to account for FTA channels only broadcast on DTT platforms. Channels typically refer to 24h services; regional services or time window channels are excluded.

## 2.9 The development of push VoD services

DTT and satellite broadcasting platforms offer one-way services. As such they are not suitable for providing Internet-based services. These platform providers are now working to enhance their broadcasting capability with broadband so as to increase the value of their offerings. But they can also deliver push VoD services[39] to end users in which:

- The broadcaster uses spare capacity[40] to distribute the same content to the whole of the target audience
- This content is stored in a set top box or PVR located at the subscriber's home for subsequent selection and viewing.

Examples of such services are described in Figure 2-15. A 500 GB set-top box providing a "movies only" service might offer a choice of 35 HD or 70 SD movies at any one time. We expect that, given trends in the price performance of storage devices[41], these numbers might increase twenty-fold or more over the next decade. Most of these deployments are based on proprietary solutions developed by platform operators and middleware vendors. HbbTV 2.0 includes an optional feature for non-real time content delivery capability, referred as the "Download feature". Appendix E.4 has more information,

**Figure 2-15: Sample push-VoD services**

In ***France***, where the embedded hard disk drive (HDD) is subject to private copy tax, TVNumeric[42] had designed a set-top-box dedicated to Push-VoD, without PVR support on DTT network. The second tuner of the device was used to receive pushed content only, and the HDD was solely dedicated to the on-demand catalogue.

In ***Italy*** Mediaset offers a push catalogue of 50 movies and TV series broadcast over its DTT platform. 12 movies are refreshed every week (including one 3D movie every month). The service also offers weekly episodes for 3-4 TV series.

In the ***UK*** BSkyB offers a subscription-based Push VoD service over its satellite platform. The catalogue includes 200 hours of movies, series and catch-up contents which is pushed during the night. The user recordings take preference in case of conflict. To ensure that the inactive set-top-boxes will receive the pushed catalogue, the content is transmitted several times. On average, 35 hours of content is delivered daily. It requires 140GB of disk space on Sky's HD set-top-box and 80GB on the SD set-top-box. Since 2009, Sky has extended their non-linear offer with a VoD service complementing the existing Push-VoD service.

We can expect that storage capabilities on PVRs will continue to grow substantially. Improvements in encoding technologies and compression algorithms might further increase the hours of video content

[39] Video on Demand (VoD) is a commonly used term. It refers to a broadband accessible service allowing the user to select at any time a movie to watch within a catalogue/content library. The end-user accesses the content of her choice as it is streamed in real-time to his device e.g. set-top-box, TV set, PC, smartphone or tablet. Push-VoD is a technique in which content is transmitted before it is actually requested by the consumer. The platform or service provider of a Push-VoD service selects in advance the content for "download" to the end-user device(s).

[40] For example channels which are underused during the night

[41] As set out in Figure 4-8

[42] TVNumeric had planned to launch a Push-VoD service over terrestrial and satellite networks in France but had to cease operations at the end of 2012 after a judicial liquidation procedure.

that can be stored in devices although a shift to higher resolution content might have the opposite effect.

A push service over a DTT network is a valid solution to offer quality AV content to households not being able to access streaming services because the fixed broadband services do not offer adequate download speeds and/or poor quality of service. This service can also be enhanced by using the fixed broadband which is available to offer a low bandwidth return path. In areas where broadband is sufficient for video streaming, DTT might also be used to reduce the costs of distributing non-linear services such as video on demand. It can be cheaper to send popular content, with many thousands of views, using a DTT push service, rather than over the broadband network.

Appendix E provides a more detailed analysis of the merits and market prospects of on-demand services over broadcast networks.

## 2.10 Developments in mobile TV

We use the term *mobile TV* to mean the ability to watch linear TV services on a mobile device. There have been a number of efforts to provide such services via terrestrial networks by embedding a TV receiver in a mobile terminal[43]:

- Through use of DVB-H
- Through use of DVB-T enabled mobile devices

The European experience with broadcast mobile TV in the form of **DVB-H** is widely accepted as a failure despite considerable optimism in the mid-2000s. Numerous trials were carried out across Europe and commercial deployments followed in several countries around the mid-late 2000s (e.g. KPN in the Netherlands; Swisscom in Switzerland; Three and Mediaset in Italy). These services typically offered some 10-20 linear TV channels with subscription prices around €10 per month.

Consumer take-up was disappointing. KPN's service "Mobiel TV" managed to sign up 40,000 subscribers in its first year of service in 2008 but by the time the service was cancelled in June 2011 the number of users had dropped to 20,000. By 2012 most of the DVB-H services in Europe were discontinued and spectrum returned for alternative uses.[44] Several reasons have been given for the failure of DVB-H including:

- Limited availability of compatible devices – only Nokia supported the standard in its devices
- Lack of consumer demand – evolving consumption patterns towards a mixture of linear and on-demand meant that consumers increasingly demanded interactivity and control over their media consumption; meanwhile a growing variety of OTT services became available over the Internet and proved more attractive for many consumers
- Lack of a viable business model – most consumers were unwilling to pay for the service and growing competition from IP-delivered services over mobile broadband contributed to a failure to create a viable business model

[43] See Appendix Q.2 for more details

[44] http://www.broadbandtvnews.com/2010/03/24/swisscom-discontinues-dvb-h-service/; http://www.broadbandtvnews.com/2011/03/30/kpn-terminates-dvb-h-mobile-tv/; http://www.telecompaper.com/news/italy-approves-transformation-of-dvb-h-frequencies--875533

- Timing – large screen mobile devices were relatively uncommon when these services were launched and the tablet came too late; meanwhile the financial crisis of 2008/09 constrained operators' investment in separate infrastructure (spectrum and network) to support DVB-H.

**DVB-T** enabled mobile devices have had some success in Germany where over one million DVB USB dongles are estimated to be sold in the last three years and there are a significant number of DVB- T receivers in cars. The use of DVB-T for handheld mobile devices, in contrast to cars or laptops, is limited by the excessive battery drain which DVB-T (and 3G) reception generates[45].

The DVB Project has now developed a new standard for mobile devices – DVB-NGH - which is based on DVB-T2 and which incorporates MIMO technology. So far there has been little in the way of trials or rollout and it is as yet unclear whether the new standard will be more successful than its predecessor - DVB-H. Appendix F discusses the development of terrestrial broadcast transmission standards in more detail.

[45] A DVB-T2 chip requires about 800 mW and 3.3 V. The storage battery of an iPhone 4S (1430 mAh) is enough for 10 hours of reproduction of stored video, 3.8 hours of DVB-T2 reproduction, 3.8 hours of video streaming via 3G or 7 hours of video streaming via a WLAN

# 3 Audio-visual consumption

## 3.1 Introduction

In this chapter we assess the current patterns of AV consumption in the EU and how they are changing. In making comparisons between different modes of consumption we use a common metric where possible – the number of minutes per day of viewing per person. We consider:

- How much time the average person spends in AV viewing
- What kind of content they watch
- How they watch this content
- Where they watch from.

This analysis then informs the AV scenarios for 2030 set out in Chapter 7.

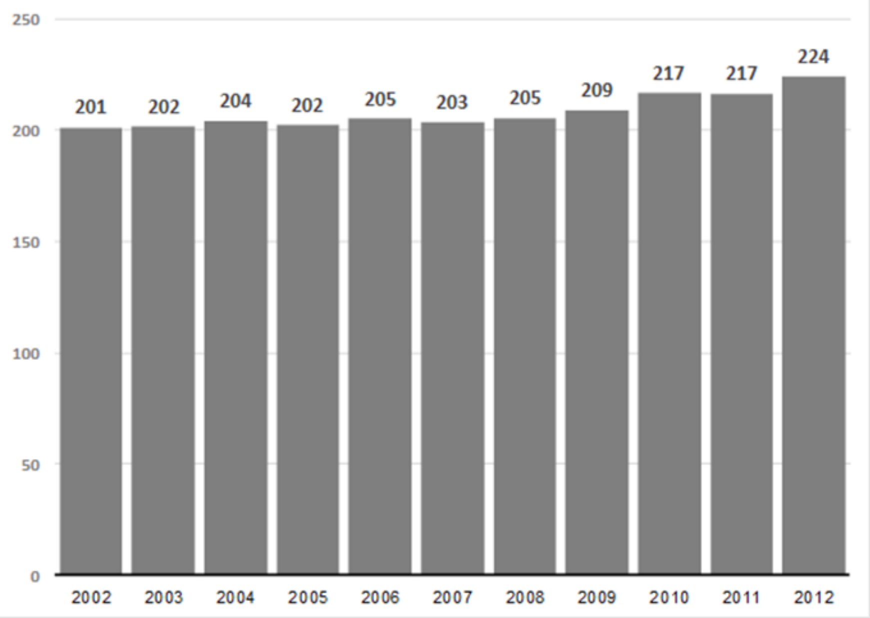
## 3.2 How much viewing?

How long does the average person in the EU spend watching AV content each day? There are a number of difficulties in answering this question:

- The metrics used to measure AV viewing are not comprehensive. Viewing of traditional TV services is measured using one set of metrics – with a focus on determining advertising rates and the reach of publicly funded channels. However, in the majority of the cases, these metrics exclude viewing of OTT content (either on TV or other devices)
- The metrics used do not distinguish between situations in which a TV set is on in the background and one in which a TV programme has the full attention of the viewer. Some argue that this distinction is important and that viewing of OTT AV content often has a higher level of attention than viewing of the main TV set
- The metrics used do not adjust for overlap in which someone may be multi-tasking between two AV streams on separate devices.

With these challenges in mind, Figure 3-1 shows a traditional metric which indicates that TV viewing in Europe is growing slowly – from 213 minutes per day 2004 to 228 minutes per day in 2011.

**Figure 3-1: Average minutes spent viewing TV per day by TV viewers in EU-28[46]**




*Source: Eurodata TV Worldwide (EAVO)*

But Figure 3-1 excludes OTT viewing. We note for example that Cisco VNI estimates that Western European households generated around 2,900 PB of OTT video data each month in 2012. This equates to roughly 20 GB of video data per household or, depending on assumptions, around 15 to 30 minutes of viewing per day[47]. In other words Figure 3-1 might, by excluding OTT video, underestimate total video viewing by up to 15%.

## 3.3 What kind of content?

### Single genre vs multiple genre TV channels

People in the EU spend most of their time watching mixed-genre rather than single-genre TV channels, as Figure 3-2 illustrates. A mixed-genre channel typically includes a range of content types such as news, drama, documentaries, general entertainment shows, and sports while a single-genre channel usually has dedicated content for a specific genre such as movies, sports, or news which accounts for most of the channel's programming. The viewing patterns shown in this figure have remained largely unchanged over the past five years. Appendix G provides more details on the viewing of mixed and single genre TV channels.

Compared with single-genre channels mixed-genre channels offer:

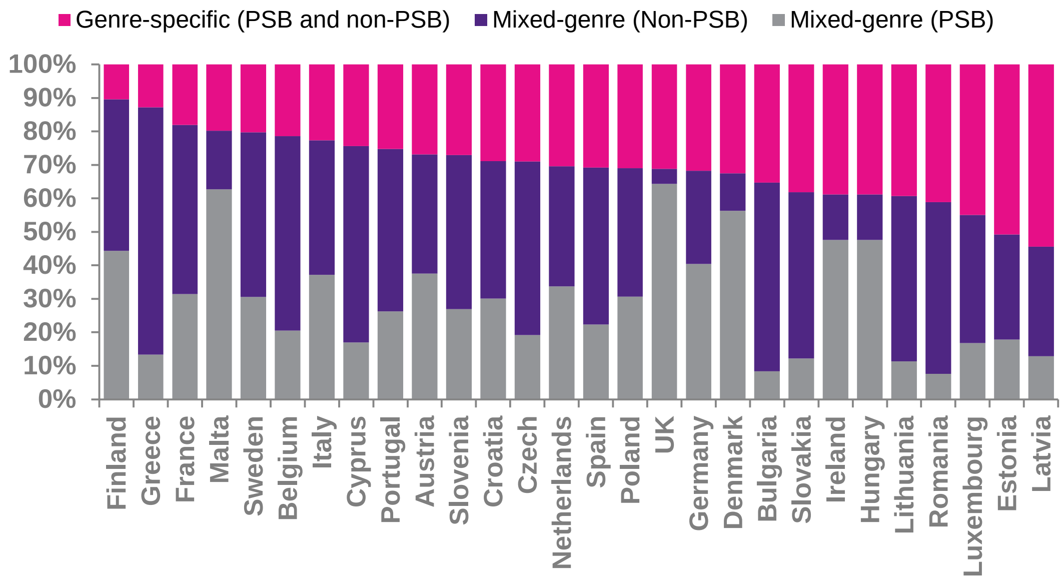
- A wide range of content which includes news, drama, documentaries, comedy, general entertainment, sports and films

46 No data available for Luxembourg & Malta

47 20GB per month at 2GB per hour is equivalent to 10 hours per month or 20 minutes per day

- A high proportion of fresh rather than rerun content. This implies a relatively high spend on content
- A schedule which caters for different viewing tastes at different times of the day
- A prominent position on the EPG. There is substantial evidence (which is set out in Appendix G) that the EPG position of a channel has a substantial impact on its viewing hours.

**Figure 3-2: Percentage of Mixed-Genre and Genre-Specific content watched in EU-28 countries**




*Source: EAVO, Farncombe analysis*

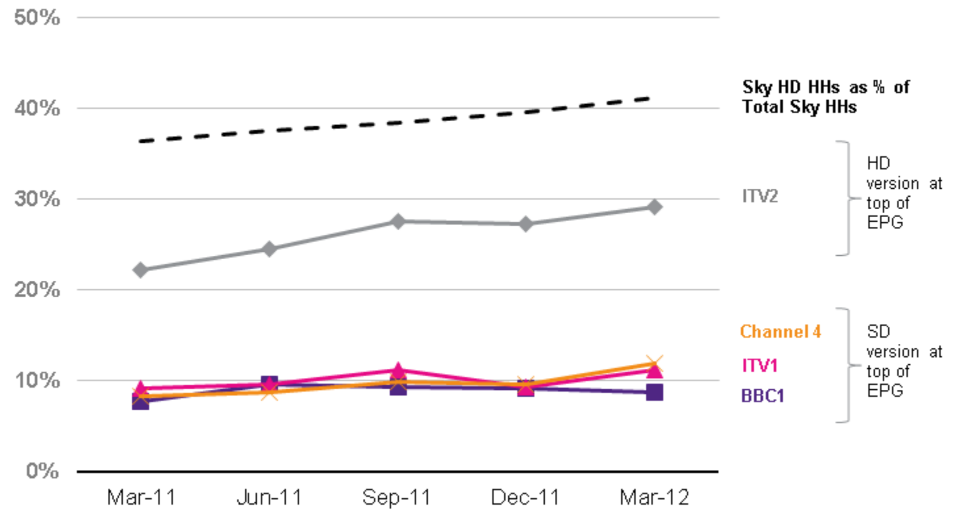
## SD vs HD viewing formats

As we noted in the previous chapter, there is a steady move towards HD formats in terms of the installed base of HD capable TV sets and the availability of HD channels. But there is little data on time spent on HD viewing. There is however some evidence to show that people want to have the option of HD viewing more than they want to watch HD format programmes.

Viewing data from the UK (see Figure 3-3) indicates that where a household is capable of receiving both the SD and HD version of a channel, the viewing share of the HD channel versus the SD channel depends on the relative EPG positions of the channels. Figure 3-3 shows how the viewing share of an HD variant of a channel compares to the total share of that channel in Sky households in the UK. We can see that:

- If the HD variant were always watched by default, we would expect the HD share to be the same as the penetration of HD subscribers (or slightly less, after adjusting for viewing on SD second sets in households which subscribe to HD).
- What we actually see is that, where an SD version of a channel is higher in the EPG than the HD version, the HD channel has significantly lower viewing than expected.

Figure 3-3: Percentage of channel viewing in HD[48] on the Sky UK platform




*Source: BSkyB, Dr. Farid El-Husseini, BARB and Farncombe analysis*

One interpretation of these observations is that the move to HD is a supplier-led trend[49], in which a significant proportion of the population were persuaded to buy HD sets but were then largely indifferent to the HD capability available to them.

## 3.4 How is content being watched?

We can divide the way in which AV content is watched into four categories:

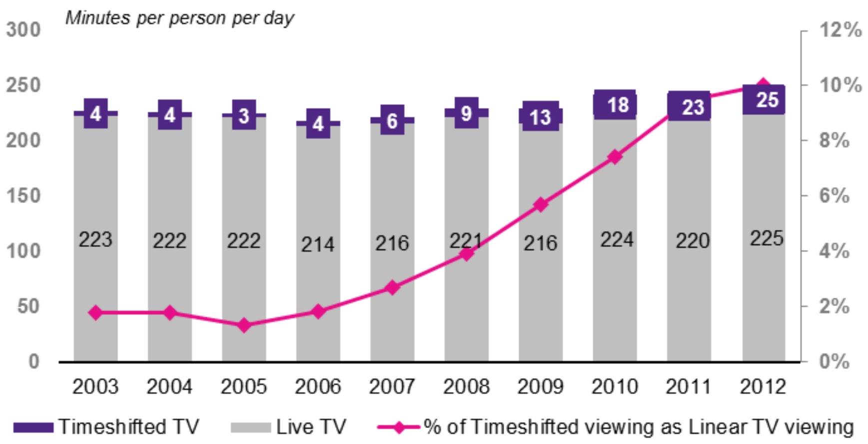
- **Live TV** where video is delivered over a broadcast/multicast network and viewed live. We include here viewing of OTT linear services where the content is a simulcast of a broadcast programme
- **Time-shifted TV** where video is delivered over a broadcast/multicast network and viewed later. This includes use of PVRs and use of IPTV delayed viewing functionality
- **Catch-up TV** where content which has been broadcast is made available for on-demand consumption within (say) 30 days of first broadcast. Often this form of viewing uses an OTT mode rather than IPTV or PVR modes
- **Non-broadcast video**. This is a catch-all category which includes OTT content which is not broadcast - such as UGC and video on demand services.

Figure 3-4 shows trends in the first two categories for the UK. We can see that live TV continues to dominate. Time-shifted TV viewing is growing in line with PVR ownership and may grow faster in future – if and when service providers introduce cloud-based PVR services on hybrid TV services. This is already a significant trend in the US.

[48] *% of channel viewing in HD = (HD share)/(SD share + HD share)*

[49] For example a trend lead by a TV-set manufacturer or a service provider

**Figure 3-4: Average minutes per day spent viewing Live and Time-shifted content, UK[50]**



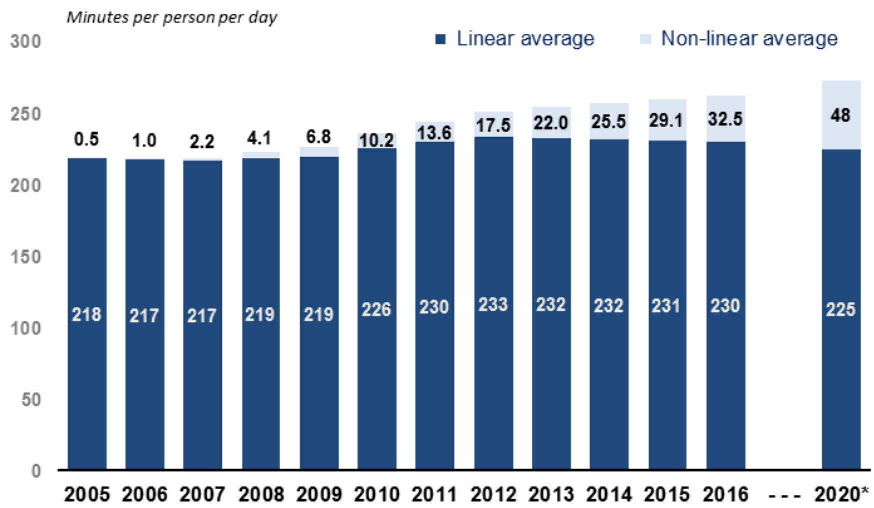

*Source: Broadcasters Audience Research Board (BARB)*

We note that:

- Screen Digest estimates that the average TV viewer in the EU-5[51] watches catch-up content on the main TV set for between 0.4 minutes (Italy, Germany, Spain) and 3.6 minutes (France) per day
- The average viewer in the UK may watch TV catch-up services for around 4 minutes per day - when summed over the various broadcast catch-up services.

Figure 3-5: shows the evolution of linear and nonlinear viewing on the large TV screen in major EU markets.

**Figure 3-5: Evolution of TV viewing in Germany, France, Italy, Spain and the UK**




*Source: IHS - Screen Digest: Cross-platform Television Viewing Time FY 2012 (Forecast for 2020 by EBU)*

[50] *Time-shifted viewing is defined by BARB as any programmes played back on a PVR within 7 days of first broadcast*

[51] France, Germany, Italy, Spain, UK

Evidence on viewing times for our fourth category, **non-broadcast video**, is even harder to find. And what we can find produces a wide range of viewing estimates. For example:

- Nielsen data for the US suggests that the average person watches 4 minutes per day (1.4% of 300 minutes) of Internet video, which may be considered as non-broadcast video
- In the US viewing of Netflix now accounts for around 10 minutes per day for the average viewer. Netflix viewing time is now growing at around 60% per annum
- Cisco VNI suggests that the average household in the US generates 32 GB of Internet video data per month. The figure for Western Europe is 20 GB. Assuming that each GB corresponds to an 60 minutes of viewing and each video is viewed by two people, this translates into viewing times per day per person of around 30 minutes in the US and 20 minutes in Europe.

Appendix H provides more details on how AV content is being watched in terms of live broadcast, catch-up and streamed services.

## 3.5 Where and on what devices is AV content watched?

We can usefully divide where AV content is watched into five categories:

- In-home viewing on the main TV set
- In-home viewing on secondary TV set
- In-home viewing on portable devices
- Out-of-home viewing on portable devices at fixed locations (where there is often access via WiFi to fixed broadband)
- Out-of-home viewing on portable devices on the move (where there is no access to fixed networks)

Appendix I sets out estimates of how much viewing each of these categories generates. We can summarise our findings as follows:

- Evidence on the current pattern of out-of-home viewing is limited
- Any estimates of viewing patterns are necessarily uncertain. We need to supplement the available evidence with plausible assumptions
- Our estimates are tabulated in Figure 3-6 for the average EU resident[52]. They suggest that:
  - In-home viewing on the main TV set remains the dominant form of viewing
  - Viewing times on portable devices is now starting to approach in-home viewing times on secondary TV sets.

[52] It is important to note that, while the estimate for in home viewing on the main TV set is based on EU wide data other estimates are based largely on UK data which may not be typical of the EU as a whole

**Figure 3-6: where is AV content consumed by the average EU resident?**

| Form of viewing | Minutes per day |
|---|---|
| In the home on the main TV set | **207** |
| In the home on a secondary TV set | **21** |
| In the home on a portable device: | |
| TV originated content | **4** |
| other content | **4** |
| total | **8** |
| Out of home on a portable device | **6** |
| …of which on-the-move | **3** |
| Total viewing at all locations | **242** |

*Source: Appendix I*

## 3.6 Are there cohort effects?

The consumption of AV content by young people is very different from that of older people. For example:

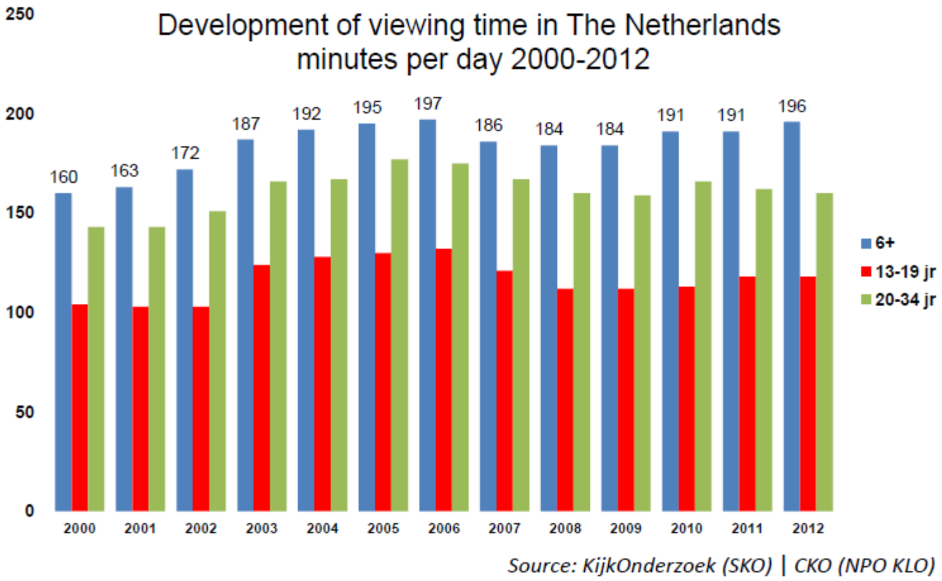
- Young people aged between 16 and 24 watched TV for 2.8 hours per day in the UK while the over 65s watch for 5.8 hours per day[53]
- Young people are nearly twice as likely to view AV content when commuting than the over 60s[54]

If these differences were to persist as cohorts of young people grew older then we might expect AV consumption patterns to change more rapidly than if the behaviour of a young cohort regresses towards that of the older cohort as it ages. We have reviewed the evidence on this point and found that it is limited. But as Figure 3-7 illustrates, the evidence which is available points to the second effect rather than the first. We can see that those in the age range 13 to 19 watch less TV than those in the age range 20 to 34. But we also noted that, by the end of the study, the teenagers at the beginning of the study period are all in the older age range while viewing time for the 20 to 34 age range does not decrease but stays relatively stable. This suggests that cohort effects might have relatively little impact on overall AV consumption patterns.

[53] BARB

[54] *TV and Media 2014*, an Ericsson Insight survey report, September 2014

**Figure 3-7: TV viewing by different age cohorts in the Netherlands over time**




## 3.7 The need for new measures of AV consumption

As this chapter illustrates there are currently authoritative and, in some cases, comprehensive measurements of the way in which AV content is consumed on the TV set at individual member state level[55]. However there is no single, consistent, public domain source measuring viewing times or type of consumption[56] of AV content on other devices. Nor is equivalent information available from all member states. Some, like the UK, are rich in information on AV consumption; others are relatively information poor. We note in particular that while traditional metrics of AV consumption suggest there is currently relatively little AV viewing via OTT services, the Cisco VNI metrics suggests this source could already account for around 15% of TV viewing. We also note the fragmented evidence on which we have had to base estimates of AV consumption on portable devices and AV viewing outside the home.

In the past, when virtually all AV content was consumed over traditional broadcasting network this did not matter. But as more and more AV content is delivered using OTT services and viewed on a range of portable devices, the need for more comprehensive and consistent, public domain, measures of AV consumption, on which to base policy decisions, grows. Ideally these metrics would measure in a consistent way – both within member states and across the EU:

- The split of viewing between OTT, IPTV and traditional TV broadcast platforms
- The split of viewing between linear, on demand and time shifted modes
- The split of viewing between portable and fixed devices
- The split of viewing between in-home and out of home consumption

[55] For example by BARB in the UK, AGF in Germany, Médiamétrie in France, SKO in the Netherlands, and Nielsen TV Audience Measurement in Croatia, Poland, Hungary, and Greece

[56] For example linear/on-demand, in-home, out of home

- The division of video consumption on portable devices between downloads, WiFi streaming and mobile broadband.

In devising these metrics it would also be important to take account of multi-tasking by viewers.

# 4 AV technology developments - broadcasting

## 4.1 Introduction

Before we can consider realistic scenarios for AV delivery in 2030 or make a sound assessment of the merits of a converged platform, we need to understand how the price/performance of the different technologies used for AV services might improve. Such analysis offers valuable clues as to how the long-term use of different platforms could change. So in this chapter we consider:

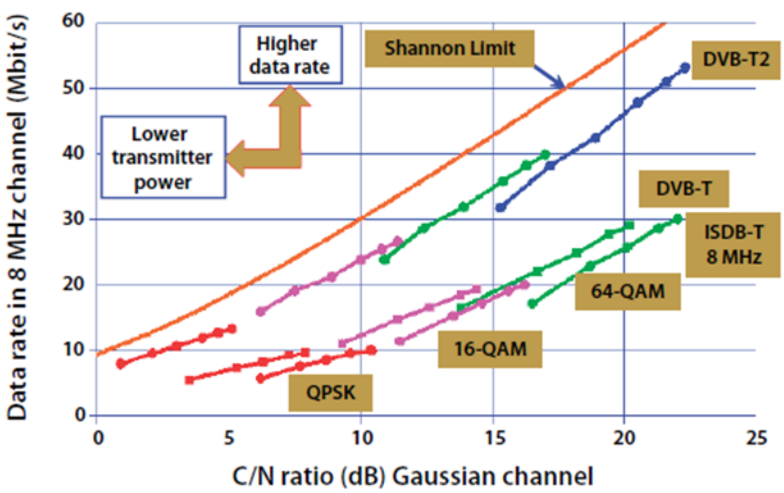
- The likely evolution of DTT transmission standards
- Current developments for cable and satellite networks
- Developments in standards for interactivity
- Developments in standards for video formats and compression.

Appendix J provides a brief description of the main organisations which develop standards for AV services.

## 4.2 DTT transmission standards

In Europe the migration of terrestrial TV from analogue to digital was based on use of the DVB-T transmission standard. Specified in 1997 the standard is now deployed widely on most continents except in parts of the Americas. In a typical European deployment, a DVB-T signal in an 8-MHz channel will carry data at between 20 and 25 Mbit/s, resulting in a typical spectral efficiency of around 3 bit/s per Hz.

Figure 4-1: Comparison of DVB-T, DVB-T2 and Shannon theoretical limit



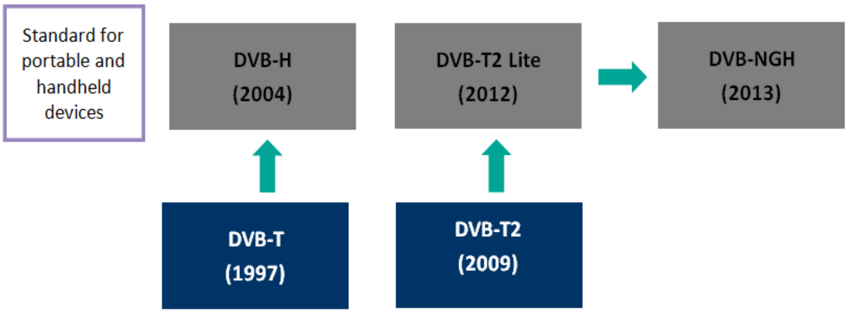

*Source: DVB.org (http://www.dvb.org/resources/public/scene/DVB-SCENE37.pdf)*

In 2008 the DVB Project published its specification for DVB-T2. This offers higher modulation schemes, additional OFDM modes, new error correction mechanisms, and new guard bands. As a consequence spectral efficiency is improved by 50 to 60% and is approaching the theoretical limits of Shannon's Law. Figure 4-1 illustrates.

As specified in Chapter 2, deployment plans for DVB-T2 vary considerably by member state. Some member states have already deployed; others have firm plans to do so; and others have no current plans to use DVB-T2.

The DVB Project has developed variants of both DVB-T and DVB-T2 for use with handheld terminals. Figure 4.2 illustrates.

**Figure 4-2: Evolution of DVB standards for handhelds**




*Source: Farncombe*

DVB-NGH is expected to be superior to its predecessor, DVB-H, in a number of areas, including[57]:

- Better indoor coverage
- The ability to transmit DVB-NGH services in-band with a DVB-T2 multiplex, so reducing the network investment required
- A smaller silicon footprint, so increasing battery life.

The DVB Project is now working on the use of MIMO technology to increase the spectral efficiency of DVB-T2 beyond the Shannon limit.

It is unclear whether there will be a DVB-T3 standard in future. But there is The Future Broadcast Television Initiative (FoBTV), established in November 2011. This is an unincorporated, not-for-profit association which aims to define the requirements of future terrestrial broadcast systems, explore the possibility of a unified terrestrial broadcast standard and promote global technology sharing.

Appendix F provides more details on all of these developments.

[57] See for example www.dvb.org/resources/public/scene/DVB-SCENE33.pdf and www.dvb.org/resources/public/pressreleases/DVB_pr219%20DVB%20Introduces%20DVB-T2%20Lite.pdf

## 4.3 Standards for cable and satellite networks

### Satellite TV networks

Satellite DTH networks using the 11/12 GHz band moved from analogue to digital in the late 1990s, deploying DVB-S to do so. In 2005 the DVB group then announced its intention to upgrade this standard to DVB-S2. According to DVB, DVB-S2's performance comes close to the Shannon limit, and typically delivers an increase in the useful bit-rate of more than 30%. By August 2012, more than 250m DVB-S/S2 receivers had been deployed globally[58]. In 2014 an extension, DVB-S2X, was approved. This offers further capacity gains of 20 to 50%, and more flexibility through channel bonding. Appendix K provides more details on DVB transmission standards for satellite TV.

### Cable TV networks

Cable operators use their hybrid fibre coax networks to deliver both digital television and broadband. DOCSIS 3.0 is the standard used to divide up the network spectrum into channels and assign them between the two applications as shown in Figure 4.3.

**Figure 4-3: Key characteristics of DOCSIS 3.0**

With a DOCSIS 3.0 enabled system the spectrum is typically divided as follows:

- The frequencies between 5 MHz and 65 MHz are used for upstream broadband and voice telephony
- The frequencies from 65 to 108 MHz are used for guard bands, pilot tones and FM radio content
- The frequencies from 108 to 800 MHz are used for a mix of analogue and digital TV channels. This spectrum is divided into over 100 individual channels. Each of these channels is capable of carrying up to 10 standard definition or two high definition television programmes in digital format
- The frequencies from 800 to 862 MHz are used for downstream broadband and voice telephony

Currently the spectrum assigned to DOCSIS 3.0 uses 8 x 6 MHz channels for downstream capacity and 4 x 6 MHz channels for upstream capacity to provide 445 Mbps downstream and 123 Mbps upstream.

*Source: previous confidential Plum studies*

The individual channels assigned for digital television transmission use the DVB-C transmission standard. Defined by ETSI in 1994, the standard was upgraded to DVB-C2 in 2010. The new standard uses Coded Orthogonal Frequency Division Multiplexing (COFDM) and allows for QAM variants all the way from 16-QAM up to 4096-QAM. It provides a 30% increase in useful bit rate over DVB-C. Chipsets for DVB-C2 became available in early 2012 but we are unaware of any deployments yet.

In terms of broadband services DOCSIS 3.0 typically provide an end user with:

- Download broadband speeds of 30 to 100 Mbps. The broadband capacity is contended - within the HFC distribution network which connects end-users to each head-end in the network. A head-

[58] Source: DVB

end might support 100 to 200 households. So the speeds vary depending on the number of simultaneous users

- Broadcast of up to 1000 SD TV channels or 200 HD channels.

An upgrade of the DOCSIS standard to DOCSIS 3.1 should be available by 2015 or 2016. This will use more advanced modulation techniques to enable significantly higher broadband speeds for both download and upload; a fourfold increase in broadband speeds is anticipated. For the moment most cable operators use DVB-C. But we can expect increased capacity for TV channels as and when cable operators adopt DVB-C2.

## 4.4 Technologies for interactivity

### Standards for interactivity

There are a number of standards which have been developed to enhance the value of broadcast services for end-users by making them more interactive. The main ones are as follows:

- The DVB-multimedia home platform (DVB-MHP) is an open DVB middleware standard for interactive TV services and applications. First published by ETSI in 2000, MHP implementations have proved to be expensive – generally costing more to create and maintain than implementations which use proprietary interactive TV solutions such as OpenTV or use alternative standards such as MHEG. But MHP has been used as the basis for a hybrid TV service in Italy
- MHEG is a standard from the Multimedia Hypermedia Expert Group (MHEG), which provides tools for the creation of simple interactive multimedia applications, and is designed to minimise the memory requirements in set-top boxes. The latest version – MHEG-5 – is designed to be interoperable with other hybrid standards such as HbbTV (see below)
- Hybrid Broadcast Broadband TV (HbbTV) originated as a broadcaster-centric Franco-German venture. HbbTV is designed with the aim of “harmonizing the broadcast and broadband delivery of news, information and entertainment to the end-consumer through TVs and set-top boxes with an optional web connection”. The goal is at the same time to provide Internet AV content on the TV screen and to enable full broadcaster control when additional online content is accessed from a linear broadcast channel. HbbTV:
  - Allows integrated display of both linear broadcast content and AV content/applications sent via the Internet (OTT) on the TV screen.
  - Allows interactive applications to provide and combine content accessed via broadband, or sent via broadcast
  - Allows each broadcaster to control the environment of interactive applications provided alongside the content of their linear broadcast channels. In other words, with HbbTV, the broadcaster controls which application can be used by the consumer when watching its channels.
  - Allows the manufacturer to configure the start screen and to select the OTT services/applications initially available to viewers.

The first HbbTV boxes were launched in Germany in the run-up to Christmas in 2009, with Version 1.1.1 of the specification being approved by ETSI in July 2010. Today, the standard is deployed across Europe, including in Austria, Czech Republic, Denmark, Finland, France, Germany, Poland, Spain, Switzerland and the Netherlands. It is now being adopted outside Europe

- YouView was developed in the UK as an independent connected TV platform. It was launched in 2012 with the aim of combining "the simplicity and value of Freeview with the choice and convenience of catch-up and on-demand". YouView has failed to meet several of its original goals (as discussed in Appendix C) and the future of YouView is now uncertain.

### Proprietary initiatives

In addition to the standards listed above, developments which are driven largely by the broadcasting community, there are a number of interactive solutions developed by consumer electronics firms, which allow the manufacturer to embed OTT content directly within (say) a smart TV using an integrated user interface and effectively enabling the supplier to act as a content aggregator. Examples include:

- Samsung's Smart TV portal. Samsung is reported to have the largest installed base of smart TVs in Europe
- The smart TV Alliance formed by LG, TP Vision and Toshiba

But we note that the consumer electronic suppliers are hedging their bets. Most of their latest smart TV models also include HbbTV capability - especially in markets like Germany and France.

### EPGs

To discover and select AV content most users rely on an electronic programme guide (EPG) which provides information such as programme schedules, information about individual programmes, recording information and video settings to the viewer. This requires the provision and delivery of EPG information and its display by the receiving device. The provision of signalling information and basic information for EPGs is standardised (eg DVB SI standard) but the provision of extended EPG information is almost all done in a proprietary fashion. Provision and delivery is bespoke to the platform and display is proprietary to the manufacturer of the receiving device. Appendix C provides more discussion of standards for interactive services and EPGs.

## 4.5 Video formats

As Figure 4-4 shows, the video resolution for TV screens is increasing significantly. There are also lower resolution standards used by smaller devices like tablets and smartphones. But, as indicated in Chapter 2, suppliers of portable devices are now adapting HD formats for many of their products.

Progress in the deployment of these formats on various platforms is discussed in Section 2.4 and more information is provided on UHD formats in Appendix L.

Figure 4-4: Video formats and likely adoption rates for DTT

| Format | Typical bitrate range (Mbit/s) | Resolution | Frame-rate | Typical encoding | Mainstream DTT adoption |
|---|---|---|---|---|---|
| SD (576i/25) | 2.5 – 5 | up to 768 x 576 | 25 fps | MPEG-2 | 1995 – 2005 |
| Legacy HD (720p/50) | 5 – 9 | 1280 x 720p | 50 fps | AVC (H.264) | 2005 – 2020 |
| Legacy HD (1080i/25) | 5 – 9 | 1920 x 1080i | 25 fps | AVC (H.264) | |
| HD (1080p/50) | 8 – 15 | 1920 x 1080p | 50 fps | AVC (H.264) | 2015 – 2025 (?) |
| Ultra HD-1[59] | 8 – 20 | 3840 x 2160p | 50 fps | HEVC (H.265) | 2025 – 2035 (??) |
| Ultra HD-2 | To be defined | 7680 x 4320p | 100 fps | To be defined | ?? |

*Source: previous Plum and Farncombe studies*

We have indicated in Figure 4-4 likely encoding methods and DTT deployment timescales. This suggests that a move to all-HD services on DTT platforms is likely by 2025 using a combination of DVB-T2 and MPEG-4. However it is likely that UHD deployment would require another technology cycle across networks, devices and content production - a cycle which is as yet highly uncertain.

Various players have experimented with 3-D video formats, and these experiments are described in Appendix M, but the results have been disappointing. Despite proven appeal in the cinema for certain genres of movie, 3D has never really taken off on TV. For example:

- Many broadcasters who launched 3D channels have now closed them down, including Foxtel in Australia, ESPN in the USA, and Canal+ in France.
- Last summer the BBC, which had high hopes the London Olympics would spark the same enthusiasm for 3D as the Beijing Games did for HD in 2008, announced it was suspending 3D broadcasts indefinitely, because of a "lack of public appetite" for the technology.

One of the reasons why TV set manufacturers are so keen to bring UHDTV sets to market ahead of UHD specifications being pinned down is that 3D capability is no longer a primary selling-point.

## 4.6 Compression standards

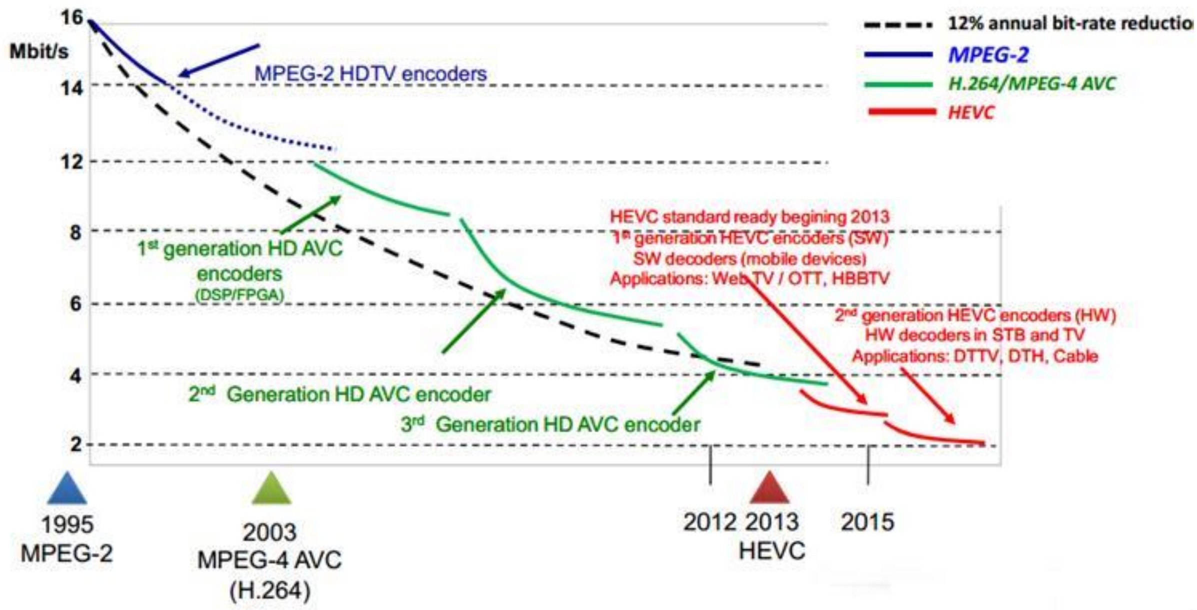
Compression enables the distribution, delivery and storage of AV content. Once digitized, AV content requires a large amount of data; for example, a single second of an uncompressed digitized SD video sequence generates 20 MB of data, and a 2-hour movie generates around 150 GB. Video compression exploits the redundancies which are inherently present in video sequences. They are of two kinds:

- Spatial redundancies: each individual picture is not random, and contains areas where pixels are correlated with each other
- Temporal redundancies: consecutive frames are often very similar, allowing the compression algorithm to use one picture as a predictor of the next.

[59] UHD-1 is often referred to as UHD 4k and UHD-2 as UHD 8k

Figure 4-5 shows how a succession of standards, such as MPEG-2, MPEG-4 and HEVC, has increased the effectiveness of compression and led to reductions in the transmission capacity required for a given quality of video by just over 10% per annum. But, as the previous section shows, these gains in capacity have largely been offset by the implementation of higher video resolutions.

**Figure 4-5: Evolution of compression efficiency and impact on HD TV (720p) service bitrates**




*Source: Thomson (http://www.braf.info/lib_upload/files/20121211%20Note%200869_Attachment.pdf)*

The transition to MPEG-4 is still in progress and this may slow down the rollout of HEVC - given that it requires end-users to purchase new set-top boxes or TVs. In addition many broadcasters, such as those in France and Germany, have delayed the rollout of DVB-T2 to await the widespread availability of cheap HEVC chipsets.

# 5 The ability of broadband networks to deliver AV services

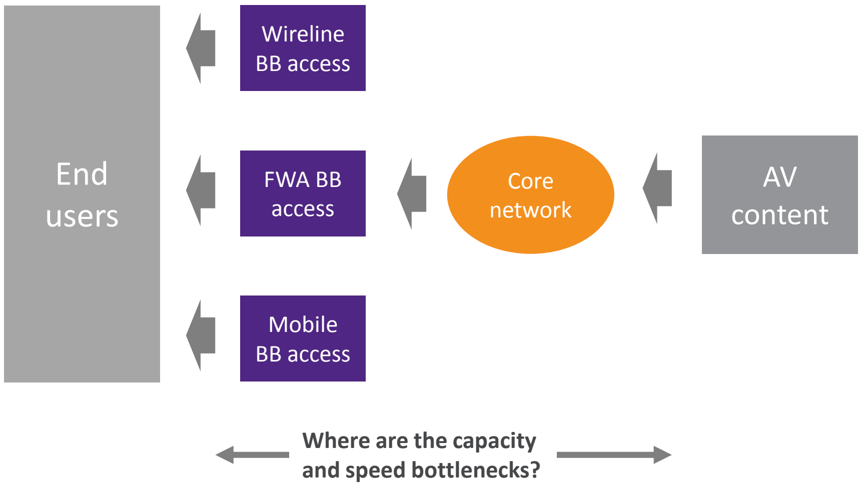
## 5.1 Introduction

How will developments in technology affect the ability of broadband networks to deliver AV services over the next 15 years? Broadband networks are designed to provide access to a wide range of Internet applications and services - delivery of AV content is just one service amongst many. In determining the extent to which broadband networks are suitable for delivering AV services we need to consider:

- Whether the core network of Figure 5-1 has the capability to carry the high volumes of data generated by an AV stream at low incremental cost
- Whether the wireline, fixed wireless or mobile access networks which connect the end-user to the core network have the necessary speeds to stream AV content in a satisfactory way
- Whether each of these access networks can carry high volumes of video data at an incremental cost which is less than the willingness to pay for the service by the end user.

There is also the issue of whether broadband networks have sufficient market reach to make broadband an attractive mechanism for AV delivery from the perspective of the content provider/aggregator. We consider this issue in the next chapter.

Figure 5-1: Where are the bottlenecks in AV content delivery in broadband networks?




*Source: previous Plum studies*

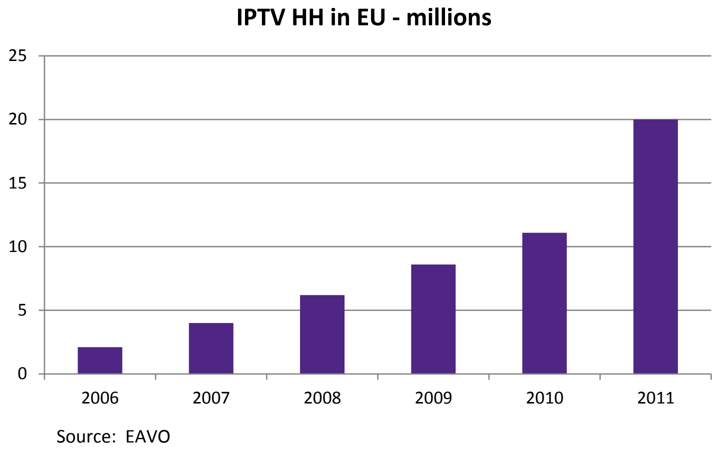
## 5.2 The evolving capability of the core network

Already the core network is used extensively for the distribution of AV content as well as for other broadband applications. For example, Cisco VNI estimates that the average household in Western

Europe generated 20 GB per month of video data for carriage over broadband networks in 2012, and predicts that this will rise to 53 GB by 2017[60].

The use of wireline broadband to deliver AV content is reflected in the growing proportion of households which use IPTV services as their prime means of access to television, as shown in Figure 5-2. But the proportion of such households varies significantly by member state; in France it has reached 35% while in Germany, Italy and the UK it is below 5%.

**Figure 5-2: The growth of IPTV households in the EU[61]**




Looking forward, we expect the data carrying capacity of the core network to increase significantly over the next 15 years. This network, which supplies both fixed and mobile broadband services, consists of a series of components which includes switches, transmission links and servers which store commonly used data/content close to individual users so as to make efficient use of the network and improve quality of service. Over the last decade we have seen spectacular improvements in the price-performance of these components[62]. This has led observers to formulate empirical "laws" which describe observed improvements. Figure 5-3 provides a summary and shows, in the final column, the potential improvements in price performance from 2014 to 2029 on the assumption that these laws continue to hold over the next 15 years. In practice this may not happen if technologies reach their quantum limits[63] within this period. But this does not mean that improvements in price performance of networks and devices will cease. Already equipment suppliers are beginning to move from electronic to optical switching. So, even if Moore's Law reaches its limits, the price performance of network switches will continue to improve substantially.

We can see from the table that the price/performance of the key components of a core wireline network – in terms of transmission capacity, processing power for routers, and storage – are all likely to improve by at least two orders of magnitude over the next 15 years[64].

[60] *Cisco Visual Networking Index: Forecast and Methodology, 2012–2017*, Cisco, 2013

[61] There are just over 200 million TV households in the EU

[62] Strictly speaking our comments relate to the performance of components. But since the price of components has remained stable while annual investment in networks has not changed substantially, we can consider these improvements as relating to price performance rather than just (technology-related?) performance.

[63] Whereby electronic components become so small that it is difficult to control the electronic behaviour of the component.

[64] Assuming that the empirical laws listed in the table continued to hold

**Figure 5-3: Changes in price performance of the technology components of a core broadband network**

| Label for empirical observation | Rule | Comment | Potential improvement over next 15 years |
|---|---|---|---|
| Moore's Law | Processing power doubles every 2 years | May reach quantum limits around 2020 | $2 \times 10^2$ |
| Gilder's Law | Network bandwidth trebles every 12 months | Will persist for next 25 years | $10^7$ |
| Hard disc storage capacity | 10 Mbytes in 1980 has grown to 100,000 Mbytes by 2006 | Magnetic domains will reach limits within next 20 years | $2 \times 10^2$ |
| Flash storage capacity | Doubling in capacity every 12 months | Quantum limitations at some point | $3 \times 10^4$ |
| Nielsen's Law | High speed bandwidth available to end users doubles every 15 months | Based on empirical observations since 1990 | $2 \times 10^3$ |

*Source: previous Plum studies*

Our analysis in Sections 4.1 to 4.6 indicates that:

- DVB standards now operate close to their theoretical limits and any significant future gains in capacity are likely to come from deployment of more advanced (MIMO) antenna designs
- Better compression technologies are leading to only modest capacity gains of around 5 to 10% per annum.

It is unclear how the price-performance of spectrum-based platforms such as DTT and satellite will improve over the next 15 years. But it is reasonable to assume, given the high costs of deploying advanced aerial designs, that it will be well under 10-fold. In contrast we can reasonably expect much greater improvements in price-performance for core telecommunications networks. In particular we conclude that the core network in 2030 will, almost certainly, have enough capacity to handle all of the AV needs of the average household. Our reasoning is as follows:

- The core network might already carry 20 GB of video data per month per household (according to Cisco VNI)
- At normal levels of annual investment in core network upgrades, we might see a 100-fold increase in price performance which would increase the video capacity of the core network to 2000 GB per household per month by 2030
- The average household generates between 120 and 240 GB of video data per month[65]
- Based on these calculations supply could exceed demand by a factor of 10.

## The use of content distribution networks (CDNs)

We already observe significant use of wireline broadband for distribution of AV content. Often this involves caching within the network – in which popular content is stored at points close to the end-users so as to reduce the traffic load on the core network.

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[65] Assuming HEVC compression, HD video formats and one to two to video streams for 120 hours per month

There are now four main categories of organisations which invest in caching:

- Independent CDN providers like Akamai[66] and Limelight, which focus mainly on caching international content for national distribution
- Providers of global Internet connectivity like Level 3, which uses CDNs to make their backbone network more cost effective
- Content distributors like Netflix, which are now investing substantially in developing their own caching infrastructure so as to minimise the network capacity required and improve service quality when delivering OTT content to end-users
- Broadband access providers, such as TDC in Denmark, which offer IPTV services to end users. These access providers may offer to distribute TV content over their multicast network for TV content distributors or for rival broadband access providers.

## Commercial relationships between AV content providers and broadband network operators

There are complex commercial relationships between OTT AV content providers and the core network operators, CDN providers, and broadband access providers which, in combination, deliver AV content to end-users over broadband networks. For example:

- An AV content provider might simply deliver content over the best efforts Internet without attempting to control the quality of service for the end user. Most user generated content from YouTube is in this category
- An AV content provider might use caching to improve quality of service for the end-user. In some cases it might use a caching network provided by a local broadband access provider - like BT in the UK. In other cases it might build its own caching network – like Netflix
- A broadband access provider might offer a managed IP service (IPTV) over which the AV content provider can be assured of the minimum quality of service. In this case the content provider is likely to negotiate to have its contents sold as part of bundle by the IPTV service provider
- An AV content provider might instead wish to offer service as a standalone OTT offering. In this case there is a question as to whether the data traffic generated counts towards an end user's data cap:
  - In some cases the AV content provider might negotiate a commercial deal with the local broadband access provider so that it, rather than the end-user, pays for the carriage of its content[67].
  - In other cases such a move has led to concerns about breaches of net neutrality. For example in the summer of 2013 Deutsche Telekom announced plans to exempt use of its own IPTV service, but not consumption of OTT services, from the tiered data cap charges it levies for broadband Internet access. This brought accusations that it was discriminating in favour of its own AV services and against those of its rivals.

[66] Akamai operated 1800 caching nodes in 84 countries at the end of 2011

[67] We note that in the US ESPN and Verizon Wireless recently attempted to negotiate such a deal

The commercial relationship between the players in the value chain for delivery of AV content over the broadband Internet is not only complex. It is also non-transparent and changing quickly as technology and the price/performance of networks evolves. One long-term issue raised by Figure 5-3 is the extent to which the role of CDNs might shrink as the price performance offered by unicast wireline networks improves over the next 15 years.

## 5.3 The capability of wireline access networks

### The download speeds required for AV streaming

AV distribution over broadband requires download speeds of around 2 Mbps (SD streaming plus simultaneous web browsing), 5 Mbps (HD streaming plus simultaneous web browsing) or 10 Mbps (two HD streams plus simultaneous web browsing) over a standard size TV set. Figure 5-4 illustrates.

**Figure 5-4: Examples of online services streaming bitrates (kbps)**

| Online service, Market | PC/Laptop Tablet/Smartphone | TV |
|---|---|---|
| BBC iPlayer, UK | 500 – 800 | 1,500 – 3,200 |
| ITV Player, UK | >600 | n/a |
| Hulu/Hulu Plus, US | 480 – 1,000 | 2,500 – 3,200 |
| Netflix, (US/European) | 1,500 | 3,000 – 8,000 |
| Lovefilm, UK | 800 | >2,000 |

*Source: Service providers' websites*

### Current download speeds

Currently most households with broadband in the EU have an the average download speed good enough for SD streaming (2 Mbps), but only a small proportion have a download speed good enough for HD streaming (5 Mbps). Figure 5-5 illustrates

**Figure 5-5: Broadband speeds and broadband take-up in selected EU member states**

| Country | Ave. DL in Mbps | % HH > 10 Mbps[68] | % HH > 4 Mbps | % HH fixed BB |
|---|---|---|---|---|
| Netherlands | 12.5 | 44 | 87 | 87 |
| Czech Republic | 11.3 | 35 | 83 | 69 |
| Belgium | 9.7 | 34 | 78 | 79 |
| Austria | 9.3 | 23 | 81 | 80 |
| UK | 8.1 | 27 | 77 | 87 |

[68] This percentage doubled in most member states over the previous 12 months

| Country | Ave. DL in Mbps | % HH > 10 Mbps[68] | % HH > 4 Mbps | % HH fixed BB |
|---|---|---|---|---|
| Germany | 7.6 | 17 | 75 | 85 |
| Spain | 6.9 | 14 | 71 | 69 |
| Hungary | 6.7 | 15 | 65 | 71 |
| France | 6.5 | 12 | 69 | 78 |
| Portugal | 5.9 | 10 | 64 | 62 |
| Italy | 4.0 | 4 | 49 | 68 |

*Source: See http://www.akamai.com/stateoftheinternet/ and http://digital-agenda-data.eu/*

## Future download speeds

The average download speed delivered over a wireline broadband network is rising steadily over time – as shown in Figure 5-6. The European Commission has set a target for all households to have access to download speeds of 30 Mbit/s by 2020.

**Figure 5-6: Average broadband download speed in Mbit/s – 2007 vs 2013 – EU5**

| Country | 2007 | 2013 | Increase |
|---|---|---|---|
| France | 3.3 | 7.8 | x2.4 |
| Germany | 3.2 | 6.5 | x2.0 |
| Italy | 2.3 | 5.0 | x2.2 |
| Spain | 2.3 | 6.9 | x3.0 |
| UK | 3.3 | 9.1 | x2.8 |

*Source Akamai*

Some future gains in broadband speeds will come from the deployment of high-speed fibre to the home and some from rising take-up of high speed cable broadband (see Section 4.3). But much of it will come from upgrades to the copper network using VDSL, and possibly g.fast, technologies, combined with deployment of fibre to the cabinet or pole within the access network. Figure 5-7 tabulates the speeds which this should provide. It shows that, where it is commercially viable to fibre to the cabinet or pole, download speeds for copper based broadband technologies should be more than adequate to provide two HD streams (10Mbps).

Figure 5-7: Broadband speeds on copper loops by technology

| Technology | Download speed (Mbps) with copper loop of | | | | Current status |
|---|---|---|---|---|---|
| | 300 m | 1000 m | 2000 m | 6000 m | |
| ADSL2 | 25 | 20 | 10 | 2 | Widely deployed across the EU |
| VDSL2 | 70 | 25 | 12 | 2 | Now being rolled out extensively in the EU |
| VDSL2 with vectoring | 100 | 50 | 12 | 2 | About to be deployed in the EU |
| g.fast | 500 | na | Na | na | Standard being ratified to avoid potential interference problems with VHF radio |

*Source: FTTH council based on IDATE research*

## The capacity of a wireline broadband access network

One of the characteristics of a wireline access network is that the link from the household to the network is dedicated to the household[69]. This means that it has a capacity well in excess of the total AV requirements of the average household. For example, at a 30 Mbit/s download speed[70] the link might carry 13 GB of data in the busy hour[71] – well in excess of the 1 to 2 GB required to meet AV needs. This means that the incremental cost of delivering all AV services into a home which has already connected to next generation wireline broadband is close to zero. The incremental cost of access is zero (since it is already in place for broadband Internet access) and, as Section 5-3 indicates, the incremental cost per GB of delivering AV content is low and continues to fall quickly.

## The limitations of wireline broadband

There are three important limitations on wireline broadband replacing traditional broadcast networks completely:

- The commercial case for rollout of wireline broadband to the last 10% of the population at speeds which allow HD (or even SD) streaming is weak in most member states and especially in some central European member states where there is little rollout of rural copper access networks
- There is currently limited take-up of broadband connections in some member states – particularly those with a lower GDP per head. See Figure 5-8. While in leading member states 85% of households now use broadband, this percentage falls to 50% for other member states
- There is currently limited take-up of wireline broadband services by older people, those with limited education and those on low income. Figure 5-9 illustrates the age difference in broadband Internet take-up in the EU as a whole. We note, however, that the development of OTT and hybrid TV services which require broadband connections might provide a major stimulus for take-up of fixed broadband by those groups which are currently non-users.

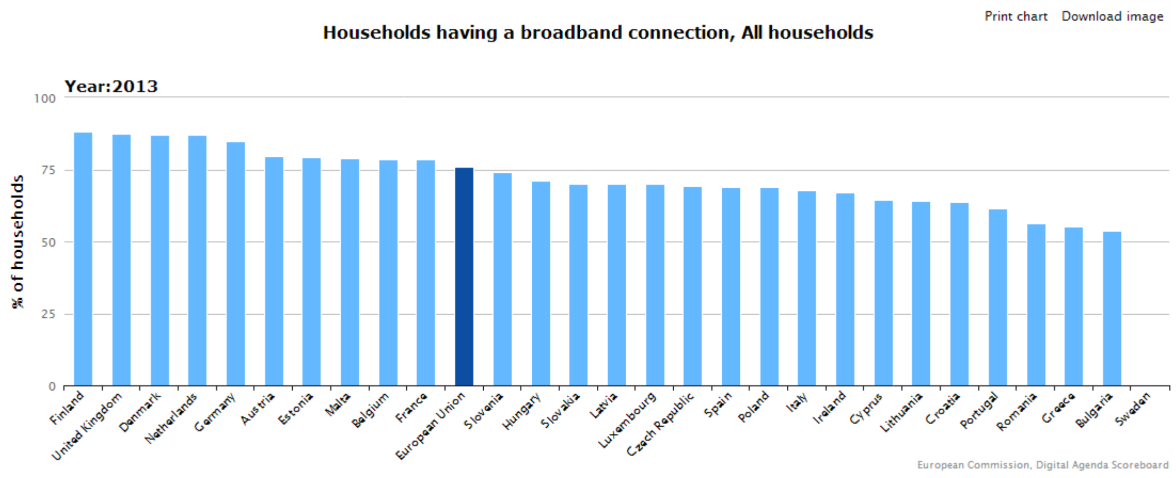
[69] Note this is true for a traditional telecommunications network but not for cable networks

[70] The DAE target speed

[71] (3600 seconds per hour x 30 Mbit/s)/(8 bits per byte)

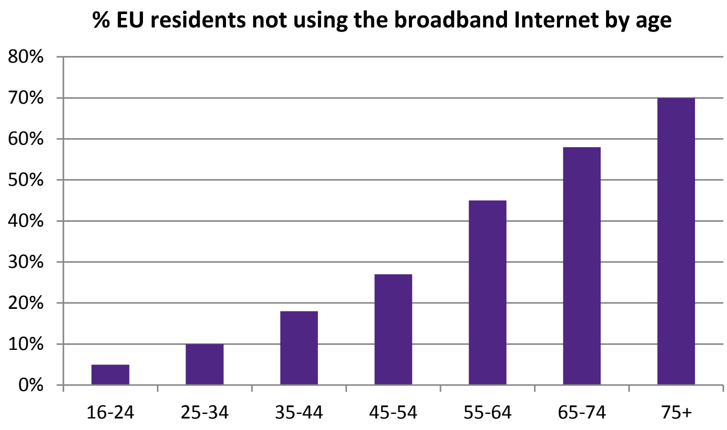
Together these factors suggest that wireline broadband may not meet current policy requirements for near universal delivery of public service broadcast content that is currently delivered over DTT.

**Figure 5-8: Broadband take-up by member state**[72]




*Source: DAE scorecard*

**Figure 5-9: Percentage of EU residents not using the Broadband Internet by age**




*Source: Eurostat*

## Conclusions

Our analysis suggests that:

- Together the wireline access network and the core network can deliver enough data to meet the AV needs of the average household future without a requirement for substantial additional investment

[72] The bulk of connections are fixed. But it is not clear if mobile broadband is also included

- Wireline broadband is likely to become an increasingly effective substitute for other AV distribution networks over the next 15 years as its price performance improves more rapidly than spectrum-based AV broadcast networks like DTT or satellite
- Distribution of AV services over wireline broadband may not meet public service broadcasting policy requirements[73].

## 5.4 The capability of mobile broadband

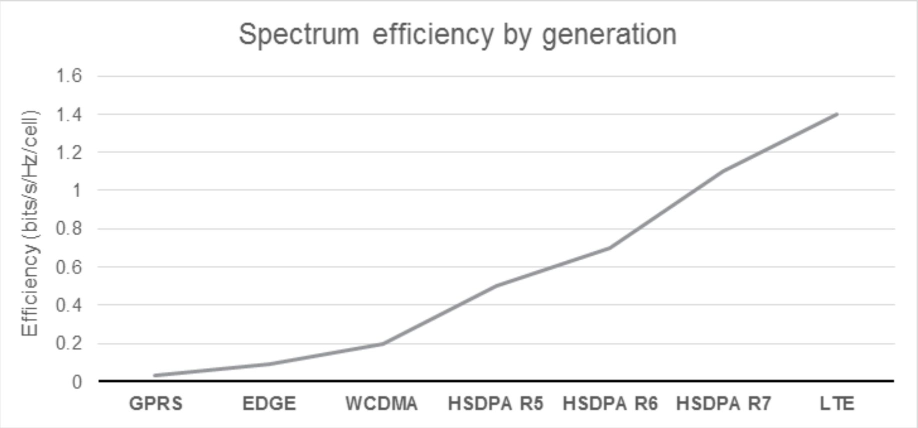
### Introduction

In this section we consider developments in commercial mobile networks and their future ability to deliver AV services. We then make an initial assessment of the role of mobile technologies and infrastructure as part of a converged platform in Chapter 7.

### Spectral efficiency

Mobile networks have moved through four generations of technology with 2G (GSM) deployed around 1992, 3G (WCDA) deployed around 2002 and 4G (LTE) starting in 2012. Within each generation there have been updates such as the move to GPRS and then EDGE within 2G and the progressive release of enhanced versions of HSDPA within 3G. The same trend of steady improvements is also expected in 4G. Figure 5-10 below shows how the spectrum efficiency of these technologies has improved over the generations.

**Figure 5-10: Developments in mobile spectrum efficiency**




*Source: Plum review of various confidential client studies*

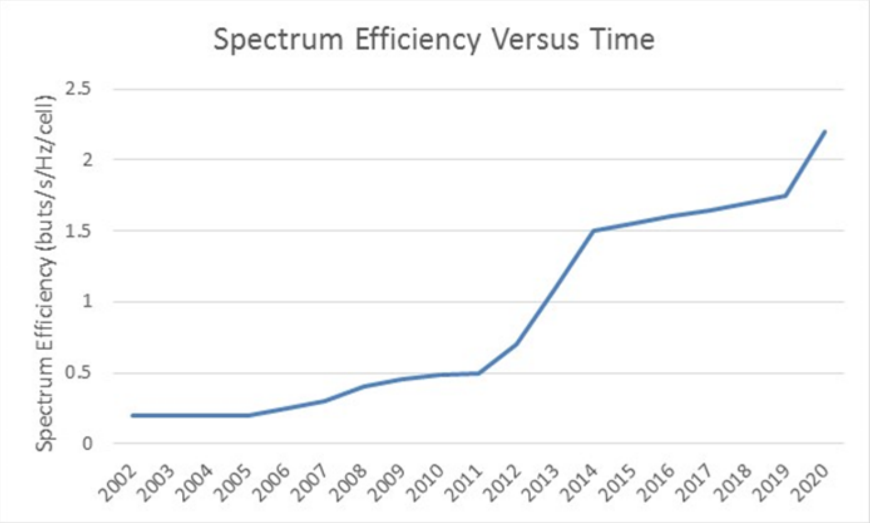
Figure 5-10 shows a steady improvement in spectral efficiency. But the general consensus among experts is that most of the practical gains have now been made and that further increases will be limited. The latest release of LTE Advanced (LTE-A), used with 4x4MIMO, might increase spectral

[73] For example in terms of coverage and provision of a free service

efficiency to 3.5 bps/Hz[74]. But at the cell edge this combination of technologies might offer only 0.1 bps/Hz.

The average spectral efficiency will depend upon the mix of technologies in use by the installed base of mobile devices. So the average will gradually increase towards the spectral efficiency of LTE-A as a higher proportion of end users adopts 4G devices. This is shown in Figure 5-11.

**Figure 5-11: Average spectrum efficiency across 2G, 3G and 4G networks in the UK**




*Source: RealWireless – "4G Capacity Gains"*[75]

## LTE technology developments

Within the LTE roadmap there are also a number of features which are designed to enable mobile networks both to use more spectrum and to increase their spectral efficiency. For example:

- Multiple-input multiple-output (MIMO) antennas, referred to earlier in this chapter, promise more efficient spectrum utilisation
- Carrier aggregation allows the network to use multiple carriers from the same or, over time, different frequency bands simultaneously to achieve higher data rates
- Supplemental downlinks (SDLs) use additional frequency bands for downlink transmission only on the basis that there is often more downlink traffic (to the mobile) than uplink traffic (from the mobile). This is because mobile users download much more data than they upload – for example downloads of videos, photos, music, maps, and applications. A number of studies involving traffic measurements suggest values for the ratio of the downlink to uplink traffic of between 4:1 and 9:1[76].

[74] Compared with 5 to 6 bps/Hz using DVB-T2

[75] http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2011/4g/4GCapacityGainsFinalReport.pdf

[76] See measurements reported in http://lib.tkk.fi/Dipl/2009/urn100072.pdf and http://www.cs.ucla.edu/~falaki/pub/imc153s-falaki.pdf

- Co-ordinated multi-point transmission (CoMP) sends the same signal to a terminal simultaneously from multiple base stations near to the terminal to increase signal strengths when in the border region between base stations
- eMBMS allows for multicast of the same data to several or all of the users in a cell without using significantly more capacity than is required for a unicast transmission. See below for a fuller description

## eMBMS

eMBMS allows operators to consolidate multiple identical transmission streams onto one downlink transmission that all users in the cell can receive. This can result in significant capacity savings where there are multiple users of the same stream in the cell.

The MBMS feature is split into the MBMS Bearer Service and the MBMS User Service. It has been defined to be offered over both UTRAN (i.e. WCDMA, TD-CDMA and TD-SCDMA) and LTE (often referred to as eMBMS). The advantage of the MBMS Bearer Service compared to unicast bearer services (interactive, streaming, etc.) is that the transmission resources in the core- and radio network are shared. MBMS may use an advanced counting scheme to decide, whether or not zero, one or more dedicated (i.e. unicast) radio channels lead to a more efficient system usage than one common (i.e. broadcast) radio channel. The MBMS User Service offers a streaming and a download delivery method. The streaming delivery method can be used for continuous transmissions like mobile TV services. The download method is intended for "download and play" services.

eMBMS has been standardized in various groups of 3GPP as part of LTE release 9. The LTE version of MBMS, referred to as multicast-broadcast single-frequency network (MBSFN), supports broadcast only services and is based on an OFDM waveform and so is functionally similar to other broadcast solutions such as DVB.

eMBMS works by determining that more than one subscriber in a cell is requesting the same content and dynamically setting up an eMBMS logical channel. It then directs the subscribers to this channel. So in theory eMBMS could increase cell capacity several thousand times over when compared with unicast video, if used in a stadium by thousands of spectators with eMBMS enabled mobile devices[77]. We note for example that Verizon reported substantial increases in video traffic volumes when it trialled eMBMS at the Super Bowl 2014.

eMBMS is now being trialled in Korea, the US, Germany and Australia. To date mobile operators have mostly focussed on trialling it for single cell use, such as multicast of AV content in a sports stadium. In Germany however city wide trials are now underway.

eMBMS is designed for commercial deployment in individual cells using a minor adaptation of existing LTE specifications. This means that it is not suitable for broadcast over an LPLT network to provide near universal free-to-view services. There are four main problems:

- The maximum cyclic prefix for eMBMS is 33 µs (compared to up to 400 µs for DVB). This is not long enough to deal with inter-site interference between base stations at the receiver when these base stations are more than 2 km apart. As a result the spectral efficiency of an LPLT eMBMS implementation is very poor in rural areas were inter-site distances of 10 km or more are common

[77] For example to view multicast action replays

- A maximum of six of the 10 sub-frames of an LTE FDD frame can be allocated as a downlink to eMBMS. To be efficient in broadcast all 10 sub-frames should be used
- The LTE standard is designed for use by subscribers who are registered with a specific mobile operator. The efficient way for an LPLT converged platform to work in broadcast mode is for just one mobile network to provide the broadcast service. This requires service without user registration – a feature which is currently supported by LTE only for services like calls to the emergency services
- eMBMS is not designed to work in supplemental downlink mode. So its use means that the paired spectrum assigned for the uplink remains unused.

Several equipment vendors, notably Qualcomm, NSN and Ericsson, have proposed that eMBMS should form the basis for a converged platform through the development of an enhanced LTE standard which would deal with these problems. This is usually referred to as LTE-B or LTE broadcast.

## 5G mobile

The research community is busy defining work programmes for the development of 5G mobile services. To date 5G research programmes are focussed on:

- Development of new, high capacity, radio access technologies at 6 GHz plus
- Tighter integration of existing LTE, WiFi and other networks
- Use of software defined networks
- New protocols to deal with both IoT (low payload, high signalling levels) and mobile broadband (high payload, low signalling levels)

It is very difficult to be certain about the capacity increases that 5G might offer. Our best estimates are that:

- There will be some additional spectrum, but this will be compromised either in that it will be shared with other services or it will be at higher frequencies making it only suitable for indoor or small-cell applications.
- Further spectrum efficiency gains will be limited. Most commentators accept that cellular systems are approaching the limits of what can be achieved in terms of bits/s/Hz and that further gains come at a very high cost in terms of complexity and battery life.
- Better integration with other small cells such as WiFi is expected, enabling devices to seamlessly roam across various generations of cellular, WiFi and any other forms of connectivity that might be available.

This suggests that 5Gs main capacity gains might come from tighter integration with WiFi. We discuss the possible role of WiFi in delivering AV services later in this chapter. So far the emerging definitions of 5G research programmes do not include work on the possible development of converged platforms.

## Use of mobile networks for delivery of AV services

LTE mobile services typically offer download speeds of 5 to 12 Mbit/s in a fully loaded 4G network. As such they are suitable for SD streaming but may not be suitable for HD streaming. However the quality of service which is available is variable in that:

- Download speeds reduce in a busy cell as more mobile devices contend for cell capacity
- Download speeds are likely to be far slower for a mobile device at the cell edge where the spectral efficiency is low.

It is highly unlikely that mobile networks - in unicast mode - will be able to meet the AV needs of the average household at an incremental cost which comes anywhere near what end users are willing to pay. Our reasoning is as follows:

- At present the average mobile consumer uses around 500 Mbytes per month of data[78]. This includes a mix of video, browsing and other data. If all TV were now delivered via mobile then around 4 hours/day of TV per person would be consumed. The data rate would depend on the device and screen size, but assuming a standard size TV, replicating the current viewing experience, then around 2Mbits/s data rate would be required. This equates to just under 120 GB per month – an increase of some 220 times over current usage. Allowing for multiple simultaneous streams and viewing of HD formats this might increase to 240 GB per month in future
- Mobile operators can increase their network capacity by using more spectrum, by using technologies which deliver higher spectral efficiency, or by deploying more cells
- The spectrum which is used by mobile networks might double over the next decade as shown in Figure 5-12
- The average spectral efficiency of the installed base of mobile devices might increase by a factor of five. See Figure 5-11
- To meet the AV needs of the average household would require operators to deploy between 22 and 44 times the number of cells[79]

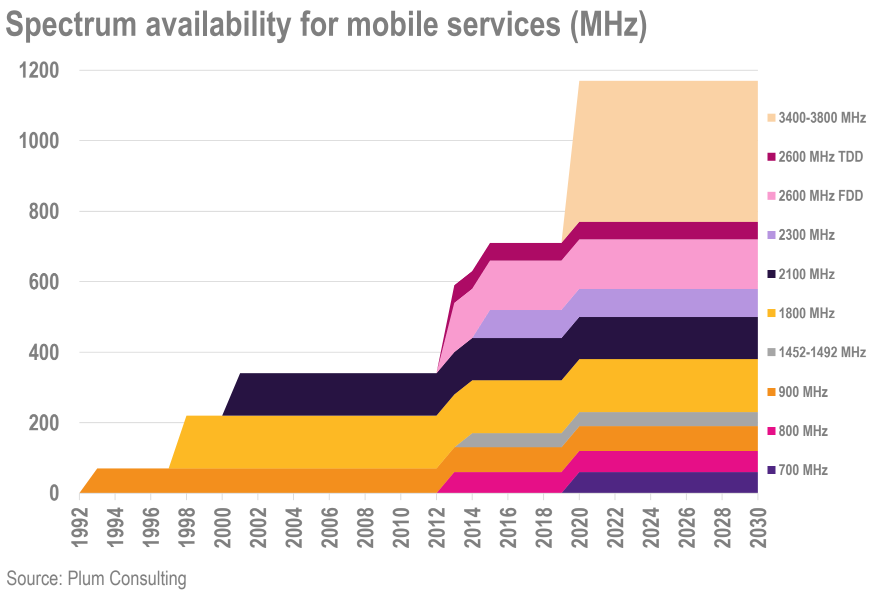
Such an increase in the number of cells would involve a massive investment programme which, if mobile operators are to remain viable, would require a very substantial increase in end user revenues to cover the additional costs[80]. It is highly unlikely that end users would be prepared to pay for such a service.

[78] Source - Ofcom Consumer Report

[79] (220 times the data)/(2 times the spectrum) x (5 times the spectral efficiency)

[80] We note that the radio access network typically accounts for 60% of the cost of mobile services

Figure 5-12: Likely mobile spectrum use (MHz) over time in the EU[81]




*Based on* Licensing of mobile bands in CEPT, *ECO, September 2014 and Plum review of various confidential client studies*

## 5.5 Fixed wireless access (FWA)

### The performance of LTE-based FWA

FWA which uses LTE and high gain roof mounted antenna offers a fixed broadband service with better performance – both in terms of download speeds and throughput – than the corresponding mobile service. Figure 5-13 compares the possible performance of FWA based on LTE technology with 4G mobile, VDSL and satellite.

[81] The spectrum at 3.6 to 3.8 GHz may be used on a shared basis with satellite in some member states

**Figure 5-13: Indicative performance of different broadband technologies**

| Technology | Wireline BB | FWA | 4G mobile | Satellite BB |
|---|---|---|---|---|
| BB speed (Mbit/s down) | 15 to 80 | 15 to 40 | 5 to 10 | 2 to 15 |
| BB speed (Mbit/s up) | 3 to 20 | 4 to 10 | 2 to 4 | 2 to 5 |
| Coverage (indoor) | 9X% | 99.X% | 98% | Near 100% |
| QoS | Good | Good | Variable | Good |
| Mobility? | No | No | Yes | No |
| Relative incremental cost per GB for unicast delivery[82] | Y | 6Y | 50Y | 500Y |

*Source: Plum review of various confidential client studies*

We can see that:

- Fixed wireline broadband based on VDSL offers the best performance in terms of both download speeds and incremental cost per additional GB of data downloaded. This makes it suitable for HD streaming of TV content. However the reach of this technology within rural areas is likely to be limited or, in some cases, non-existent. Figure 5-14 shows how much broadband availability varies between rural and urban areas in the EU at the moment for wireline broadband technologies such as ADSL, VDSL, FTTP and cable
- FWA based on LTE offers a much superior performance to 4G mobile both in terms of download speeds and incremental cost per GB[83]. But the incremental cost per GB is nearly an order of magnitude higher than for fixed wireline broadband[84]. This raises issues of how much AV streaming a household might use before it reached the limit of its willingness to pay for a service priced on a cost orientated basis
- The most cost-effective way to deploy LTE FWA is likely to involve using the existing infrastructure of the mobile operators, rather than for stand-alone local operators to implement FWA networks from scratch. The former deployment leverages both economy of scale advantages and existing facilities of the mobile operators. We note that mobile operators in Germany now provide FWA in this way in both in rural and urban[85] areas
- It is likely that FWA will have much greater geographical reach than wireline broadband for a given level of subsidy. In most member states deploying FWA on the existing infrastructure of mobile operators in rural areas would allow it to reach – in combination with fixed BB in more densely populated areas - over 99% of households in most member states[86]. There is also limited evidence from our stakeholder interviews that this deployment may, in some member states, involve little or no government subsidy

[82] The cost estimates assume that the FWA network uses the infrastructure of a mobile network

[83] Mainly because its use of high gain roof mounted antenna pointed at the base station gives it a superior radio link budget to 4G mobile

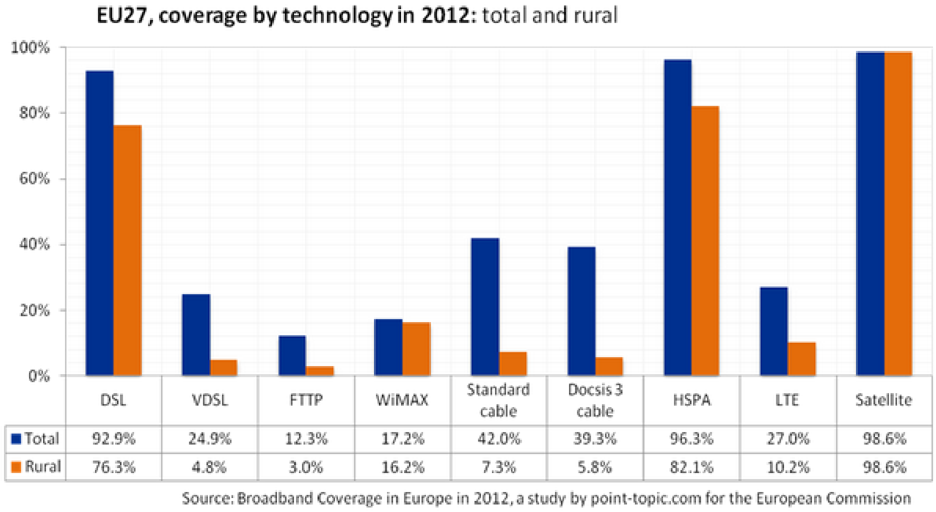
[84] As data use increases the cell reaches capacity and the FWA operator then need more spectrum or to split cells. Either option incurs significant additional costs

[85] Where the low market share of the mobile operators in the fixed broadband market makes FWA a viable technology to deploy

[86] The remaining 1% of households are typically located in an area where the population density is so low that satellite broadband is a more cost-effective technology for broadband Internet access than any terrestrial technology

- With such implementations LTE-based FWA offers a cost-effective way to extend high-speed fixed broadband in rural areas where wireline broadband is expensive to provide. Such deployment is likely to be important in helping to meet the Digital Agenda Europe target for universal availability of broadband with a 30 Mbit/s download speed by 2020
- Satellite fixed broadband, which offers reasonable download speeds[87] for basic broadband applications, is likely to be an order of magnitude more expensive than 4G mobile technology per GB downloaded and two orders of magnitude more expensive than FWA technology. This reflects the use made of scarce and expensive transponder capacity on the satellite.

**Figure 5-14: Broadband coverage in the EU – urban versus rural areas by technology**




*Source: Point Topic study for European Commission*

A key issue in deploying LTE FWA is what spectrum to use. Deployment across all of the mobile bands would be expensive. Realistic options include:

- Use of 2.6 GHz spectrum for FWA in a rural area[88] with 800 MHz spectrum being used for mobile services in the same area. We understand that BT is considering such a deployment in the UK
- Use of 2.3 GHz spectrum in rural areas for FWA. For example, this spectrum is being deployed for fixed wireless access as part of the national broadband network in Australia
- Use of the same band for LTE FWA and 4G mobile together. For example, this proposal has been made in Germany for use of the 700 MHz band.

We note that this last option may lead to degraded performance for the FWA service. With shared spectrum, active mobile devices at the cell edge would absorb almost all of the spectrum resources within the cell, leading to a substantial reduction in the broadband speeds available to FWA users. It is possible to set minimum quality of service constraints for the FWA users. But this might mean that the band is often not available for mobile use.

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87 At say 4 Mbps

88 In urban areas FWA might not be deployed, given the availability of wireline broadband. In this case the 2.6 GHz spectrum could be used there for mobile devices

### The role of LTE FWA in delivering AV services

Our assessment of the performance of LTE FWA suggests that it is a cost-effective way to deliver a wide range of non-video broadband services to rural households, and can offer a useful urban fixed broadband service to a limited proportion of urban households. However it is very unlikely to meet the full AV requirements of a rural household without extensive subsidy. Our reasoning is as follows:

- The average rural household would need to download 120 to 240 GB of video data per month to meet its AV needs
- By 2020 an LTE FWA network which uses 2x20 MHz of spectrum might deliver 30 GB of data per month to each rural household using the existing grid of a mobile operator's base stations – equivalent to 60 minutes of viewing per day.  Appendix N provides details on how we make these estimates
- The scope for increasing capacity further through additional spectrum and improvements in spectral efficiency after this date is limited
- Meeting the full AV requirements of a rural household using LTE FWA would therefore require extensive investment in new cell sites – so raising the payments required from households to a level which is likely to be beyond their willingness to pay.

It is of course possible that public service broadcasters might be willing to subsidise an expansion of the grid of existing base stations beyond that which is commercially viable. But it is more likely that they would wish to use other, more cost effective, technologies like DTH satellite to fulfil their PSB obligations.

## 5.6 The role of WiFi

Fixed broadband services, both wireline and fixed wireless access, are already enhanced by the use of local wireless tails provided by WiFi.  Over the next few years we can expect to see a very substantial increase in the performance of WiFi – both in terms of the throughput available at a single access point and the distance from the access point at which WiFi can be used. There are three main contributing factors:

- The performance of the WiFi standard has improved rapidly as shown in Figure 5-15
- The amount of licence exempt spectrum which WiFi access points can use has increased significantly and will increase further in the near future.  Figure 5-16 illustrates. This figure assumes that current proposals for opening the whole the 5 GHz band to WiFi services are adopted in Europe from 2016.  This looks increasingly unlikely.  But we should still see some expansion in use of the 5GHz band for WiFi following WRC-15
- In terms of range, the 802.11ac standard uses beam-forming techniques to focus the energy on stationery devices and extend the distance over which it provides (say) a 50 Mbps connection. Reviews suggest significant but unquantified improvements.

But there are also unresolved uncertainties here. In particular satellite operators using the 5 GHz band have reported interference from WiFi – possibly because users of WiFi devices at 5 GHz have switched off functions designed to prevent interference or use them inappropriately out of doors. Resolving these issues could substantially delay or even reduce the availability of 5 GHz spectrum.

Many of the WiFi devices in the current installed base use legacy standards (e.g. 801.11g) and it will take several years for the majority of devices to migrate to the latest standard. Given this migration we expect that:

- WiFi capacity in a typical home will increase 20 to 40 times over the next 10 years
- The distance from an access point over which WiFi can be used will increase as the technology moves from 802.11n to 802.11ac

Such improvements in WiFi performance will impact on AV consumption in three main ways:

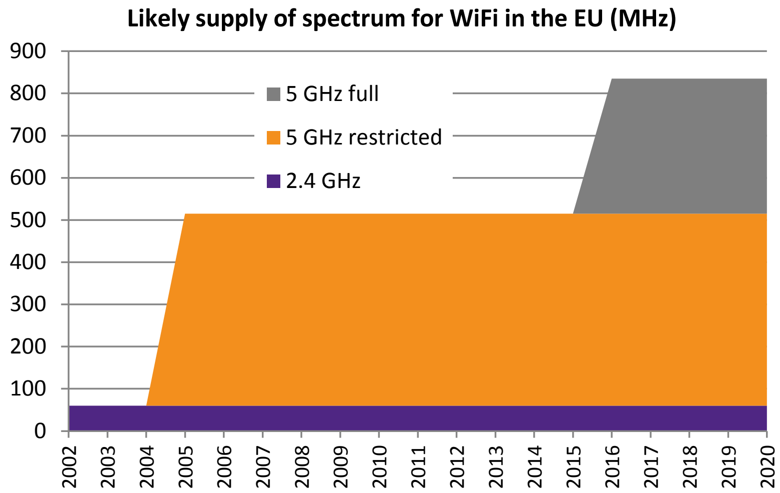
- WiFi in the home could fundamentally change the way AV content is distributed
- WiFi in the home could change secondary set viewing habits
- Use of public WiFi services could provide a major substitute for mobile distribution of AV content.

**Figure 5-15: The throughput of a WiFi access point by standard**

| Standard | Date introduced | Headline speed possible |
|---|---|---|
| 802.11 | 1997 | 2 Mbps |
| 802.11b | 1999 | 11 Mbps |
| 802.11g | 2002 | 54 Mbps |
| 802.11n | 2007 | 150 Mbps |
| 802.11ac | 2014 | 3500 Mbps |

*Source: Plum research*

**Figure 5-16: The spectrum available for WiFi use over time**



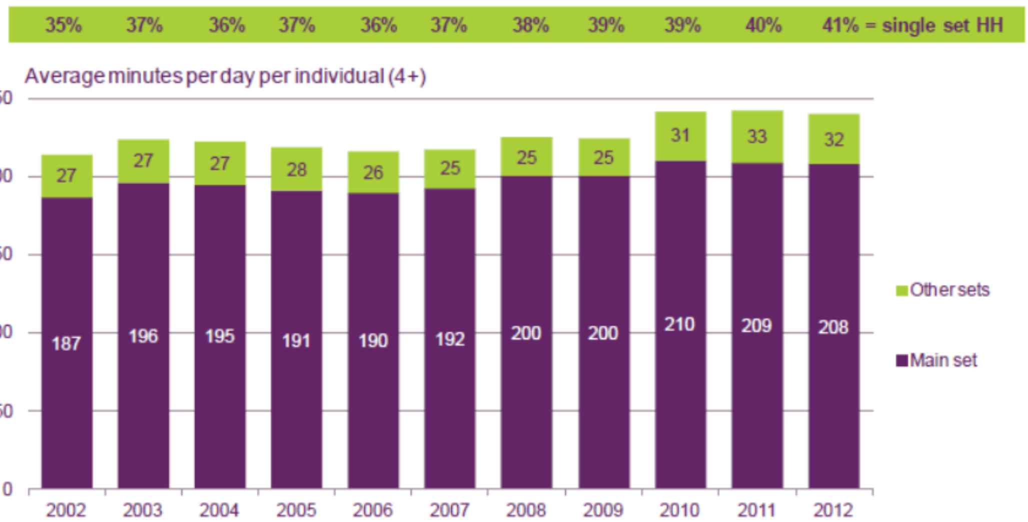

*Source: Future proofing Wi-Fi – the case for more spectrum, Plum for Cisco, January 2013*

## The distribution of AV content around the home

At the moment the typical household views the majority of its AV content on a primary television set in the living room which is fed by cable carrying a DTT, satellite or cable broadcast signal, while a minority view using secondary sets – usually using DTT feeds - in other rooms. For example:

- The average household in the EU owns just under two DTT TV sets
- On average across the EU 33% of households use DTT platforms as the primary means of viewing. But we estimate that this proportion rises to 57% when secondary sets are taken into account
- Secondary viewing represents around 15% of total hours viewed in the UK as Figure 5-17 illustrates.

**Figure 5-17: Proportion of TV viewing on secondary sets in the UK**




*Source: Ofcom Communications Market Review 2013*

The advent of high-capacity WiFi in (virtually) every fixed broadband home[89] could lead to a fundamental reconfiguration of the way AV content is distributed:

- Away from the primary/secondary viewing architecture we see in a typical home today
- Towards a situation in which a home hub takes some mix of fixed broadband, cable, satellite and DTT inputs of AV content on the network side and distributes it as an IP stream to a wide range of connected devices over WiFi on the end-user side.

Connected devices might include large screen monitors for family viewing and laptops, tablets and smart phones for individual viewing. WiFi might also be used on a device-to-device basis - for example with a mobile device transmitting (over a direct WiFi link) video content which was recorded earlier in the day to a large monitor in the living room for family viewing.

[89] This includes both wireline broadband homes and homes using other forms of fixed broadband such as fixed wireless access and satellite

Will this become a reality?

- There are at least two substantial studies which suggest that WiFi capacity will not be a constraint on such developments – one from Plum[90] and another from WIK[91]. Both studies modelled likely future demand for home WiFi on the assumption that it is used for HD TV distribution and concluded that, provided the 5 MHz band is fully open for WiFi, there should not be any capacity constraints.
- However, any move towards a home hub concept threatens the existing business models of many major consumer electronics manufacturers[92] and pay-TV service providers who want to control access into the home via their own smart TV or proprietary set top box. So we might anticipate significant resistance to implementation of such an idea. As a result the developments described above are uncertain.
- Unresolved issues of possible interference between WiFi and satellite services in the 5 GHz band add to this uncertainty.

## 5.7 Changes in secondary set viewing

At the moment the bulk of secondary set viewing is done on DTT-based TV sets. But there are signs that this might change given that:

- The number of tablets in EU households is growing rapidly. In the UK, for example, the proportion of households which owned one or more tablets grew from 11% to 24% in the 12 months to March 2013[93] and there is little sign of this growth in tablet ownership slowing significantly[94]
- Just over half of these tablets are used to watch video and just under half are used to watch TV – either streamed broadcasts or catch-up services[95]
- There is anecdotal evidence that tablets are substituting for DTT sets for secondary viewing in table households. But there is as yet no firm statistical evidence for such a trend.

Given these trends there is a prospect that tablets[96], using a combination of WiFi and wireline broadband, might replace DTT-based TV sets as the main means of secondary set viewing over the next decade. If this prospect were realised then this would significantly weaken the case, at least in some member states, for preserving the DTT broadcast network.

[90] *Future proofing WiFi – the case for more spectrum*, Plum for Cisco, January 2013

[91] *Study on Impact of traffic off-loading and related technological trends on the demand for wireless broadband spectrum*, WIK and Aegis for the European Commission, Undated

[92] Some consumer electronics suppliers might see WiFi as a way of stimulating sales of equipment and so might embrace, rather than resist, the home hub concept

[93] *Communications Market Report 2013*, Ofcom, August 2013

[94] For example Forrester predicts that tablet ownership in the EU will increase from 12% in 2012 to 55% in 2017 http://techcrunch.com/2013/02/20/forrester-tablet-ownership-in-europe-to-rise-4x-in-5-years-55-of-regions-online-adults-will-own-one-by-2017-up-from-14-in-2012/

[95] *Communications Market Report 2013*, Ofcom, August 2013

[96] Along with other connected devices such as OTT dongles combined with secondary TV sets

## 5.8 Using public WiFi services for AV distribution

In theory public WiFi[97] offers a low-cost urban substitute for mobile broadband when users are outside their home or office environment – where private WiFi is now generally available. There are two main modes of consumption:

- Downloading for later viewing. For example a commuter might download content from a public WiFi service at a railway station for subsequent viewing on her journey
- Streaming. For example someone might watch a simulcast of broadcast TV on a smart phone while drinking coffee in a café.

Such patterns of consumption are in their infancy as Figure 5-18 illustrates. But they could increase significantly given:

- The efforts now being made to automate the authentication process for registering a mobile device on public WiFi hotspots through initiatives such as Hotspot 2.0. We note for example that Telefonica recently launched a service in central London which required only a one time registration. This service now generates traffic which is several times the mobile traffic in the same area, rather than the very small proportion shown in Figure 5-18
- The growing number of public WiFi access points. At the moment there might be a few thousand access points available for public use in a typical member state[98]. But in leading countries like Hong Kong there are now firm plans to deploy around 50,000 access points for public WiFi services[99]
- The European Commission's proposals - as set out in its single market draft regulation[100] - to make the deployment of public WiFi services easier
- The emergence of roaming facilitators, such as Boingo and iPass which enable subscribers to one public WiFi service to roam onto another in the same or a different country
- Growth in use of the FON service which allows subscribers to use capacity on private WiFi routers.

[97] We include within the term public WiFi commercial public WiFi services acquiring subscription, free WiFi services privately provided in publicly accessible places such as cafes and hotels, and Metropolitan wide area networks which use WiFi such as those provided by municipalities.

[98] *Study on Impact of traffic off-loading and related technological trends on the demand for wireless broadband spectrum*, WIK and Aegis for the European Commission, Undated

[99] Announced deployment plans of HGC, HKBN and PCCW for 2014 and 2015

[100] *Connected Continent: Building a Telecoms Single Market*, European Commission, September 2013

Figure 5-18: The use of WiFi as a percentage of traffic generated by Android mobile devices

| Country | % on mobile network | % on private WiFi | % on public WiFi |
|---|---|---|---|
| Brazil | 19 | 79 | 2 |
| Canada | 23 | 75 | 2 |
| France | 21 | 77 | 2 |
| Hong Kong | 27 | 71 | 1 |
| India | 47 | 52 | 1 |
| Italy | 29 | 69 | 2 |
| Thailand | 28 | 67 | 5 |
| United Kingdom | 18 | 80 | 1 |
| United States | 32 | 66 | 2 |

*Source: Connected Televisions: Convergence and Emerging Business Models, OECD Digital Economy Papers, No. 231, 2014*

## 5.9 WiFi on public transport

There is substantial demand for WiFi coverage outside of the home. Many devices, including a high proportion of tablets, can only be connected via WiFi and even for those devices with cellular connectivity WiFi can often provide a cheaper and faster option. This demand is generally well catered for in static locations such as coffee shops and shopping malls. However, the demand is less well met on public transport such as buses, trains, coaches, underground trains and planes.

We are now seeing a significant number of organisations offering WiFi access on public transport[101] [102] [103] in which the vehicle receives and transmits data using an external antenna and then distributes it within the vehicle using WiFi. This helps overcome the "Faraday cage" problem experienced by smartphone and tablet users who attempt to connect directly using mobile broadband from within the vehicle (where the radio signal is significantly attenuated as it passes into the vehicle and thus service quality is low).

The main problem in delivering WiFi on public transport is providing the backhaul - the transmission of the traffic from the WiFi router to the Internet. For fixed routers this is simply a case of connecting to a DSL phone line or similar.  But for a mobile router wireless backhaul must be used. Typical wireless backhaul includes the following options as shown in Figure 5-19.

[101] http://www.zdnet.com/WiFi-on-public-transport-faces-access-monetization-road-bumps-7000015326/

[102] http://www.vancitybuzz.com/2014/08/free-wifi-telus-select-metro-vancouver-public-transit-buses/

[103] http://www.independent.co.uk/life-style/gadgets-and-tech/transport-for-london-trials-free-wifi-on-buses-9653244.html

Figure 5-19: Backhaul solutions for WiFi on public transport

| Type | Data rates | Cost | Coverage |
|---|---|---|---|
| Cellular | Up to a few Mbit/s | Similar to cellular tariffs | Good in cities but can be poor on train tracks |
| Satellite | Around 1Mbits/s for small dishes | Higher than cellular | Good across the country but a dish needed |
| Microwave | Over 10Mbits/s | Typically high capex to install | Poor, limited to beams of coverage from masts |
| Dedicated solutions | Can be over 10Mbit/s | High capex cost to deploy bespoke coverage solutions | Can be tailored to need but at a cost |

*Source: Plum analysis of confidential client studies*

For example, WiFi backhaul from buses and coaches will generally be cellular. From trains it is a mix of cellular and satellite with bespoke solutions deployed alongside tracks in some cases. For planes it tends to be satellite with some bespoke solutions over land.

There are two implications of the backhaul constraint:

- Data rates are lower. The WiFi router is limited to providing service at the backhaul rate. For a router on, for example, a bus with a 5Mbits/s cellular backhaul (which will vary with coverage) and 20 passengers on the bus, each passenger will get 250kbits/s – well below the rate needed for quality video.
- Costs are high. These may be borne directly by the consumer, for example on planes, or indirectly in the ticket cost.

There are no significant solutions on the horizon for this backhaul issue. The best systems at present tend to use multiple parallel 4G data streams. However this is not attractive to the mobile operators as such an arrangement can quickly consume much of the capacity of a cell. Satellite systems are progressively increasing in data rates but are still relatively slow and expensive compared to static WiFi solutions. Smart antenna systems tend to be of little use because of the difficultly of steering them and the lack of space to mount unwieldy multi-antenna arrays on most transport systems.

This analysis suggests that:

- It will remain difficult to stream quality unicast video cheaply while travelling.
- Many travellers will continue to download video content before starting their journey as a quicker and cheaper approach.

## 5.10 Dealing with variable quality of service in broadband access networks

One of the problems with delivering AV content over a broadband access network is the variable quality of service which it offers. Broadband access networks contend for capacity - especially FWA and mobile networks. There are two techniques deployed to minimise this problem:

## Progressive download

A simple solution to the problem of variable transmission quality is to use HTTP, which is the "universal" protocol of the World Wide Web. A standard use of HTTP guarantees that all end users who have the most basic access to internet will be able to access the service. Based on TCP, HTTP guarantees the integrity of the transported content. This has been the basis of Progressive Download, which is basically a file transfer using HTTP, but where the client is allowed to start the playback of the AV content while the transfer is still in progress.

To absorb variations in throughput, the client will start the playback only a few seconds after the file transfer has started so as to build a security buffer. However, if the average throughput is lower than the bit-rate at which the content has been encoded, the playback will suffer interruptions.

## Adaptive Bit-Rate (ABR) Streaming

ABR protocols have been created and deployed since 2008 – with more widespread take-up after 2010. Their aim is to provide the user with the highest quality possible given the network characteristics, while ensuring (if possible) that the playback will not suffer interruptions. In other words, the ABR protocol will adapt the audio/video quality to the available network throughput.

The most deployed ABR protocols are:

- 3GPP Adaptive HTTP Streaming (AHS): specified by 3GPP and released in September 2010
- HLS: specified by Apple and released in November 2010
- SmoothStreaming: specified by Microsoft and released in November 2010
- HDS: specified by Adobe and released in June 2010.

In April 2012, MPEG published the MPEG-DASH specification, which is a standardized ABR protocol (mostly based on AHS). This protocol is agnostic to the video and audio codecs used as well as to the content protections technologies (DRMs) used.

MPEG-DASH now benefits from the support of major equipment manufacturers and is a good candidate to mitigate market fragmentation issues caused by the diversity of existing ABR protocols. However it is not yet as widely deployed as other ABR standards such as HLS or SmoothStreaming.

# 6 Broadcast-Broadband convergence

## 6.1 Convergence vs substitution

Broadcast and broadband developments over the next 15 years will change the way end users consume video through both substitution effects and complimentary combinations of broadcast and broadband. We define the latter as *convergence effects* and discuss them below. *Substitution effects* are covered in Chapter 7.

## 6.2 The different forms of convergence

Previous chapters on market developments have demonstrated that converged services, as a result of combining broadcast and broadband services, are driven by consumers' needs coupled with technological developments across devices and networks. Market analysis has also shown that suppliers follow different approaches when it comes to the introduction and provision of converged services:

- Broadcasters may prioritise cross-platform content monetisation and interactivity
- Device manufacturers may focus on improving product functionality and
- Platform operators may develop features to ease user interaction and enable a multi device/screen experience.

Hence, there are different ways in which broadband and broadcasting services might converge to deliver video content to end users. We describe one taxonomy for future converged services below.

## 6.3 The different forms of broadcast-broadband convergence

There are three main forms of convergence of broadcast and broadband services:

- Convergence at the ***device level*** to enable the user to view services delivered over broadband (fixed or mobile) and broadcast networks on the same device[104]
- Convergence at the ***service level*** to make linear and/or on-demand services accessible seamlessly between devices. Here the user accesses the same service when s/he switches devices and service provision may be enabled over different networks. While the user is on the go, mobile broadcast and broadband networks can be used to deliver the content. Inside the home terrestrial broadcast and fixed broadband networks can enable service provision. For example, a linear service may be watched at the main TV screen at home and switched over to a mobile device when the viewer is outside the home. Similarly, the on-demand content watched while a viewer is outside the home on her mobile handset (for example when commuting) may be switched to the TV-set when the viewer is at home. Service level convergence also enables the viewer to switch content watched on her personal device at home to the big screen and vice versa

[104] A user might already be able to receive both TV and non-TV originated content on a mobile device via a unicast mobile service. This is not broadcast-broadband convergence since there is no broadcast component

- Convergence at the ***infrastructure level*** in which broadcast and broadband services use a common network infrastructure. This form of convergence is the focus of the study and the most promising options for a converged platform are assessed later in the report.

## 6.4 Convergence at the device level

Convergence at the device level can take one of two main forms.

With ***content*** convergence in the device the user accesses/switches between linear/broadcast and on-demand/broadband modes to view video content. For example:

- Set-top boxes with PVRs (or other devices with storage capabilities) offer access to linear and on-demand content. Content may be delivered by either broadcast or broadband services or a combination of both
- Smart TVs now offer combined access to fixed broadband and DTT/satellite services for viewing of broadband and broadcast video content on household devices
- Some mobile devices use DVB tuners to allow the user access to both broadcast linear video content and unicast personalised video content sent over the mobile network

With ***application level*** convergence the same application offers access to live/linear broadcast video streams, to video on-demand, to catch up services and, in some cases, to OTT video from the Internet. Examples of application convergence include:

- The development of "backwards" EPGs with improved accessibility to both linear and catch up content via a single user interface[105]. In some cases, the user is able to scroll across different on-demand and catch-up services. Some services allow users to customise their EPG by prioritising or removing channels
- Content search/discovery applications which combine search capabilities for both linear and on-demand content including, in some cases, stored content in the device, by accessing metadata information, which is usually centrally stored. The application accesses the metadata database and when combined with user preferences information can provide recommendations for content selection across linear channels and on-demand services. Real-time content ratings (or even audience measurements for live/linear content) from other users with similar preferences can provide another dimension for content filtering making the discovery process even more personal for the viewer
- The development of interactive applications which enable more active viewer participation such as integrating social media engagement or accessing click-to-buy apps to make purchases related to the linear or on-demand content watched. These applications may be content independent. For example, by launching a click through app, the viewer can be directed to a catalogue of possible purchasing items[106] as seen in the linear AV content s/he was watching. The viewer can then make a purchase, request additional information about the items or ask for the relevant links to be sent to his tablet or mobile device for later browsing or other promotions. Other applications may be directly linked to the content. Examples include displaying background information on the subject or persons in the TV programme, participation in opinion-polls and

[105] YouView and Virgin's TiVo set top boxes in the UK already provide a backwards EPG

[106] The concept of any item which appears in a video stream is a potential sale item is usually referred as embedded advertising

voting or giving the viewer control over the video or audio which appears on the screen, such as changing the camera angle or selecting subtitles on his/her language or format preference

- Targeted advertising which dynamically matches household/user demographic and behavioural information, such as viewing habits, age, location, and other attributes, with a library of adverts and may insert them in a live ad break, as a pre- or post- roll advert or a pause during an on-demand viewing, as a banner in other applications or while the viewer is browsing the EPG, etc.

## 6.5 Market prospects for different forms of convergence

**Content** convergence at the device level is already extensively deployed. The great majority of the cases include content delivered over a combination of broadcast and fixed (but not mobile) broadband networks. We expect such deployments to be the default, across Member States, by 2020 at the latest.

**Application** convergence at the device level is now being promoted and widely implemented by a number of market players (broadcasters, consumer electronics suppliers, platform operators) to differentiate their product and service propositions, to enhance and personalise user experience and/or to monetise content. We can expect that the development and adoption of hybrid standards (e.g. HbbTV) and their ecosystem together with an expanding evolution of third-party apps will facilitate and accelerate market-wide adoption of application convergence across devices. It is possible that future applications will enable new functionalities of audio-visual content navigation and discovery offering a more personalised/tailored user experience.

**Application** convergence is currently focussed on the TV set; applications on mobile handsets and tablets are, in most cases, designed to enhance the role of the TV set. They are designed to complement TV watching (or radio listening[107]) by displaying content that is contextual and synchronised to what is showing on the primary screen - whether that is live or on-demand[108]. Clearly one reason for this development is the lack of broadcast services on mobile devices. In theory it should also be possible to implement such convergence on mobile devices – if and when there is sufficient demand.

**Service** convergence is currently limited to simple forms such as streaming video content between in-house devices using external[109] adapters or proprietary implementations like TiVo. The provision of more advanced forms of service convergence across devices and platforms[110] represents a complex proposition since content is currently consumed heterogeneously over different networks (fixed, mobile, wireless) and a large range of devices. Such levels of service convergence would require costly implementations and major investment in both network infrastructure and end-user devices. There are also significant barriers to service convergence in terms of existing content rights. At the same time there is as yet no hard evidence on the scale of market demand for service convergence.

**Infrastructure** convergence already exists for fixed networks through Cable and IPTV networks. We consider the merits of implementing such a converged platform for mobile broadband and DTT broadcast in Chapters 8 to 11.

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[107] See Appendix X.4 for more detail

[108] http://www.bbc.co.uk/blogs/legacy/researchanddevelopment/2010/11/the-autumnwatch-tv-companion-e.shtml

[109] e.g. Chromecast or similar

[110] e.g. unified provision/consumption between different environments such as on the go and /stationary, in-house and outside the home

## 6.6 Member state variations

Broadcast-broadband convergence, in any of the forms described above, is taking place from different starting points and at different rates across different Member States. This reflects the different market conditions and market structures in Member States.

In particular the market strength of the various stakeholders which make up the AV distribution chain differs by member state. Different stakeholders are in turn driven by different opportunities and risks in promoting broadband-broadcast convergence, as illustrated in Figure 6-1. This means that we are likely to see convergence developing in different ways in different Member States over the next 10 years.

**Figure 6-1: Impact of broadcast-broadband convergence on stakeholders**

| Key stakeholder | Opportunities | Risks |
|---|---|---|
| Content owners | New ways to monetise and market content<br>By-pass traditional distribution chain (direct distribution) | Challenging audience measurement and user behaviour tracking mechanism<br>Content rights management |
| Content distributors/aggregators<br>Broadcasters | Availability of wider options of reaching existing audiences<br>Access to new audiences - potential for new sources of revenues<br>Ease/improve content "discoverability"<br>Potential for reduced content distribution costs (in some cases e.g. infrastructure convergence and under certain conditions) | Accelerating audience fragmentation<br>Maintaining privileged position as own (branded) content becoming less visible due to content availability and commoditisation of access to content<br>Challenging audience measurement and user behaviour tracking mechanism |
| DTT Network operators | Enabling new, "converged" services by leveraging existing relationships with content distributors and broadcasters<br>Potential for partnerships and cooperation with other infrastructure providers | Competition from non-conventional distribution networks (part of substitution effects)<br>Impact on core business |
| Platform/Service providers | New media business models<br>Market expansion by offering a wider range of services to individuals (rather households) enabling new revenue streams<br>Potential for reduced service provision costs (under certain conditions) | Increased competition from other "converged" service providers (e.g. 3rd party, application-based, etc.) |
| Device manufacturers | Growing demand of advanced devices with new, innovative user interfaces and functionality | Increased competition from proliferation of devices for accessing/consuming AV content<br>Support/Choose between different standards |
| End users | Availability of alternative or complementary services - wider choice/flexibility of searching, accessing and consuming content<br>Enhanced personalisation prospects of AV services | "Converged" service propositions may increase end user complexity<br>May require interacting with different interfaces (e.g. platform/service provider, network operator, device manufacturer, etc.) |

## 6.7 The need to assess the idea of a converged platform

Most of the convergence effects described above will succeed or fail through the normal functioning of the markets, given that they involve incremental change. Here the parties concerned will face two substantial challenges if converged services are to combine linear broadcast TV and interactive mobile services:

- The population of mobile terminals with DVB receivers would need to grow substantially. Some broadcasters believe that there are several major consumer electronics suppliers which might supply such terminals for their own competitive advantage
- Mobile operators might resist the prospects of their subscribers diverting time which they now spend using mobile devices for revenue generating activities to watching revenue-free free-to-air TV instead.

But market mechanisms alone are unlikely to lead to infrastructure convergence, in which mobile and terrestrial broadcasting services use a common infrastructure. Such convergence involves a costly and disruptive change which affect both the mobile and broadcast sectors and which might not occur without public policy interventions. For example, moving to a converged platform would:

- Involve major changes to equipment in a substantial proportion of EU households
- Require very substantial capital investment
- Require significant changes to the regulations governing DTT networks (as noted in ECC Report 224[111])
- Require major changes to the way UHF spectrum is used and extensive coordination between member states to prevent cross-border interference.

As such it is important to assess whether the concept has economic and social merit first. This assessment is the core concern of later chapters of our report.

In making this evaluation it is important to note that convergence at the device or service level can take place independently of convergence at the infrastructure level. In other words, it is possible to capture the bulk of the benefits of device and service level convergence without the need for a converged platform. In some cases convergence may simply require consumer electronics suppliers to modify devices (content level). In others commercial cooperation between broadcasters and network operators (such as fixed broadband and mobile operators) may be required. This point is an important one to keep in mind when considering the incremental benefits of a converged platform.

[111] *Long Term Vision for the UHF broadcasting band*, ECC TG6, November 2014]

# 7 AV services in 2030

## 7.1 An introduction

What might AV markets look like in the EU in 2030? In this chapter we draw together the findings from the previous four chapters and present four scenarios for AV services 15 years from now.

## 7.2 The future of fixed broadband

Our analysis in the previous chapter suggests that **wireline broadband** will play a central role in shaping the development of AV services over the next 15 years. Wireline broadband is already a powerful complement to DTT and satellite networks in the development of hybrid TV services. In future it could also act as a complement in the development of more personalised and interactive TV services – for example through the development of targeted advertising and website click through services to enable online transactions.

But wireline broadband-based AV services could also act as a strong substitute for DTT (and perhaps satellite TV) based services in future:

- We have already seen IPTV services displace DTT over the last few years in markets like France
- We observe strong growth in the use of OTT services for AV consumption
- We expect wireline broadband to become strongly cost competitive with DTT as an AV delivery network over the next 15 years - given that the price performance of wireline broadband might improve 100-fold while that for DTT might improve by two to four-fold.

However, we think it is unlikely that wireline broadband services alone will replace DTT as long as current public service broadcasting policy, which requires near universal delivery of key AV content on a free-to-air basis, remains in place[112]. It is unlikely that AV services based on wireline broadband will have the reach and the quality of service required to meet PSB requirements. In particular we are concerned about the use of fixed wireless access to deliver all AV services to a rural household. As a contended access technology it would be difficult to meet quality service requirements which are delivered by DTT without substantial investment in the rural cellular network.

We see **FWA based on LTE** complementing wireline broadband in the delivery of high-speed broadband access, primarily in rural areas, so as to help deliver DAE broadband targets in the EU. But LTE FWA will not have the throughput required to meet all of the AV needs of the average household[113]. As a result we see it acting as a complement to DTT or satellite in the supply of hybrid AV services. But we do not see it substituting for established AV services in the same way as wireline broadband might - even after taking account of expected technology developments over the next decade.

[112] Appendix D provides a more detailed analysis of these requirements

[113] As discussed in Section 4.11

## 7.3 Future prospects for DTT

The future prospects for DTT are uncertain. In our analysis we have identified a number of factors which suggest that DTT might maintain its current position as a primary platform in the delivery of AV services across the EU. But equally we have identified other factors which suggest a substantial decline in demand for DTT over the next 15 years. We simply do not know which of these factors will prevail.

### Factors sustaining demand for DTT

**Factor 1**: the move from DVB-T to DVB-T2 and higher encoding standards over the next few years will enhance the capability of the DTT platform and enable it to deliver a wider range of HD and perhaps greater than HD format channels. We note, however, that:

- Only half of EU member states are currently committed to a DVB-T2 upgrade
- Moving the 700 MHz band to mobile use will reduce the spectrum available for DTT and, to some extent, offset the enhanced capacity offered by the DVB-T2 upgrade.

**Factor 2**: the development of hybrid TV services which combine online and DTT inputs over an integrated user interface should substantially enhance the value of DTT. Hybrid TV services also offer the possibility of additional revenue streams, such as targeted advertising.

**Factor 3**: the implementation of DVB-NGH could enhance the value of the DTT network. Mobile TV services, using existing DTT infrastructure in which portable devices use DVB-NGH based receivers to view DTT broadcast content on a free-to-air basis, will be enabled. We note that this development is far from certain. No NGH services have been launched yet which would enable us to assess the impact of such viewing in terms of the battery life of portable devices and the coverage quality.

**Factor 4**: DTT remains the only AV delivery platform which fully meets PSB policy requirements for near universal delivery of key AV content on a free-to-air basis.

### Factors which might drive a substantial reduction in demand for DTT by 2030

**Factor 1**: the cost competitiveness of the DTT network as a way of delivering AV content will decline relative to wireline broadband. See Section 7.2 above. As a result smaller commercial channels, which are often highly cost sensitive, could switch from DTT to wireline broadband and satellite-based platforms[114]. This might undermine the viability of DTT.

**Factor 2**: tablets might replace DTT TV sets as the main means of secondary viewing in the home. We note that there is so far only anecdotal evidence based on discussion with stakeholders to support this claim.

**Factor 3**: spectrum limitations may restrict DTT networks in delivering UHD format AV content and make them less attractive to end-users than services offered by rival networks. We note that there is no evidence so far that UHD services will be a key feature for consumers when selecting platform, while it is clear that end-users want a wide range of channels to choose from.

[114] Which generate operating costs which are substantially lower than those for existing DTT platforms

**Factor 4**: the percentage of the EU population which consumes the bulk of their AV content using online services will grow substantially[115]. As a result a significant proportion of households could move from DTT to online only. It is hard to judge the strength of this effect over the next 15 years. But our analysis is set out below.

## 7.4 The move to online services

Already some viewers in the EU have switched off traditional linear broadcast and now rely on online services delivered over broadband networks to meet their AV needs. There are three key questions to answer in determining the extent to which other consumers might move to online services over the next 15 years:

- To what extent will online services reproduce content and features of existing linear services in the future and so act as substitutes?
- To what extent will end users change their viewing habits as they age and move from the relatively ***passive*** viewing encouraged by traditional TV services towards the more ***active*** viewing which is encouraged by today's online services?
- To what extent will the price performance of broadband networks constrain such a move?

### Replication of established AV services

To replicate the content of existing AV services and, in particular, mixed genre channels, an online service would need to:

- Provide high quality and original content
- Offer varying schedules designed to meet the needs of different audiences throughout the day
- Provide easy methods for viewers to discover content of interest
- Have the potential to reach into a large number of homes.

Our analysis on the extent to which online services might replicate the content of existing AV services is presented in Appendix O. Its main findings can be summarised as follows:

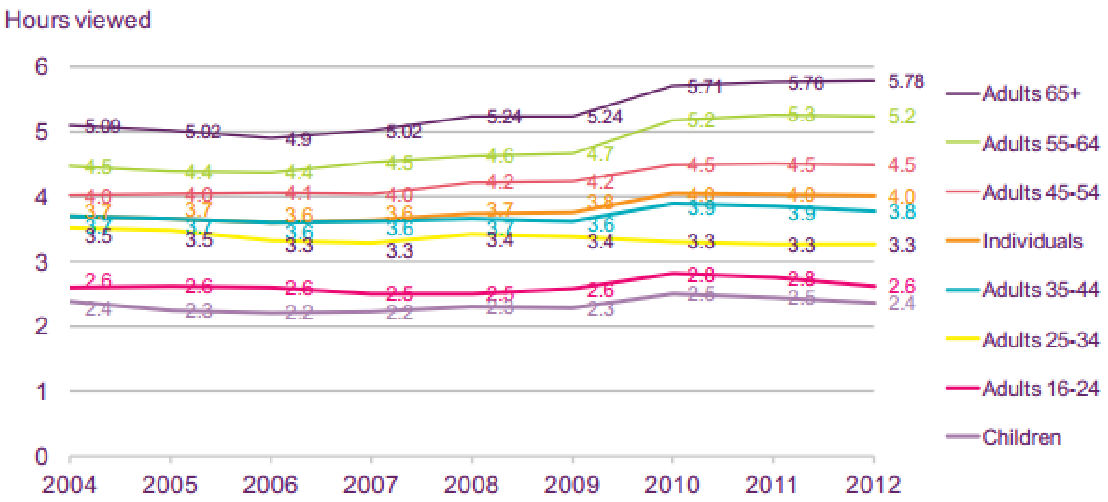
- The extent to which online services already replicate existing linear AV services varies depending on the type of online service
- In general there is a substantial gap between online and existing AV services, especially in terms of the limited extent to which online services offer ease of discovery and schedules which vary across the day
- This gap will close to some extent over the next 15 years.

[115] See Section 5.8 for quantification

## Changes in viewing habits with age

There is already substantial evidence that young people spend less time viewing established linear TV services than the older generations. Figure 7-1 suggests that young people watch less than half as much traditional television as those over 65. But, as we discuss in Section 3.6, the limited evidence available suggests that the behaviour of young people shifts towards that of their elders as they age. This uncertainty makes it difficult to predict the extent to which households will in future switch from broadcast-based to online-based households.

**Figure 7-1: TV viewing by age in the UK in 2012**




*Source: BARB*

## Broadband network constraints

Our analysis, set out in Chapter 5, suggests that:

- The price performance of wireline broadband networks will not constrain a move to online AV services in future for those households which choose to subscribe to broadband Internet services
- The price performance of fixed wireless access and mobile broadband services will constrain this move – in that the cost of carrying all of the AV content consumed in most households is likely to exceed the willingness to pay for carriage over a FWA network.

## 7.5 The future role of WiFi

WiFi, in combination with wireline broadband, will almost certainly play an important role in shaping AV services in next 15 years. As we discussed in Chapter 5, there are three main possibilities:

- WiFi could lead to new AV distribution patterns around the home, based on a home hub rather than the main TV set and/or associated set top box
- WiFi could enable a major shift in secondary set viewing from DTT sets located outside the living room to tablets used anywhere in the house

- Public WiFi services could act as a major substitute for mobile broadband services so as to meet the bulk of consumer requirements of AV consumption outside the home.

But again there are substantial uncertainties surrounding all of these developments. For example:

- There are unsolved interference issues as a result of potential interference between WiFi and satellite services using the 5 GHz band.
- The home hub concept conflicts with the existing business models of some major consumer electronics suppliers and pay-TV providers - who want their smart TVs or proprietary set-top boxes to provide the household gateway to hybrid broadcast/broadband services
- Evidence on tablets replacing DTT TV sets secondary viewing is so far no more than anecdotal
- Use of most public WiFi services is limited to date – although we note that mobile operators which have made an effort to automate the registration of smart phones and tablets at public WiFi access points have seen traffic grow very substantially.

## 7.6 The role of mobile broadband

It is clear from our analysis in Chapter 5 that:

- Unicast 4G mobile services offer average download speeds which make SD streaming, and possibly HD streaming, feasible
- The quality of service available over a 4G network for AV viewing will vary considerably - depending on the time of day and the location of the mobile device relative to the nearest base station
- 4G services do not have the capacity to meet all the AV needs of the average household without massive and unrealistically high levels of investment in more cells.

In the home a combination of fixed broadband and WiFi will offer better and cheaper delivery of AV services to portable devices than 4G mobile. At the same time we expect the great majority of households to subscribe to fixed broadband. Indeed the development of high value hybrid TV services might drive further take-up of fixed broadband in the 22% of EU households which did not subscribe to broadband at the end of 2013.

The role of mobile services in delivering video outside the home is also uncertain in two ways:

- It is difficult to predict what proportion of out-of-home viewing on portable devices uses public WiFi services or pre-stored content rather than mobile broadband
- There is the possibility that portable devices will use DTT receivers based on the DVB-NGH standard to view a high proportion of content outside the home.

## 7.7 Scenarios for 2030

In all of the findings set out above there is a high degree of uncertainty. To take account of this we have developed a number of scenarios for AV services in the EU in 2030. In Chapter 10 we evaluate the most promising options for a converged platform against each scenario to see how robust they are to uncertainty about the future.

We have designed our scenarios to present a set of descriptions of what AV services might look like in the EU in 2030 in which:

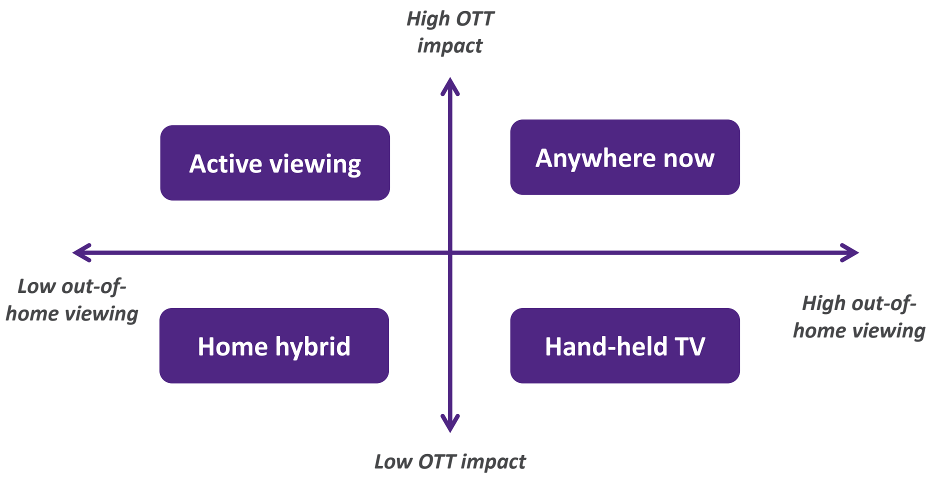
- Each scenario offers a possible set of outcomes which is both consistent with existing evidence and internally coherent
- Each scenario is itself plausible
- The scenarios together span the range of outcomes which are reasonably likely.

In developing the scenarios we focus on those aspects which have informed the extent to which DTT and mobile broadband networks might be used to deliver AV services in 2030.

Figure 7-2 shows our four scenarios. These are a function of:

- Whether the move to OTT based AV services has a strong or weak impact on the overall market
- Whether there is strong or weak demand for out-of-home viewing on portable devices.

**Figure 7-2: AV scenarios for 2030**




The four scenarios are as follows:

- **Home hybrid**: under this scenario the impact of pure OTT services is relatively modest. DTT hybrid services, like those now supported by the HbbTV standard, are very successful and OTT services supplement rather than replace DTT. As a result the DTT share of TV households remains at current levels. At the same time demand for AV services remains largely within the home. Out-of-home viewing is done mostly by viewing pre-stored content on portable devices or through access via public WiFi services. As a result use of mobile broadband for AV services is modest.
- **Hand-held TV**: again the impact of pure OTT services is modest and hybrid DTT proves popular. But in this scenario there is a much stronger demand for out-of-home viewing - in line with a general move towards the mobile Internet. DTT receivers in portable devices, based on DVB-NGH are popular and meet much of the demand for out-of-home viewing. Pre-stored content in portable devices is also popular

- **Active viewing**: under this scenario demand remains primarily in the home. But in this case OTT and IPTV substitute strongly for DTT, driven by:
  - A move away from passive and towards active viewing, with discovery mechanism switching from EPGs to social media, as the young people of 2014 grow older
  - The growing cost competitiveness of wireline broadband-based platforms for AV delivery.
- **Anywhere now**: this scenario combines high OTT impacts and high demand for out-of-home viewing. As a result consumers want AV services anywhere and at any time. There is a strong demand for on-the-move viewing, especially for commuting journeys.

## 7.8 Quantifying our scenarios

Before we can use our four scenarios to evaluate the merits of a converged platform, we need to provide some plausible quantification of what we mean by high and low OTT impacts and high and low out-of-home demand. This is largely a matter of informed judgement. We propose the following for a typical. In practice we will also need to take into account the variability between member states highlighted in Chapter 2.

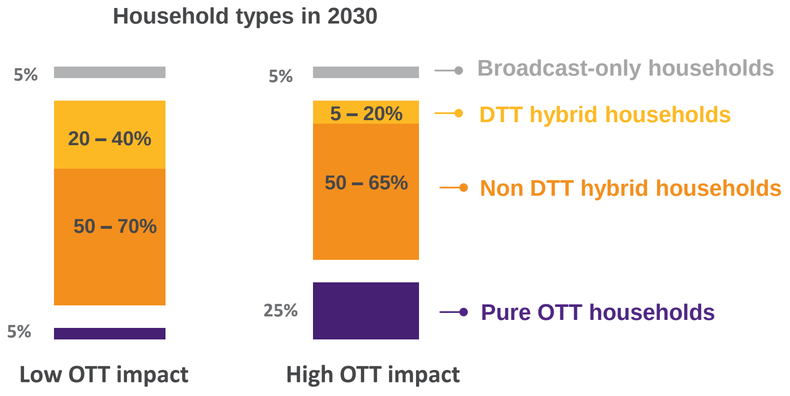
### OTT impacts

Figure 7-3 provides quantification of what we mean by high and low OTT impacts which is consistent with the available evidence. We have divided households into four categories:

- Broadcast only households
- Households which use hybrid broadcast/broadband services based on DTT
- Households which use hybrid broadcast/broadband services based on other broadcast platforms such as satellite, cable and IPTV
- Households which use pure OTT services.

With low OTT impacts the DTT platform retains between 20% and 40% of households; with high OTT impacts it drops to between 5% and 20%. Put another way under the high OTT impact scenario demand for DTT might drop by 70%, while under the low OTT impact scenario it might drop by only 10%.

Figure 7-3: Quantification of high and low OTT impacts by 2030[116]




*Source: Farncombe and Plum analysis*

## Out-of-home viewing on portable devices

In Appendix P we estimate that:

- The average person currently spends around 6 minutes per day on AV viewing when on the move
- This is consistent with Cisco's VNI estimate of mobile video use in 2013
- Cisco VNI projections suggest very substantial increases in this level of use by 2025. But such long term projections do not take account of time budgets. People like to watch at home and the time they spend on the move is limited.

Using a time budget approach we estimate the likely level of on the move video consumption (using portable devices) as shown in Figure 7-4.

[116] We assume that 10% of viewing in hybrid households is OTT for the low impact outcome and this rises to 25% for the high impact outcome

**Figure 7-4: Out-of-home viewing using portable devices in 2030**

| Measure | Low demand scenario | High demand scenario | Comment |
|---|---|---|---|
| Minutes per day per person on AV viewing while commuting | 12 | 12 | See Appendix P |
| Mark up for other use of out-of-home portable devices for AV viewing | x1.5 | x3 | Scenario assumption |
| Total out-of-home AV consumption via portable devices in minutes per day per person | 18 | 36 | Calculated |

*Source: Farncombe and Plum analysis*

## Combining the impacts

Figure 7-5 shows how the scenarios of Figure 7-2 and the quantification of Figures 7-3 and 7-4 relate to one another.

**Figure 7-5: Quantification of platform and consumption scenarios**

| Scenario | Home hybrid | Handheld TV | Active viewing | Anywhere now |
|---|---|---|---|---|
| % reduction in DTT primary households | 10% | 10% | 70% | 70% |
| AV minutes per person per day out-of-home using portable devices | 18 | 34 | 18 | 34 |

*Source: Farncombe and Plum analysis*

# 8 Options for a converged platform

## 8.1 The concept of a converged platform

We define a broadcast-broadband converged platform as one in which a common network infrastructure (of masts, access and backhaul) uses UHF spectrum to deliver both terrestrial broadcasting services and mobile broadband services to fixed and mobile terminals. As discussed in Chapter 6:

- A converged platform is a way of implementing convergence at the **infrastructure** level rather than the **device** or **service** level
- It is likely that all of the converged services listed in Chapter 6 could be implemented through commercial cooperation between mobile operators and broadcasters, without the need for such a converged platform.

Proponents of a converged platform argue that, by moving terrestrial TV broadcast and mobile services to a common platform, it is possible to:

- Substantially improve the efficiency with which UHF spectrum is used and so release a substantial amount of valuable spectrum for other uses
- Reduce the combined operating costs of the broadcast and mobile networks through economies of scope
- Develop interactive multimedia services which use the combined functionality of the broadcast and mobile networks
- Provide a DTT platform which can respond more easily, quickly, and cheaply to changing market demand.

In the next four chapters we assess the validity of these claims.

## 8.2 Basic requirements for a converged platform

Before it can be considered for detailed evaluation, any option for a converged platform must fulfil three basic requirements.

**Firstly,** it must provide broadcast services which offer near universal coverage to existing fixed DTT receivers with free to air reception. Here we note the analysis of Appendix D on PSB requirements. This shows that the existing HPHT DTT networks typically offer between 95% and 99% population coverage but that, in a few member states, coverage reaches 99.9%.

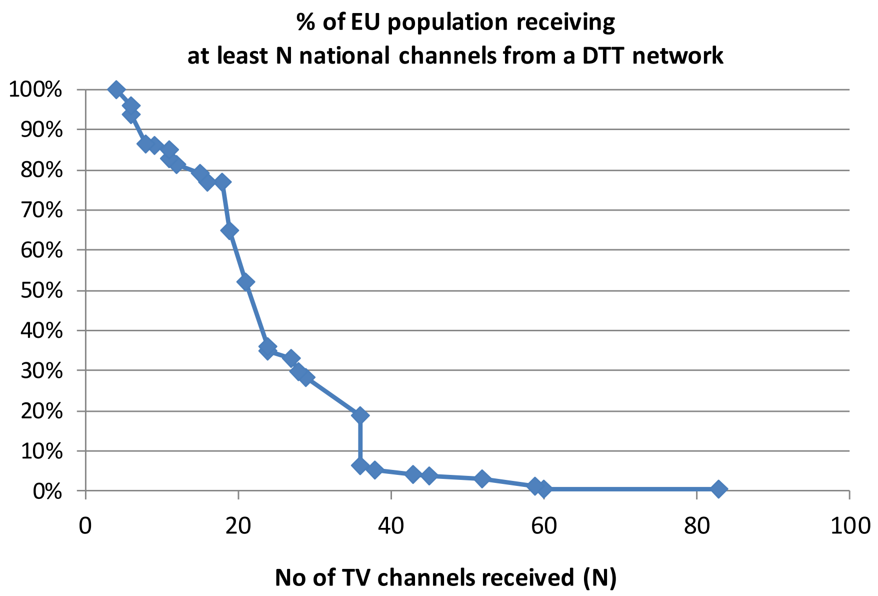
**Secondly,** it must deliver an adequate number of TV channels. Here we consider three cases.

- **Case 1**: the converged platform requires 60 Mbps capacity for TV broadcasting. For a few member states this is likely to give reasonable scope for expansion in channel choice and upgrade of video format from SD to HD and perhaps UHD given:
  - The current number of TV channels broadcast over DTT. Figure 8-1 shows that 20% of the EU's population currently receive less than 15 national TV channels using a DTT platform. By 2025 this could require 20 to 30 Mbps in SD format or three times this in HD format

– The long term trend towards use of IPTV, OTT and possibly satellite services as a way of increasing end-user choice.

- **Case 2**: the converged platform requires 180 Mbps capacity for TV broadcasting. By 2025, the total number of TV services in a payload of 180Mbps might range from 90-125 for SD services, 30-40 for HD services and 6-18 for >HD services. This is roughly equivalent to 6 multiplexes of 8 MHz, each operating at a spectral efficiency of 3.5 bps/Hz. We assume that this represents the maximum DTT broadcasting load which a converged platform might be required to carry
- **Case 3**: the converged platform requires 120 Mbps – midway between Cases 1 and 2. We use this TV payload in the central case for our CBA.

**Figure 8-1: DTT TV channels[117] vs EU population**




*Source: Study team analysis of EAVO data*

These cases refer to the number of ***national*** TV channels which are received. We discuss the capacity of a converged platform to deliver ***regional*** channels in Chapter 9.

**Thirdly,** a converged platform should free up a substantial amount of sub-700 MHz spectrum, from its current use for broadcasting, so that it can be used for interactive broadband services in some way so as to create incremental benefits which outweigh the costs of making a transition to a converged platform. We refer to this effect from now on as *spectrum release* and discuss it in more detail in Chapter 9.

The spectrum released from broadcast use in this way might then be used in a variety of ways. For example:

- It might involve a single operator providing both broadcast and unicast services over a common converged platform or it might involve a converged platform operator providing broadcast services

[117] We exclude national TV channels within a member state which are received by a restricted % of the population and are not offered on a near universal coverage basis

using part of the sub-700 MHz spectrum while the remainder is used by competing mobile operators. We discuss possible commercial models further in Section 11.6

- It might involve integration of the broadcast and broadband services to increase the value of the former (as discussed in Section 10.5), it might involve independent use of the freed spectrum for mobile broadband services, or it might involve some mix of these two possibilities.

In carrying out a CBA we have allowed for all of these possibilities.

## 8.3 The spectrum which a converged platform would use

This study starts from the premise that a converged platform would use spectrum in the frequency range below 1 GHz. At present broadcast TV in Europe uses the UHF broadcasting band which spans the 470 to 790MHz frequency range and also uses, to a much lesser extent, the VHF broadcasting band at 174 to 230MHz[118]. In practical terms this limits the choice of band to either the UHF or VHF broadcasting band, as these are the frequencies that can be received by household TV aerials.

The UHF broadcasting band is the obvious candidate band for a converged platform as:

- The creation of a LPLT converged platform could free up substantial amounts of spectrum at UHF (as discussed later in the report) and its use avoids the need to equip households with new aerials (which would be very costly).
- In practice the amount of available spectrum at VHF is very limited in many countries because the band is used by a variety of other incumbent applications including T-DAB, PMSE, land mobile and defence systems[119]. Also in some member states households do not have aerials that can access the VHF frequency range[120]. These factors also mean that VHF spectrum will have a limited role for simulcasting in the transition to a converged platform.

The frequencies from 694 to 790 MHz (the 700 MHz band) are being actively considered for mobile use by CEPT and a number of national administrations, and this has also been proposed in the Lamy Report[121]. These initiatives are described in Appendix R. Taken together they suggest that the 700 MHz band is likely to be reallocated to use by mobile broadband in a 2017-2025 timeframe. This proposition was not disputed by stakeholders we interviewed or who attended the study workshops.

## 8.4 Possible options for a converged platform

ECC Report 224[122], produced by Task Group 6 (TG6), looks at options for long-term use of the 470 to 694 MHz spectrum band, given evolving market demand and technology developments. As such it forms a useful starting point for identifying possible options for a converged platform. The report sees

[118] The Use of Band III in Europe, EBU Factsheet, 1 September 2014.

[119] Op.cit.

[120] We have not found any data on the extent of VHF antennas in EU member states, although we understand that in Germany, Spain and the UK there are no household VHF TV antennas.

[121] Results of the Work of the High level Group on the Future Use of the UHF Band (470-790 MHz), Report to the European Commission, Pascal Lamy1 September 2014, http://ec.europa.eu/digital-agenda/en/news/report-results-work-high-level-group-future-use-uhf-band

[122] *ECC report 224: Long Term Vision for the UHF broadcasting band*, October 2014

a growing need for cooperation between terrestrial broadcasting and mobile broadband in use of this band for the distribution of AV content. It identifies 11 possible scenarios for long-term use of the band, many of which will require changes to national regulations if they are to be realised. The report also provides guidance to national administrations on the factors they should consider in deciding which scenario to choose. We have used this set of scenarios as the basis for identifying possible options for a converged platform. Figure 8-2 lists the scenarios and Figure 8-3 provides an assessment of which of them represent possible options for a converged platform.

**Figure 8-2: TG6 scenarios for future use of sub-700 MHz spectrum**[123]

| No. | Service | Terminal/ user device | Usage environment | Delivery | |
|---|---|---|---|---|---|
| | | | | Technology | Network |
| 1 | AV linear, AV non-linear | Large screen, small screen/tablet | Stationary, portable outdoor/indoor | DTT | HPHT |
| 2 | AV linear, AV non-linear | Large screen, small screen/tablet | Stationary, portable outdoor/indoor | DTT | LPLT |
| 3 | AV linear, AV non-linear | Large screen, small screen/tablet | Stationary, portable outdoor/indoor | DTT (outdoor), WiFi (indoor) | HPHT/ LPLT |
| 4 | AV linear, AV non-linear | Large screen, small screen/tablet | Stationary, portable outdoor/indoor | DTT (outdoor), WiFi (indoor), DTT chips inside UE | HPHT/ LPLT |
| 5 | AV linear, AV non-linear | Large screen, small screen/tablet | Stationary, portable outdoor/indoor | LTE Broadcast | HPHT |
| 6 | AV linear, AV non-linear | Large screen, small screen/tablet | Stationary, portable outdoor/indoor, mobile | LTE Broadcast | LPLT |
| 7 | AV linear, AV non-linear, data | Large screen, small screen/tablet | Stationary, portable outdoor/indoor, mobile | LTE Broadcast | LPLT |
| 8 | AV linear, AV non-linear, | Large screen, small screen/tablet | Stationary, portable outdoor/indoor, mobile | DTT, LTE | HPHT/ LPLT |
| 9 | AV linear, AV non-linear, | Large screen, small screen/tablet | Stationary, portable outdoor/indoor, mobile | LTE, LTE Broadcast | HPHT/ LPLT |
| 10 | AV linear, AV non-linear, | Small screen/tablet | Stationary, portable outdoor/indoor, mobile | LTE | LPLT |
| 11 | Smart data quantities | Smart communication unit | Stationary, portable outdoor/indoor, mobile | Dynamic cognitive communication | HPHT/ LPLT |

*Source: ECC report 224: Long Term Vision for the UHF broadcasting band, October 2014*

[123] *Long Term Vision for the UHF broadcasting band*, ECC Report 224, Draft, October 2014

**Figure 8-3: Mapping the TG6 scenarios to options for a converged platform**

| TG6 ref | Converged platform option? | Comment |
|---|---|---|
| 1 | No | Not a converged platform |
| 2 | Yes – Option A | A converged platform with DVB broadcast over LPLT infrastructure with released UHF spectrum used for unicast mobile SDLs |
| 3 | No | Not a converged platform |
| 4 | No | Not a converged platform |
| 5 | Yes – Option B | A converged platform with LTE broadcast over HPHT network |
| 6 | Yes – Option C | A converged platform with eMBMS broadcast over LPLT infrastructure with released UHF spectrum used for unicast mobile SDLs |
| 6 | Yes – Option D | A converged platform with LTE-broadcast over LPLT infrastructure with released UHF spectrum used for unicast mobile SDLs |
| 7 | Yes – Option E | As for Scenario 6 but with uplink as well as downlink use of release UHF spectrum |
| 8 | No | Not a converged platform but a spectrum transfer from DTT to mobile use |
| 9 | No | Not a converged platform but a scenario for complementary working of DTT and mobile services |
| 10 | No | Not a converged platform but a spectrum transfer from DTT to mobile use |
| 11 | No | A scenario for possible future evolution of broadcasting and broadband technologies which is not sufficiently defined to be considered in our study |

On the basis of these tables we have identified five converged platform options for consideration. These are as follows.

Under **Option A** the DTT payload is transferred to the LPLT infrastructure of a mobile network where it is broadcast using DVB standards. This (potentially) releases UHF spectrum which is used by mobile operators as supplemental downlinks in unicast and/or multicast mode. We consider this option in detail.

Under **Option B** the existing HPHT network is used to broadcast to LTE receivers – primarily linear TV content but also applications like software updates for mobile services. We do not consider this option further. It is inferior to other converged platform options in that:

- The potential for spectrum release is limited when compared with other options. For example LTE based transmission offers lower levels of spectral efficiency than DVB
- There is little improvement in the coverage of linear TV services on handheld devices when compared with options which use an LPLT network

Under **Option C** the DTT network transfers to the LPLT infrastructure for mobile network. Linear TV is broadcast using the existing eMBMS standard and the UHF spectrum released is used by mobile operators for unicast/multicast SDLs. Again we do not consider this option further given that the eMBMS standard is not suitable for TV broadcast in a number of respects. In particular:

- The cyclic prefix is too short to prevent destructive interference between transmission from adjacent base stations in rural areas

- There are limits on the proportion of a carrier which can be used in SDL mode. This reduces the spectral efficiency of the carrier for broadcast applications
- eMBMS does not allow non-subscribers to watch broadcast content on a free-to-view basis which is required for public service broadcasting and to support the business case for commercial free to air services.

**Option D** is similar to Option C but TV broadcast uses an evolved form of the eMBMS standard in which the shortcomings identified above are removed. We use the term **LTE broadcast** to refer to this standard. We consider this option in detail. We also note that developing the LTE broadcast standard would require significant changes to the LTE technical specification. Whether these changes are made will depend upon the views of those attending 3GPP meetings. Mostly these are the mobile equipment manufacturers who tend to take their lead from the requirements of the MNOs. So only if the MNOs ask for these changes are they likely to come about. In our interviews, none of the MNOs have expressed any interest in developing the eMBMS standard in this way and were not currently proposing to ask manufacturers for change. This had been noted by some research organisations who feel that the main opportunities for change now lie in the development of 5G standards.  Figure 8.4 tabulates some of the key differences between LTE-B and eMBMS.

**Figure 8-4: Key differences between LTE-B and eMBMS**

| Factor | eMBMS | LTE broadcast |
|---|---|---|
| Coverage | Used in selected cells e.g. sports arena or city-wide | Used in large number of cells to offer near universal national population coverage |
| Content | Selected content e.g. enhancements to live sports event on a temporary basis | Predefined set of TV channels including PSB channels on an ongoing basis |
| Standards development | Exists now | Requires future development by 3GPP |
| Cyclic prefix | 16 or 33 µs | 100 or 200 µs to enable effective coverage in rural areas |
| Access by end users | Commercial service offered by a mobile operator to its subscribers | Free to air access to any user with appropriate receiver technology |

*Source: Plum analysis*

**Option E** is similar to Option D but allows for released UHF spectrum to be used for both mobile uplinks and down links (rather than just for down links). We set out in Appendix Q a discussion of the difficulties involved in deploying mobile services using sub-700 MHz spectrum. Many of these difficulties can be avoided by using the released spectrum in downlink only mode.  At the same time, given the big asymmetry in mobile traffic[124], this restriction does little to affect the economic value of any sub-700 MHz spectrum which is released. We therefore reject this option on the grounds that Option D is superior.

[124] With download volumes an order of magnitude greater than uplink volumes

There is also another option which we have rejected. Proponents of the LPLT LTE broadcast option argue that:

- Many TV programmes have audience shares of 1% or less (niche channels) while others have audience shares of 10 to 20% (popular channels)
- This means that in many cells of an LPLT network there would be only a handful of households watching niche channels on average through the day - especially in rural areas where the number of households in a cell is small.
- Fewer spectrum resources may be consumed by transmitting these niche channels in unicast mode if the market share is low enough. This could release substantial amounts of spectrum for other mobile applications.

In assessing the merits of this option we must first distinguish between:

- Local and temporary multicast of AV content - where eMBMS is appropriate. This is likely to be used in a single cell (such as current trials in sports arenas). But it is possible that there might be economic value in extending it to citywide applications (such as the trials of eMBMS in Munich).
- Nationwide and permanent broadcast of AV content where LTE-B or DVB is the appropriate technology for the broadcast downlink.

Our focus in selecting options for a converged platform is on the latter.

We then need to establish at what market share a niche channel is more efficiently transmitted in unicast rather than broadcast mode. This is estimated in Figure 8-5.

We must then take account of the fact that each cell in an SFN must broadcast identical content for the SFN to function. So a cell in an urban part of an SFN and a cell in a rural part of the same SFN[125] must broadcast the same content. Only if, when averaged across the day, the market share of the niche channel falls below 3/N in urban cells would a TV channel switch to the unicast transmission mode.  We estimate (in Figure 8-6) that this would typically require an audience share of 0.06% in urban areas. Based on anecdotal evidence and discussions with stakeholders, we believe that it is unlikely that TV channels with such a low audience share would find it commercially viable to use a DTT platform by 2025.

We note that there may be substantial diurnal variation in the TV payload on DTT – for example because some TV channels only broadcast in the evening. The whitespace in the early hours of the morning is likely to be of little value for mobile services. But any dip in TV payload during the day could be of value as a sub-700 MHz unicast downlink - assuming that the capacity available could be configured in contiguous 5 MHz blocks .The latter depends on numerous market specific factors[126]. So the scale of any benefit here, and the extent to which it could be captured with existing HPHT DTT networks, is uncertain.

[125] Almost all SFNs have both urban and rural parts

[126] For example whether there are multiple multiplex operators, whether they are permitted to share capacity by regulation, and/or whether they have incentives to do so)

Figure 8-5: When is unicast more efficient than broadcast for transmission of niche channels?

Broadcast mode uses capacity C to transmit the niche channel. This capacity requirement does not change as the number of viewers in the cell changes

In unicast mode we assume that:

– There are N households in the cell

– The market share of viewing hours for the niche channel is x%

– The average household views TV for four hours per day.

With these assumptions the total hours spent viewing the niche channel in the cell each day = 4Nx

We assume that this viewing is distributed uniformly across a 12 hour period in the day and that there is no viewing in the other 12 hours. In practice demand for capacity will vary through the 12 hour window as viewers tune in and switch off (and spill over a bit beyond the 12 hour window). But it is reasonable to assume that if peaks in demand in unicast mode displace mobile broadband applications while troughs release additional capacity for mobile broadband, then this variation will have little impact on overall economic welfare

With this assumption the capacity required for unicast viewing of the niche channel is [4NxC/12] and unicast mode uses less network capacity than broadcast mode for the niche channel if 4NxC/12 < C ie x <3/N

Figure 8-6: The audience share at which unicast mode is more efficient

The population density in a typical urban area 1500 households per square kilometre

The cell size for an LPLT broadcast cell (1.5 km radius) is 6.5 square kilometre

So the potential audience for an urban broadcast cell in the busy hour is 1500 x 6.5 = 10,000 households

50% of these households might use DTT – 5,000 households

The audience share at which unicast becomes more effective is 3/N (from Figure 8-6) or, in this case, 3/5,000 = 0.06%

## 8.5 Options for detailed assessment

Based on the analysis set out above, we assess two options for a converged platform in detail:

- Option A - which we refer to as the **LPLT-DVB** option from now on
- Option D – which we refer to as the **LPLT-LTE** option from now on.

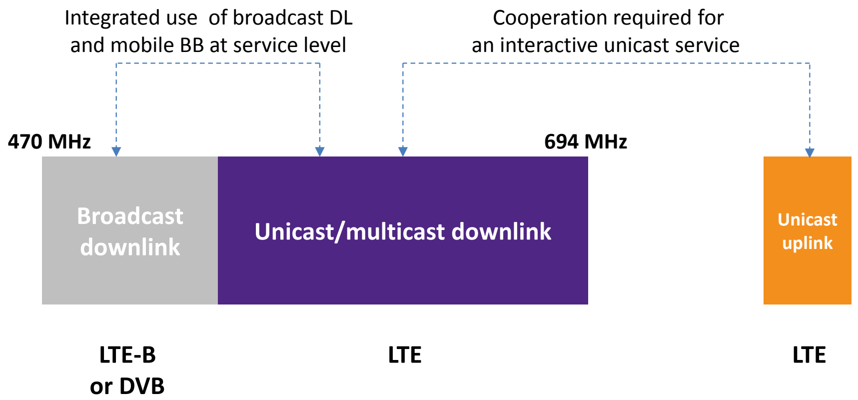
Figure 8-7 shows how the two options might use spectrum to provide services. The sub-700 MHz spectrum is used for two downlinks – with the top end of the band used for a unicast mobile downlink (so as to maximise the efficiency of mobile antennas) and the bottom end of the band used for the broadcast downlink. The broadcast downlink might use DVB or LTE broadcast transmission technology. The following points are important to note:

- There is a requirement for service level integration between the services offered over the broadcast downlink and those offered over the unicast/multicast links if the converged platform is to deliver integrated broadcast-broadband services
- The broadcast downlink is implemented on selected cell sites so as to provide near universal coverage to fixed roof top aerials as required by the specification of Section 8.2. We estimate (in

Appendix T) that around 40% of the macro cell sites of one mobile operator might require upgrade to reach this level of coverage

- The unicast downlink is implemented on the same cell sites (or more depending on the business model adopted). If we assume that the unicast downlink is implemented on the same cell sites as the broadcast downlink, then this would provide reasonable geographic coverage. But, given the lower gain antennas used on portable devices, it would not offer the same (near universal) coverage as the broadcast downlink
- Figure 8-7 shows the mobile unicast uplink using spectrum above 700 MHz. Such an arrangement is designed to minimise the coexistence problems between broadcast downlinks and mobile uplinks which are highlighted in Appendix Q. But, depending upon the business model which is used for deployment of an LPLT converged platform, the uplink might use the top end of the sub-700 MHz spectrum instead.

**Figure 8-7: Use of spectrum by the preferred options**




*Source: Plum analysis*

Both the LTE and DVB options meet our definition of a converged platform – as one in which a common wireless network infrastructure (of masts, access and backhaul) uses sub-700 MHz UHF spectrum to deliver both terrestrial broadcasting services and mobile broadband services to fixed and mobile terminals. And in both options a range of business models for licensing sub-700 MHz spectrum and for delivering converged services is possible. For example:

- A single provider might sell capacity on both the broadcast and unicast downlinks to broadcast content aggregators, to mobile operators and to collaborative ventures between these two types of players to deliver converged services, while purchasing uplinks from mobile operators
- Separate broadcast and unicast downlink providers might enter into commercial arrangements with mobile operators and content aggregators to sell them both broadcast and unicast downlink capacity for broadcast only services, for mobile broadband only services and for broadcast-broadband converged services
- There might be a single broadcast downlink provider and several mobile operators using the unicast downlink. Again this could lead to a wide variety of possible commercial arrangements to deliver DTT, mobile broadband and converged services.

We discuss possible commercial models further in Section 11.6. It is as yet too early to tell which the business models might emerge if a converged platform is implemented. So we have left this is an open question and developed a cost benefit analysis which allows for a wide range of business models.

The LTE and DVB options differ in a number of respects which affect the costs and benefits which each generates. These differences are discussed in Section 9.10 But in terms of service creation and control there is little to choose between the two options. For example to implement an interactive cloud-based service using a converged platform would, under either option, require:

- Use of both the unicast downlink using sub-700 MHz spectrum and a mobile broadband uplink using frequencies harmonised for uplinks in spectrum within or above the 700 MHz band – for example in the 800 MHz or 900 MHz bands
- Commercial agreements between the parties controlling the downlink and the uplink. The form of this agreement, and who provides the control functionality required to create the cloud-based service, would depend upon the business model used.

# 9 Moving to a converged platform

## 9.1 Introduction

Before we can assess the merits of a converged platform we need to consider a number of key issues:

- When might a converged platform be implemented?
- How would other users of sub-700 MHz spectrum be accommodated?
- What are the main steps in moving to a converged platform?
- Would moving to a converged platform release sufficient spectrum to justify the cost of transition?
- Is it feasible to make the transition to a converged platform given the need to create simulcast spectrum and avoid cross-border interference?

We consider these issues in this chapter and, as a result, identify some of the main costs of migrating to a converged platform for inclusion in our cost benefit analysis in Chapter 10. We provide a summary of our findings in Section 9.11.

## 9.2 The timing of the move to a converged platform

Based on the analysis given above we assume that the 700 MHz band will be vacated by DTT in a 2017-2025 timeframe. It appears that, in most member states, this will be facilitated by either a market or government driven move from DVB-T to the more efficient DVB-T2 technology over the same (or longer) timeframe[127]. These changes require complex (and potentially costly) changes to UHF spectrum use (nationally and across Europe) and changes to consumer equipment. Experience with digital switchover suggests the release of the 700 MHz band will require extensive bilateral co-operation between countries on the timing of changes in spectrum use and communication plans aimed at informing consumers of the changes at national level.

Introducing a converged platform at UHF in parallel with the refarming of the 700 MHz band and DVB-T2 migration would be problematic, both in terms of achieving the necessary changes in spectrum use at a European level and in gaining consumer (and political) support for the changes. There is a risk that some consumers could end up having to make two changes to their DTT reception equipment in quick succession and incur extra costs. There could also be misunderstanding and confusion among consumers on the changes that are required.

Hence we conclude that introducing a converged platform at UHF in parallel with the release of 700 MHz would not be practical. This means we assume that a converged platform is implemented in 2025 or later.

[127] More detail is given in Appendix R

## 9.3 Dealing with the displacement of existing and potential users of the spectrum

The current uses of the 470-694 MHz band in the EU are as follows[128] [129]:

- 470-790 MHz – TV broadcasting and cable networks
- 470-790 MHz - programme making and special events (PMSE), in particular audio applications such as wireless microphones and in ear monitors
- 608-614 MHz – radio astronomy
- 470-494 MHz – wind profilers

If, as envisaged, the converged platform is implemented in a way that removes a great deal of the existing white space between TV transmissions, then the services that use this white space (PMSE, wind profilers) may not be able to continue operations in the UHF band. Radio astronomy uses an exclusive allocation because of the sensitivity of receivers and there is a risk it could be displaced by a converged platform.

The implications of a converged platform for the three existing applications – PMSE, wind profilers and radio astronomy – and two potential new applications – unlicensed white space devices and a PPDR mobile broadband network – are assessed in Appendix R. TV broadcasting will be included in the converged platform, however, all other applications could be negatively affected by the implementation of a converged platform. Our findings, from the analysis presented in Appendix R, are summarised as follows.

### Cable networks

If TV broadcasting is to be accommodated by a converged platform, there is potential for interference from a converged network in relation to cable networks. This issue has been raised in the discussion over the future use of the 700 MHz band[130]. CEPT has noted that its review will be able to be used by the standards bodies (ETSI and CENELEC) to undertake activities to address cable industry concerns and that CEPT will not be addressing compatibility studies for cable networks[131]. We assume the same arrangements would apply were 470-694 MHz to be used for a converged network.

[128] European Common Allocation Table, ERC Report 25, October 2013 http://www.onlineconversion.com/downloads/european_frequency_allocations.pdf

[129] In addition 830-860 MHz is used by the aeronautical radio navigation service (ARNS) in Poland however this service will be discontinued in December 2017. Proposed amendment POL 42 of the Council of Ministers' Regulation from the 29th of June, 2005 on the National Table of Frequencies' Allocation (O.J. no. 134, item 1127)

[130] Cable Europe. Contributing to Draft ECC Mandate to develop harmonised technical conditions for the 694–790 MHz frequency band. Presentation, April 2014 http://www.cept.org/Documents/ecc-pt1/17760/ECC-PT1(14)INFO-06_Contributing-to-Draft-ECC-Mandate-to-Develop-Harmonised-Technical-Conditions-for-the-694-%E2%80%93-790-MHz-Frequency-Band

[131] ECC. Response to Cable Europe, 14 March 2014 http://www.cept.org/Documents/ecc-pt1/16581/ECC-PT1(14)INFO-03_ECC-response-to-Cable-Europe

## PMSE

The 470-790 MHz band is the main band used by wireless audio systems in Europe[132]. The re-allocation of the 800 MHz band to mobile and the likely reallocation of the 700 MHz band will significantly reduce the spectrum available for wireless audio systems while most studies point to increasing demand for spectrum for wireless audio applications[133]. Hence CEPT, the European Commission and member states have initiated work to find alternative and additional spectrum for PMSE on a harmonised basis. Estimates of the spectrum required differ. However it appears that, after taking account of the impact of re-farming of the 800 MHz and 700 MHz bands and potential future growth in demand for PMSE audio, requirements at large events will only be met in future if new bands can be identified. Some member states have identified a number of possible bands in the 1 to 2GHz frequency range. However there may be problems concerning body absorption and free space propagation loss to address at these frequencies.

The implementation of a converged platform will further reduce the UHF spectrum available for PMSE use, and in some locations could remove it altogether. This then raises the issue of whether some spectrum at UHF should be reserved for PMSE use or whether alternative frequency bands should be found for the service. The situation is likely to vary significantly between member states with some having sufficient spectrum at UHF spectrum to accommodate both a converged platform and PMSE use. In others, typically those member states with large densely populated urban areas, the spectrum required for audio PMSE and a converged platform will both be high. In these cases it will be a national issue as to whether or not spectrum would be reserved for PMSE at UHF, potentially informed by a detailed cost-benefit analysis of the possible options.

In the cost-benefit analysis of the converged platform given in Section 10 we take an extreme case in which we assume all PMSE use of UHF must end and the service migrates to other bands. We estimate[134] that the cost of migrating PMSE to other frequency bands, once they have been identified, is up to €700m[135]. This is likely to be an overestimate of the costs as in some member states PMSE may be able to remain at UHF.

## Wind profilers

There are relatively few wind profiler radars across Europe (four though more are expected to be installed) and they use small amounts of spectrum (around 5 MHz within the 470-494 MHz range) on a geographically shared basis in rural and suburban areas. If in the worst case the 470-494 MHz frequency range could not be used by wind profilers then in theory other frequencies around 400-470

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[132] Other bands include 863-865 MHz, 1785-1800 MHz, 1492-1518 MHz (indoor only) and the range 1800-1804.8 MHz (in addition to 1785-1800 MHz though this is not widely used because it is allocated to digital wireless microphones and there are latency problems with this equipment). ERC Recommendation 70-03 http://www.erodocdb.dk/docs/doc98/official/pdf/rec7003e.pdf

[133] See Report from the Commission to the European Parliament and the Council on the Radio Spectrum Inventory, 1 September 2014, COM (2014) 536 final. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2014:536:FIN; VVA Consulting presentation on the socio-economic aspects of spectrum harmonisation for PMSE equipment. May 2013 http://ec.europa.eu/digital-agenda/en/news/public-workshop-socio-economic-aspects-spectrum-harmonization-pmse-equipment Plum, Aegis, Whatif and Quotient. Entertainment in the UK in 2028. Report for Ofcom, 2009 http://www.plumconsulting.co.uk/pdfs/Plum_July09_Entertainment_UK_2028.pdf

[134] In Appendix R

[135] This only includes the costs of new equipment. It is therefore assumed that there is a zero opportunity cost for the new spectrum used by PMSE.

MHz might be used, though this could be difficult given heavy use of these frequencies by land mobile, telemetry and defence applications. However, given the small number of installations, it seems likely these services could continue to operate on a protected basis if a converged platform were implemented.

### Radio astronomy

Similar to the situation with wind profilers there are relatively few locations in Europe where the UHF frequencies (608-614 MHz) are used by radio astronomy. Countries with radio telescopes using this frequency range may choose to accommodate the service even if a converged platform were implemented and we note this approach is being taken by the United States in its plans to reallocate the 600 MHz band from TV to mobile use.

### PPDR mobile broadband

Use of parts of the 700 MHz band for dedicated mobile broadband networks for public protection and disaster relief (PPDR) services is being proposed by CEPT. This requirement is unlikely to extend below 694 MHz and so is unlikely to be impacted by a converged platform.

### Unlicensed white space devices

A converged platform will reduce, but probably not completely remove, the spectrum available for white space devices and the applications they support, as not all mobile downlink frequencies would be used in all locations. Also there are numerous other frequency ranges where the regulatory model envisaged for spectrum access by unlicensed white space devices could be adopted. Hence the impact of a converged platform on the amount of spectrum available for white space devices is likely to be small (possibly zero) and we do not include any costs for this impact in our cost-benefit analysis.

## 9.4 Current spectrum use by DTT networks

The starting point for any transition to a converged platform is the way UHF spectrum is currently used by high power high tower (HPHT) networks for TV broadcast. Here the majority of the population is served from a relatively small number of towers often located on high ground and with mast heights of 100m or more. These transmit at very high power levels in the region of 20-100kW and cover areas with a radius of 50km or more. In most countries a small number of such towers are needed. They are supplemented by relays – lower power transmitters that fill in coverage holes such as those that can occur in deep valleys and that extend coverage in rural areas. Figure 9-1 shows the number of main and relay sites used by DTT networks in a range of European countries.

**Figure 9-1: Number of main and relay sites in DTT networks in various European countries**

| DTT Network | Main sites | Relay sites | Total sites |
|---|---|---|---|
| Austria | 9 | 441 | 450 |
| Croatia | 50 | 159 | 209 |
| Czech Republic | 27 | 55 | 82 |
| Estonia | 10 | 23 | 33 |
| Finland | 137 | 648 | 785 |
| France | 112 | 1,514 | 1,626 |
| Germany | | | 350 |
| Hungary | | | 90 |
| Italy | | | 2,300 |
| Spain | | | 3,300 |
| Sweden | 54 | 520 | 574 |
| UK | 67 | 1,157 | 1,224 |

*Source: Farncombe research, compiled from websites of national DTT network operators, regulators or similar*[136]

These HPHT networks vary by member state in their use of spectrum:

- The number of 8 MHz multiplexes which are used to transmit TV channels varies. Some member states use only two multiplexers (broadly equivalent to the Case 1 TV traffic load) while others might use six multiplexes to provide viewers with a wider choice of TV channels (broadly equivalent to the Case 2 traffic load)
- Some member states use multi-frequency networks (MFNs) in which neighbouring main transmitter sites broadcast on different frequencies to avoid destructive interference at the receiver. A spectrum repeat pattern of four or five might then be required. So, rather than 48 MHz of UHF spectrum (6 multiplexers x 8 MHz each), an MFN might require 240 MHz of UHF spectrum (6 multiplexers x 8 MHz each x a repeat pattern of 5)
- Other member states use single frequency networks (SFNs) where the same content is broadcast on the same frequencies in neighbouring cells. As long as the transmissions are tightly synchronised and some redundancy is inserted into the transmitted data to allow for propagation time differences between cells then receivers can correctly decode the transmissions. But again a spectrum repeat pattern of four or five is common to enable regional broadcasting. In this case different regions receive different content. To avoid interference to TV receivers in the border areas between regions, different regions use SFNs operating at different frequencies.

Figure 9-2 shows examples of where SFNs and MSNs are used in the EU.

[136] See also the BNE/Progira. High and low tower broadcast networks, April 2014 http://www.broadcast-networks.eu/wp-content/uploads/2014/05/High-and-Low-Tower-Broadcast-Networks.pdf

Figure 9-2: Examples of SFN and MFN deployments in UHF in Europe

| Network type | Countries |
|---|---|
| SFN | Belgium, Cyprus, Greece (regional), Hungary, Italy (national and regional), Latvia, Luxembourg, Malta, Netherlands, Poland |
| MFN | Bulgaria, Czech Rep, Finland, France, Ireland, UK |
| Mixed | Austria, Germany, Sweden |

*Source: Farncombe research*

The frequencies which are used in both MFNs and SFNs also require international coordination to prevent interference across national borders. This is currently achieved through the GE06 spectrum plan and procedures, established through an agreement reached in Geneva in 2006. This plan imposes further constraints on the UHF frequencies which national SFNs and MFNs can use.

## 9.5 Will a move to a converged platform generate sufficient spectrum release?

There is a need to get substantial sub-700 MHz spectrum release[137] to justify the cost of making the transition to a converged platform. One possible way to do this is by increasing the capacity of each multiplex by:

- Using more efficient transmission mechanisms with higher spectral efficiency such as DVB-T2 rather than DVB-T
- Compressing the TV programmes more efficiently so that fewer bits are required for each minute of video. This has led to a move from MPEG-2 to MPEG-4 compression technology and now towards HEVC.

But, as we discuss in Chapter 7, such developments offer only modest gains which are largely or entirely offset by demand for higher resolution video formats such as HD or UHD.

Substantially greater spectrum release might be achieved through use of SFNs. For example moving from a repeat pattern of 5 to a repeat pattern of one in a country which uses six multiplexers could reduce spectrum requirements for TV broadcast from 240 to 48 MHz (with use of DVB-T2 transmission).

The move to an LPLT converged platform based on SFNs could create opportunities for spectrum release which approaches this level. Moving to a LPLT converged platform means very substantial reductions in DTT transmitter power (from 50kW to 50W) and hence in the size of the coverage area for transmitter cells. This in turn means a substantial reduction in the size of the border area between regional SFNs where there is co-channel interference – typically from a border with a width of 50 to 100 km to one with a width of 5 to 10 km. This means that co-channel regional SFNs might work for 80 to 90% of the population, once existing aerials are realigned to point at the new transmitters.

But the move to an SFN-based converged platform is made more challenging by the need to meet requirements for regional broadcasting. As Figure 9-3 shows regional broadcasting is widespread on DTT networks.

137 This term is defined in Section 8.2

Figure 9-3: The extent of regional broadcasting on DTT networks

| Country | DTT TV channels (FTA/Pay) | Regional/Territorial variants (all platforms) | Country | DTT TV channels (FTA/Pay) | Regional/Territorial variants (all platforms) |
|---|---|---|---|---|---|
| Austria | 28 | 7 | Italy | 18 | 95 |
| Belgium | 15 | 23 | Latvia | 83 | 0 |
| Bulgaria | 11 | 61 | Lithuania | 59 | 0 |
| Croatia | 45 | 0 | Luxembourg | 11 | 0 |
| Cyprus | 16 | 0 | Malta | 60 | 0 |
| Czech Republic | 11 | 77 | Netherlands | 27 | 16 |
| Denmark | 38 | 2 | Poland | 6 | 1 |
| Estonia | 43 | 0 | Portugal | 6 | 2 |
| Finland | 36 | 4 | Romania | 4 | 16 |
| France | 19 | 69 | Slovakia | 24 | 59 |
| Germany | 21 | 51 | Slovenia | 8 | 10 |
| Greece | 12 | 45 | Spain | 29 | 82 |
| Hungary | 24 | 0 | Sweden | 52 | 6 |
| Ireland | 9 | 1 | U.K. | 36 | 19 |
| Slovakia | 24 | 59 | | | |

*Source: EAVO, Farncombe analysis*

Regional broadcasting is important:

- For social and political reasons – so as to provide TV content which reflects specific regional events, culture and, in some cases, language
- For commercial purposes – to enable local advertising which helps to generate additional revenues for commercial free-to-view channels.

Some stakeholders argue that co-channel regional SFNs (with a repeat pattern of 1) could work for close to 100% of households provided that there is:

- A modest redefinition of regional boundaries
- A careful choice of LPLT DTT transmitters sites from among the mobile base stations available
- Selective installation of household aerials in the border region between regional SFNs which discriminate strongly between the signals received from in front of the aerial and those received from behind the aerial
- The building of (a few) new transmitter sites in border areas where required.

Others argue that this is not possible. For example the BBC submitted a paper to ECC TG6[138] which shows that, without the measures listed above, around 5 to 10% of households would suffer unacceptable interference if co-channel regional SFNs were deployed. In response Qualcomm commissioned a study from ATDI[139] which indicated that, the measures listed above, co-channel regional SF ends might deliver virtually 100% coverage.

We assume in our cost benefit analysis that co-channel regional SFNs will work subject to a mix of the engineering mitigation remedies listed above. For simplicity we include costs for high discrimination aerials but not for new transmitter sites. But we note that:

- This assumption is of uncertain validity.
- Further technical work would be required to test its validity if our cost benefit analysis indicated that there was a case for proceeding with a converged platform. There is plenty of time for such work if a converged platform is to be implemented in 2025.
- The measures will have a cost of implementation which needs to be factored into the analysis.
- If national SFNs do not prove possible then it is hard to envisage sufficient spectrum release to justify the costs of moving to a converged platform.

## 9.6 The spectral efficiency offered by a converged platform

A key factor in determining the scale of spectrum release is the spectral efficiency of an LPLT SFN. This depends on the converged platform option under evaluation. Assessing spectrum efficiency is always difficult as has been seen across many generations of cellular technologies. It can depend on a very wide range of factors including deployment methodologies, topographies, technology, implementation issues and more. Even after multiple networks have been deployed the actual spectrum efficiency achieved can still be unclear and can change over time as networks are optimised. Hence, we cannot be definitive about the efficiency of broadcast technologies. Equally, we need an estimate in order to be able to draw conclusions about the benefits of a converged platform. Hence, we propose spectrum efficiency numbers here based on the best information available to us, understanding these will be inexact but indicative.

In the case of the **LTE broadcast** option the spectral efficiency is uncertain and in dispute. This is not helped by the fact that LTE-B is not currently defined and so not all relevant parameters are known. It is primarily a function of:

- The inter site distance (ISD) between transmitters. Longer ISDs both weaken the signal at receivers at the cell edge and increase the destructive interference between transmissions from neighbouring cells at such receivers. As a result spectral efficiency falls
- The cyclic prefix used. Increasing the length of this prefix from (say) 33 µs[140] to 100 or 200 µs reduces the destructive interference between cells, increases constructive interference and so increases spectral efficiency at longer ISDs

There are three main sets of estimates of the spectrum efficiency of the LPLT-LTE broadcast option:

[138] *Frequency reuse of one for broadcast content*, BBC, May 2014, TG6(14)064

[139] *Low Power Low Tower SFN networks Interference Analysis*, ATDI, October 2014

[140] The maximum length in the current LTE specification

- IRT has estimated the spectral efficiency[141] for fixed receivers using rooftop aerials and a 33 µs cyclic prefix
- TDF[142] has estimated spectral efficiency, again for fixed rooftop aerial reception, using 100 µs and 200 µs cyclic prefixes
- Qualcomm[143] has produced estimates on a similar basis to TDF.

Figure 9-4 compares these estimates of spectral efficiency.

**Figure 9-4: Spectral efficiency for a LPLT converged platform using LTE**

| Source | Cyclic prefix (micro seconds) | ISD (km) | Spectral efficiency (bps/Hz) |
|---|---|---|---|
| IRT | 33 | 10 | 0.5 |
| TDF | 100 | 10 | 1.2 |
| Qualcomm | 100 | 10 | 3.2 |
| TDF | 200 | 10 | 2.0 |
| Qualcomm | 200 | 15 | 3.2 |

*Source: Contributory papers to work of ECC TG6 by IRT and Qualcomm plus internal paper sent to Plum by TDF*

We can see that:

- A cyclic prefix of 33 µs leads to a spectral efficiency which is too low for a viable SFN based on 10 km ISDs. Hence our choice of the evolved LTE-broadcast option, with longer cyclic prefixes, instead
- There are some differences between the TDF and Qualcomm estimates which remain unresolved.

Based on the findings of Figure 9-4 we consider an LPLT LTE-broadcast converged platform with spectral efficiencies of 2 bps/Hz at an ISD of 10 km.

In the case of the **DVB option** there are no issues of destructive interference. The DVB standard is designed to be used on an HPHT technology with inter-site distances of 40 to 50 km. So deploying this technology with an LPLT topology does not lead to interference between adjacent transmitters. We assume a spectral efficiency 3.5 bps per Hz – similar to that observed in practice for DVB-T2 use on an HPHT DTT network.

Some have argued that since LTE-B can adopt the same techniques as DVB then it should be able to achieve the same spectrum efficiency. Clearly, in the extreme, if LTE-B were to adopt the DVB standard then it would be identical. It is simply a matter of what the 3GPP standards body decides based upon the degree of change to the LTE standards judged worthwhile and the commonality sought between LTE and LTE-B. We note here that convergence of the spectrum efficiencies of the two technologies might occur over time dependent on the priorities set by standards bodies. In

[141] *TV distribution via cellular networks*, Brugger and Schertz, IRT for EBU technical review Q2 2014

[142] *LTE broadcasting in rural areas based on Qualcomm proposal – technical analysis*, TDF, July 2014

[143] *Simulation results for cellular based broadcast*, Document TG6(14)048, Qualcomm, April 2014

practice, unless there are major variations in spectrum efficiency[144] this will not materially change the conclusions we derive in this report. However, before any actual spectrum planning took place more work would be needed in this area.

With these assumptions and providing co-channel regional SFNs become a reality with LPLT broadcast networks, there is substantial scope for release of spectrum for unicast downlinks. This might come close to 180 MHz – greater than the combined spectrum available for unicast downlinks in the 700 MHz, 800 MHz and 900 MHz bands. However the effective spectrum released from moving to an LPLT converged platform would vary considerably by member states depending on the TV payload and the option used. The Case 1 TV payload of 60 Mbps combined with the DVB option might, in the long run, lead to effective release of just over 170 MHz[145]. With the Case 2 payload of 180 Mbps using the LTE option this figure falls to just over 110 MHz[146]. See Section 10.3 for more details on how these estimates are derived.

In estimating this level of spectrum release we note that the arrangement and cost of base station antennas remains a topic of some uncertainty. The ideal arrangement for LTE-B is an omni-directional antenna mounted high on the base station mast. However, most cell towers are configured in a sector-arrangement, typically with 3 sectors. They may have a single antenna per sector covering all the frequency bands used by the operator or multiple antennas each optimised to a particular band. Typically these antennas will have some down-tilt to control inter-cell interference. An operator deploying LTE-B will need to decide whether to use a dedicated antenna, to add new sectorial antennas, to upgrade existing antennas to cover the lower UHF band or some variant of these approaches. Adding extra antennas to a mast typically increases rental costs and may not be possible in some cases due to a lack of space. Reusing existing antennas may result in sub-optimal performance, reducing range or achievable bit rate. Antennas themselves may improve as designers turn their attention to solutions that can cover the UHF band, but the timing and degree of success is uncertain. Broadly, the anticipated performance should be achievable using some form of engineering solution. However the precise cost of that solution is difficult to predict at present.

## 9.7 Dealing with cross-border interference

How might cross-border interference between DTT networks from neighbouring countries be dealt with when moving to a converged platform?

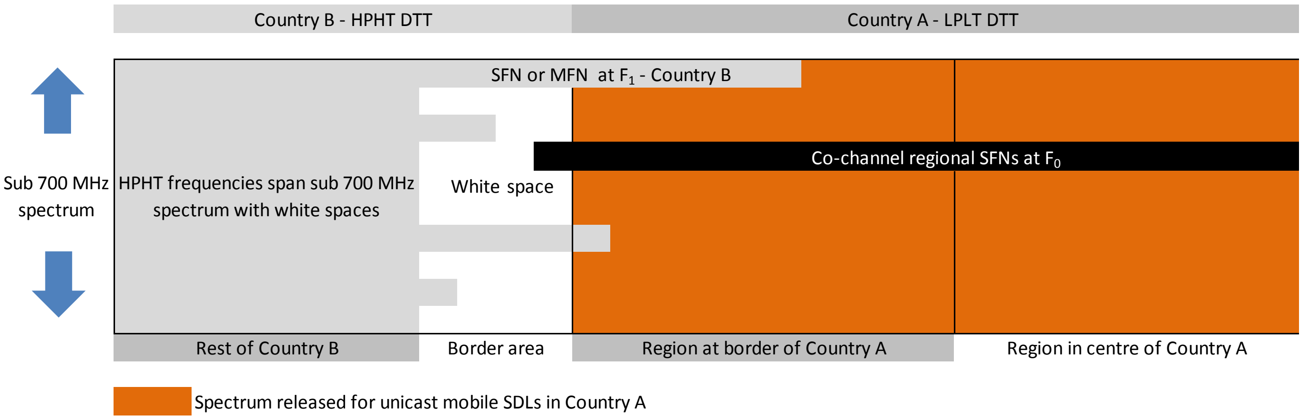
In the ideal world Country A, an early mover to an LPLT DTT network, would create a simulcast frequency band $F_0$ and use it to implement co-channel regional SFNs. This frequency would be different from the frequency used at its border by all neighbouring HPHT countries. Following HPHT network switch-off in Country A use of frequencies might then look like Figure 9-5.

[144] Of the order of 50% or more from the figures quoted above

[145] [224 MHz – 60Mbps/3.5 bps per Hz]*0.85. The 15% discount allows for poor mobile antenna performance at lower UHF frequencies and the need for a practicable band plan

[146] [224 MHz – 180Mbps/2 bps per Hz]*0.85

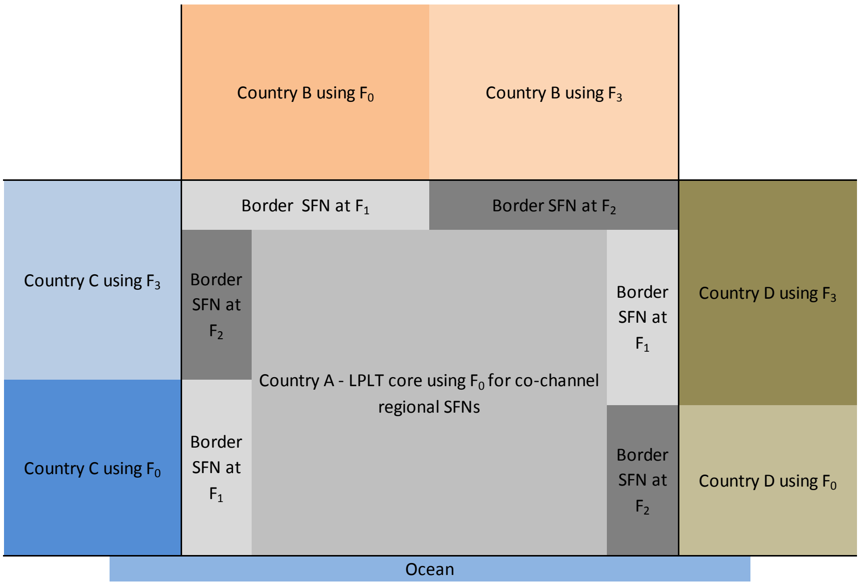
Figure 9-5: Spectrum release – ideal situation




*Source: Plum analysis*

In practice it might be difficult to find $F_0$ through a process of national and international spectrum replanning. So border SFNs might be required to isolate the co-channel regional SFNs from interference as shown in the plan-view diagram of Figure 9-6 (with Country A represented as the central square for ease of illustration).

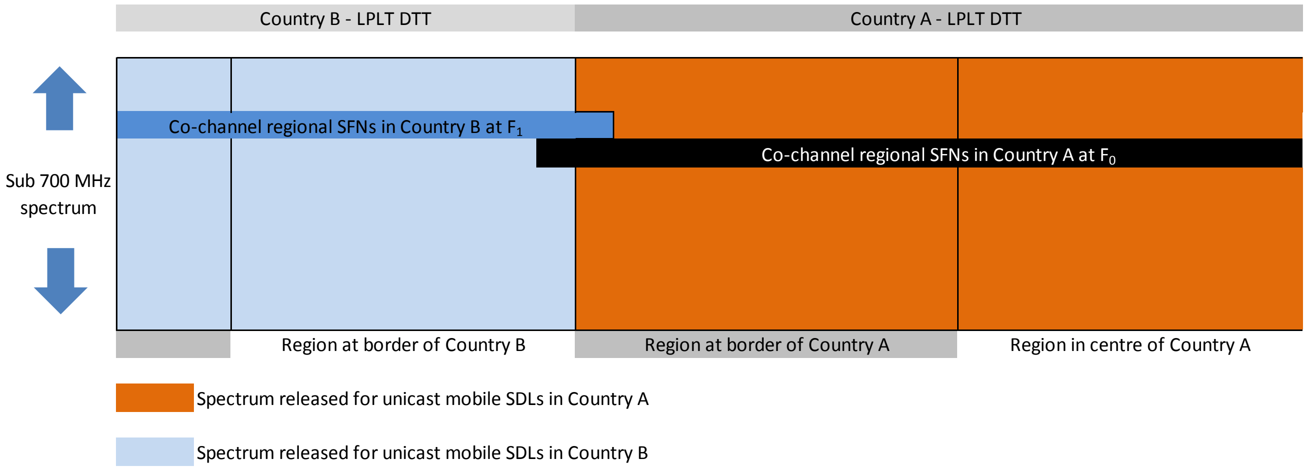
Figure 9-6: The use of border SFNs




*Source: Plum analysis*

In the case of an early mover, which is surrounded by HPHT countries, these border SFNs would need to be 50 to 100 km wide for those in the border areas of Country A to receive TV free from cross-border interference. Depending on the size of Country A, this requirement for wide-border SFNs could substantially reduce the release of spectrum for unicast mobile SDLs. But this effect could be temporary if the EU as a whole moved to LPLT SFNs. Once the neighbouring countries had made the transition, the border SFNs in Country A could be retuned to $F_0$ at modest cost to release more spectrum, so reaching the position shown in Figure 9-7.

**Figure 9-7: Spectrum release – adjacent countries both on LPLT**




*Source: Plum analysis*

## 9.8 Is a transition to a converged platform possible for the LPLT-LTE option?

We set out below the steps which are required in order to move to a converged platform. We consider the LPLT-LTE option (and discuss how the LPLT-DVB option differs in Section 9.10). To move the DTT platform from its current HPHT configurations using DVB receivers to a LPLT network with LTE broadcast receivers would involve the following steps[147]:

- Upgrade the LTE standard to enable LTE broadcast – for example by adding an option of a longer cyclic prefix and open access by end users to the broadcast transmission, as discussed in Section 8.4
- Get manufacturers to make equipment, such as set top boxes or dongles, available to upgrade TV sets and get TV set manufacturers to produce and sell TV receivers with LTE as well as DVB capability
- Equip LPLT sites with the necessary transmitters and backhaul capacity to provide near universal coverage. We estimate that this might require upgrades to around 40% of the macro-cell sites of one mobile operator[148].
- Set aside UHF spectrum for broadcast use by the converged platform alongside the spectrum used by the HPHT DTT platform. A key decision is whether simulcasting on the HPHT and LPLT platforms should occur to allow a period of transition or whether there should be a single “hard” switch-over date. While hard switch-over is simpler it would not allow time for activities such as

[147] For simplicity we have excluded from this process the steps required to mitigate interference between regional SFNs discussed in Section 4.3

[148] This might consist of all rural sites and one third of urban macro-cell sites - where there are a substantial number of macro-cells installed for capacity rather than coverage reasons

antenna realignment or for testing of the new solution. For these reasons we assume a period of simulcasting.

- Carry out the necessary frequency coordination to avoid cross-border interference with neighbouring countries. See Section 9.7 above
- Switch on the national LPLT LTE broadcast transmission
- Initiate a publicly funded programme to ensure that all end-user equipment is upgraded from DVB to LTE receivers. A proportion of the installed base of TV receivers will have LTE capability by the time the LPLT converged platform is switched on if TV receivers with dual DVB/LTE capability are sold in the preceding years. The remainder will require LTE capable set top boxes to be installed
- Test the need for aerial realignment to receive the LTE broadcast transmission and provide realignment support as required
- Progressively switch off HPHT DVB transmission and move the LTE broadcast transmission to its final frequency band if required.

Many of these steps generate significant costs which we have included in our cost benefit analysis. The most challenging step, and one which may not be possible in some member states, is the requirement to create simulcast spectrum.

## 9.9 Creating the simulcast spectrum

A member state which moves to an LPLT converged platform would need to run the existing HPHT DTT network in parallel for a period of time. This means that there is a requirement for additional spectrum which:

- The LPLT network could use during the simulcast period
- Does not interfere with the existing HPHT network in the transiting country
- Does not interfere with DTT networks in neighbouring countries.

The amount of simulcast spectrum required will depend primarily on:

- The LPLT option chosen (DVB versus LTE broadcast)
- The spectral efficiency assumed
- Whether border SFNs are required in order to make the spectrum coordination required to avoid cross-border interference. If they are then this might triple the amount of simulcast spectrum required.

Figure 9-8 tabulates the amount of simulcast spectrum which needs to be found under the various assumptions. Given that 224 MHz of spectrum will be available to accommodate both HPHT and LPLT platforms simultaneously, we can see that finding simulcast spectrum for the transition is most likely to be possible in the cases where we have shaded the cell in the final column of the table.

Figure 9-8: The simulcast spectrum required

| TV traffic load | Spectral efficiency (bps/Hz) | LPLT option | Border SFNs required | Simulcast spectrum required (MHz) |
|---|---|---|---|---|
| 60 Mbps | 2 | LTE-broadcast | No | 30[149] |
| 60 Mbps | 2 | LTE-broadcast | Yes | 90[150] |
| 60 Mbps | 1.2 | LTE-broadcast | No | 50 |
| 60 Mbps | 1.2 | LTE-broadcast | Yes | 150 |
| 60 Mbps | 3.5 | DVB | No | 17[151] |
| 60 Mbps | 3.5 | DVB | Yes | 51 |
| 180 Mbps | 2 | LTE-broadcast | No | 90 |
| 180 Mbps | 2 | LTE-broadcast | Yes | 270 |
| 180 Mbps | 1.2 | LTE-broadcast | No | 150 |
| 180 Mbps | 1.2 | LTE-broadcast | Yes | 450 |
| 180 Mbps | 3.5 | DVB | No | 50 |
| 180 Mbps | 3.5 | DVB | Yes | 150 |

Figure 9-8 indicates that it may be impossible to find the required simulcast spectrum for a member state with a Case 2 TV traffic load unless:

- It adopts the DVB option
- It opts for a late transition - once neighbouring member states have already moved to a converged platform
- It introduces a temporary but significant reduction in the number of TV channels which are broadcast and/or in the picture quality which is broadcast
- It has available VHF, as well as UHF, spectrum and household aerials which can receive VHF TV transmissions.

The analysis set out above suggests that:

- Any transition to a converged platform across the EU may require pan-European spectrum coordination
- It would be important to start the migration in member states with lower (Case 1) traffic loads and leave countries with higher (Case 2) traffic to the end of the migration process
- It is not clear, without further detailed work, whether member states with Case 2 traffic loads could ever create the simulcast spectrum required to make the transition to a converged platform
- The process of creating simulcast spectrum would require retuning of HPHT transmitters in the transiting country and, in some cases, in neighbouring countries.

[149] 60 Mbps/2bps/Hz

[150] [60 Mbps/2bps/Hz] x 3 to allow for border strips

[151] 60 Mbps/3.5bps/Hz

Given this analysis we have assumed in our cost benefit analysis that it is possible to create the required simulcast spectrum and then included within our estimates of the incremental costs of a converged platform the costs of creating the required simulcast spectrum.

## 9.10 The LPLT-DVB option

The DVB and LTE options are similar in many respects. Like the LTE option:

- The DVB option uses the same basic OFDM technology for transmission
- Implementing the DVB option should lead to more efficient use of spectrum than at present, with release of sub-700 MHz spectrum for mobile broadband use
- Implementing the DVB option will allow for the possibility of integration of broadcast and broadband services. In both cases devices will receive both broadcast and broadband downlinks and in both cases the devices will need uplinks which use supra-700 MHz spectrum in order to enable the creation of two-way broadband services.

However the DVB option involves the use of two separate transmission technologies – both DVB and LTE – for the downlinks. This means:

- The upgrade and maintenance of two separate technologies (DVB and LTE) on the same LPLT network infrastructure is more expensive than with the LTE option
- The cost of manufacturing mobile devices with integrated DVB tuners is expected to be (slightly) higher
- In some cases additional processing may be required in receiving devices to convert the DVB data to an IP stream for integration with two-way broadband. But in many cases, and especially when delivering content to a standard TV set in the home, such processing would not be required
- Any changes in spectrum assignment between broadcast and unicast downlinks (as demand patterns change) might require manual retuning of DVB receivers by end users. This is done automatically with the LTE option.

The DVB option has two main advantages over the LTE option

- There is no need to upgrade TV receivers when moving to the DVB option
- DVB offers a higher spectral efficiency (>3.5 bps/Hz versus >2 bps/Hz for the LTE option). This makes migration easier because the amount of simulcast spectrum required for LPLT broadcast is smaller. At the same time it increases the amount of UHF spectrum released.

## 9.11 Summary of findings

We find that:

- Implementation of a converged platform would not be practicable before 2025.
- The problem of finding suitable and adequate spectrum for PMSE voice services has to be solved before a converged network can be implemented at 470 to 694 MHz.

- The move to an LPLT converged platforms based on a national SFN or co-channel regional SFNs could generate substantial effective spectrum release of between 110 and 175 MHz from the sub-700 MHz band
- SFN topology could support extensive regional broadcasting if regional co-channel SFNs are possible. We have assumed that they are possible - and allowed for the engineering cost of implementing them in our CBA. But we recognise that further work will be required to test the validity of this assumption before taking any decision to proceed with a converged platform.
- The spectral efficiency offer by a converged platform will depend on the option chosen. We assume in our CBA that the DVB option will offer a spectral efficiency of 3.5 bps/Hz and the LTE option a spectral efficiency of 2 bps/Hz at inter-site distances of up to 10 km.
- Moving to an LPLT converged platform creates challenges for spectrum planners - both in terms of dealing with cross-border interference and in terms of finding the simulcast spectrum required to run the existing HPHT DTT network and the new LPLT DTT network in parallel.
- Creating the required simulcast spectrum is challenging. It may be impossible to find the required simulcast spectrum for a member state with a high TV traffic load unless:
  - It adopts the DVB option
  - It opts for a late transition – after neighbouring member states have already moved to a converged platform
  - It introduces a temporary but significant reduction in the number of TV channels which are broadcast and/or in the picture quality which is broadcast
  - It has available free VHF as well as UHF spectrum and household aerials which can receive VHF TV transmissions
- Significant effort is also required to mitigate cross-border interference – especially in the member states which first move to a converged platform. In some cases this might require the creation of temporary border SFNs. These in turn substantially increase the amount of simulcast spectrum required.

Given these conclusions we have in our cost benefit analysis:

- Assumed that it is possible to create the required simulcast spectrum
- Included within our estimates of the incremental costs of a converged platform the costs of multi-lateral spectrum coordination, subsequent national spectrum re-planning, and retuning of HPHT transmitters.

# 10 The cost benefit analysis

## 10.1 Introduction

In this chapter we consider the incremental costs and benefits of moving:

- From a counterfactual in which the sub-700 MHz UHF spectrum (470 to 694 MHz) is allocated for exclusive use by an HPHT DTT platform for TV broadcasting using DVB transmission technology
- To a situation in which the sub-700 MHz spectrum is used by an LPLT converged platform – with some of the spectrum being used for DTT broadcast and the rest used for mobile unicast/multicast SDLs.

Note that we estimate the incremental costs of a converged platform relative to an HPHT DTT counterfactual. We do not estimate the costs and benefits of the counterfactual. With our approach such a step is unnecessary. See Figure 10-1 below for a further discussion of this point.

In our cost benefit analysis (CBA) we calculate the net present value (NPV) of these incremental costs and benefits:

- Using a discount rate of 4% per annum – the social discount rate recommended by the European commission for impact assessments
- Over a 20 year period with terminal values set to zero[152]
- With all costs and benefits expressed in 2014 prices.

We have carried out the CBA for a hypothetical case study country with a population of 20 million and 10 million TV households. Given that nearly all costs and benefits scale with population, the results from the case study country should be valid across almost all member states. We consider this issue further in Section 10.12.

We estimate the incremental costs and benefits from the perspective of the case study country as a whole. This means we ignore transfer payments between stakeholders. So, for example, we do not consider the charges which flow between stakeholders in the delivery of audio-visual services. Nor do we consider any termination charges for long term contracts if DTT services are transferred from an HPHT to an LPLT network.

## 10.2 The incremental benefits of a converged platform – introduction

Figure 10-1 shows the possible benefits which arise from convergence. It distinguishes between those benefits which arise in any case with the counterfactual and those which arise in addition when a converged platform is implemented. We can see that there are three main potential incremental benefits from implementing a converged platform:

[152] That is the net benefits (benefits less costs) in Year 21 and subsequent years are set to zero. Implicit in this assumption is the idea that market and technology uncertainties have accumulated over 20 years to the extent that any further value is negligible

- Potential Benefit A: the avoided costs which arise because sub-700 MHz spectrum release creates both additional mobile broadband capacity and cheaper in-building and rural mobile capacity for unicast services (when compared with using higher frequency spectrum)
- Potential Benefit B: the benefits from better mobile TV which come from using an LPLT network rather than an HPHT network for broadcast of free-to-air linear TV channels
- Potential Benefit C: the benefits from being able to integrate TV broadcast and broadband services more easily (especially with the LTE option) on mobile devices to create interactive multimedia services[153].

We consider each of potential benefits A, B and C in the next three sections of this chapter.

**Figure 10-1: The incremental benefits of moving to a converged platform**

| Benefits from counterfactual [154] | Incremental benefits of moving to a CP | Comments on incremental value |
|---|---|---|
| Value of using sub-700 MHz spectrum for DTT broadcast | **Benefit A:** a % of sub-700 MHz spectrum is made available for mobile broadband generating incremental benefits from:<br>• Avoided costs of additional mobile broadband capacity<br>• Premium value of sub 1 GHz spectrum because of better propagation characteristics | Value can be estimated using relevant auction prices and then adjusted for:<br>• Poor antenna performance sub-700 MHz<br>• PMSE migration costs<br>• Temporary sterilisation of mobile broadband use in border areas |
| Value of FTA broadcast on near universal basis for PSB and main commercial TV channels | No additional value - converged platform replicates this requirement | - |
| Value of personal video unicast to mobile devices on a commercial basis | No additional value - beyond that already counted under spectrum release benefit | - |
| Value of commercial eMBMS services | No additional value | eMBMS is designed for selective video multicast in individual cells for a limited time.<br>A converged platform is designed to replace HPHT DTT platform with 24 hour per day broadcast of predefined set of video channels on near universal coverage basis |
| Value of linear TV broadcast to mobile devices using HPHT DVB technology | **Benefit B:** Additional value (LTE option only) from:<br>• Cheaper mobile devices<br>• Lower battery drain than counterfactual (?)<br>• Expanded population of mobile devices capable of receiving linear TV broadcast cf the counterfactual | Experience in Korea and Japan suggests linear TV broadcast to mobile devices of little economic value – whether for counterfactual or converged platform |

[153] See Section 8.4 for a discussion of the possible relationship between sub-700 MHz down links and the spectrum used for the corresponding uplink to enable two-way mobile broadband

[154] To remain with separately evolved DTT and mobile BB platforms

| Benefits from counterfactual [154] | Incremental benefits of moving to a CP | Comments on incremental value |
|---|---|---|
| Value of integrating linear broadcast and personalised unicast video on TV sets and portable devices in the home | **Benefit C:** Additional value of easier integration of linear broadcast and personalised unicast mobile video on portable devices with a converged platform | Depends on:<br>• Value of integration (which is currently uncertain)<br>• What % of future AV viewing time will take place on portable devices using mobile broadband<br>• % of this benefit which cannot be realised under the counterfactual. |

It is important to note that we have been unable to identify any end-user converged services where a converged platform is essential. It is of course possible that new forms of converged services will emerge where this is the case.  But, as far as we can tell, it should be possible to deliver all of the converged services described in Chapter 6 by combining broadcast and broadband functionality at the device or through commercial cooperation between broadcast and mobile network operators. As such it should be possible to capture a significant proportion of the benefits of such services in the counterfactual.

## 10.3 Benefit A: the economic value of spectrum release

Sub-700 MHz spectrum has good propagation characteristics and can be used more cheaply to add additional mobile broadband capacity in rural areas and for indoor coverage than using higher (above 1 GHz) spectrum. We can measure this benefit in terms of the value which mobile operators place on sub-1 GHz spectrum at auctions or by using cost models to estimate the avoided costs directly. In doing so we need to recognise that:

- There is substantial variation between member states in auction prices which adds considerably to uncertainty over the benefits at the individual member state level. See Figure 10-2 below.
- Avoided cost values provide a lower bound on spectrum value as these estimates do not include any benefit arising from the possibility of using additional spectrum to launch new types of services[155].  Auction values on the other hand should include the benefits (from the additional spectrum) that operators expect to gain over and above savings in network costs[156]
- The avoided cost values provide a lower bound on spectrum value as these estimates do not include any benefit arising from the possibility of using additional spectrum to launch new types of services.   Auction values on the other hand should include the benefits (from the additional spectrum) that operators expect to gain over and above savings in network costs.
- We can expect the incremental value to diminish as additional sub-1 GHz spectrum is made available to mobile operators. For example, the 800 MHz spectrum (first release) will have a

[155] We note that Bengt and Molleroyd (2011) obtain the counterintuitive result that avoided cost estimates exceed values revealed through auction.  Their modelling appears to assume additional spectrum reduces costs across the whole network at the point of rime when the spectrum is acquired. However, it is more likely that costs are only avoided in locations where demand peaks occur i.e. in cities and that the benefits accrue in the future when all existing spectrum holdings are fully utilised. http://wireless.kth.se/SoB/wp-content/uploads/sites/6/2011/10/M%C3%B6lleryd_and_Markendahl_ITS_2011_valuation_of_spectrum_final.pdf

[156] If benefits are passed on to consumers a demand stimulus could occur.  This is not taken into account in avoided cost estimates, although it may be reflected in auction values.

higher value per MHz pop than the 700 MHz band (second release) and the sub-700 MHz spectrum will have a lower value still (all else being equal)

- The value of supra 1 GHz spectrum[157], which is provided for additional capacity purposes, might form a lower limit on the value of sub-700 MHz spectrum. Some stakeholders have argued that the economic value of sub-700 MHz spectrum might even fall below this level, especially if radio access network sharing is extended to spectrum sharing over the next decade. We do not consider this possibility. Instead we give weight to the argument that NRAs would reject such developments so as to preserve infrastructure based competition between mobile operators
- There may be problems in meeting the RF emission limits of the ICNIRP[158] when adding a substantial number of sub-700 MHz carriers to urban masts. This could lead to operators incurring additional costs and so reduce the net value of this spectrum. We discuss this issue in detail in Section 11.3

Appendix S provides an analysis of the prices paid at auction for 800 MHz and 2.6 GHz spectrum. It also provides estimates (for the UK) of the likely economic benefits of moving the 700 MHz band to mobile use. The results are summarised in Figure 10-3, along with other spectrum benchmark values, and expressed in terms of the value of spectrum per MHz and per head of population.

**Figure 10-2: Variations in the price paid for 800 MHz spectrum in Europe (as of March 2014)**


Source: Plum analysis based on data from national regulators

[157] At 1.8, 2.1 or 2.6 GHz

[158] RF exposure limits specified by the International Commission on Non-Ionizing Radiation Protection and adopted by EU in the European Council Recommendation 1999/519/EC

Figure 10-3: Relevant spectrum values in the EU[159]

| Source | Value per MHz pop | Assumptions |
|---|---|---|
| Average auction value for 800 MHz spectrum | €0.53 | Average over most EU member states with 20 year licence |
| Average auction value for 2.6 GHz spectrum | €0.07 | Average over most EU member states with 20 year licence |
| Average recent auction value for 1.8 GHz spectrum | €0.25 | Average over most EU member states with 20 year licence |
| Average recent auction value for 2.1 GHz spectrum | €0.35 | Average over most EU member states with 20 year licence |
| Economic value of 700 MHz spectrum | €0.22 | Ofcom CBA of May 2014 to estimate the avoided cost benefits |
| Value of sub-700 MHz spectrum:<br>Lower limit<br>Mid-point value<br>Upper limit | <br>€0.10<br>€0.25<br>€0.40 | <br>Used in the CBA |

*Source: Plum research and analysis*

We can use these values to estimate the economic value of sub-700 MHz spectrum. But we then need to adjust these estimates in four main ways to calculate Benefit A:

- To subtract the amount set aside for the LPLT DTT platform. We consider three cases - a low TV payload of 60 Mbps, a central TV payload of 120 Mbps and a high TV payload of 180 Mbps and assume that the new DTT platform offers a spectrum efficiency of 2 bps/Hz for the LTE broadcast option and 3.5 bps/Hz for the DVB option
- To subtract from the benefits the costs of moving PMSE audio services to another band (s). We estimate that this cost is €700 million across the EU or €28 million in the case study country[160].
- To discount for poor antenna performance at low UHF frequencies and for the temporary sterilisation of spectrum used for unicast mobile SDLs during the transition phase[161]. We assume a 15% discount on the amount of spectrum released given that:
  - Degraded antenna performance might reduce the signal power at the mobile device by 3dB, so reducing the cell sizes by around 10%
  - We might expect a sterilisation zone of up to 50 km within the transitioning country's borders for a period of three to five years.
- To adjust for use of the released spectrum in a standardised band plan. For example broadcast downlinks normally use 8 MHz channels and unicast mobile downlinks 5 MHz channels. We have allowed for this adjustment in the 15% discount factor.

[159] We also note the findings of a recent Aetha report for the broadcasting community. This suggested that the value of sub-700 MHz spectrum might lie between zero and €0.1 per MHz pop (*Future use of the 470–694MHz band*, a report for Abertis, Arqiva, BBC, BNE, EBU and TDF by Aetha, November 2014)

[160] See Appendix R for a discussion of how this estimate is derived

[161] When continuing HPHT DTT transmissions from neighbouring countries sterilise mobile use in the border regions of the member state moving to an LPLT converged platform

## 10.4 Benefit B: the incremental benefits of better mobile TV

We define mobile TV as linear TV broadcast received on a mobile device at the same time as it is broadcast on the HPHT DTT network to fixed receivers. We contrast this with the supply of mobile video services which are delivered over a mobile network using unicast or multicast technology on a commercial basis. We find that, while the market for personalised, unicast, mobile video services is likely to be very substantial, the market for broadcast linear TV on mobile devices is likely to be small.

There are a number of reasons to suggest why the market for ***mobile video services*** is potentially significant:

- The installed base of smart phones and tablets with user interface and other functionalities which eases mobile video viewing is growing rapidly
- Consumer habits and expectations are changing. People expect to be able to access video content at any time throughout the day while there is a shift towards a personalised and socially interactive IP-based TV experience[162]
- There is a fast-growing ecosystem of apps, designed for portable devices which enable delivery of video and audio services over mobile devices while incorporating features such as an electronic programme guide, podcasts and weather information[163]

But the evidence of any substantial demand for (linear) **mobile TV** is far less compelling:

- The evidence to date suggests a limited consumer benefit from mobile TV:
  - In Europe trials of DVB-H mobile TV in the late 2000s suggest that consumers' willingness to pay for a subscription-based mobile TV service is low[164]
  - The successes have come in countries where mobile TV services are available free to air (for example Korea and Japan) or where operators use mobile TV as a loss leader to acquire customers (such as Brazil). However this success suggests that end users place little value on mobile TV and that mobile TV therefore generates relatively little in the way of consumer surplus and economic benefits
  - Consumer research suggests that consumption of content on mobile phone/smartphones tends to be user-generated content and short videos rather than long form linear content[165]
- Demand for mobile TV is like to be strongest while commuting. We note that the commuting journeys in Europe are generally half of those in Korea or Japan[166] where consumption of mobile TV is significant
- Our scenarios for AV consumption in 2030 suggest that the amount of time spent consuming video on-the-move – the main source of demand for mobile TV – is likely to be a modest fraction of future AV consumption. It is clear that from the growth of video traffic over broadband networks that consumers value the ability to access TV over their mobile devices but most of the evidence so far indicates that a high proportion of this occurs within the home or at locations where WiFi is

[162] Ericsson. The Forever Evolving Experience, May 2014.

[163] Euroradio. Planet of the apps. April – October 2013.

[164] Market research suggests that the maximum acceptable price for most users is US$5 (€3.60) per month. PA Consulting.

[165] *Video-over-internet consumer survey 2013*. http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture-Video-Over-Internet-Consumer-Survey-2013.pdf

[166] See for example http://www.oecd.org/els/family/43199696.pdf

available. It is likely that many of the benefits from mobile TV would be confined to high profile live events (such as live sport) where there is likely to be more demand for linear TV viewing on the move.

- Consumption of mobile TV may not be welcomed by mobile operators in that such a service might divert users time and battery resources away from revenue generating activities on their mobile devices to a (free) mobile TV service. As such it may have the effect of reducing the profits of the mobile operators.
- End users may prefer the active control available on commercial mobile video services to the passive experience of watching mobile TV. As the consulting firm PA put it in a recent report[167]:

  *However, at the moment there appears to be only limited demand to distribute broadcast content over mobile networks. For mobile TV, currently the main broadcast application, consumers increasingly demand control over their media consumption instead of passive consumption of linear content.*

We conclude that:

- There is strong and growing demand for video services on portable devices – both in the home and on-the-go – as the installed base of smartphones and tablets grows
- The big economic value created by this trend is through personal unicast services and not through viewing of linear TV broadcast - where the economic value is close to zero
- The broadcast content aggregators (as opposed to the HPHT DTT network operators) will be keen to reach mobile devices with their content through personal unicast services
- There is nothing to prevent broadcast content aggregators from reaching commercial deals with mobile operators on the distribution of their video content on a personal unicast basis (as the mobile video market develops) in the absence of an LPLT converged platform[168]. Any benefits from such deals arise within the counterfactual and are not incremental benefits of a converged platform
- The development of eMBMS – which enables cost efficient delivery of broadcast linear video to multiple users in a cell – is now being trialled[169]. This may well be widely deployed in mobile networks in future[170]. So, in cases there is a peak in demand for linear video on the move such as major sporting events, this demand would then be met using eMBMS within the counterfactual. As such it would not count as an incremental benefit of a converged platform
- The future economic benefits of mobile TV (linear broadcast to mobile devices) in the EU are likely to be modest – however the service is implemented. So we do not consider them further in our CBA. In particular, given that the benefits of mobile TV are likely to be small, we do not need to consider the incremental benefits which might result from moving mobile TV to an LPLT network compared to the counterfactual.

[167] *LTE brings a new capability to mobility: how might it enable a range of cross sector services?* A report for Ofcom by PA, November 2013

[168] Indeed we understand that several broadcast aggregators are already looking at how best to repurpose video in this way

[169] See for example http://www.irt.de/no_cache/de/aktuell/news/view/article/in-bayern-startet-forschungsprojekt-imb5-zur-rundfunkuebertragung-in-lte.html

[170] http://www.telecoms.com/275302/ee-says-4g-broadcast-in-uk-is-inevitable/

## 10.5 Benefit C: Making broadcast services on mobile devices interactive

An LTE broadcast implementation of a converged platform, would enable easier integration of broadcast services with personalised unicast mobile services to create interactive mobile services which might, for example enable:

- More active participation in the viewing of linear TV, for example through real time voting on TV shows
- Targeted and transaction based advertising inserted into linear TV broadcasts
- Gambling and gaming services based on linear TV
- Support for transactions like on-line purchases or additional, tailored, information to enhance the value of advertising.

What scale of benefits might such integration of linear broadcasts and interactive services on mobile devices generate? Our analysis here is as follows:

- Over the next decade, as we conclude in Chapter 3, the bulk of video consumption will remain in the home
- In the home it is possible to add value to linear broadcast through interactivity at substantially lower cost through fixed broadband rather than through (unicast) mobile broadband. The broadcast community is now starting to exploit this capability through hybrid TV sets and TV services based on broadcast networks, including HPHT DTT networks and fixed broadband. We expect demand for such services to grow strongly over the next few years[171]
- This value-add is available in the counterfactual and is not an incremental benefit which accrues to an LPLT converged platform
- The scale of this value-add is as yet unclear. It might or might not be substantial. Even if it is substantial this does not mean that the extension of this concept to mobile devices on-the-go will be substantial. This will depend on the how much viewing of linear video content takes place outside the home and what proportion of this uses mobile networks rather than pre-stored downloads or streamed WiFi access

In combination these points suggest that there is, as yet, little evidence that integrated interactive/broadcast services on mobile devices will generate substantial economic value. Of course the markets could change substantially. Moving DTT broadcast to an LTE broadcast converged platform would substantially widen the opportunity for innovative, interactive, multimedia services and could generate substantial incremental benefits as a result. However a significant proportion of any integration benefits might be captured under the counterfactual through commercial arrangements between DTT operators and mobile network operators.

[171] We also note that:

- On current trends 95% of EU homes will be connected to fixed broadband services (wireline or fixed wireless access) by 2025
- Those which are not (e.g. the households of the old and the poor) are the least likely to own the smart phones and tablets which would make mobile video a possibility
- A lot of secondary viewing in the home will switch from DTT TV sets to tablets (and perhaps smartphones) years. But this will mostly use WiFi/fixed broadband rather than the mobile networks for cost reasons

We conclude that there is as yet little firm evidence to suggest major incremental benefits from broadcast-broadband integration using a converged platform relative to a counterfactual in which there is device or service level convergence through commercial collaboration between HPHT DTT service providers and broadband service providers – whether fixed or mobile.

## 10.6 The overall benefits

Our analysis indicates that the bulk of the benefits of moving to an LPLT converged platform will come from spectrum release and that Benefits B and C are small in comparison. So in our CBA we do not estimate Benefits B and C. But we also ignore any effects which relate to lack of global standards for sub-700 MHz spectrum which would tend to reduce its value relative to our benchmark values in Figure 10-3. These are all globally standardised.

Using these assumptions we estimate that the benefits of a move to a converged platform in a member state with a population of 20 million are as follows.

**Figure 10-4: The range of incremental benefits from a converged platform**

| TV payload | Low (60 Mbps) | Central (120 Mbps) | High (180 Mbps) |
|---|---|---|---|
| Capacity required for the LPLT CP (Mbps) | 60 | 120 | 180 |
| | | | |
| Possible effective spectrum release – LTE broadcast option (MHz) | 165 | 139 | 114 |
| NPV of released spectrum (€m) - LTE broadcast option | | | |
| low spectrum value | 302 | 251 | 200 |
| mid-point spectrum value | 797 | 669 | 542 |
| high spectrum value | 1291 | 1087 | 883 |
| | | | |
| Possible effective spectrum release – DVB option (MHz) | 176 | 161 | 147 |
| NPV of released spectrum (€m) - DVB option | | | |
| Lower limit | 324 | 295 | 265 |
| Mid-point | 851 | 778 | 705 |
| Upper limit | 1379 | 1262 | 1145 |

*Source: Plum CBA*

Figure 10-4 indicates that:

- The level of possible benefits is highly uncertain – ranging from €200 million to just under €1400 million
- The benefits are slightly higher for the DVB option than for the LTE option because the former operates at higher spectral efficiency and therefore releases more spectrum

- In countries where there is a high TV traffic load for the converged platform to carry, benefits are reduced by over 30% for the LTE option and by just under 20% for the DVB option - relative to the low TV payload.

## 10.7 The incremental costs of a converged platform

There are three main components to the incremental costs of moving to an LPLT converged platform:

- The incremental capital and operating costs of the converged platform
- The cost of ensuring that end users can use the platform
- The costs of freeing the simulcast spectrum and mitigating interference

There are also a number of dimensions to consider when estimating the incremental costs of a converged platform. These are as follows:

- What technology options are we considering for the converged platform - the LTE broadcast or DVB option?
- What is the current level of HPHT DTT penetration in terms of primary TV sets? We look at 10%, 40% and 70%
- How will the level of penetration of DTT households change by 2025 to 2030? We consider a 10% reduction by 2025 to 2030 (low OTT and IPTV impacts) and a 70% reduction (high OTT and IPTV impacts)
- What level of TV traffic must the converged platform carry? We consider three payloads – low (60 Mbps), central (120 Mbps) and high (180 Mbps).

To estimate the incremental costs of moving to, and operating, a converged platform we make the key assumptions listed in Figure 10-5 for a hypothetical case study country of 20 million people. Appendices T and U then provide further details on assumptions and sources.

In making our assumptions it is important to note the following:

- Broadcasters have often proposed estimates for parameters which are based on eMBMS rather than LTE-broadcast. We have not used such estimates because we have rejected an eMBMS option for the converged platform for the reasons discussed in Section 8.4
- Mobile operators have so far shown little interest in the idea of a converged platform and have been unable to provide us with estimates of parameters for the CBA. As a result some of our estimates, and especially those which relate to upgrading a mobile network to create an LPLT DTT network, are subject to significant uncertainty. We consider this uncertainty further in Section 10.13, where we carry out sensitivity analysis on our CBA findings.
- We assume that cross-border interference between a new LPLT DTT platform in one country and existing HPHT platforms in neighbouring countries is avoided through spectrum coordination and have included this cost in our CBA
- We assume that the use of co-channel regional LPLT SFNs (which enable regional broadcasting) is possible subject to:
  - Use of network optimisation techniques

- Modifications to regional boundaries
- Installation of new aerials with high front-to-back discrimination between transmissions from desired and undesired base stations in border regions. We have set the proportion of DTT aerials requiring such replacement at 5%

- We assume that the decision to move to an LPLT converged platform might be taken in 2020 and be implemented within the next six years. This might then mean that 50% of the installed base of TV receivers would be LTE ready (at an assumed cost of zero) and 50% would require retrospective upgrades through a set top box (at €50 plus €20 for end-user time)[172].
- We set the TV receiver upgrade costs of the DVB option to zero. Some stakeholders argue that the costs of DVB-T2 and HEVC upgrades should be included here. We see such costs as part of the counterfactual and therefore do not count them as part of the incremental cost of moving to an LPLT converged platform

[172] Based on DSO experience in UK and Sweden

**Figure 10-5: Key assumptions on the incremental costs of a converged platform**

The case study country has :

- 20 million people and 10 million households
- A population density of 250 per sq km – the average for Germany and the UK

There are 5000 macro-cells per MNO.

2320 of these base station sites need to be upgraded. See Appendix T for details.

It costs €60,000 per site capex to upgrade for the LTE-broadcast option and €64,000 for the DVB option. See Appendix T for details.

A 20% capacity upgrade for LPLT backhaul is needed (given prior upgrade of mobile backhaul to LTE using fibre and Gbps microwave by 2025). This is included in the upgrade costs above.

There are operating costs of €14500 per year per site for the LTE-broadcast option and €15300 per year for the DVB option. See Appendix T for details.

30% of households require aerial reorientation at €70 per household. See Appendix T for details.

An HPHT DTT platform would generate €45 million pa in operating costs.

It costs €50 million for new platform development and implementation - including the cost of regulatory and market related structural changes e.g. establishing CP industry groups and ecosystem).

There is a 5 year simulcast period for HPHT and LPLT with 20% of sites upgraded each year.

50% of DTT TV sets will have LTE capability by the time a converged platform is implemented.

50% will require an upgrade via a set-top box at a cost of €70 per DTT household per TV set for the LTE broadcast option but not for the DVB option.

It costs €40 million (high OTT impacts) and €100 million (low OTT impacts) for transition management costs.

There is an average cost of €10 million per country for spectrum re-planning process and €70 million for retuning of HPHT DTT networks to avoid cross border interference and create the simulcast spectrum.

5% of DTT households will require new high discrimination aerials at €200 per aerial installed to enable regional co-channel SFNs.

No additional expenditure is needed to improve network reliability of LPLT DTT platform. See Chapter 11 for a discussion of this assumption.

There are no problems with safe radiation emissions. See Chapter 11 for a discussion of this assumption.

- We ignore the cost of upgrading mobile devices to include DVB receivers under the DVB option, but count the cost of upgrading TV receivers for LTE reception under the LTE option as set out above. Our rationale here is that the replacement cycle for mobile devices is much shorter than for TV receivers
- We set aerial reorientation costs at €70 per household. This is significantly lower than the €190 used by Ofcom in recent analysis. This latter estimate includes the cost of aerial replacement and rewiring which we consider unnecessary

- Our calculations indicate that the operating costs of an LPLT platform based on LTE-broadcast in our case study country[173] are roughly €10 million per annum lower than those of the existing HPHT DTT platform:
  - Based on operating costs in Germany, Spain and the UK, we estimate the operating costs for an HPHT DTT network in our case study country at €45 million per year
  - In contrast we estimate the operating costs of the LPLT network (in Appendix T) at between €34 million and €36 million per year.

  This means that the incremental operating costs of the LPLT network are negative. Many stakeholders have argued that the operating costs for the LPLT network should be higher than those of an HPHT network. So we have reviewed our estimates to take account of these arguments. However we have reached the same conclusion - we believe that the operating costs of the LPLT networks may well be cheaper:
  - Through economies of scale and scope effects in moving from two separate networks to a single network with cheap backhaul by 2025
  - Through use of LTE broadcast rather than eMBMS. This leads to a substantial reduction in the number of sites requiring upgrades
  - Through the use of substantially lower power equipment – for example at 50 W rather than 50,000 W
- We assume a five-year simulcast period for the transition to a converged platform. This is assumed to be done a regional basis - converting 20% of DTT households per year and switching off the HPHT network in that region at the end of the year
- We calculate only the incremental costs of implementing and operating an LPLT DTT platform. We do not consider the incremental costs of implementing and operating the unicast mobile SDLs. These are already accounted for in the benefits calculation in that the value of the released spectrum takes account of these costs
- We estimate, based on information from various stakeholders, that the cost of upgrading a LPLT site is likely to be €4000 per site higher for the DVB option as compared with the LTE-broadcast option. This primarily reflects the need for more complex electronics
- The estimated cost of retuning the HPHT transmitters, to implement the programme of spectrum coordination required to free the simulcast spectrum and avoid cross-border interference, is based on the UK cost estimate for clearing the 700 MHz band for mobile use. Our estimate uses the following assumptions:
  - The UK costs of retuning for the 700 MHz clearance is €360 million (least costly option)
  - The cost in this case study country would be €120 million[174]
  - 60% of transmitters would be affected.

  We expect this cost to vary from country to country depending on the status of the DTT network[175], the extent of modification works required at DTT primary and relay sites[176], the

[173] 20 million population

[174] After adjusting for the reduction in population from 60 to 20 million

[175] For example the number of MUXs, national and regional services

[176] For example design and structural assessment, civils, logistics and other labour works, site location and accessibility

availability of backup or redundant equipment[177] and the level of DTT service continuity required during the transition.

- Some highly uncertain costs are not quantified. This includes any impacts on platform competition and fragmentation and on advertising and other revenues during simulcast; standardisation costs (for example activities required on a regional/global level with standards bodies; and the cost of decommissioning HPHT sites). We estimate that these last costs represent less than 1% of total costs.

## 10.8 Comparing the incremental costs and benefits in the central case

We start to explore the findings of the CBA by comparing the NPV of the incremental benefits of Section 10.6 and the NPV of the incremental costs of Section 10.7 for a central case in which:

- There is a current 40% DTT penetration in our hypothetical case study country
- The converged platform carries a TV payload of 120 Mbps
- The converged platform uses the LTE broadcast option.

We then tabulate our findings for both the high OTT impact scenario and the low OTT impact scenario in Figure 10-6. The key assumptions of these two scenarios are as follows. Under the ***low impact*** scenario:

- The percentage of DTT households reduces from its 2014 level by 10% by 2025-2030 as a result migration to OTT and IPTV services
- Over this period the number of DTT secondary sets in use in DTT households reduces by 30% as use of tablets, smart phones and other portable devices for audio-visual consumption grows
- At the same time the number of secondary DTT TV sets in non-DTT households reduces by 70%

Under the ***high impact*** scenario:

- The proportion of DTT households reduces by 70% rather than 10%
- The proportion of secondary DTT sets in use reduces by 85% in DTT households and by 95% in non-DTT households.

[177] For example masts, antennas, combiners, transmitters, power supply

Figure 10-6: CBA – central case[178]

| NPV (€m) | OTT/IPTV impacts | |
|---|---|---|
| | Low | High |
| Capex for building LPLT network | 184 | 184 |
| NPC of LPLT opex (versus HPHT) | -57 | -57 |
| End-user costs | 430 | 132 |
| Costs of spectrum changes[179] | 116 | 92 |
| | | |
| Total incremental costs | 674 | 352 |
| Total incremental benefits[180] | | |
| Lower limit | 251 | 251 |
| Midpoint | 669 | 669 |
| Upper limit | 1087 | 1087 |

*Note: More heavily shaded cells indicate where benefits exceed costs*

We can see that:

- The prospects of net benefits are better under the high impact scenario where the number of DTT TV receivers requiring conversion to LTE is significantly lower than under the low impact scenario
- The CBA is negative if the benefits lie towards the lower end of the expected benefits range
- Only if we move to the high-end of the expected benefits range is the CBA unambiguously positive.

## 10.9 Variations on the central case – low impact scenario

How does the situation change as we vary our assumptions relative to the central case? In this section we consider such variations whilst assuming the low impact scenario for future DTT demand.

We can reduce the cost of the converged platform in the low impact scenario by moving from the LTE to the DVB option. As Figure 10-7 shows, this substantially reduces end user transition costs, by eliminating the need to convert TV receivers, and marginally increases the likely benefits, because the higher spectrum efficiency of DVB leads to greater spectrum release. As a result there is a good possibility of net benefits.

178 LTE broadcast, support for primary TV sets only, 40% DTT HH in 2014, 120 Mbps TV payload

179 To create the simulcast spectrum while avoiding interference

180 The level of incremental benefits is unaffected by the strength of OTT/IPTV impacts

**Figure 10-7: DVB vs LTE – low impacts scenario**

| NPV (€m) | LTE –B | DVB |
|---|---|---|
| Capex for building LPLT network | 184 | 193 |
| NPC of LPLT opex (versus HPHT) | -57 | -34 |
| End-user costs | 430 | 176 |
| Costs of spectrum changes | 116 | 116 |
| Total incremental costs | 674 | 451 |
| | | |
| Total incremental benefits | | |
| Lower limit | 251 | 295 |
| Midpoint | 669 | 778 |
| Upper limit | 1087 | 1262 |

*Note: More heavily shaded cells indicate where benefits exceed costs*

Figures 10-8 and 10-9 then compare the costs and benefits for the low impact scenario with two other variations on the central case. In Figure 10-8 we look at the effects of varying the TV traffic load and in Figure 10-9 we consider member states with different starting levels of DTT penetration in 2014. The current level of DTT penetration varies considerably from one member state to another:

- 42% of the EU population lives in countries of **Type I** with 0-20% of DTT (primary) households
- 34% live in countries of **Type II** with 20-60% DTT penetration and
- 24% live in countries of **Type III** with greater than 60% DTT penetration.

The costs and benefits of these three categories of member states are tabulated in Figure 10-9. We can see that, as DTT penetration rises, so too do the costs of converting end users receivers and mitigating interference – driving net benefits negative as they do so.

**Figure 10-8: Varying TV payload - low impacts scenario**

| NPV (€m) | 60 Mbps | 120Mbps (central case) | 180 Mbps |
|---|---|---|---|
| Capex for building LPLT network | 184 | 184 | 184 |
| NPC of LPLT opex (versus HPHT) | -57 | -57 | -57 |
| End-user costs | 430 | 430 | 430 |
| Costs of spectrum changes | 116 | 116 | 116 |
| Total incremental costs | 674 | 674 | 674 |
| | | | |
| Total incremental benefits | | | |
| Lower limit | 302 | 251 | 200 |
| Midpoint | 797 | 669 | 542 |
| Upper limit | 1291 | 1087 | 883 |

*Note: More heavily shaded cells indicate where benefits exceed costs*

Figure 10-9: Varying the current level of DTT penetration - low impacts scenario

| NPV (€m) | % DTT primary households in 2014 | | |
|---|---|---|---|
| | Type I - 10% | Type II - 40% | Type III - 70% |
| Capex for building LPLT network | 184 | 184 | 184 |
| NPC of LPLT opex (versus HPHT) | -57 | -57 | -57 |
| End-user costs | 246 | 430 | 615 |
| Costs of spectrum changes | 89 | 116 | 143 |
| Total incremental costs | 462 | 674 | 885 |
| | | | |
| Total incremental benefits[181] | | | |
| Lower limit | 251 | 251 | 251 |
| Midpoint | 669 | 669 | 669 |
| Upper limit | 1087 | 1087 | 1087 |

*Note: More heavily shaded cells indicate where benefits exceed costs*

We can see that:

- There are good prospects of net benefits in member states with low TV payloads[182] and low current penetration of DTT households[183]
- The CBA is an unambiguously positive if benefits are at the upper end of the benefits range and unambiguously negative if benefits are at the lower end of the range.

## 10.10 Variations on the central case – high impact scenario

The prospects of net benefits for an LPLT converged platform are significantly brighter under the high impact scenario – as Figures 10-10 to 10-12 illustrate:

- If we assume that the benefits realised are at the high end of the benefits range then the CBA is positive for all variations
- If we assume that the benefits realised are at the low end of the benefits range than the CBA is unambiguously negative.

[181] The level of incremental benefits is unaffected by the proportion of DTT primary households in 2014

[182] Leading to increased spectrum release

[183] Where there are fewer TV receivers to convert

**Figure 10-10: DVB vs LTE – high impacts scenario**

| NPV (€m) | LTE –B | DVB |
|---|---|---|
| Capex for building LPLT network | 184 | 193 |
| NPC of LPLT opex (versus HPHT) | -57 | -34 |
| End-user costs | 132 | 65 |
| Costs of spectrum changes | 92 | 92 |
| Total incremental costs | 352 | 316 |
| | | |
| Total incremental benefits | | |
| Lower limit | 251 | 295 |
| Midpoint | 669 | 778 |
| Upper limit | 1087 | 1262 |

*Note: More heavily shaded cells indicate where benefits exceed costs*

**Figure 10-11: Varying TV payload - high impacts scenario**

| NPV (€m) | 60 Mbps | 120Mbps (central case) | 180 Mbps |
|---|---|---|---|
| Capex for building LPLT network | 184 | 184 | 184 |
| NPC of LPLT opex (versus HPHT) | -57 | -57 | -57 |
| End-user costs | 132 | 132 | 132 |
| Costs of spectrum changes | 92 | 92 | 92 |
| Total incremental costs | 352 | 352 | 352 |
| | | | |
| Total incremental benefits | | | |
| Lower limit | 302 | 251 | 200 |
| Midpoint | 797 | 669 | 542 |
| Upper limit | 1291 | 1087 | 883 |

*Note: More heavily shaded cells indicate where benefits exceed costs*

Figure 10-12: Varying the current level of DTT penetration – high impacts scenario

| NPV (€m) | % DTT primary households in 2014 | | |
|---|---|---|---|
| | Type I - 10% | Type II - 40% (central case) | Type III- 70% |
| Capex for building LPLT network | 184 | 184 | 184 |
| NPC of LPLT opex (versus HPHT) | -57 | -57 | -57 |
| End-user costs | 74 | 132 | 191 |
| Costs of spectrum changes | 83 | 92 | 101 |
| Total incremental costs | 284 | 352 | 419 |
| | | | |
| Total incremental benefits | | | |
| Lower limit | 251 | 251 | 251 |
| Midpoint | 669 | 669 | 669 |
| Upper limit | 1087 | 1087 | 1087 |

*Note: More heavily shaded cells indicate where benefits exceed costs*

## 10.11 Interpreting the CBA findings

Figure 10-13 summarises the findings of the CBA. It indicates the circumstances under which an LPLT converged platform might generate net economic benefits. It indicates that:

- At the low end of the benefits range there are no circumstances in which there is an economic case for a converged platform
- At the midpoint in the benefits range the CBA is always positive if the high impact scenario is realised, but negative in some cases under the low impact scenario
- If we assume the upper limit of the benefits range then the CBA is unambiguously positive under either scenario.

Figure 10-13: When does the CBA yield net benefits?

| Benefits assumed at | Lower limit | | Mid-point value | | Upper limit | |
|---|---|---|---|---|---|---|
| OTT/IPTV impacts | Low | High | Low | High | Low | High |
| Central case (LTE option)[184] | No | No | No | Yes | Yes | Yes |
| DVB rather than LTE option | No | No | Yes | Yes | Yes | Yes |
| Low TV payload (60 Mbps) | No | No | Yes | Yes | Yes | Yes |
| High TV payload (180 Mbps) | No | No | No | Yes | Yes | Yes |
| 10% DTT HH in 2014 | No | No | Yes | Yes | Yes | Yes |
| 70% DTT HH in 2014 | No | No | No | Yes | Yes | Yes |

*Note: More heavily shaded cells indicate where benefits exceed costs*

[184] LTE broadcast, support for primary TV sets only, 40% DTT HH in 2014, 120 Mbps TV payload

These findings do not mean that we should recommend implementation of an LPLT converged platform, especially given that:

- The economic case for a converged platform disappears if it turns out that the benefits lie at the bottom end of the range of likely values
- The high impact scenario may not be realised. Under the alternative low impact scenario the incremental costs of an LPLT converged platform exceed the benefits in a wide variety of circumstances
- There are issues of network reliability and meeting ICNIRP RF emission limitations which could significantly weaken the case for an LPLT converged platform. These are discussed in Sections 11.2 and 11.3
- There may be other ways of meeting TV broadcast requirements which are more cost-effective than an LPLT converged platform.

The first three arguments point to the idea that policymakers might wish to review the case for an LPLT converged platform in (say) five years' time when the current uncertainty may have reduced substantially.

The last argument points to the need to consider the converged platform alongside other options for the delivery of TV services (and especially for the delivery of public service broadcasting services) which are currently delivered over the HPHT DTT network. These options include:

- Deployment of a single national SFN on the existing HPHT network (perhaps offering limited regional broadcasting)
- Eventual closure of the existing DTT network to be replaced by a mix of (free) satellite and IPTV services. Ofcom in the UK has indicated[185] that it is now considering this long-term possibility.

We note here that the circumstances in which moving to an LPLT converged platform offers the strongest economic case[186] are also the circumstances in which satellite DTH might offer a cheaper alternative to the current HPHT DTT platform than an LPLT converged platform. Figure 10-14 compares the cost of the LPLT converged platform and satellite DTH in these circumstances using the assumptions listed in Appendix V[187].

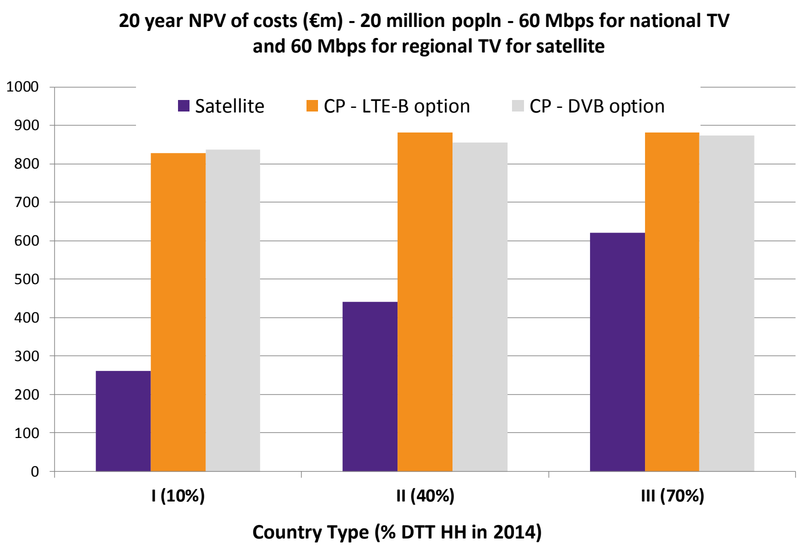
This analysis suggests that DTH satellite is a more cost-effective alternative to the HPHT DTT network than an LPLT converged platform for our case study country of 20 million people. If we then increase the population from 20 million to 60 million the satellite option becomes even more cost-effective than a converged platform. This reflects the fact that, in contrast to a converged platform, the cost of satellite coverage is largely independent of the population served. But if we increase the TV traffic load from 60 to 180 Mbps the satellite option is much less cost effective. This reflects the increased cost of the satellite option which is largely driven by the cost of transponder capacity. Again Appendix V provides more details.

[185] *The Future of Free to View TV - A discussion document*, Ofcom, May 2014

[186] That is in member states where there is a low TV payload and where the high impact scenario is realised

[187] Note that this figure shows the NPV of the **total** cost of a converged platform (and of satellite delivery) and not the **incremental** cost relative to the cost of using an HPHT network instead

Figure 10-14: Comparison of the costs of DTH satellite and a LPLT DTT network[188]




Of course DTH satellite is not a direct substitute for a DTT network – whether HPHT or LPLT. We note that although DTH may be considered a cost effective way to free-up spectrum, when compared with a Converged Platform, this option has other possible implications –for example in terms of coverage, regional broadcasting and platform control by national governments. The impact of these issues, if and where applicable, may vary among member states. Analysis of these impacts is outside the scope of this study.

## 10.12 The impact of population and population density on findings

The findings presented above indicate that the case for an LPLT converged platform cannot yet be made on the basis of current evidence. These findings apply to our hypothetical case study country with a population of 20 million and a population density of 250 people per square kilometre. But do our findings remain valid in member states with populations of 1 million or 60 million or in member states with low population densities of (say) 10 to 20 people per square kilometre?

### The effect of population size

Most of the incremental costs and benefits of moving to an LPLT converged platform scale with population. But around €50 million of the costs[189] in our CBA are largely independent of population. So, as we shrink the population of a member state from 20 million to 1 million these costs do not scale down to any great extent. As a result the ratio of incremental benefits to incremental costs falls and the economic case weakens. Conversely as we increase the population from 20 million to 60 million the case for an LPLT converged platform improves. Figure 10-15 provides a simplified example to illustrate this effect.

[188] Assuming a 60 Mbps TV payload and the high impact scenario

[189] Of creating and implementing a new DTT platform system

Figure 10-15: The impact of population on the CBA findings

| Cost/benefit | Country with a population of | | |
|---|---|---|---|
| | 1 million | 20 million | 60 million |
| NPV of incremental benefits (€m) | 25 | 500 | 1500 |
| NPV of incremental costs which scale with population (€m) | 20 | 400 | 1200 |
| NPV of incremental costs which do not scale with population (€m)[190] | 50 | 50 | 50 |
| Net benefit (€m) | -45 | +50 | +250 |
| Benefit to cost ratio | 0.33 | 1.11 | 1.20 |

Figure 10-15 shows that:

- The economic case for an LPLT converged platform is dramatically weakened for a small member state with a population of (say) 1 million
- The case is marginally better for a large member state with a population of 60 million. In this situation the ratio of benefits to costs increases from 1.1 to 1.2. But if we apply this ratio to the findings of Figures 10-6 to 10-12 we find that it makes little difference to the CBA findings. Moreover we note that, as a general rule, member states with the largest populations (and the biggest potential TV revenues) are those with the highest TV payload where there is, as yet, no case for an LPLT converged platform.

## The effect of low population density

As discussed in Chapter 9, an LPLT converged platform works best in member states with high or medium population density where the inter-site distances between existing rural cell sites of a mobile network are typically 10 km or less. But in countries with low population density this assumption may not be valid. In this case there are three main options:

- Option 1: base the LPLT converged platform on existing rural cell sites and move the small percentage of the rural DTT households which this network does not reach to DTH satellite
- Option 2: add new LPLT cell sites to the converged platform to increase its reach
- Option 3: use a solution proposed by KTH in Sweden[191], illustrated in Figure 10-16 in which:
  - TV channels are divided into popular and niche channels
  - Both are broadcast on SFN1 in urban areas
  - Niche channels are transmitted in unicast mode in rural areas to release spectrum. Unicast offers greater range than the broadcast SFN and so increases coverage

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[190] In practice these costs may scale to some extent with population

[191] *Spectrum Requirement for Cellular TV distribution in UHF Band from Urban to Rural Environment,* L. Shi, K. W. Sung, and J. Zander, " Proc. IEEE Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySPAN), April 2014

– Popular channels are broadcast on SFN2 in rural areas, using a lower modulation technique to increase the effective range of the transmission so as to increase coverage. This uses some of the spectrum released from unicast transmission of the niche channels.

**Figure 10-16: Using unicast to extend LPLT TV coverage**

| TV channel type | Urban areas | Rural areas |
|---|---|---|
| Popular | SFN1 | SFN2 |
| Niche | SFN1 | Unicast |

In all three cases low population density leads to a slight weakening of the economic case for a converged platform – either by adding to the costs (Options 1 and 2) or by reducing spectrum release and hence benefits (Option 3).

### Conclusion

Our CBA indicates that the case for moving to a converged platform in our hypothetical case study member state[192] is not yet made. Based on the analysis set out above, we can broaden this conclusion to include all member states given that the case for moving the converged platform:

- Is very much weaker in smaller member states
- Does not strengthen appreciably for bigger member states
- Is slightly weaker for countries with low population density.

## 10.13 Sensitivity analysis

We have identified five input parameters for our CBA which are especially uncertain. These are tabulated in Figure 10-17, together with our judgement on the credible range for each of them around the central value used in our CBA.

[192] With a population of 20 million and a population density similar to that of Germany and UK

Figure 10-17: The credible range for five uncertain CBA input parameters

| Parameter | Low value | Central value for CBA | High value |
|---|---|---|---|
| Proportion of DTT aerials requiring reorientation | 10% | 30% | 50% |
| No of sites to upgrade<br>(% of total macro sites per MNO) | 1,260<br>(25%) | 2,320<br>(46%) | 3,314<br>(66%) |
| Cost of retuning HPHT network to create the simulcast spectrum whilst avoiding cross-border interference | €35m<br>(-50%) | €70m | €105m<br>(+50%) |
| Percentage of high discrimination aerials required to allow regional SFNs | 2% | 5% | 15% |
| Percentage of sites requiring major upgrade for LPLT network | 10% | 25% | 50% |

Figure 10-18 then shows the impact of varying each of these parameters across its credible range on the NPV of the costs of moving to an LPLT converged platform. We can see with only two of the five parameters – the number of macro cells requiring upgrade and the proportion of these which require a major upgrade[193] – have any significant impact on the NPV of the costs.

Figure 10-18: The impact of varying the five parameters[194] on NPV of costs

| Parameter | Low value | Central value for CBA | High value |
|---|---|---|---|
| Proportion of DTT aerials requiring reorientation | -5% | 0% | +5% |
| No of sites to upgrade | -72% | 0% | +67% |
| Cost of retuning HPHT network | -9% | 0% | +9% |
| Percentage of high discrimination aerials required to allow regional SFNs | -2% | 0% | +2% |
| Percentage of sites requiring major upgrade for LPLT network | -39% | 0% | +66% |

In turn this variation in these two parameters affects the outcome of the CBA. Figure 10-19 indicates that:

- For the low impact scenario, moving the parameters to the bottom end of the credible range turns the CBA from negative to positive for the LTE option
- For the high impact scenario, varying these two key parameters makes no difference to the CBA outcome.

[193] Because of lack of space for an additional antenna and/or electronics

[194] With low impacts scenario, 40% DTT penetration, LTE-broadcast, 120 Mbps TV payload, benefits (spectrum value) assumed at mid-point value

**Figure 10-19: The impact of varying the key parameters on the CBA result**

| Scenario | LPLT option | Parameter | Value | | |
|---|---|---|---|---|---|
| | | | Low | Central | High |
| Low impact | LTE | No. of sites to upgrade | Yes | No | No |
| | | % requiring major upgrade | Yes | No | No |
| Low impact | DVB | No. of sites to upgrade | Yes | Yes | Yes |
| | | % requiring major upgrade | Yes | Yes | Yes |
| High impact | LTE | No. of sites to upgrade | Yes | Yes | Yes |
| | | % requiring major upgrade | Yes | Yes | Yes |
| High impact | DVB | No. of sites to upgrade | Yes | Yes | Yes |
| | | % requiring major upgrade | Yes | Yes | Yes |

*Note: More heavily shaded cells indicate where CBA result changes as we move from central value*

Overall we conclude that:

- Lack of certainty over the costs of upgrading macro-cells for an LPLT DTT network adds to existing uncertainty in our CBA over both the level of benefits and how AV consumption might move towards OTT and IPTV over the next decade
- There is a need to carry out further work to narrow the range of values for this parameter, if and when the case for a converged platform is re-examined.

# 11 Qualitative assessment of a converged platform

## 11.1 Introduction

Moving from an HPHT DTT network to an LPLT converged platform raises a number of issues which are either inherently qualitative in nature or where a quantitative evaluation would require detailed work by industry which has not yet been undertaken[195]. In this chapter we provide a qualitative (and semi-quantitative) assessment of these issues which include the following:

- Would a move to an LPLT converged platform lead to a reduction in the reliability of DTT broadcasting?
- What are the environmental impacts of an LPLT converged platform?
- What impact would an LPLT converged platform have on radio broadcasting?
- Would a move to a converged platform significantly impact the opportunity for governments to disseminate essential information to the public in the case of a national emergency?
- How might a move to an LPLT converged platform work in commercial terms?
- Would a coordinated pan-European move to a converged platform be desirable?
- Would an LPLT converged platform give the EU greater flexibility in changing DTT service delivery to match evolving market demand?

## 11.2 The reliability of an LPLT converged platform

We set out in Appendix W our research findings on the relative reliability of LPLT mobile networks and HPHT broadcast networks. We can summarise these as follows:

- Different measures of reliability are used for the two network types. Measures of reliability for HPHT networks focus on the uptime for main transmitter sites while reliability measures for LPLT networks focus on overall network uptime. But providing we make two simplifying assumptions for HPHT networks – that the reliability of the broadcast network is determined by the reliability of the main transmitter sites, and that failure at any one transmitter is independent of failure at any other – then we can compare reliability in terms of network uptime.
- There is a big difference in the information available in the public domain on the reliability of the two network types. There is good information on HPHT broadcast networks but only limited information on the reliability of LPLT mobile networks. There is some information from the Middle East and Hong Kong but no information from EU member states – where network reliability is considered commercially confidential by mobile operators
- The limited data which are available suggest that reliability of broadcast HPHT and mobile LPLT networks are similar. But they do not allow us to determine which network is the more reliable

In addition we note that:

[195] Mobile operators are currently focused on determining how best to use the 700 MHz band and, in particular, on how and when they might use it. They have not yet considered the merits of a converged platform in any detail

- There is some anecdotal evidence which suggests that HPHT networks are more reliable than LPLT networks. For example BNE reports that, during a recent spell of bad weather, a significant proportion of the mobile networks in Sweden were out of action while the broadcast network continued to operate.

It is important in making any comparison to note that moving DTT to the mobile network would not mean that end users experience the varying quality of service which they receive when using a hand-held mobile terminal. TV receivers would continue to be fed by rooftop aerials which are oriented, where required, to point at the nearest base station.

## 11.3 The environmental impacts of an LPLT converged platform

Moving DTT to an LPLT network raises two main environmental questions. Would such a move:

- Lead to damaging visual impacts?
- Breach the radio-frequency exposure limits set by the International Commission on Non-Ionising Radiation Protection (ICNIRP)?

### Visual impacts

Visual impacts are likely to be small.  Upgrading selected macro-cells on one network should not have a substantial visual impact when compared with other upgrades to add additional frequency ranges to the existing grid of base station sites.

### RF exposure limits

RF exposure limits as specified by the ICNIRP, have been adopted by the EU in European Council Recommendation 1999/519/EC, and are applied in most European countries. Some countries have established additional limitations that there are more stringent than ICNIRP. This includes Bulgaria, Estonia, Greece, Lithuania, Luxembourg, Poland, Slovenia, and parts of Belgium. To avoid exposing the general public to levels of radiation in excess of these limits there are exclusion zones around transmission sites, the size of which depends upon the power of the radio transmissions.

Radio emissions at UHF could be especially damaging to human health and play a major role in determining the size of the exclusion zone. The EBU has calculated[196] how the size of the exclusion zone varies with the number of LTE carriers at 700 MHz. Based on this work Figure 11-1 tabulates our estimates of how the transmission power and size of the exclusion zone increase as LTE carriers are added to a base station.

[196] *Delivery of broadcast content over LTE networks*, Annex 8 of EBU Technical Report 027, May 2014

**Figure 11-1: The exclusion zone required to meet ICNIRP RF limits**

| No. of 20MHz LTE carriers | Likely scenario | EIRP[197] | Radius of exclusion zone at 700 MHz |
|---|---|---|---|
| 2 | 1. Baseline position for mobile operators using 700, 800 and 900 MHz for LTE | 36dB | 12 m |
| 4 | 2. As Scenario 1 plus 2 carriers for 60 Mbps TV payload | 39dB | 15 m |
| 7 | 3. As Scenario 1 plus 5 carriers for 180 Mbps TV payload | 41.5 dB | 18 m |
| 12 | 4. As Scenarios 2 or 3 plus carriers used as SDLs for mobile broadband | 43.8 dB | 23 m |

Figure 11-1: shows that adding DTT transmission to an urban macro cell of a mobile network, while continuing to meet ICNIRP requirements, could be challenging. In particular:

- Carrying the high TV payload of 180 Mbps (Scenario 3 of Figure 11-1) could more than double the area of the exclusion zone
- Using in addition released spectrum for mobile supplemental downlinks (Scenario 4) could nearly quadruple the area of the exclusion zone.

We simply do not know how many urban sites would be compromised by adding extra LTE carriers in this way. But it is likely that meeting RF emission requirements could significantly affect the results of our CBA and weaken the case for an LPLT converged platform. This is especially true in member states which apply stricter RF limits than those specified by ICNIRP. There are two possible main effects. Meeting the RF emission limits might:

- Require the LPLT DTT operator to reduce transmission power at urban sites and upgrade additional sites for DTT use, so adding to the costs. In certain cases the LPLT DTT operator might even need to build new sites
- Reduce the value of sub-700 MHz spectrum release by limiting the extent to which SDLs could be used for mobile broadband.

## 11.4 Possible impacts on radio broadcasting

We set out in Appendix X our assessment of the market for radio services in general and the role of radio broadcasting within this market over the next 15 years. We can summarise our findings as follows:

- Radio listening is a key activity in the EU with 50% of EU citizens tuning in on a daily basis and 74% listening at least once a week. In general radio audiences are older than the population as a whole and older audiences listen more frequently than their younger counterparts.
- Data on radio sector revenues for 10 European countries suggests that over the last three years revenues from radio broadcasting have either been static or in decline depending on the country.

[197] Assuming each carrier transmits at 40 W and there is a 17 dBi antenna gain

- The rate of migration from analogue to digital broadcast for radio has been slow and analogue FM radio continues to be the dominant platform. This is due to a wide range of factors including fragmentation of digital standards, the large number of analogue devices (both standalone and embedded), lack of financial incentives for radio broadcasters to provide digital services and little push from governments because there is little in the way of a spectrum dividend. There are no firm deadlines for analogue radio switch-off in any EU country although Denmark is considering analogue switch off at the end of 2019.
- Internet radio is taking a small but growing share of the audience (around 5%) as broadband penetration and take-up of internet-connected devices with radio software, such as smartphones and tablets, increases. Internet radio provides a substitute to analogue and digital radio broadcast which offers the advantages of digital radio (such as wide choice, interaction and information) at a lower cost for broadcasters
- Switching off analogue radio broadcasting is a possibility, but our analysis suggests that this is unlikely before 2030:
  - Digital radio switchover is a possibility if migration towards DAB gathers pace over the next decade. But DAB implementation is lacking in half of Europe, while deployment in countries with DAB suggests that voluntary migration by consumers is likely to be a long and slow process
  - A migration to internet radio would depend on the pace of take-up of online radio listening. Online radio services are already widely available. But FM radio remains firmly established across the EU while fixed and mobile broadband coverage across Europe cannot yet match the near universal coverage of FM
  - A converged platform using the UHF band is another option for digital radio switchover. However, a converged platform may not to be implemented across the EU much before 2030.

Given such developments what impact would a move to an LPLT converged platform have on radio broadcasting? We have identified two main issues for analysis. Would such a development:

- Lead to any significant additional spectrum release?
- Threaten the viability of radio stations?

## The possibility of spectrum release

A converged platform could in principle carry radio broadcasting as well as TV broadcasting services. But this is unlikely to result in significant benefits from spectrum release given that:

- The level of analogue radio listening is still high and there has been only modest growth in digital radio broadcasting and Internet radio listening so far. This means that analogue shutdown may not occur (i.e. no frequencies would be released)
- The frequencies used by analogue radio broadcasting are not in high demand from other services, either because of the low bandwidths available[198] and/or the “noisy environment” in all bands used by radio broadcasting.

[198] 20 MHz or less for frequency modulated radio and significantly less for amplitude modulated radio

Nor are there any major functional benefits from moving radio broadcasting to the LPLT topology. Radio is already available on a mobile basis through a variety of means. This includes analogue and digital car radios, personal analogue radios, and (possibly in future) Internet radio over 4G mobile networks. At the same time any move of radio broadcasting to an LPLT converged platform would be limited by the need to convert the installed base of broadcast radio receivers (standalone and embedded) to the appropriate technology.

### The viability of radio broadcasting

Various stakeholders have argued that a move to a LPLT converged platform would lead to the closure of the HPHT TV network and, as a result, leave radio broadcasters without access to low cost high tower sites. This could drive some commercial radio stations, which are already only marginally profitable, out of business. While this outcome is possible there are two main reasons why the impacts may be less severe than feared:

- The high towers of the HPHT network are currently used extensively for other wireless applications such as microwave fixed links and mobile base stations. This demand for use of HPHT sites may remain (or even grow) with a move to an LPLT converged platform. This could mitigate any increase in access costs at HPHT sites for radio broadcasting
- It is unlikely to be in the interests of HPHT operators to force radio broadcasters into bankruptcy. The tower operators would then have no radio broadcasting revenues.

## 11.5 Disseminating essential information in a national emergency

Would the move to an LPLT converged platform reduce the ability of public authorities to disseminate essential information in a national emergency? It is beyond the scope of the study to provide a full analysis of this question. But we note the following:

- Broadcast services such as radio and TV are an excellent way to disseminate essential information to the bulk of the population. They have near universal reach and do not suffer from congestion problems
- The extent to which broadcast services will be disrupted by a national emergency will depend upon its nature. Typical examples include major floods, earthquakes, hurricane damage, failure of a nuclear power station, the effects of a tsunami and major terrorist attacks
- In assessing these effects we need to consider the disruption which the national emergency might cause to both transmitters and receivers within a broadcast network
- Often national emergencies lead to major disruption of the mains electricity supply. In these circumstances radio receivers are much more likely to continue to work than TV sets, which are usually powered by mains electricity
- Disruption to the main electricity supply is much less likely to affect transmitters which are invariably equipped with stand-alone independent power supplies as backup to mains electricity
- Closure of the HPHT DTT network would mean that TV transmitters are located on an LPLT network which is shared with mobile services. It is possible that this network will be more vulnerable in a national emergency than the HPHT network it replaces

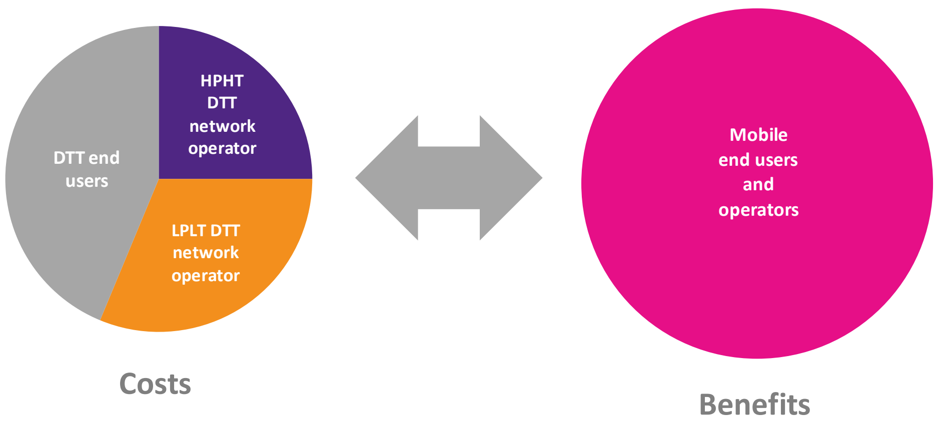
- However closure of the HPHT DTT network does not mean closure of the high towers on which frequency modulated analogue and digital radio broadcasting depend. As we discuss in Section 11.4 the high towers would continue to form part of the LPLT network. As a result national radio broadcasting would continue to use these high towers and have broadly the same reach as before. At the same time we note that many member states continue to provide amplitude modulated analogue radio broadcasting from a separate set of transmitters

We conclude that the ability for the authorities to broadcast information to battery-powered radios would remain largely unaffected by the DTT network moving to an LPLT topology.

## 11.6 Commercial issues

In our CBA we have assessed the incremental costs and benefits of moving to an LPLT converged platform in a variety of member states under a range of assumptions. In doing so we have assessed the costs and benefits from the perspective of the member state as a whole and ignored the perspective of individual stakeholders. But, as Figure 11-2 shows, the incremental costs fall on one set of stakeholders while the benefits accrue to another set.

Figure 11-2: The distribution of costs and benefits between stakeholders[199]




If a move to converged platform is to work in practice – assuming that there are future market conditions in which the incremental benefits exceed the incremental costs by a reasonable margin – then it may be necessary to redistribute costs and benefits to make the implementation of a converged platform practicable. This in turn will depend upon the business model under which the converged platform operates. There is a wide variety of such models. For example:

- Some stakeholders suggest a model in which all of the sub-700 MHz spectrum is operated by a single entity, which then sells DTT capacity on the LPLT network to broadcasters and SDL capacity to mobile operators (or partnerships between mobile operators and broadcasts) on a wholesale basis

[199] In which benefits exceed costs

- Others suggest that a single operator would run a free-to-air LPLT DTT network, while the mobile operators would acquire and use the released UHF spectrum on a competitive basis.

Both these models have their merits. The first option offers more efficient and flexible use of sub-700 MHz spectrum, while the latter does more to preserve infrastructure-based competition between mobile operators and incentives for innovative investments in radio access network.

To highlight some of the challenges which arise, we set out below a process which would realign costs and benefits for the second of these two business models. In this process:

- Firms[200] bid to build and operate a converged platform and to meet the end-user cost of adapting their primary TV sets to use it
- Firms compete to win the right to build and operate the LPLT DTT platform by offering a lower subsidy than other bidders - given that the winner's revenues (from charges to broadcasters) are likely to fall a long way short of its costs. We note here that:
  - There are no offsetting benefits for end-users in moving to LPLT broadcast (as there were during the digital switchover process)
  - Asking the end-user to pay €50 to €70 per household for a device which provides few additional benefits is likely to be difficult to sustain politically
  - As a result it is likely that a proportion of end-user costs will need to be met by the bidder[201]
- The government pays the tendered subsidy to the winner
- The government auctions the released spectrum to the mobile operators and keeps the auction proceeds to compensate for the subsidy paid to the winner
- Mobile operators use the released spectrum in SDL mode to deliver competitive services over their networks. These services may be separate from, or integrated in some way with, the LPLT DTT services.

Under this model:

- Member state governments need to play a central role if there is to be successful transition. This creates potential state aid issues which would need resolution, perhaps on the grounds that the transition is demonstrably in the public interest
- There are risks for governments in that the proceeds from the auction may be less than the subsidy paid to the winner
- There are risks for the winner - which might underestimate the cost of implementing the converged platform.
- The scale of these risks will depend upon a variety of factors. But for both parties the risks are likely to be smaller with the LPLT-DVB option where there are no end-user costs of converting TV receivers to LTE.

[200] Such as DTT operators and mobile operators

[201] Or by another party under variants on this process

## 11.7 Future use of the UHF broadcasting band elsewhere

Spectrum developments in respect of the future use of the UHF TV broadcasting band in other regions (and possible use for a converged platform) could have a significant impact on European options, given the need for very large markets to support low cost, competitive equipment production. This is illustrated clearly by the current discussion around the 700 MHz band, where Europe (for the first time) is likely to adopt a band plan based on that developed for the Asia Pacific region.

Appendix Y presents our analysis of relevant activities in other parts of the world. We have not identified any specific activities elsewhere in ITU Region 1 and in much of Africa the first digital dividend (800 MHz) has yet to be released. Refarming of the first digital dividend is also progressing slowly in Asia and we have not identified any initiatives there aimed at reallocating more of the UHF TV band to mobile or converged services.

In the Americas the US is proceeding with proposals to auction the 600 MHz TV band in 2015 in the expectation this will be used for mobile services in future. The resulting band plan proposals are specific to the US market, with much of the spectrum paired, and so would not obviously support linear TV delivery. We have not identified any specific US activity directed towards delivering broadcast TV services over mobile networks though early work on the next generation digital TV standard (ATSC 3.0) is intended to provide (amongst other things) robust reception on mobile devices.

## 11.8 The flexibility offered by a LPLT converged platform

EU member states are currently in very different positions in terms of use of UHF spectrum for broadcasting. In some member states sub-700 MHz spectrum is relatively lightly used by DTT. In others it is heavily used. At the same time future demand for spectrum for DTT is highly uncertain - it might decline significantly over the next 15 years in some member states but grow in others.

HPHT architectures are difficult and costly to change in response to such changes in demand. In particular the large cell sizes of an HPHT topology make changes in national border areas challenging. Moving to an LPLT topology with much smaller cell sizes substantially reduces these problems. So an LPLT DTT network is more flexible - although the cost of making the one-off transition is substantial.

Such flexibility has value and we need to consider the extent to which flexible use of sub-700 MHz spectrum might be enhanced by moving to an LPLT converged platform for DTT. Our analysis is as follows:

- In some member states the sub-700 MHz spectrum is only lightly used and there is a lot of whitespace which could be used by for mobile unicast downlinks while leaving DTT on HPHT. Any such spectrum release for mobile broadband is part of the counterfactual and is not an incremental benefit of a converged platform
- Having made the transition, an LPLT topology allows for easier and lower cost subsequent changes to DTT delivery networks as market demand for AV services changes. Reconfiguring the boundary between the broadcast and unicast downlinks is relatively straightforward while avoiding cross-border interference is much easier with LPLT topology - especially if co-channel SFNs are possible

- Moving to an LPLT converged platform raises possibilities for dynamic broadcasting - in which the spectrum boundary between the broadcast downlink and the mobile broadband supplemental downlink changes over the day. This might release UHF spectrum for mobile broadband use when demand from a broadcast channel in a cell is zero or at a level at which unicast transmission is more efficient than broadcast. However, dynamic broadcasting in this way on a cell-by-cell basis is not feasible since every cell in an SFN must broadcast the same content. The reasoning is set out in Section 8.4
- Dynamic broadcasting across an SFN is feasible if there is substantial diurnal variation in the TV payload on DTT because some TV channels only broadcast in the evening. The whitespace in the early hours of the morning is likely to be of little value for mobile services. But any dip in TV payload during the day could be of value as a sub-700 MHz unicast downlink assuming that the capacity available could be configured in contiguous 5 MHz blocks .The latter depends on numerous market specific factors[202]. So the extent of any benefit here, and the extent to which it could be captured using the existing HPHT topology networks rather than moving to an LPLT topology, is uncertain.
- The idea of dynamic broadcasting could be extended to transmission of niche TV channels which broadcast during the day but where demand is so low that unicast transmission is more efficient. The calculations given in Section 8.4 suggest that this is unlikely to be the case in most markets given that:
  - Every cell in an SFN must broadcast the same content. So demand in **urban** cells must be at levels where unicast is more efficient than broadcast before the channel moves to unicast
  - This implies a viewing market share for the niche channel of below 0.1% for a typical SFN
  - At such a market share it is unlikely that DTT would be commercially viable as a distribution network for the channel in a 2025 timeframe - when OTT/IPTV delivery is likely to be more attractive.

[202] For example whether there are multiple multiplex operators, whether they are permitted to share capacity by regulation, and/or whether they have incentives to do so)

# 12 Conclusions and next steps

## 12.1 AV consumption

The way people consume video services in the EU is changing. There is a move:

- From viewing on fixed TV sets in the home to viewing on portable devices[203]
- From broadcast to broadband-based services
- From viewing in the home to viewing outside the home and on the go.

However, so far these changes have had little impact on the amount of viewing of traditional broadcast services on TV sets in the home, while the available evidence[204] suggests that young people, who view substantially less TV than average, increase their TV viewing as they age. Hence there is considerable uncertainty over the way AV consumption will evolve over the next 15 years. In particular there is uncertainty over:

- The extent to which DTT platforms in member states will maintain their market share or be displaced by OTT and IPTV services
- The extent to which secondary viewing on DTT receivers will decline as the population of tablets, smartphones and other portable devices with AV viewing capability grows
- The extent to which users will view streamed AV content on their portable devices using mobile broadband services.

The metrics currently used to monitor consumption of video services are incomplete, inconsistent and difficult to interpret. Better metrics are required to measure both current consumption patterns and trends in these patterns so as to better inform future policy decisions.

## 12.2 Broadband-broadcast convergence

Broadcast and broadband developments over the next 15 years will change the way end users consume video - both through substitution effects and through complementary combinations of broadcast and broadband. Substitution will mainly involve video delivery over fixed broadband replacing video delivery over traditional broadcast services. Complementary combinations will lead to a variety of possible convergence services. There are three main categories:

- Convergence at the ***device level*** which enables the user to view services delivered over broadband (fixed or mobile) and/or broadcast networks on the same device. Initially such convergence will be focused on integration between fixed broadband and broadcast services in the home. The extent to which demand for such integration will extend to mobile broadband is not yet clear. Such convergence will also involve integration of interactive broadband with traditional linear broadcast to enable greater viewer participation in linear broadcasts and targeted/interactive TV advertising. Again the focus is currently on fixed broadband integration with broadcast services

[203] For example a mobile device may be used for content reception only and/or for control of the display which may be a (fixed) large screen

[204] Set out in Section 3.6

- Convergence at the ***service level*** to make linear and/or on-demand services accessible seamlessly between devices so that the user can access the same service when s/he switches devices. The scale of demand and level of investment required for such services is not yet clear
- Convergence at the ***infrastructure level*** in which broadcast and broadband services use a common network infrastructure. This concept is already implemented for fixed broadband through cable and IPTV networks but could be extended to mobile broadband as well - with DTT broadcast and mobile broadband sharing UHF spectrum

Most of the convergence effects described above will succeed or fail through the normal functioning of the market. But this is unlikely to be the case for infrastructure convergence. Such convergence involves a costly and disruptive change which affects both the mobile and broadcast sectors and which might not occur without public policy interventions. This means that it is important to assess whether the concept of a converged platform has economic and social merit. In making this evaluation it is important to note that integration at the device or service level can take place independently of integration at the infrastructure level. In other words it is possible to capture the bulk of the benefits of service or device integration without the need for a converged platform.

## 12.3 The case for a converged platform

### Timing and future scenarios

It is unlikely that it will be possible to implement a converged platform until after:

- The 700 MHz band has moved to mobile use
- Those member states currently planning a move to DVB-T2 have largely done so
- A new spectrum home has been found for PMSE audio services.

As a result there is a growing consensus that the bulk of EU member states are unlikely to be in a position to implement a converged platform before 2025.

Any assessment of the economic and social merits of a converged platform needs to take account of the considerable market uncertainty over future AV consumption and broadband-broadcast convergence. To reflect this uncertainty we have constructed four scenarios for market outcomes by 2030 which are illustrated in Figure 7-2. Under these scenarios we assume:

- The number of DTT primary households in a member state might remain close to current levels (low OTT/IPTV impact) or reduce by up to 70% (high OTT/IPTV impact)
- The amount of time spent by the average EU resident on out-of-home viewing using portable devices might grow to between 18 minutes (low) and 36 minutes (high) per day
- A significant proportion of this viewing might use mobile broadband. But viewing of downloaded content on the move might also be significant.

## Promising options for a converged platform

There is a wide range of possible options for a converged platform. We have narrowed down the range to the two options that best meet the three criteria required for any transfer of DTT from the existing HPHT network to a LPLT network[205]. That is:

- They can offer near universal coverage of free-to-view television to existing DTT receivers
- They can deliver an appropriate TV payload of between 60 and 180 Mbps of national TV channels and a range of regional channels
- They lead to a significant reallocation of sub-700 MHz spectrum so as to free up space for other uses, such as mobile broadband or more converged services, and therefore generate benefits which might justify the cost of moving to a converged platform.

First, there is the **LPLT LTE-broadcast** option. Here the DTT network transfers from the current HPHT infrastructure to the LPLT infrastructure of a mobile network, linear TV is broadcast using the LTE-broadcast standard[206], and the UHF spectrum released is used by mobile operators for unicast/multicast SDLs - either independently of, or integrated in some way with, the broadcast downlink.

Second, there is the **LPLT DVB** option. This is similar to the LTE option but uses DVB rather than LTE broadcast as the transmission technology for the broadcast downlinks.

Under either of these options the broadband downlink of the converged platform needs to be used in combination with uplink spectrum assigned to provide interactive services. These services might be data only cloud-based services or converged services in which two-way interactive mobile broadband is combined with the broadcast downlink in some way. The uplink might you spectrum from the top end of the sub-700 MHz band or supra-700 MHz spectrum allocated to the mobile operators.

## Moving to a converged platform

The spectrum which might be used by a converged platform is the 470 to 694 MHz frequencies. Implementing a converged platform in this spectrum range would not be practicable before 2025.

Moving to a converged platform is a complex and costly process which must generate substantial spectrum release if it is to generate benefits which might justify the transition costs (as analysed in Chapter 10).

The key to spectrum release is the use of SFNs. Without widespread use of SFNs there would be insufficient spectrum release for the converged platform to have the potential to generate net benefits. Use of SFNs has proved challenging with some HPHT implementations but many of these problems disappear with an LPLT implementation.

To make SFNs work the regional border issue must be overcome. We believe that a mix of rearranging borders and engineering of antennas in these regions might allow co-channel regional SFNs to work, but this is not proven. SFNs at national borders are more problematic and probably will require temporary border strip SFNs operating at different frequencies.

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[205] We have rejected options which use eMBMS, options which include use of uplinks in sub 700 MHz spectrum, and options which involve LTE broadcasts from existing HPHT networks.

[206] This is an evolution of the current LTE standard. It does not yet exist

Whether the LPLT network uses LTE or DVB technology is a finely balanced secondary issue. DVB brings higher spectrum efficiency and the ability to reuse existing TV receivers but it offers less flexibility - both around integration of broadcast and broadband services and changes to the spectrum boundary between broadcast and broadband downlinks as market demand evolves.

To create the required simulcast spectrum is challenging. It may be impossible to find the required simulcast spectrum for a member state with a high TV traffic load unless:

- It adopts the DVB option
- It opts for a late transition – after neighbouring member states have already moved to a converged platform
- It introduces a temporary but significant reduction in the number of TV channels which are broadcast and/or in the picture quality which is broadcast
- It is able to use available VHF as well as UHF spectrum and its household aerials can receive VHF TV transmissions.

Significant effort is also required to mitigate cross-border interference – especially in the member states which first move to a converged platform. In some cases this will probably require the creation of temporary border SFNs. These in turn substantially increase the amount of simulcast spectrum required.

## The benefits of a converged platform

In assessing the merits of these options we consider their incremental benefits over a counterfactual in which DTT broadcast TV services and unicast personal mobile video services evolve separately. This gives us the three potential incremental benefits of spectrum release, better mobile TV and more interactive linear broadcast (as shown in Figure 10-1).

The incremental benefits of spectrum release are potentially substantial. If LPLT SFNs can be made to work, then this could lead to spectrum release of between 110 MHz and 175 MHz. We calculate that the NPV of such spectrum release lies between €200 million and €1380 million in a hypothetical case study country with a population of 20 million. But it is important to note that this benefit is contingent in many member states on the viability of co-channel regional SFNs operating in an LPLT topology. If co-channel regional SFNs are not viable then a substantial restructuring of (and reduction in) regional broadcasting would be required in order to realise this benefit.

The incremental benefits of better mobile TV are small. Here the evidence to date, primarily from Japan and Korea, shows that there is little if any willingness-to-pay by end users for such a service - and that the big demand is for unicast personalised video delivered to mobile devices. The economic value of mobile TV is therefore limited and we exclude this benefit from the CBA.

There is as yet no evidence for substantial incremental benefits through service integration between video broadcast services and unicast mobile broadband services. We may see very substantial benefits from integration of this kind by 2025 as the market evolves. But for the moment:

- The overall scale of benefits from integration of linear broadcast and broadband is unclear
- It seems likely that integration between broadcast and fixed broadband services, which form part of our counterfactual, will capture the bulk of these additional benefits

- A significant percentage of the benefits which do arise from integration of linear broadcast and mobile broadband may be captured in the counterfactual.

## The costs of a converged platform

There are three main costs in moving to an LPLT converged platform:

- The cost of building the LPLT network and the incremental cost of operating it – net of the operating costs of the HPHT platform it replaces. This cost might be positive or negative
- The transition costs of ensuring that end users can use the new platform – through converting TV receivers to the required transmission standard and reorienting rooftop aerials to point to the new transmitters
- The transition costs of freeing the simulcast spectrum and mitigating interference – both between regional SFNs and across national borders.

These costs vary considerably depending on:

- The characteristics of each member state in terms of current levels of DTT penetration and TV payloads
- The assumptions made about the impact of OTT and IPTV on demand for DTT services over the next 10 to 15 years[207] and the option chosen[208].

By far the largest cost is the transition cost of ensuring that end users can use the new platform. Total costs are estimated to range from €300 million to €900 million (in NPV terms) for a hypothetical case study country of 20 million.

## The incremental costs and benefits compared

Figure 12-1 summarises the findings of our CBA. It tabulates the circumstances in which the NPV of the incremental benefits exceeds the NPV of the incremental costs and indicates that:

- At the low end of the benefits range there are no circumstances in which there is an economic case for a converged platform
- At the midpoint in the benefits range the CBA is always positive if the high impact scenario is realised, but negative in some cases under the low impact scenario
- If we assume the upper limit of the benefits range then the CBA is unambiguously positive under both scenarios.

As we demonstrate in Section 10.12, the findings from Figure 12-1 apply to virtually all member states – regardless of population density. But it is important to note that the case for a converged platform is significantly weaker in small member states.

[207] The high and low impact scenarios

[208] LTE broadcast or DVB

**Figure 12-1: When does the CBA yield net benefits?**

| Benefits assumed at | Lower limit | | Mid-point value | | Upper limit | |
|---|---|---|---|---|---|---|
| OTT/IPTV impacts | Low | High | Low | High | Low | High |
| Central case[209] | No | No | No | Yes | Yes | Yes |
| Low TV payload (60 Mbps) | No | No | Yes | Yes | Yes | Yes |
| High TV payload (180 Mbps) | No | No | No | Yes | Yes | Yes |
| DVB rather than LTE option | No | No | Yes | Yes | Yes | Yes |
| 10% DTT HH in 2014 | No | No | Yes | Yes | Yes | Yes |
| 70% DTT HH in 2014 | No | No | No | Yes | Yes | Yes |

*More heavily shaded cells indicate where benefits exceed costs*

In addition to the quantitative CBA there are a number of qualitative factors to consider (as discussed in Chapter 11). Here we find, based on the limited information in the public domain, that:

- A move to an LPLT converged platform might lead to a reduction in the reliability of TV broadcast services. However the limited availability of data here means that our analysis is inconclusive[210]
- An LPLT converged platform operator might struggle to meet the RF emission limits set by the ICNIRP without incurring substantial additional costs in urban areas. This could materially affect the results of our CBA as set out in Figure 12-1
- Radio broadcasters using high power high tower sites may face higher transmission costs but the effects are likely to be limited. At the same time there would be opportunities for radio broadcasting to use the converged platform
- Moving to an LPLT converged platform is unlikely to affect a government's ability to disseminate essential information to the bulk of the population in the event of a national emergency
- Moving to an LPLT converged platform would create a DTT network which offers greater flexibility than the current HPHT topology in making changes to meet evolving market demands for AV consumption.

Further investigation is needed to determine how these qualitative issues might affect the case for a converged platform. This work would require close cooperation from industry, and especially from the mobile sector.

## Interpreting the findings of the CBA

Our CBA suggests that the economic case for moving to a converged platform has not yet been made. There are circumstances in which an LPLT converged platform might generate net benefits in our hypothetical case study country – for example if we assume benefits towards the upper end of the range. But equally there are many circumstances in which the incremental costs exceed the incremental benefits. For example:

[209] LTE broadcast, support for primary TV sets only, 40% DTT HH in 2014, 120 Mbps TV payload

[210] As discussed in Appendix W

- If the benefits lie at the bottom end of the likely range then the economic case for a converged platform disappears
- If the benefits lie at the midpoint in the range and the low impact scenario is realised, the incremental costs of an LPLT converged platform exceed the benefits in several cases.

The qualitative factors listed above could also have a significant impact on the case for a converged platform. Issues of reliability and the need to meet RF emission limits might weaken the case, while the increased flexibility offered by a converged platform in response to changing market demands for DTT should strengthen the case.

Whether or not a converged platform generates net benefits depends upon the assumptions we make about market developments and parameters which are currently far from certain. This high level of uncertainty rises in two main ways. **Firstly,** there is uncertainty about future market developments. For example:

- The scale of benefits from spectrum release is highly uncertain. We estimate the NPV of benefits to lie between €200 million and €1,380 million for our hypothetical case study country
- The CBA findings are sensitive as to whether the high or low impact scenario is realised
- The scale of demand for value-added video services which integrate linear TV with mobile broadband is, on current evidence, limited. But if there were future strong demand for such services then these incremental benefits might increase substantially

**Secondly,** there are parameters in our assessment which remain highly uncertain and/or where current evidence is limited. For example:

- It is not yet clear whether co-channel regional SFNs are practicable
- The extent to which meeting the ICNIRP limits on radio emissions raises the costs of a converged platform is not yet known
- The extent which TV services in member states with high TV payloads would need to be reduced in order to create the necessary simulcast spectrum requires detailed further work
- There are significant uncertainties over the cost of upgrading mobile macro cells to create an LPLT DTT network which materially affect the outcome of the CBA.

## 12.4 Possible next steps

Even though the case for a converged platform is not yet made our study has highlighted a number of areas where further work over the next few years would be useful. In making these recommendations we have taken into account the findings of the Lamy report[211].

***Recommendation 1:*** *The Commission and industry should consider how best to develop and implement comprehensive metrics for measurement of video consumption, which are consistent across EU member states over time, so as to inform future policy decisions.*

Existing metrics[212] do not measure traditional AV consumption and OTT AV consumption in a consistent way. Nor are there reliable statistics on the split of AV viewing between home and out-of-

[211] *Results of the work of the high level group on the future use of the UHF band* (470-790 MHz), Pascal Lamy, Undated

home, between fixed and portable devices, and between WiFi and mobile network access. Ideally metrics should measure video consumption in terms of:

- The split of viewing between OTT, IPTV and traditional TV broadcast platforms
- The split of viewing between linear, on demand and time shifted modes
- The split of viewing between portable and fixed devices
- The split of viewing between in-home and out of home consumption
- The division of video consumption on portable devices between downloads, streaming and mobile broadband.

In devising these metrics it would also be important to take account of multi-tasking by viewers.

There are initiatives underway in individual member states to tackle this problem. But it is not clear how quickly these initiatives might deliver results or whether they will lead to consistent and comprehensive procedures across all member states. At the same time such new metrics are urgently needed and the ECC has proposed such metrics[213].

The development and use of such metrics, which are also proposed by the ECC in its recent report[214], would fit well with the recommendation of the Lamy report. Having accurate measures of AV consumption along the lines set out above should help inform the review proposed by Lamy in reassessing the future role of DTT.

***Recommendation 2:*** *The broadcast community should provide relevant guidance to 5G research programmes.*

To date 5G research programmes are focussed on:

- Development of new radio access technologies (at 6 GHz and above)
- Tighter integration of existing LTE, WiFi and other networks
- Use of software defined networks
- New protocols to deal with both IoT (low payload, high signalling levels) and mobile broadband (high payload, low signalling levels)

As far as we can tell there are few, if any, initiatives to define broadcast capabilities for 5G networks. This is needed in the near future if it is to have any significant influence on research programmes. Such guidance will need to take account of the fact that the broadcast community is looking for free-to-air and near universal coverage for broadcast services. It will be challenging to find a business model for delivery of such requirements over a 5G network. This suggests three possible research options for the broadcasting and 5G communities to consider:

- Research into the viability of incorporating broadcast as well as unicast/multicast capability in 5G networks in a way which can be deployed at low incremental costs in parallel with existing HPHT broadcast networks

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212 Such as those provided by BARB in the UK or the Cisco VNI estimates of mobile video use

213 *Long Term Vision for the UHF broadcasting band*, ECC Report 224, Draft, October 2014

214 Report 224 from TG6

- Research into how existing HPHT networks might be integrated into a 5G heterogeneous network in a way which delivers added value. Such research would need to take into account the likely evolution of, and future demand for, HPHT DTT networks
- Research into the potential for distribution of AV content using dynamic switching between unicast and multicast modes in 5G networks.

***Recommendation 3:*** *The relevant spectrum authorities should specify a long-term spectrum home for PMSE audio services and consider whether some spectrum at UHF should be reserved for PMSE use[215].*

Such work is important given that:

- PMSE audio is a key input to a substantial proportion of video content
- Finding a long-term home for PMSE audio spectrum is on the critical path of most options for best use of sub-700 MHz UHF spectrum.
- There is a need for clarity on this issue to remove uncertainty from any future review of the merits of a converged platform.

***Recommendation 4****: The broadcast and mobile communities should investigate further the feasibility and cost of implementing co-channel SFNs.*

Viable co-channel SFNs would both enable regional broadcasting in a spectrum efficient way and help deal with cross-border interference. We note here that some member states have experienced problems with HPHT SFNs. This is unlikely to occur with a LPLT topology.  The reported problems with HPHT SFNs are caused by tropospheric ducting under anomalous atmospheric conditions which carry signals hundreds of kilometres from transmitters. This results in receivers seeing co-channel interference where the delay is greater than that allowed in the system design (the cyclic prefix period) which cannot be resolved by the TV transmitter and disrupts reception. In a LPLT configuration this is highly unlikely to occur because ducting only happens when the signal enters the horizontal duct at a narrow entry angle. It requires high transmitters on high sites (eg the top of a tall hill) for isotropic ducting to occur. But LPLT sites are, by definition, low sites and rarely on tops of tall hills. Further, LPLT sites tend to use down-tilt which results in little signal leaving the transmitter at the slightly elevated angle needed to enter the duct. Finally, the lower power signal has less chance of surviving a long duct before being attenuated below the noise floor.

If viable, the use of co-channel SFNs over an LPLT topology could help to substantially increase the flexibility with which sub-700 MHz spectrum might be used. It would enable individual member states greater freedom in managing sub-700 MHz spectrum independently of neighbouring countries and, at the same time, enable greater spectrum release when they do so.

***Recommendation 5:*** *The Commission should initiate another review to reassess the merits of a converged platform once market uncertainties are substantially reduced.*

Within three to five years we expect that:

- The value of the 700 MHz band, established through spectrum auctions, should be clear.  This should help to substantially reduce uncertainty over the benefits of a converged platform

[215] See Section 9.3 for a discussion

- The market impacts of broadband-broadcast convergence, in terms of both integration and substitution, should be clearer
- It should be possible to reduce the uncertainty in key CBA parameters through further work by the industry and by mobile operators in particular. By 2018 we might reasonably expect that mobile operators will have shifted the focus of their attention from use of the 700 MHz band to the best use of sub-700 MHz spectrum.

We suggest that the review should compare a converged platform with other options for use of sub-700 MHz spectrum and delivery of broadcast TV services which currently use the HPHT DTT network. Our study has considered the merits of the converged platform relative to a counterfactual in which the HPHT network continues to deliver DTT services. But there is a wider question about the best use of sub-700 MHz spectrum. Here policy makers need to consider the converged platform alongside other options for the delivery of TV services (and especially for the delivery of public service broadcasting services) which are currently delivered over the HPHT DTT network. These other options include:

- Deployment of a single national SFN on the existing HPHT network (perhaps offering limited regional broadcasting)
- Eventual closure of the existing DTT network to be replaced by a mix of (free-to-ait) satellite and IPTV services
- Allowing mobile operators to use white space in the sub-700 MHz spectrum[216] provided it does not inhibit the development of HPHT DTT services.

Ofcom in the UK has indicated[217] that it is now considering the first two of these long-term possibilities while the Lamy report has proposed[218] the third option. In addition our analysis suggests that, in the circumstances in which an LPLT converged platform is most likely to deliver net economic benefits, a DTH satellite service is likely to offer an (imperfect) substitute at substantially lower costs.

The review proposed in this recommendation might usefully inform the proposed Lamy review on the long-term future of DTT services. We propose a review, as set out above, before 2020. Lamy proposes his review before 2025.

In making Recommendation 5 we do not intend to inhibit market or technology developments in broadcast-broadband convergence prior to the review. Specifically we propose that work on Recommendations 1 to 4 and Recommendation 7 below should take place in advance of action related to Recommendation 5.

***Recommendation 6:*** *Those carrying out such a future review should resolve uncertainties in key CBA parameters and technical assumptions*.

This work will need close cooperation with industry players (and especially mobile operators). It should cover:

- The reliability of an LPLT network (as discussed in Section 11.2)
- The impact of safe RF emission limits on the cost benefit analysis (as discussed in Section 11.3)

[216] Both current and any future release from broadcast use

[217] See for example *The Future of Free to View TV - A discussion document*, Ofcom, May 2014 for consideration of the second of these two options

[218] *Results of the work of the high-level group on the future use of the UHF band*, Pascal Lamy, August 2014

- The practicability of creating simulcast spectrum in different member states and the extent to which reduction in the number of regional or national TV channels would be required in some member states to make the transition to a converged platform possible
- The cost of upgrading mobile macro-sites to carry an LPLT DTT network (as discussed in Section 10.7)

***Recommendation 7**: Between now and the next review, the broadcast and mobile communities should seek ways of working together to produce innovative broadcast-broadband converged services which are commercially viable and deliver added value to end users.*

Our research suggests that there is relatively little activity of this kind as yet. The broadcast community has focused to date on broadcast-broadband convergence involving fixed broadband while the mobile community has focused efforts on seeing the 700 MHz band transferred to mobile use. Yet, with the rapidly growing population of smartphones and tablets, which offer a personalised and immersive AV experience to individuals, the opportunity should emerge for commercially viable broadcast–mobile broadband services which use the existing infrastructure of the broadcasters and the mobile operators. The development of such services would change the counterfactual against which a converged platform is re-evaluated in future and might materially alter the findings of a future review.

## 12.5 EU level commitment

Assuming that the review concludes that a converged platform is the best option for use of sub-700 MHz spectrum, then the Commission would need to consider an overall strategy including what role it, and other EU level institutions and relevant bodies, should play in facilitating the transition to a converged platform. In defining this strategy there are a number of factors which need to be taken into account.

**First,** there is currently a wide variety of audio-visual market conditions in different member states. Such variation could have a substantial influence on whether a converged platform might make economic sense at the individual member state level in future. If the economic case for a converged platform were to strengthen substantially then it is likely that some member states, with low reliance on the DTT network and low DTT payloads, would enjoy benefits from moving to a converged platform, while other member states, with high reliance on DTT and high DTT payloads, would not. Such considerations suggest that any EU-wide move to a converged platform should be made in a flexible way in which different member states can move at different speeds with implementation.

**Secondly,** we note that an EU-wide commitment to move to a converged platform would help maximise its benefits. In particular it would:

- Ensure maximum spectrum release by minimising the border areas in which unicast SDL use is not possible. A neighbouring country which continues to use a HPHT network might create such a border area which is 50 km wide. By moving to a LPLT network the border area could be only 5 km wide. See Section 9.7 for more detail
- Give individual member state governments the confidence required to play a role in enabling the transition to a converged platform. Specifically this would give those member states which are early movers to a converged platform the confidence that their neighbours will follow suit so as to allow them to enjoy the full benefits of the move to an LPLT converged platform

- Support the spectrum coordination required to mitigate cross-border interference between member states moving early to a LPLT converged platform and neighbours which (temporarily) continue to use an HPHT DTT platform.

**Thirdly**, an EU-wide move to a converged platform is likely to create winners and losers amongst member states, even if the move creates net benefits overall. The main losers are likely to be countries with high reliance on DTT and high DTT payload, depending on the time frame for transition.

**Fourthly,** it is not clear to what extent a coordinated EU-wide move to a converged platform would help complete *the single market* in consumption of AV services. An EU-wide commitment would:

- Give suppliers the confidence required to invest in scale production of the chip sets needed by mobile devices for use of sub-700 MHz spectrum
- Allow EU citizens to use portable devices across the EU to consume converged AV services.

But the problem of national content rights would remain and citizens roaming in another member state may still be prohibited from viewing content originated in the home member states using (say) OTT catch-up services. If substantial single market benefits are to be generated by moving to a converged platform then this problem would also need to be tackled.

**Finally,** there is, as yet, no evidence that an EU wide commitment to a converged platform would give the *EU industrial policy leadership* on a global basis. As we point out in Section 11.7 of the report, there is as yet little evidence that other world regions would be interested in implementing a converged platform.

## 12.6 Subsequent steps if a future review is positive

If the future review proposed in Recommendation 5 suggests that the converged platform offers the best long-term solution for use of sub-700 MHz spectrum, then a number of other pieces of work would be required:

### Develop the LTE- broadcast standard

Industry players would need to develop existing LTE standards for mobile to include options for an LTE-broadcast mode at 3GPP - assuming that the LTE broadcast option proves superior to the DVB option. This work would include:

- Creating LTE modes which allow for longer cyclic prefixes so as to prevent destructive interference between transmission from adjacent base stations, in particular in rural areas
- Removing the current limits on the proportion of a carrier which can be used in SDL mode
- Allowing non-subscribers to watch broadcast content on a free-to-view basis.

### Review national regulations governing DTT platforms

The regulations which currently governed DTT platforms vary significantly by member state, and in some cases place restrictions on the nature of the DTT platform, its ownership and its use. These restrictions could make it difficult to move DTT to a converged platform in an efficient way. If such barriers are to be removed then member states would need to review national regulations governing DTT platforms. For example, they would need to consider:

- Are there technology, coverage and other restrictions on how UHF spectrum can be used by DTT platforms which would impede a move to an LPLT network? For example, in some member states regulations currently specify the transmission and compression technologies to be used by the DTT network, the locations which can be used for transmission, and the power of these transmissions
- Are there regulations which link content aggregators to use of DTT platforms[219] that might impede a move to an LPLT network?
- Are there ways of modifying regional broadcasting services so as to enable a move to a converged platform without significantly impacting on policy objectives for regional broadcasting?

Ways of overcoming such regulatory barriers while preserving national policies of plurality, promotion of cultural objectives and social cohesion, would need to be found. In particular, it would be important to preserve the delivery of free-to-air TV services on a near universal basis.

## Develop licensing, authorisation and commercial models

Industry and member states would need to develop practicable authorisation and commercial models for the transition to a converged platform as discussed in Section 11.6. Such models would need to answer the following questions:

- Who would be eligible to bid to run an LPLT DTT network and under what conditions?
- Should the successful bidder be allocated all sub-700 MHz spectrum or just that required for the LPLT DTT platform?
- To what extent would competition between mobile operators in use of sub-700 MHz spectrum be preserved?
- What enabling role, if any, should member state governments play in such commercial models?
- How could commercial models be made consistent with state aid rules?
- How would the commercial model used ensure access to the uplink spectrum required to offer interactive services over the converged platform?

## Develop the necessary spectrum management and frequency coordination arrangements

Member states, both individually and in cooperation with each other[220], would need to develop the necessary spectrum management and frequency co-ordination arrangements in terms of:

- The future band plan and harmonised technical conditions for spectrum use in the 470-694 MHz frequency range through CEPT (under mandate from the EC) and the Radio Spectrum Committee. We set out proposals for such a band plan in Appendix Z where we propose that:

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[219] Such as must carry and must offer rules

[220] For example through bilateral, EU, ETSI and CEPT engagement

- Sub-700 MHz spectrum is used in downlink only mode by a converged platform
- The boundary between the mobile unicast and broadcast down links is left flexible to allow for different TV payloads in different member states
- The broadcast downlink is located at the bottom end of the sub-700 MHz band
- Rights for spectrum use are assigned to converged platform operators so as to provide the certainty needed to encourage investment

Assuming the band is used solely as a supplemental downlink no change in allocations at the ITU level would be required.

- Putting in place detailed arrangements for addressing the needs of incumbent uses in terms of:
  - Migrating PMSE use to alternative harmonised frequency ranges
  - Providing suitable protection to radio astronomy and wind profiler radars, where national governments decide that these services are to be maintained in the band
  - Develop technical conditions in ETSI and CENELEC to address any interference issues between cable systems and the LPLT converged radio network.
- The development of bi-lateral and possibly EU-wide plans for frequency coordination. Information on approaches to and progress with such co-ordination could be disseminated by setting up a working group comprising representatives of EU member states. Such an initiative could help facilitate deployment of the LPLT network in border areas during the simulcast period and the creation of a contiguous band for the LPLT network in the longer term.

# Appendix A: Higher resolutions than HD

## Introduction

Large scale viewing of >HD content (content in resolutions higher than HD e.g. 4k, 8k, etc.) could have a significant impact on broadcast and IP-based delivery of content. These technologies are at an early stage, both in technical development and in consumer awareness and take up. As such, predictions of the impact of these technologies have a high level of uncertainty, and are mainly based on industry opinions and qualitative analysis of the likely drivers of take up and usage.

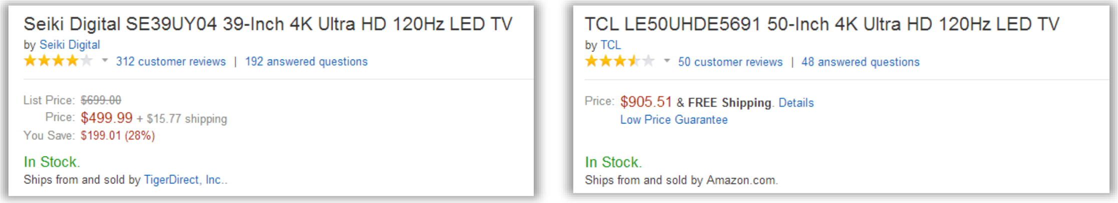
We have examined what we perceive to be the three key determinants of >HD take up and viewing:

- TV set display resolutions and pricing
- Consumer exposure to and expectations for >HD content
- Amount of professional >HD content available

## TV set display resolutions and pricing

4k television sets are rapidly dropping in price as shown in Figure A-1. The first 4k sets for under $1000 are now available in the US. These sets are basic and lack some features which will be expected in most >HD TV sets, but give an indication of where costs of these sets will tend towards over the next few years.

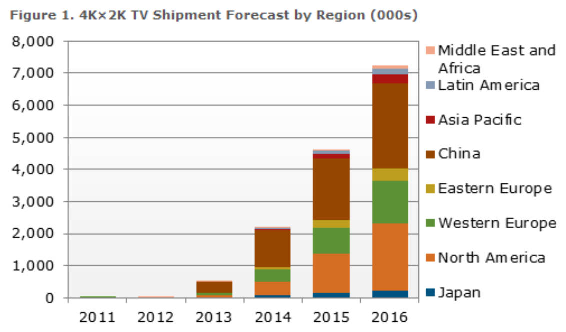
Figure A-1: Sub-$1000 4k resolution TV sets in the US

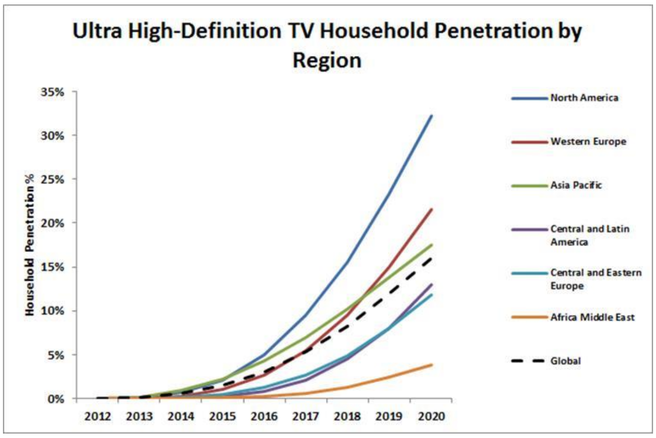



*Source: Amazon.com, 4th March 2014*

Research analysts (see Figure A-2) forecast gradually increasing sales of UHD TV sets, but with HD sets retaining the large majority of sales. Based on these forecasts of sales, it looks reasonable to assume that UHD TV sets will probably still be in a minority of households by 2030.

## Figure A-2: Forecasts of sales of 4k TV sets and TV household take-up



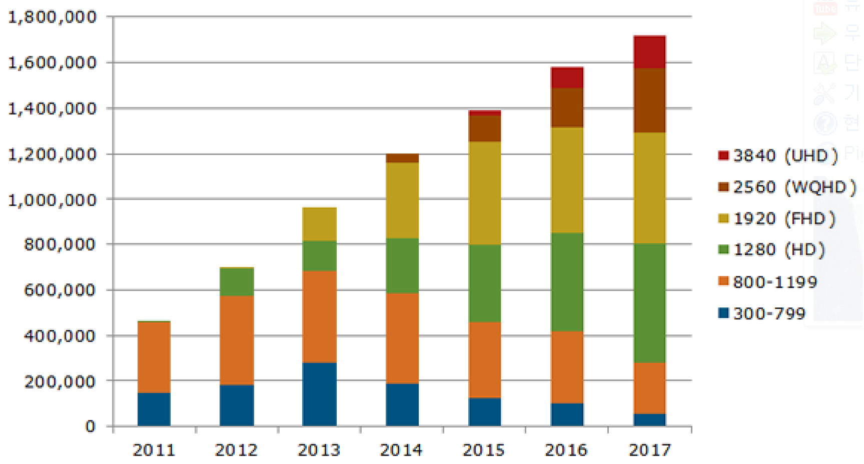




*Source: NPD Display Search (left); Strategy Analytics (right)*

## Consumer exposure to and expectations for >HD content

There is an industry expectation that >HD uptake could be driven by consumers' exposure to higher resolution content away from the TV set, on laptops, tablets and even smartphones. There is a clear industry trend towards ever-increasing screen resolutions: Figure A-3 shows that >HD smartphones (WQHD and UHD) are expected to account for just under a quarter of all smartphone sales in 2017. Indeed sales for UHD smartphones in 2017 are expected to be higher than sales of UHD TV sets (~100m vs. <20m).

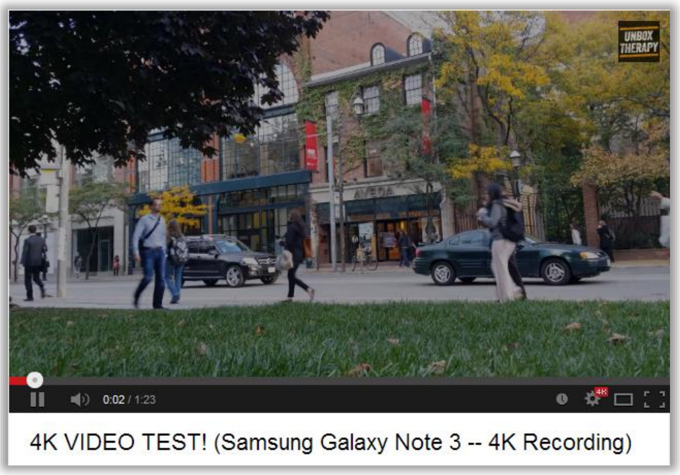
**Figure A-3: Global sales of smartphones by resolution type (000s)**




*Source: NPD Display Search (Feb 2014)*

Along with the exposure to >HD displays, consumers will also be able to record 4k video on smartphones and tablets, which can then be viewed on YouTube (see Figure A-4).

**Figure A-4: 4k video recording from Samsung Galaxy Note 3 on YouTube**




*Source: YouTube, 4th March 2014*

Given these factors, we believe that the understanding of >HD and the desire to "have >HD" may be driven by non-TV activities as much as, or more than, it is driven by the provision of >HD TV services.

## Availability of professional >HD content

However quickly the uptake of >HD TV sets occurs, the amount of >HD content viewed will depend largely on how much is made available by broadcasters and other content providers. As many content producers have only just made the transition to HD broadcasting, there is some doubt in the industry as to how quickly they will upgrade to >HD.

It is likely to be Pay TV operators leading the production of >HD content for TV, as a point of differentiation. In terms of current activity, Netflix has announced that its original programming from 2014 has been created in 4k resolution. Other Pay TV operators are testing 4k services: BskyB has announced that it has been testing sports broadcasting with 4k cameras.

As Figure A-5 shows, the impact of higher resolutions depends on the type of content and how it is filmed. Whilst 4k content can feasibly be used successfully for drama (as with Netflix's original series), higher resolutions may be restricted to immersive content such as sports events. This decreasing applicability of higher resolutions may mean that, in the long term, the provision of >HD content is more selective, and therefore less common, than the use of HD.

**Figure A-5: Immersive vs. Cinematic content**


| Immersive content | Cinematic content |
| --- | --- |
| • Designed to make viewer feel like they are there<br>• Fixed camera views, all areas of picture in focus<br>• User can choose which area to focus on<br>• Suitable for "spectacles" (sporting events, theatre, etc.) | • Designed to show directorial vision of scene<br>• Fast/slow-moving or fixed camera views, sometimes with little of picture in focus<br>• Director determines which part of picture should be focused on<br>• Suitable for dramatic content |

*Source: Farncombe analysis*

# Appendix B: Developments in OTT services

## B.1 Introduction

Compared with traditional broadcast television, the provision of online video, in both technical and commercial terms, is still in its infancy and business models are continuously changing. In this appendix we look at the range of services that are currently available to consumers, and how these services have developed in terms of functionality.

## B.2 Short-form and User Generated Content (UGC)

Most video content available for streaming on the internet in the early 2000s was short-form content: video clips provided through "portals", such as Yahoo!

The launch of YouTube in 2005 led to the proliferation of UGC content as the primary driver of short-form content on the internet. UGC still produces by far the largest number of unique video views on the internet, though in terms of video traffic it has now been displaced - mainly by ad-funded Video-on-Demand Services (AVoD) and to a lesser extend Subscription Video-on-Demand (SVoD) services.

Development of Short-form and UGC services has included:

- Addition of pre-roll video advertising for revenue generation
- APIs (application programming interfaces) allowing integration with third-party websites, in particular social media sites, resulting in wider reach across the Internet
- Provision of professional content from broadcasters and rights owners (including some long-form content)
- Ability to create and watch playlists and "channels"
- Addition of Paid-for VoD content
- Increased quality of video content (multiple resolutions are available, including a 4k resolution of 4096x2160 pixels on YouTube – see Figure B-1)

Figure B-1: Available YouTube resolutions


*Source: YouTube (March 2014)*

## B.3 Broadcaster Catch up and SVoD

Catch up OTT services usually allow the viewing of content from linear broadcast channels from the previous 7-30 days. These platforms have developed significantly over the last 7 or so years, from websites only accessible via laptops, to a broader range of propositions, including:

- Website-based access from laptops (and other web browsing-enabled devices)
- App-based[221] access across a range of devices (laptops, tablets, mobiles, consoles etc.)
- Portal access through FTA and Pay set top boxes and Connected TVs
- Access to catch up content through YouTube and other websites
- Access to catch up content directly through the linear broadcast EPG.

Broadcasters have also experimented with non-advertising based business models including:

- SVoD services (e.g. Hulu Plus)
- Episode/Series rental and purchase models (e.g. ITVPlayer).

## B.4 Non-broadcaster SVoD

Non-broadcaster SVoD services grew out of the online subscription DVD rental business, which flourished in the early 2000s. Netflix, a provider of these services, introduced its “Watch Instantly”

[221] In a recent announcement, German media company ProSiebenSat.1 will launch an application for smartphones and tablets in June on which all of its free-to-air channels will be offered as live-streams. The OTT service will comprise Sat.1, ProSieben, kabel eins, sixx, Sat.1 Gold and ProSieben Maxx. 7TV, as the app will be called, will also contain a catch-up TV service on which the programmes of the past seven days can be watched in full length. A marketing collaboration has been set up with German mobile network company e-plus which will offer the app to its 6 million customers (Source: http://www.broadbandtvnews.com/2014/05/08/prosiebensat-1-to-launch-live-tv-app/).

product in 2008, a streaming service which has now grown into the major part of its business. SVoD services are now provided by a variety of industry players, including:

- DVD Rental/Pure SVoD players e.g. Netflix, Lovefilm (now Amazon Prime) – these are global businesses, though content availability is regional
- Broadcasters e.g. Hulu Plus
- Pay TV operators e.g. Now TV.

In terms of global subscriber numbers (with over 44m subscribers as of end-2013), Netflix has been by far the most successful of these services. The key features of Netflix's technological and product development have been:

- Compatibility with a large range of devices (Game consoles, Blu-ray players, TV sets, Set-top-boxes, Home Theatre Systems, Phones and Tablets, Laptops), translating into high reach for the service
- Low-cost monthly subscription with no contract and a one-month free trial period
- Unlimited use of devices by each subscriber
- Aggressive content strategy, competing directly with Pay TV operators and broadcasters both in terms of third-party rights acquisition and production of original programming.

## B.5 Hybrid broadcast/OTT services

We discuss the emergence of hybrid broadcast standards such as HbbTV, MHP and YouView in more detail in Appendix I. Aside from these standards, which are primarily designed for Free-To-Air platforms, Pay TV operators around Europe are starting to roll out hybrid set top boxes. Here we outline some of the key technical features and functionality of some of these devices.

YouView (UK) offers:

- Integrated search function across TV schedule, recorded PVR content and Catch Up content.
- Online-only channels integrated into the linear EPG
- Pay TV live and on demand OTT services integrated into user interface
- Backwards EPG functionality allows users to access on demand versions of previously aired shows for multiple channel providers.

TiVo (Virgin Media UK, ONO Spain) offers:

- Integrated Search function searches for content across TV schedule, recorded PVR content, Catch Up, On Demand and web (e.g. YouTube)
- In UK, backwards EPG allows users to scroll to previously aired shows in the EPG for ITV, Channel 4 and Five.

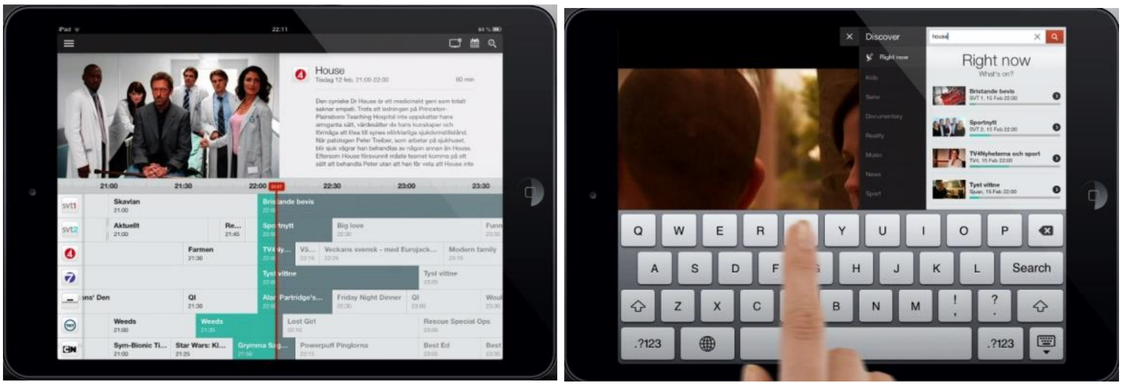
## B.6 Pure OTT TV services

More recently, some pure-OTT services have emerged focused on providing internet access to linear broadcast services, as opposed to catch up and on demand content. These linear-OTT services have come in a variety of forms, both legal and illegal (or at least of disputed legality).

For example:

- TVCatchUp.com is a UK website offering free live streams of UK channels. Due to content rights issues, not all DTT channels are available – where channels are not available, the website directs users to broadcasters' own online services, or to catch up services where possible. The service can be accessed on PCs, tablets and smartphones
- Aereo and its competitor, FilmOn, offer an OTT TV service in parts of the US. Both services use "antenna farms", arrays of miniature aerials, to receive digital terrestrial TV signals and supply the feed from the aerials to users over an internet connection (each aerial is only accessed by one viewer at a time). The services also offer network PVR functionality and delivery of channels to laptops and portable devices.
- Magine (Sweden, Germany, and Spain) is a subscription-based OTT service founded in Sweden in 2011. It aims to provide an enhanced linear TV experience available through applications across a range of devices. The service has a linear EPG as with broadcast television, but as all content is streamed, channels can be paused, rewound and fast-forwarded, and a backwards EPG gives access to catch up content. In Sweden the service offers[222] 43 channels, of which 32 are available for On Demand viewing at a cost of 99kr (around €12) per month. Magine has deals to provide connected TV applications with LG, Panasonic and TP Vision (Philips TV). As of October 2013, the service was reported[223] to have 500,000 subscribers in Sweden and versions are available in Germany[224] and Spain, with further European launches expected. Unlike re-streaming services (see TVCatchUp and Aereo), the service relies on securing content rights with broadcasters in advance.

**Figure B-2: Magine iPad user interface**




*Source: Magine*

[222] As of 3rd March 2013, source: Magine website; the number of channels may have been reduced to 34 according to press reports (http://swedishstartupspace.com/2014/03/17/tv4-ends-collaboration-magine/)

[223] By Rethink Research

[224] Commercial launch took place in April 2014

- Wilmaa (Switzerland) is an OTT TV service in Switzerland, offering internet access to 48 free-to-air channels. The basic service is free, and a premium service is offered from CHF 5.26/month (€4.3/month). The premium service includes a network PVR service which continuously records 7 days' worth of content across all channels. The network PVR feature allows pause and rewind functionality for live TV as well as 7 day catch up across all channels.
- Zattoo offers live TV content (Germany and Switzerland, Spain, France, Denmark and the UK) with country specific channel offerings. Zattoo's live TV service can be received across a range of devices. Each registered user receives an account that can be used on all devices on which Zattoo is available for use. The company has recently commenced distribution of the free-to-air channels of German TV group ProSiebenSat.1 as live-streams. In addition to six channels from Mediengruppe RTL Deutschland, Zattoo's premium package HiQ also offers German internet users Sat.1, ProSieben, kabel eins, sixx, Sat.1 Gold and ProSieben Maxx. Besides the total of 12 channels provided by Germany's two largest commercial TV groups which are distributed in standard resolution, HiQ also contains 22 commercial and public TV channels in high definition. The HiQ package complements the more than 70 live-streams of TV channels provided by Zattoo free of charge.[225]
- Intel On Cue (USA, now owned by Verizon) was a service being developed by Intel, designed to be a competitor to cable and satellite Pay TV platforms in the US. The platform's business model was to be the same as cable or satellite operators in the US: broadcasters were paid carriage fees; subscribers paid for the set top box and paid monthly subscription fees roughly in line with current cable charges. According to industry reports[226] of On Cue demos, the user interface had tight integration between broadcaster channels, on demand and SVoD content and the service used a network PVR capability to give continuous access to the previous three days' content. In January 2014, Intel announced that it had sold the assets of On Cue to Verizon.

[225] http://www.broadbandtvnews.com/2014/04/08/prosiebensat-1-channels-go-live-at-zattoo/

[226] http://mashable.com/2014/01/21/intel-oncue-failed/

farncombe plum

# Appendix C: Interactivity standards for DTT

## C.1 Introduction

Interactive TV services represent a set of applications with a varying level of user interactivity. They typically range from basic broadcasting services (using extra functions 'buried' in the broadcast stream, which could be invoked without the need for a return-path – e.g. teletext) to enhanced interactive broadcasting services (using extra functions which depended on sending data upstream to the service-provider using a return-path – e.g. impulse pay-per-view) and internet services (using extra functions which depended on the use of an IP return-path plus 'browser' – e.g. viewing Web pages in real time).

## C.2 MHP

DVB-Multimedia Home Platform (DVB-MHP) is an open DVB middleware standard for interactive TV services and applications. Interactive applications can be delivered using the broadcast channel and may offer information services, games, interactive voting, etc. MHP applications can use an additional return (IP) channel.

The first version of MHP was published by ETSI in July 2000, following initial demonstrations of the middleware at IFA in Germany the previous year. The first MHP services (on the Finnish DVB-T platform) followed in 2002.

MHP's core is a Java virtual machine (VM) – a feature designed to ensure interoperability across all platforms. In theory, although a dedicated Java VM still needs to be created for each different set-top box operating-system, the VM should abstract the layer below it and allow the same interface to be presented to any application running on it. In other words, in an MHP environment, it should be possible to write an interactive TV application once and run it on all MHP-compliant terminals.

In practice, MHP implementations proved to be both expensive – generally costing more to create and maintain than ones using proprietary interactive TV solutions such as OpenTV, MediaHighway or alternative standards such as MHEG. Moreover, the implied economies of scale and scope could only be derived from such a set-up if the entire market were to adopt the standard, which did not happen with MHP. With the notable exception of the Italian[227] DTT market, MHP has never been widely adopted.

A recent example of the use of MHP there is the new tivùon OTT application developed by tivù, a joint venture formed by RAI, Mediaset and Telecom Italia Media. The tivùon OTT solution for set-top boxes is based on the MHP standard, uses MPEG-DASH (see below) for streaming and Marlin DRM for secure catch-up TV and VoD.

In the meantime, MHP has been used as a basis for GEM – or Globally Executable MHP – a DVB-independent derivative of MHP, which has emerged as the more significant technology: it is incorporated into the high-definition optical disc standard Blu-Ray; forms the basis for the US Opencable standard (under the brand 'tru2way'); and underpins Brazil's interactive middleware

[227] Government subsidy was made available for interactive TV set-top boxes. The latest figure DVB offers for MHP in its fact-sheet was that it was deployed in 14.5m receivers by April 2010. The vast majority of these are in Italy.

standard Ginga-J. GEM is also compatible with the US and Japanese digital terrestrial broadcasting standards.

## C.3 MHEG

MHEG-5 is one of a suite of standards from the Multimedia Hypermedia Expert Group (MHEG), which provides tools for the creation of simple interactive multimedia applications, and is designed to minimise the memory requirements in set-top boxes. An MHEG-5 engine, for instance, can fit into a few hundred kilobytes. The aim is that any interactive TV application developed using the MHEG standards will run on any device that supports MHEG.

MHEG takes the form of a 'declarative' programming language: a 'page' or screen is created by building up a series of defined objects and stipulating how they relate to each other and how they can trigger other objects. This page is delivered over-the-air to a DTT receiver – whether a set-top box or IDTV – via a data 'carousel' inserted into the broadcast stream, where it is received and processed by an MHEG-5 engine, in a similar manner to the way a Web browser behaves.

MHEG-5's simplicity has led some to describe it as a mere 'graphics toolbox'. Certainly, for the first decade of its existence as a UK standard within the so-called 'D-Book'[228], it was confined to the lowest level of the interactive TV hierarchy, in which interactive applications such as Teletext are delivered without the requirement for a return-path.

However, in March 2009, the DTG published the 6th edition of the D-Book – which introduced a broadband return-path for MHEG-5 with a view to enabling catch-up TV, e-government and transactional services. Two years later, the publication of D-Book 7 launched a fully-fledged 'Connected TV' specification that further extended MHEG-5 and was designed to be interoperable with other hybrid standards such as HbbTV (see below).

### C.3.1 'Open' Hybrid TV standards

#### HbbTV

Hybrid Broadcast Broadband TV (HbbTV) originated as a broadcaster-centric Franco-German venture, of which the principal originators were broadcasters Canal+, France Télévisions and TF1 on one side of the border, and the German-language PSBs' research institute, Institut für Rundfunktechnik (IRT), plus satellite operator SES Astra's German unit on the other.

HbbTV was formally launched in August 2009 at the IFA exhibition in Germany, with the ambition of "harmonizing the broadcast and broadband delivery of news, information and entertainment to the end-consumer through TVs and set-top boxes with an optional web connection."

The HbbTV standard is based on the re-use and combination of elements of existing standards and Web-based technologies from the Open IPTV Forum (OIPF), CEA-2014, W3C and DVB.

[228] The 'D-Book' defines the UK DTT standard, and is published and maintained by the UK digital TV industry group, the Digital Television Group (DTG). Although in theory an 'open' standard, it is available only to paying members of the DTG.

The main aim of the initial specification was to extend broadcasters' control of their existing broadcast services into the online domain. For the IRT, HbbTV would "build on the success of the existing SD teletext service which is used by more than 14 million consumers each day in Germany by providing a high quality video text service more suited to HD receivers". For its part, France's HD Forum, tasked with the creation of the second-generation DTT platform, TNT 2.0 (DVB-T had been launched there, as in the UK, without a return-path), sought to "make DTT interactive in France" by exploiting HbbTV's ability to "mix broadcast and online services while retaining the broadcasters' control".

HbbTV's most original characteristics are:

- It allows interactive applications to be either accessed via broadband, or sent via broadcast
- It allows each broadcaster to control the life-cycle of interactive applications appearing on their channels. In other words, with HbbTV, the broadcaster controls which application can be used by the consumer watching its channels.

The first HbbTV boxes were launched in Germany in the run-up to Christmas in 2009, with Version 1.1.1 of the specification being approved by ETSI in July 2010. By this time the HbbTV consortium claimed 60 supporters from broadcasters, software providers and consumer electronics device manufacturers.

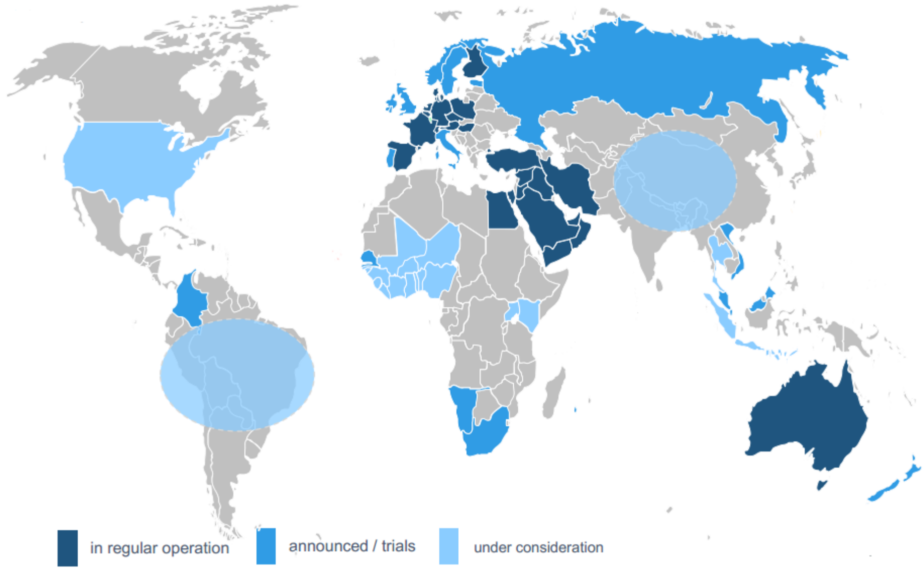
In April 2012, significant enhancements to the standard were announced as Version 1.5, introducing support for HTTP adaptive streaming based on the recently published MPEG-DASH specification (see below). HbbTV 1.5 also allows content providers to protect DASH delivered content with a common encryption allowing the terminal to support different Digital Rights Management (DRM) technologies.

Together, these two enhancements, driven by HbbTV's French partners through the country's HD Forum as part of the TNT 2.0 development programme, paved the way for broadcasters to optimise the quality of their catch-up TV offerings in preparation for the possible monetization of premium-based video services.

Today, the standard is deployed across Europe, including in Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Poland, Spain, Switzerland and the Netherlands (Figure C1 illustrates). The HbbTV consortium claims that most connected TV sets sold in Western Europe integrate HbbTV, while there are more than 5 million active HbbTV units around the world. This, it says, gives HbbTV a potential reach of over 110 million homes[229]. HbbTV is supported by most TV vendors, and integrated into a growing percentage of connected TV sets. Future HbbTV deployments have also been announced in Europe, Russia, Australia, Malaysia, and Vietnam.

[229] www.hbbtv.org/pages/news_events/pdf/03.2013_PressRelease_HbbTV_Logo_Licensing.pdf

**Figure C-1: Adoption status of HbbTV worldwide (October 2014)**




*Source: HbbTV.org (www.hbbtv-symposiumeurope2014.com/wp-content/uploads/2014/10/1-1-Keynote-HbbTV-Chairman.pdf)*

Version 2.0[230] of HbbTV is already under discussion. Key enhancements will include support for HTML-5, which for the first time defines a standard way to embed video in a Web-page (previously, third-party plugins such as Quicktime or Flash were required for playback); and push-VoD, according to which video can be 'pushed' to receiver hard drives (for instance overnight during broadcast down-time or low-traffic broadband periods) for later replay.

## YouView (UK)

The UK has developed an independent connected TV platform known as YouView[231].

This hybrid platform was originally developed to provide an upgrade to the Freeview DTT platform, which lacks a return-path, and to exploit the growing popularity of catch-up TV in the UK by providing a unitary media-player for this type of broadband content.

The platform launched in July 2012, with the aim of combining "the simplicity and value of Freeview with the choice and convenience of catch-up and on-demand". The principal use-case originally envisaged consumers accessing content services on their living room TV set using a broadband connection and a YouView hybrid DTT/IP box purchased at retail (current price £200-300) – although subsidised devices are obtainable from TalkTalk or BT bundled with a broadband connection.

YouView differs in several significant ways from HbbTV: It builds runs and promotes an open-source connected TV specification and retains tight control over the user interface – so it is more a platform

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[230] www.hbbtv-symposiumeurope2014.com/wp-content/uploads/2014/10/2-1-HbbTV-Roadmap.pdf

[231] Part B of the DTG's D-Book 7 (see above) incorporates HbbTV 1.5 and extends it to meet UK digital TV requirements. These extra UK features have been submitted to HbbTV as candidates for inclusion in HbbTV 2.0, and the DTG is officially committed to seeking greater harmonisation with European standards. In this respect it is notable that the UK's free-to-air satellite platform, Freesat, is deploying HbbTV alongside MHEG-5 in its second-generation receivers.

than a specification. It is also more set-top box focused than HbbTV, since TV manufacturers have not elected to integrate the technology into connected TV sets. IP content delivery is available through support for HTTP progressive download (PDL); HTTP adaptive bit-rate streaming; and IP Multicast.

YouView has fallen short of its original ambitions in two main ways.

First, mainly for regulatory reasons, the idea of a single media player that could play back all the JV partners' catch-up TV services never materialised. Although YouView deploys an innovative EPG which integrates access to live, recorded and catch-up TV programming in a single screen, separate media players are still triggered prior to viewing catch-up programming depending on its source.

Second, it has not developed – like the original Freeview offering – as a horizontal retail proposition. While there are around a million YouView set-top boxes installed so far, only around 3% of these were purchased at retail: the rest have been delivered by BT and TalkTalk as part of subsidised broadband bundles.

Recent press reports suggest that YouView broadcast partners could abandon the platform to start up a rival platform called 'Freeview Connect' – or perhaps simply create a unified 'app' for their catch-up TV services which could eventually become available on any UK smart TV or broadband-enabled set-top box.

### Hibrida

Hibrida is Spain's DTT connected TV platform, which began rolling out in the second half of 2013, co-ordinated by Spanish transmission company Abertis Telecom.

Hibrida is closely based on the use of the HbbTV 1.5 standard, and offers viewers with connected TV sets or hybrid set-top boxes a range of services ranging from VoD, participation in surveys or contests, or enhanced information about programmes being viewed.

The Spanish implementation of HbbTV is based on a specification co-ordinated by Spanish industry group AEDETI under the supervision of the country's Digital Television Forum, which brings together operators, broadcasters and manufacturers.

Abertis is responsible for running the certification programme for HbbTV-compliant DTT receivers.

### Manufacturer-centric terrestrial interactivity standards

Both HbbTV and YouView are standards that put the broadcaster more or less in control of how 'connected' interactivity works in a hybrid context. However, there are a number of competing approaches that are manufacturer-centric.

Samsung, which according to market reports has the largest share of the connected or 'smart' TV market in Europe, has its own proprietary approach, through which it embeds on-demand TV content and services directly within its smart TV sets under a unified interface. These are accessed via branded content-provider 'apps' within Samsung's own Smart TV Portal – Samsung effectively acting as the content aggregator.

Meanwhile, the Smart TV Alliance (founded by LG, TP Vision and Toshiba) is promoting a cross-manufacturer approach through which makers of smart TV sets agree a common technology that would allow developers of such ‘apps’ to create and run them on all supported Smart TV Alliance platforms.

The Smart TV Alliance says it uses open solutions technology and that Smart TV Alliance Apps can be developed using HTML-5.

Both the Samsung and Smart TV Alliance approaches allow third party content provider to stream content to the main TV sets, hence competing with the more traditional broadcasters.

It is not yet clear which approach will prevail. Most smart TV manufacturers are hedging their bets by including HbbTV stacks in their European models by default.

The above developments might lead to a greater degree of standards fragmentation that is threatening the entire ‘connected TV’ concept, since alternative, cheaper technologies are emerging such as Wi-Fi enabled dongles that effectively turn ordinary TV sets into smart TVs or apps that allow tablets and smartphones to ‘cast’ OTT streams to the main TV screen.

Here, in contrast to the ‘connected TV’ environment, HTML-5 based video delivery is becoming standardised, MPEG-DASH is emerging as a common denominator for HTTP-based adaptive streaming, and practical multi-DRM approaches are emerging.

The latter approach is likely to be easier for broadcasters to pursue, and there might be a scenario in the future where connected TVs are no longer used for the “connected” features but solely as displays connected to streaming devices such as smartphones, tablets or dongles. In this scenario, the consumer and service providers would emerge as the beneficiaries, since secure streaming would have become possible on a wide variety of interoperable devices.

## C.4 EPGs

The provision of Electronic Programme Guides (EPGs) relies on three activities:

- **Provision** of EPG information by channel providers to the broadcast platform manager.
- **Delivery** of EPG information alongside the broadcast content.
- **Display** of EPG information by the receiving device.

EPG information must be **provided** in a format that matches the format used by the platform provider. Data included in the EPG information may include:

- Programme information (programme name, description etc.)
- Programme timings
- Subtitles and audio description data
- Audio and video format data
- Recording information (e.g. recording triggers, alternative programme time, series record, split event etc.)
- Parental guidance.

The required **format** of this information depends upon the platform, and could be bespoke to each platform, although many platforms will use similar formats. Depending on the platform, some data is required and other data optional.

**Delivery** of the information is also bespoke to the platform. There are some standards for how EPG data is carried in the broadcast signal (e.g. DVB and ATSC carry EPG data in a defined way), though the EPG data may be encrypted (as with the Freesat platform in the UK), so that decryption of the EPG data relies on a proprietary mechanism.

**Display** of EPG information is generally proprietary to the manufacturer of the reception device, and does not follow any technical standards. In other words, once a device has access to the EPG information, it can display that information in whatever way it wants. In some states this is subject to regulation (e.g. PSB channels should appear at the top of the EPG), but often this is not the case, and indeed the user is free to adjust the order in which channels appear. In some cases, display of the EPG and User Interface (UI) is specified in detail (as with YouView in the UK), though this is unusual.

EPG is also considered as an area for differentiation and innovation among User Interface (UI) vendors and/or device manufacturers especially for horizontal markets. Current providers of hybrid broadcast-broadband platforms have designed their own methods of collecting EPG information from the relevant content providers and delivering that information in a way that enables devices to display information, regardless of whether it relates to broadcast or over-the-top content.

Similarly, the operation of a successful converged platform might include the ability of devices to receive accurate data regarding the available content on the platform, but will not necessarily require a defined method of displaying the data (with the exception of any regulatory constraints).

# Appendix D: Public service broadcasting requirements in the EU

## D.1 Introduction

The role of public service broadcasting (PSB) is to contribute to the democratic, social and cultural needs of a particular society, such as adequate pluralism and linguistic and cultural diversity, which commercial broadcasters have weak incentives to provide. PSB content have traditionally been funded through public licence fees and delivered free-to-air over terrestrial TV broadcast networks to ensure universal coverage. Over time as new transmission platforms emerge (cable, satellite, IPTV) and viewing habits have evolved, policymakers have introduced new rules to ensure that PSB objectives can continue to be achieved, the most notable being must-carry obligations on alternative TV platforms. In this chapter we review existing PSB policy and rules and propose minimum requirements which any converged platform option will need to meet.

Each member state of the EU has its own PSB policy and rules. These rules vary considerably from one member state to another. To examine the nature of these rules we have reviewed:

- A recent survey by the EBU[232] on the availability of PSB channels by TV platforms in 26 CEPT countries (in which 20 of the EU28 member states are covered)
- A number of papers looking at must carry rules in the EU.

## D.2 PSB rules – the current situation

To ensure universal coverage national governments and regulators typically mandate a required level of coverage for DTT, especially for PSB multiplexes. The majority of the EU28 Member States have placed coverage obligations for national DTT multiplexes as shown in Figure D-1 below. While the obligations vary across Member States, most require at least 85% population coverage for national free-to-air DTT services.

Figure D-1: National DTT coverage obligations for EU28 member states

| Country | FTA DTT coverage obligation | Coverage obligation | Coverage achieved |
|---|---|---|---|
| Austria | Y | 95% | 97% |
| Belgium | Y | | 95% to over 98% |
| Bulgaria | Y | 95% | 96% |
| Croatia | Y | | 92% to 98.5% |
| Cyprus | Y | | 95% to 100% |
| Czech Republic | Y | | 99.9% |
| Denmark | Y | 99.80% | 99.8% |
| Estonia | Y | | 100% |
| Finland | Y | 99.9% | 99.9% |

[232] *Availability of PSB programmes on TV distribution platforms*, EBU for ECC TG6, March 2014

| Country | FTA DTT coverage obligation | Coverage obligation | Coverage achieved |
|---|---|---|---|
| France | Y | 95% | 97% |
| Germany | Y | various | 90% to 100% (national) |
| Greece | Y | | 95% |
| Hungary | Y | 94% | 96% |
| Ireland | Y | similar to analogue | 98% |
| Italy | Y | various | over 90% to over 99% |
| Latvia | Y | | 99.9% |
| Lithuania | Y | | 96.3% |
| Luxembourg | N | NA | 40% to 95% |
| Malta | Y | | over 95% (geo) |
| Netherlands | N | NA | NA |
| Poland | Y | | 95% |
| Portugal | Y | 85% | 93% |
| Romania | Y | 90% | pending mux licences award |
| Slovakia | Y | | 97.8% to 98.6% |
| Slovenia | Y | | 89% to 99% |
| Spain | Y | 98% | 96% to 99% (national) |
| Sweden | Y | 99.8% | 99.8% |
| United Kingdom | Y | 98.5% | over 90% to over 98.5% |

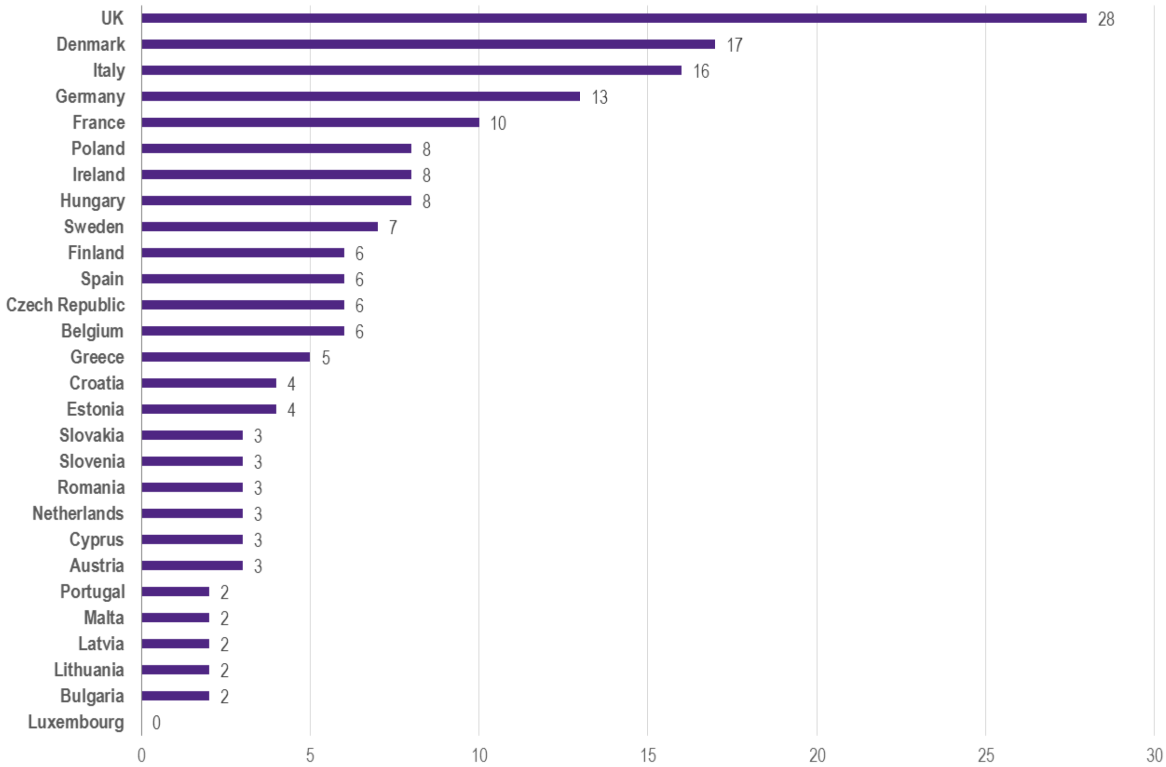
*Source: RSPG questionnaire responses (September 2012), Plum research*

PSB policy and rules are set by each member state, subject to compliance with the Universal Service Directive which states that:

> *“Member States may impose reasonable "must carry" obligations, for the transmission of specified radio and television broadcast channels and complementary services, particularly accessibility services to enable appropriate access for disabled end-users, on undertakings under their jurisdiction providing electronic communications networks used for the distribution of radio or television broadcast channels to the public where a significant number of end-users of such networks use them as their principal means to receive radio and television broadcast channels”*

In practice these rules mean that a number of channels are available on a free-to-air basis to almost all of the population with DTT coverage often exceeding 98% according to the EBU. Figure D-2 shows the number of national terrestrial TV services in the EU28 Member States – note that commercial services may not be subject to PSB rules such as coverage and must-carry requirements.

Figure D-2: National terrestrial TV services – public and commercial




*Note: Not all national terrestrial TV services are covered by must-carry obligations*
*Source: EAVO Yearbook 2012*

Different platforms play different roles in delivering PSB requirements:

- In many member states the DTT network alone provides free-to-air delivery of public service channels on a near universal basis
- In some member states[233] DTT coverage is supplemented by use of satellite delivery
- Must carry rules sometimes apply to the cable network as well as the DTT platform e.g. in the Netherlands where the cable footprint is near universal
- IPTV and cable networks in most member states require subscription and often offer limited geographical coverage. As such they do not meet PSB requirements
- Satellite services are available on a commercial basis in all member states but offer open access free-to-air reception in only a few countries e.g. Germany and the UK
- In some other member states free-to-air channels are available over satellite once a subscriber has a free-to-view access card e.g. Austria, France, Ireland, Italy and Portugal

[233] Austria, Finland, France, Germany, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Slovakia, Spain, UK

- The role of satellite transmission as a substitute for terrestrial distribution was the subject of a recent questionnaire by the Commission's working group on Communications Broadcast. The results of the questionnaire are summarised in Figure D-3.
- Regional programming is common among EU Member States. According to data reported in the European Audiovisual Observatory (2012), all but two of the EU28 countries (Cyprus and Malta) have some form of regional or local TV programming (by public and private broadcasters). Regional programming is especially important in member state with several languages e.g. Belgium, Spain, and the UK
- The bulk of regional TV channels are provided over the DTT platform in most member states. The extent to which the DTT platform offers regional TV – whether using SFN or MFN architectures – varies considerably - from zero in Cyprus and Malta to over 100 regional channels in Spain
- There are exceptions to this rule. For example in the Netherlands regional and local TV channels are provided over the cable platform rather than by the DTT platform.

**Figure D-3: Views on the role of satellite as a substitute for DTT**

Satellite transmission is not considered a substitute for terrestrial distribution by the authorities of Belgium, Czech Republic, Denmark, France, Cyprus, Sweden and UK

The German authorities do not consider that regional and local distribution patterns can be implemented in a cost-efficient manner via satellite.

Satellite viewing is very low or on the decline in Estonia and the Netherlands. This makes substitution difficult.

In many countries (CZ, DK, HR, IT, LV, LT, LU, HU, NL, PL, RO, SI), there is (almost) complete simultaneous satellite transmission of the DTT channels.

Several other countries (ES, IE, IT, PT, FI, SE) use satellite transmission as a complementary service in areas which are not covered by the DTT signal.

*Source: COCOM. Results from the questionnaire to Member States on digital broadcasting, 8 January 2014*

# Appendix E: Push VoD services

## E.1 Concept description

Traditional broadcast networks are inherently one-way systems. The transmission mechanism of these systems restricts their capability to provide “true” (or pull) on-demand AV services, when the user/viewer interacts with the content source via a return path. It is obvious that one-way broadcast networks are not able to serve unicast (e.g. internet/web browsing, VoIP) traffic.

However, there are ways for broadcast platforms to deliver AV and data services which can be consumed on-demand. The basic principle is based on broadcast networks pushing content (or data) into devices with storage capabilities (e.g. Personal Video Recorder - PVR or Digital Video Recorder - DVR). In general, this is similar to a local caching where, typically, popular content or other data is stored locally for later consumption.

In push systems, the platform provider broadcasts one single instance of the content to all users at the same time. Content can be broadcast in segments and/or at different times during the day and is consumed once it has been “downloaded” and compiled at the device. Therefore, it is not necessary to transmit using a permanent broadcast channel; content can be pushed in intervals or transmission windows.

In practice, there are broadly two ways to implement push content:

- Use spare, in most cases, overnight and less expensive capacity to push the content over a high bandwidth channel
- Use underutilised capacity throughout the day to push the content over a low bandwidth channel.

The “downloaded” content can be refreshed regularly (e.g. daily or weekly) depending on the device storage capability and consumers viewing habits. By design, the amount of content of a push service is limited; both by the device storage space and also by the download capacity.

### Non-linear services to PVRs

A push service has increasing capability as the storage space in the device grows, as more content can be made available to the consumer. In 2002, PVRs in the UK market had 10-20GB of storage capacity. By 2013, retail PVRs (i.e. PVRs available for the free-to-air market) had storage space of 250-500GB.

A number of Pay-TV service providers offer STBs with higher PVR storage space e.g. 1,000GB (1TB) and 2,000GB (2TB), given the increase of higher definition services and the need to store higher quality content.

### Non-linear services to other devices

The push concept described above can be extended to other personal devices like smartphones and tablets. The push delivery mechanism applies to other types of network and it can be used to deliver any type of media content, not limited to video, and to other consumer devices with storage capabilities like laptops, smartphones and tablets.

In this case, devices need to be able to receive DTT signals (e.g. via an integrated DTT tuner or a DTT dongle) or other mobile broadcast services (e.g. LTE-Broadcast). Other data or applications might be also pushed e.g. software/firmware updates, application updates, multimedia magazines, newspapers, etc.

Clearly, at present, the storage capabilities of a smartphone or tablet are limited compared to those of a PVR. Internal storage for tablets typically varies between 8GB and 64GB, although high-end models now have 256GB of storage. Latest smartphone models have an entry level of 32GB and some more advanced ones offer 256GB. The mobile industry is working towards higher storage capabilities[234]. We can expect also that not all of the device storage to be available to store push content; the device OS and other critical applications use a certain amount of the device's storage. Consumer will use additional amount for personal use (photos, music, video clips, etc.).

## E.2 Deployment examples

Push, and in particular push video-on-demand[235], services have been implemented in various EU markets[236] and worldwide. Push on-demand over satellite (DTH) platforms is more common and in most cases is part of a Pay-TV service. A limited number of push services are using DTT networks. Broadcast networks require additional bandwidth to enable push services. Availability of bandwidth is not as critical on satellite platforms where, generally, more capacity is available. Typical take-up rates are in the range of 5 to 20% of a Pay-TV operator's subscriber base offering push VoD services.

Push content usually includes catch-up episodes and TV series, movies and sporting highlights. Figure E-1 shows the amount of movies and or catch-up content which can be stored in a typical 500GB PVR, assuming that 50% of the storage space is reserved for consumer's own recordings. Figure E-2 then shows the amount of movies and/or catch-up content which can be stored in a smartphone or tablet with 128GB and 64GB storage capability respectively, assuming that 50% of the storage space is reserved for consumer's own recordings. We note that, although, advertisements can also be "pushed" to the device, these are typically of a very short duration e.g. 30-60sec at the beginning and end of the content and therefore they occupy a negligible amount of the device's storage (30-40MB), hence not shown in the following graph.

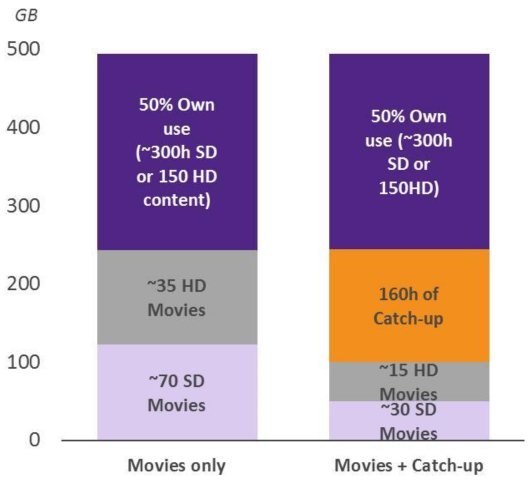
[234] http://news.yahoo.com/samsung-chips-could-lead-smartphones-384gb-storage-014502632.html

[235] Video on Demand (VoD) is a commonly term used for different cases. VoD refers to a broadband accessible service allowing the user to select at any time a movie to watch within a catalogue/content library. The end-user accesses the content of his choice as it is streamed in real-time to his device e.g. set-top-box, TV set, PC, smartphone or tablet.

Push-VoD is a technique in which content is transmitted before it is actually requested by the consumer. The platform or service provider of a Push-VoD service selects in advance the content for "download" to the end-user device(s).

[236] Italy, Spain, France and the UK are some examples

**Figure E-1: Example of content stored (500GB PVR)**

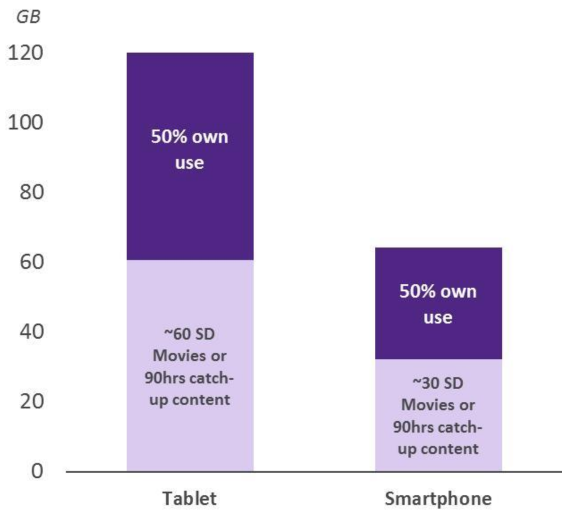



Notes: Assumptions: H.264 encoding, 2Mbps for SD quality, 4Mbps for HD quality (720), 60min catch-up episode, No ads

We assume:

- 2Mbps for SD content. So a 2hrs SD movie would require, 2Mbps x 60 x 60 x 2h /8 = 1.8GB
- Using a 5Mbps channel broadcasted over night for six hours, 13GB of data are "downloaded" to the device i.e. 7 SD movies (rounded-down to allow for re-transmission margin)
- If content is refreshed weekly, 7 x 4 = 28 SD movies would be available for viewing during a month

**Figure E-2: Example of content stored (128GB tablet/64GB smartphone)**




Notes: Assumptions: H.264 encoding, 1.5Mbps for SD quality (Tablet), 0.8Mbps for SD quality (Smartphone), 60min catch-up episode

As we noted earlier “push” content may also include data like popular websites (e.g. news, weather, travelling information, etc.) for mobile devices and tablets. We haven’t included those in the above graph due to their negligible storage requirements compared to video content (an average webpage requires ~1.5MB; 1GB of the device’s space, which could correspond to just 1.5% of the tablet’s space for owner’s use, could store around 600-700 webpages).

In France, where the embedded Hard Disk Drive (HDD) is subject to private copy tax, TVNumeric[237] had designed a set-top-box dedicated to Push-VoD, without PVR support on DTT network. The second tuner of the device was used to receive pushed content only, and the HDD was solely dedicated to the on-demand catalogue.

In Italy, Mediaset offers a push catalogue of 50 movies and TV series broadcast over its DTT platform. 12 movies are refreshed every week (including one 3D movie every month). The service also offers weekly episodes for 3-4 TV series.

In the UK, BSkyB offers a subscription-based Push VoD service over its satellite platform. The catalogue includes 200 hours of movies, series and catch-up contents which is pushed during the night. The user recordings take preference in case of conflict. To ensure that the inactive set-top-boxes will receive the pushed catalogue, the content is transmitted several times. On average, 35 hours of contents is delivered daily. It requires 140GB of disk space on Sky’s HD set-top-box and 80GB on the SD set-top-box. Since 2009, Sky has extended their non-linear offer with a VoD service complementing the existing Push-VoD service.

## E.3 Benefits & Limitations

### Consumers

Push services offer a number of benefits for consumers. For example push services:

- Simulate an on-demand experience for market segments with no broadband access or not able to access pull on-demand services
- Offer an alternative to access high quality, on-demand content in cases where broadband usage limitations may restrict true video-on-demand consumption; as data caps for fixed broadband services increase, they are expected to be less of a limiting factor compared to mobile broadband services where current data caps restrict an extended use of video-on-demand services
- Facilitate alternative way for in-home content distribution; content stored on DVRs could be “re-packaged” for IP delivery and used for secondary distribution for other devices within the home
- Mitigate household demand for broadband bandwidth using a shared push content library where various devices access the internet for video streaming.

Nevertheless, push services have some inherent limitations. For example:

- They require the purchase of a storage device; TV-sets have no storage capabilities, although an external USB hard drive may be supported. This is however a complex proposition and may result in limited use of the service as the mass storage could be shared between several applications

[237] TVNumeric had planned to launch a Push-VoD service over terrestrial and satellite networks in France but had to cease operations at the end of 2012 after a judicial liquidation procedure.

- The storage capability of the device limits the amount of content to be pushed over a refresh cycle. Recommendation engines might optimise the storage use by filtering content and fine-tuning the catalogue (personalising the recording function of the PVR based on consumer's viewing preferences or habits and only recording content which matches with these preferences e.g. movies, soaps, documentaries, etc.). This way, push services can enable user-targeted content to be stored.
- PVR storage management requires synchronisation of storage usage between push and user's recorded content
- Transactional models would require consumer interaction (e.g. pre-pay or call/SMS) to receive authorisation for content purchase in cases a return channel is absent; a low bandwidth return channel (e.g. using the phone line or a mobile connection) might mitigate this issue
- Storage devices have to remain "always on" to receive push content during transmission windows, even when the consumer is not using the service; this might have an impact on consumer/household's power consumption and regulatory implications about standby requirements for electrical appliances.

## Platform/Service providers

For platform providers, push services can create a range of opportunities. Examples include:

- Utilising existing broadcast infrastructure (no need for additional network capital investment)
- Increasing utilisation of spectrum use
- Helping mitigate IP (unicast) traffic demand (which nowadays impacts CDN costs for service and content providers) for delivery of high quality or popular catch-up content
- Generating potential for extra advertising revenues (e.g. if adverts are pushed into the PVR alongside the content) or subscription/pay-per-view revenues in the case of a Pay-TV service package
- Preserving broadcast quality of non-linear content (with at least the same quality as linear services) over the DTT footprint.

Limitations for platform providers:

- Competition from other on-demand service offerings; the limited content catalogue compared to true on-demand services (typically in the range of 5,000 – 6,000 titles) might make the service proposition less appealing to consumers
- Device compatibility (push services typically requires device standardisation to create a horizontal market or an integrated solution within a single platform, in which case a Pay-TV service provider would usually subsidise the device)
- Increasing broadband availability and higher speeds across EU member states might limit the primary target market for push services in the future
- Refresh cycle management requiring intelligent content programming and managing content retransmissions to overcome reception errors

- Complexity or lack of audience measurement mechanism may limit the ability to monetize the service or use subscription-based models; although a low speed broadband connection can be used for audience measurement, service promotion and user targeting.

## E.4 The future role of DTT networks for non-linear content

DTT networks have the ability to offer non-linear AV and data content. Most existing implementations are based on pushing content into PVR devices.

We can expect that storage capabilities on PVRs will continue to grow. Based on a CAGR between 2002 and 2013 of around 40% in PVR capability, the storage space might reach 4TB by 2020 and exceed 7TB by 2025 assuming that current price performance trends continue at the same pace. Improvements in encoding technologies and compression algorithms might further increase the amount (or quality) of content that can be stored in devices. A likely shift to higher resolution content though might result in a similar amount of (higher quality) content that could be stored overall.

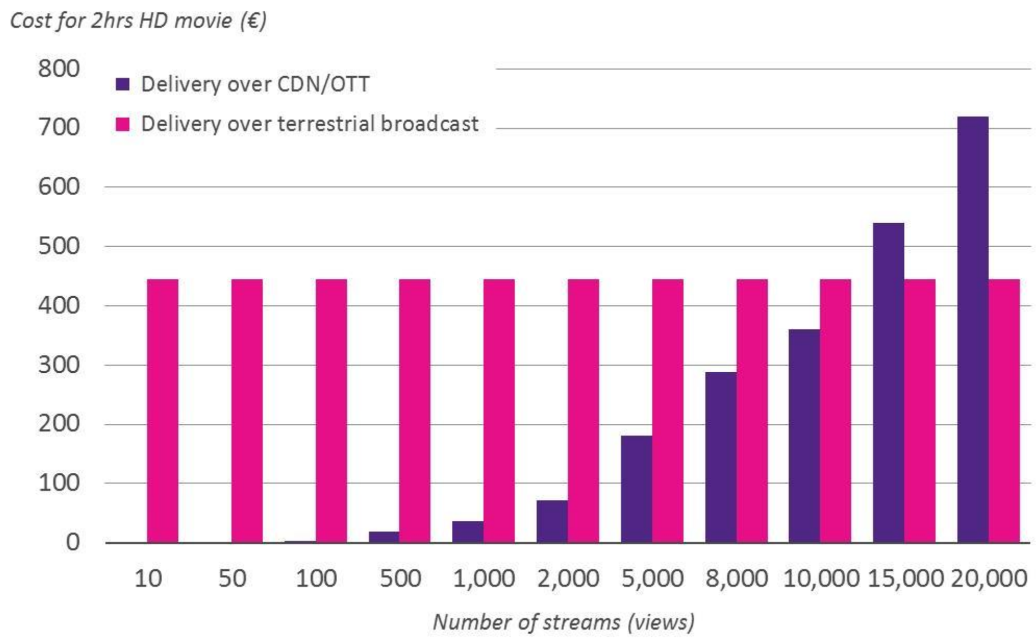
DTT broadcast networks have high population coverage. As a result, a push service over a DTT network is a valid solution to offer quality AV content to households not being able to access streaming services because the fixed broadband services do not offer adequate download speeds and/or poor quality of service. This service can also be enhanced by using the fixed broadband which is available to offer a low bandwidth return path. In areas where broadband is sufficient for video streaming, DTT might also be used to reduce the costs of distributing non-linear services such as video on demand. It can be cheaper to send popular content, with many thousands of views, using a DTT push service, rather than over the broadband network. This is illustrated in Figures E-3 and E-4. These indicate that the crossover point at which the DTT push service becomes cheaper is between 10,000 and 15,000 streams. This crossover point might increase in future as the price performance of the fixed network improves.

**Figure E-3: The potential for terrestrial broadcast to carry non-linear content**

We assume that:

- 4Mbps is required for HD content
- A 2hrs HD asset would require, 4Mbps x 60 x 60 x 2hrs /8 = 3.6GB
- For an average CDN cost of €0.01 per GB for streaming, the HD asset would cost €0.036 for a single viewing
- 1Mbps data channel on DTT broadcast during night time only (e.g. between 00:00H and 06:00H) delivers 6hrs x 1Mbps x 60 x 60 /8 = 2.7GB per day and 2.7 x 30 = 81GB per month
- €10,000 per month for 1Mbps off-peak channel on DTT, would cost €440 for the HD asset
- No additional costs for content preparation or other overheads
- Under these assumptions, comparing the CDN costs of the content delivery over broadband networks with the cost of carrying the content on terrestrial broadcast networks, shows that unicast delivery becomes more expensive when content is viewed (streamed) more than 12,000 times during a month
- Assuming an EU country with average population of 15m and 7m households, a broadband penetration of 50% and VoD take-up of 10%, the threshold of 12,000 viewings corresponds to 3.4% of VoD subscribers.

**Figure E-4: Cost comparison for non-linear content delivery**




*Source: Farncombe*

Finally, standardization can enable retail TV-sets (and other devices in general) to become compatible with push services, and increase the installed base. Since 2013, the HbbTV consortium (see Appendix I) has been working on new features that will be part of the upcoming 2.0 version of the HbbTV standard. As part of this activity, the non-real time content delivery has been added, referred as the "Download feature". It specifies the mechanism to download AV contents from either a broadcast or broadband channel into the storage space of an HbbTV compliant device. This implies a specific hardware profile of the device (HDD and recording capabilities). However, this feature remains optional for device manufacturers.

# Appendix F: Terrestrial transmission standards

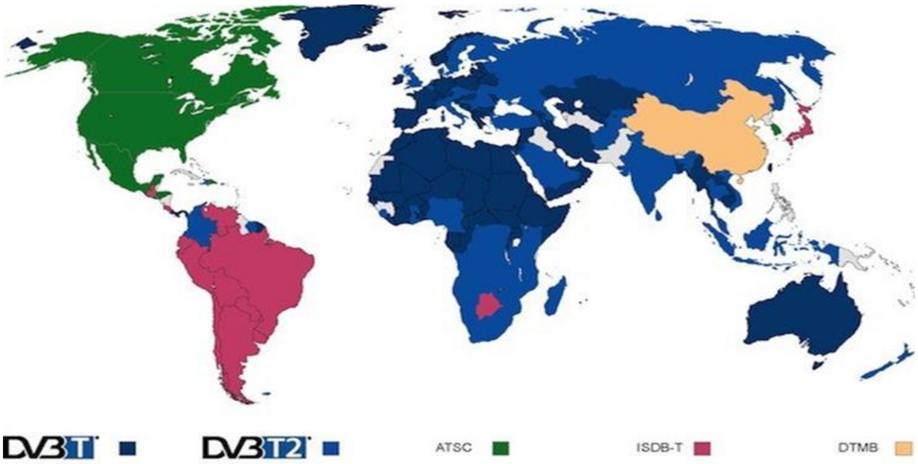
## F.1 DVB-T

DVB-T is one of the DVB Standard for modulation of broadcast signals. It is part of a family of DVB specifications containing amongst others:

- DVB-C and DVB-C2 for broadcast distribution over cable
- DVB-S and DVB-S2 for broadcast distribution over satellite
- DVB-T and DVB-T2 for broadcast distribution over terrestrial networks

DVB-T has been specified in 1997, and has been first deployed in the UK in 1998 by OnDigital. It is currently in use in all European countries, as well as in Australia, a significant part of Africa, and most of Asia (China excluded). In 2006, the DVB organisation issued a press release, claiming that over 100 countries had adopted DVB-T as their unique Digital Broadcast standard for terrestrial networks. Since then, a number of countries have joined this list (Philippines adopted DVB-T end-2006, Uruguay in 2007, Columbia in 2008, Panama in 2010, etc.), while some DVB-T countries have migrated towards DVB-T2. Figure F-1 illustrates the use of the main digital broadcast standards for terrestrial networks over the world.

Figure F-1: Adoption of DTT broadcast standards




*Source: DVB.org*

### Principles

DVB-T had been designed to co-exist with PAL/SECAM analogue TV signals (mostly organized in 7 or 8 MHz-wide channels), and to leverage as much as possible the existing transmission infrastructures (existing masts, transmission cells, etc.). It is based on OFDM, which is a signal modulation technique dispatching the digital information over a multiplicity of subcarriers. DVB-T uses two possible modes:

- 2k mode using 1,705 subcarriers
- 8k mode using 6,817 subcarriers

This is done by splitting the main digital stream into several streams, and modulating each of them on a different subcarrier, i.e. on a slightly different frequency.

On each subcarrier, different modulation schemes can be used (QPSK, 16QAM, 64QAM), the error correction can be set with different coding rates, and the guard interval can take different values. This results in a variety of possible modes, each of them having its own characteristics, in terms of transported bit-rate, resilience to noise, resilience to multiple echoes, and resilience to interferences between transmitters.

### DVB-T Spectral Efficiency

The overall maximum bit-rate enabled by DVB-T in an 8 MHz channel is 31.7 Mbit/s.

The Spectral Efficiency quantifies the capacity of a transmission scheme to carry as many bits per second as possible in a given bandwidth. For DVB-T, the spectral efficiency highly depends on the selected mode, the selection of which is highly dictated by the network topology and field constraints.

In a typical European deployment, a DVB-T signal in a 8-MHz channel will carry between 20 and 25 Mbit/s, resulting in a typical Spectral Efficiency of ca. 3 bit/s/Hz (bit per second per Hertz).

## F.2 DVB-T2

In 2006, the DVB consortium started to study how DVB-T could be improved. This resulted in the DVB-T2 standard, which was published in June 2008. The initial target of DVB-T2 was to optimize reception for fixed and portable devices, i.e. increase the maximum carried bandwidth under similar network conditions, in comparison with DVB-T.

#### Major technical differences between DVB-T and T2

DVB-T2 is mostly an extension of DVB-T, with the addition of new possible modes. The major exception to this are the error correction algorithms, which cannot be considered an extension, since the DVB-T ones (Reed Solomon and Convolutional Coding) have been replaced by new, more efficient ones (low-density parity-check (LDPC) and BCH cycling codes).

The main additions are listed below:

- Modulation schemes: 256QAM, in addition to QPSK, 16QAM and 64QAM
- OFDM modes (number of subcarriers): 1k, 4k, 16k, and 32k, in addition to 2k and 8k
- Error correction puncturing rates: 3/5 and 4/5, in addition to 1/2, 2/3, 3/4, 5/6
- Guard Intervals: 19/256, 19/128 and 1/128, in addition to 1/4, 1/8, 1/16, and 1/32.

The error correction codes used by DVB-T2 are significantly more complex than the previous ones. Moreover, as the above list shows, the number of possible combinations of the available parameters literally explodes, resulting in a much higher potential efficiency of the standard, a much higher capacity to adapt to specific characteristics and constraints of the infrastructures in which it is used, but a much higher complexity in both transmitting and receiving sides.

## DVB-T2 Spectral Efficiency

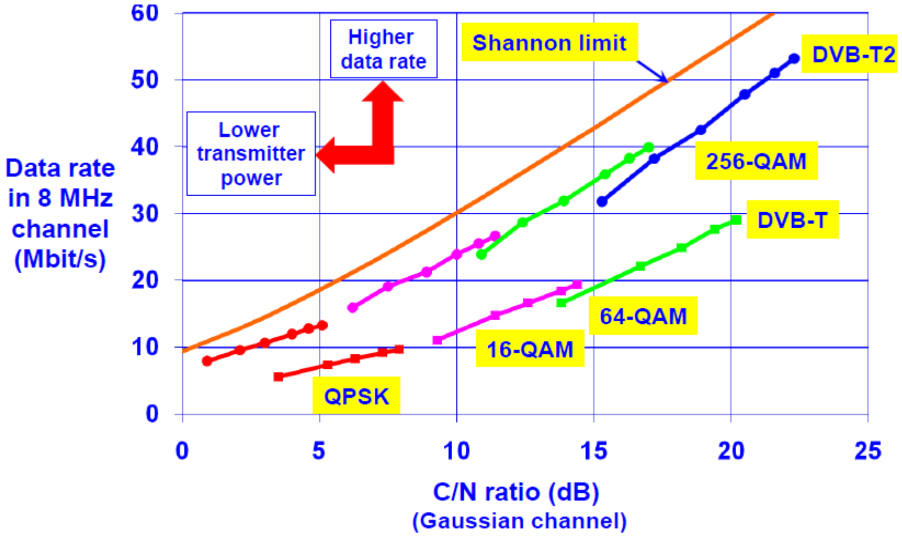
The overall maximum bit-rate that DVB-T2 can carry in an 8 MHz channel is 50.3 Mbit/s (according to DVB-T2 implementation guidelines), which represents a gain of ca. 60%.

In comparable transmission conditions, the gain of channel capacity between DVB-T and DVB-T2 is most often estimated around 50%, and even more.

Moreover, when we compare the actual measured performances of DVB-T2 to the theoretical maximum channel capacities (Shannon theoretical limit, see Figure F-2), this shows that:

- DVB-T2 is currently the terrestrial transmission standard which is the closest to the theoretical limit
- DVB-T2 shows to be so close to the theoretical limit that the room for improving the standard is very limited, making it unlikely that a successor will exist in the near future. And if it were the case, the expected improvements would not be significant.

Figure F-2: Comparison of DVB-T, DVB-T2 and Shannon theoretical limit



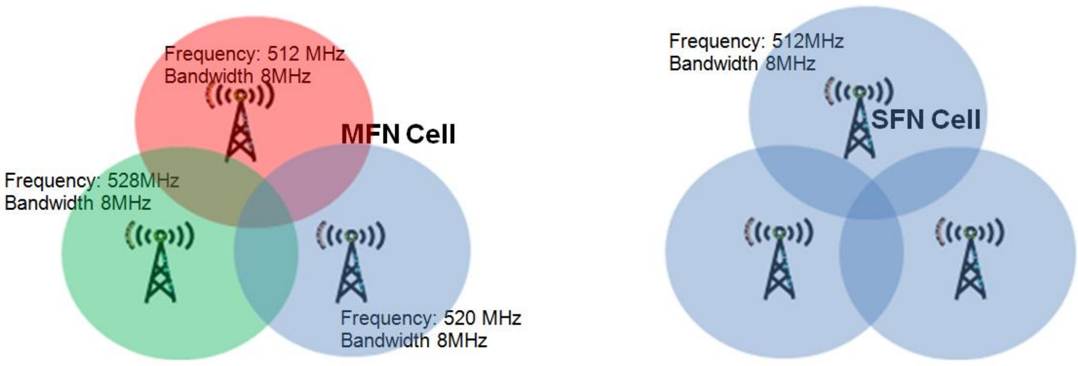

*Source: DVB.org*

In a typical European deployment, a DVB-T2 signal in a 8-MHz channel will carry between 30 and 40 Mbit/s, resulting in a typical Spectral Efficiency of ca. 4.5 bit/s/Hz (bit per second per Hertz).

## SFN vs. MFN

Besides the gains in Spectral Efficiency, an important benefit of DVB-T2 over DVB-T is that it greatly eases the efficient implementation of Single Frequency Networks (SFN). An SFN network is a (typically national) terrestrial network where the same signal is transmitted on the same frequency across the network. An MFN network is a (typically national) terrestrial network where the same frequency is never used by two adjacent regional cells, in order to avoid interferences. Figure F-3 illustrates the difference between these two infrastructures.

**Figure F-3: SFN & MFN network infrastructures**




The MFN is the network infrastructure which is directly inherited from the analogue era. Since analogue TV signals had no robustness to interferences, using the same frequency in two adjacent cells was not possible in order to avoid interference in overlapping areas between cells. DVB-T and DVB-T2 are designed to be robust to interference allowing SFN implementation.

The main drawback of MFNs is the poor Spectral Efficiency: all the frequencies within one cell are unusable in adjacent cells, a lot of "holes" in the frequency plans have to be managed, making the use of the frequency resource sub-optimal. SFNs can use the same frequency between adjacent cells making them much more spectral efficient.  They have a number of additional advantages:

- Signals from individual transmitters can add together, increasing their strength, thus margins for 99% DTT coverage availability can be reduced
- There is more uniform coverage, with fewer locations having poor reception
- Better mobile/portable reception: a moving DTT receiver does not have to retune at the cell boundary of each adjacent transmitter.

However, there are also disadvantages:

- Transmissions have to be synchronised to avoid interference from distant transmitters broadcasting out-of-phase signals, which add additional complexity and cost into the distribution network
- All transmitters in the SFN must carry the same multiplex data: thus there is no potential for regional services.  If regional services are required (as they are in almost all member states) then the gap in effective spectral efficiency between SFN and MFN narrows considerably
- There is greater potential for interference to neighbouring countries, since all transmitters along the border are transmitting using the same frequency might cause greater disruption on that particular frequency
- If the network has widely-spaced transmitter-sites, SFNs require large guard intervals, resulting in lower achievable data transmission rates.

As stated above, SFNs allow a much more efficient use of the scarce spectrum resource. By migrating from MFN to SFN, significant gains in Spectral Efficiency can be expected for certain scenarios. A six

MUX SFN would typically require 12-18 channels, in order to accommodate regional service requirements.

Thanks to its improved robustness to multipath propagation, DVB-T2 drastically relaxes the constraints on SFN implementation. Moreover, by permitting longer guard intervals, DVB-T2 allows for much larger-cell SFN network architectures than its predecessor.

## Migrating from DVB-T to DVB-T2

As explained above, DVB-T2 is a recent transmission standard. Choosing DVB-T or DVB-T2 is independent from the choice of the video definition (SD or HD), and from the choice of the video compression algorithm (MPEG-2 (H.262), AVC (H.264) or HEVC (H.265)).

DVB-T2 is not backwards compatible with DVB-T. This means that a DVB-T terminal cannot process a DVB-T2 signal. Consequently, if a country decides to move from DVB-T transmission to DVB-T2, it implies that DTT viewers would need to replace their terminals.

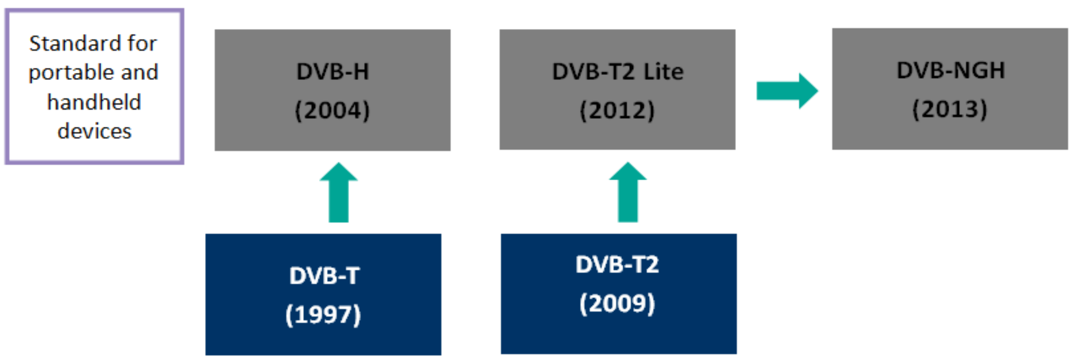
Some countries in Europe have already started using DVB-T2, and in parallel enabling HD services over the DTT network. The use of DVB-T2 is reserved for new HD services; DVB-T has remained for existing SD services. HD services may incentivise consumers to replace their DVB-T terminals with DVB-T2 (HD) receivers. The co-existence of the two versions (and simulcasting of SD/HD versions of TV services) is critical until a high percentage of audiences migrate to DVB-T2. This has implications for the use of UHF spectrum during the transitional period.

Other countries have not opted yet to migrate to DVB-T2, mainly due to the cost for viewers to replace their receivers.

## DVB-T2 Lite and DVB-NGH

Both DVB-T2 Lite and DVB-NGH are the DVB transmission standards for handhelds. DVB-T2 Lite is considered as the first step towards DVB-NGH.

**Figure F-4: Evolution of DVB standards for handhelds**




*Source: DVB.org*

## DVB-T2 Lite

The DVB-T2 Lite standard has been incorporated into the DVB-T2 standard in 2011, targeting receivers that are used in portable or handheld devices. DVB-T2 Lite is a subset of the DVB-T2 standard, but uses only a limited number of available modes that are best suited for mobile reception. The modes that require more complexity and larger amounts of storage memory have been removed in order to reduce the complexity of DVB-T2 Lite only receivers so as to minimize the cost and power consumption of handheld devices.

Thanks to the Multiple Physical Layer Pipes (MPLP) features in DVB-T2 standard, DVB-T2 Lite allows the mixing of multiple services with different robustness settings in one multiplex. Therefore, no modification is required to the multiplex when transmitting the DVB-T2 Lite signals via DVB-T2 multiplex. Moreover, the Future Extension Frames (FEF) had been incorporated into the DVB-T2 standard to allow for the inclusion of future improvements in modulation technology. With FEF, it is possible to share the capacity of one frequency channel between different T2 signals, with each signal having specific time slot, i.e. the FEF mechanism allows DVB-T2 Lite to be transmitted in parallel with DVB-T2 via the same RF channel.

DVB-T2 Lite trials have taken place in some European countries recently. In Italy, RAI used the same DVB-T2 multiplex for transmitting both fixed and mobile terminals. The trials in Copenhagen which launched on January 2012 use UHF channel 39 to cover more than 700,000 households.

## DVB-NGH (Next-Generation Handheld)

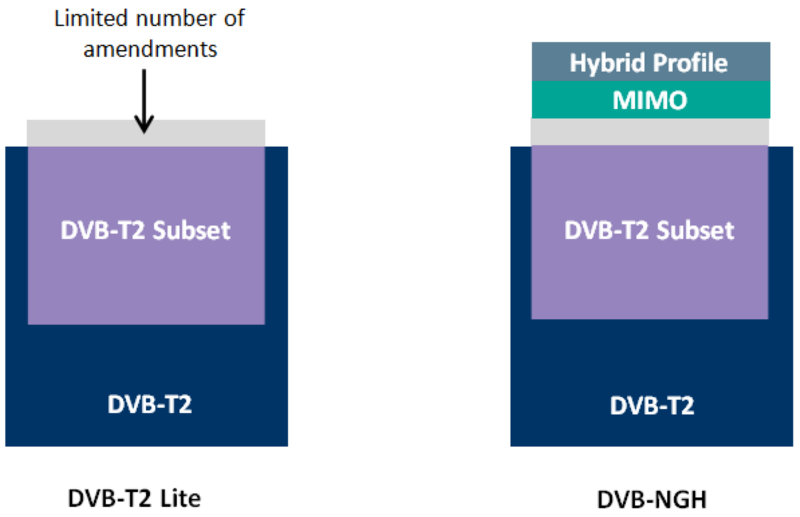
DVB-NGH is based on the DVB-T2 standard, covering advanced modulation and coding technologies designed to future proof broadcast to handheld and mobile services.

DVB-NGH has been thought to be the successor to DVB-H, launched to provide linear TV and radio services to handheld devices, taking account the evolution of content consumption beyond traditional linear and into new forms of audio and video, including on-demand and push download to memory. According to DVB, the major improved of DVB-NGH is the robustness and indoor coverage expressed as 50% higher throughput than with DVB-H. Other advantages compared to DVB-H is the possibility to transmit DVB-NGH services in-band within a DVB-T2 multiplex in the same RF channel because of the Future Extension Frame (FEF) concept of DVB-T2. This feature alleviates the investment required to start providing DVB-NGH services, since it is possible to reuse the existing DVB-T2 infrastructure without deploying a dedicated DVB-NGH network.

Also, the Time Frequency Slicing (TFS) adopted in the DVB-T2 standard makes it possible to transmit one service across several RF channels with frequency hopping and time-slicing i.e. discontinuous transmission. Multiplex signals is spread across several linked frequencies, thus can give significant statistical multiplex gain of 20% and frequency planning gain of 5dB, compared with DVB-H.

Finally, it has a silicon footprint nearly half that of DVB-T2, made possible largely by memory savings. This implies longer battery-life and smaller chipsets – but it is not yet clear whether DVB-NGH solves the battery drain problems which are associated with previous use of DVB receivers in mobile handsets.

**Figure F-5: Differences between DVB-T2 Lite and DVB-NGH**




*Source: DVB.org*

DVB-NGH has several additional features, such as Multiple Input Multiple Output (MIMO) to overcome the Shannon limit of single antenna wireless communications and allowing the deployment of an optional satellite component forming a hybrid terrestrial satellite network topology to improve coverage in rural areas.

The standard defines four profiles:

- Base profile - Terrestrial transmission with single antenna and tuner on the receiver
- MIMO profile - Terrestrial transmission with multiple antennas on the transmitter's and receiver's sides the receiver requires two tuners to support MIMO mode
- Hybrid profile - Supports combination of terrestrial and satellite transmissions; it requires a single tuner on the receiver
- Hybrid MIMO profile - combination of MIMO and Hybrid profiles.

The new ETSI standard for DVB-NGH was published in 2013. Research indicates that there are no announcements of DVB-NGH trials carried out yet.

According to the DVB.org, the implementation options for DVB-NGH represent a solution for platform operators who are seeking to offer a mobile broadcast service – in contrast to broadcasters who might already committed to offering DVB-T2, for whom T2-Lite would be a better fit.  Again it is not yet clear to what extent DVB-NGH might lead to significant improvements in coverage for mobile handsets when compared with previous DVB standards.

DVB.org also believes that DVB-NGH could be used by mobile operators for capacity reasons, claiming that the broadcast modes available within the LTE/4G standard are not able to match what DVB broadcast modes can offer.

## MIMO

The Multiple Input Multiple Output (MIMO) is the use of multiple antennas at both transmitter and receiver to improve communication performance. MIMO is a key technology that allows for significant increased system capacity and network coverage area. It is already included in 4G cellular communication systems and internet wireless networks, e.g. WLAN, to cope with the increasing demand of high data rate services.

DVB-NGH is the world's first broadcast system to include MIMO technology. The introduction of MIMO in DVB-NGH is a key technology to provide a significant increase in system capacity and network coverage area. The implementation of multiple antennas at the transmitter and the receiver side is the only way to overcome the limitations of the Shannon capacity limit for single antenna transmission and reception (SISO) without any additional bandwidth or increased transmission power. DVB-NGH uses cross polar antennas MIMO system. In this system, one antenna uses vertical polarisation whilst the other uses horizontal polarisation, at both transmitter and receiver. Signal processing would be needed at the receiver to separate the two transmissions, since they are inevitably mixed partially together. By using this MIMO technique, up to twice the capacity could be gained.

DVB-T2 did not use the MIMO, but contains Multiple Input Single Output (MISO) as an option. This means that two transmitting antennas may be used to radiate the same transmitted signal as an SFN. Instead, adjacent symbols are transmitted repeatedly once by one and once by the other transmitting antenna in accordance with modified Alamouti principle. This is an attempt to come closer to the Shannon limit, especially in the mobile channel.

Currently the technical module in DVB Group has formed the study group which aimed to determine the possibility to employing MIMO in the current terrestrial broadcasting systems. In particular, the study group focused on:

- The likely design, construction and appearance of a MIMO domestic antenna to achieve the spectral efficiency gains and the cost of such an antenna relative to an existing terrestrial antenna
- Co-existence of existing DVB-T/T2 broadcasts with new MIMO broadcasts and the implications on network frequency planning
- The implications of MIMO on a domestic terrestrial installation, such as new cabling requirements, additional RF mixers/muxes/amplifiers, etc.
- The related consequences on a receiver RF design, such as the number of tuners required and the number of external connectors, particularly for PVRs, including the cost relative to a DVB-T2 design
- The implications of MIMO on a broadcast installation, such as additional antenna arrays, additional RF amplifiers, additional power consumption, etc.

## Appendix G: Mixed vs single genre channels

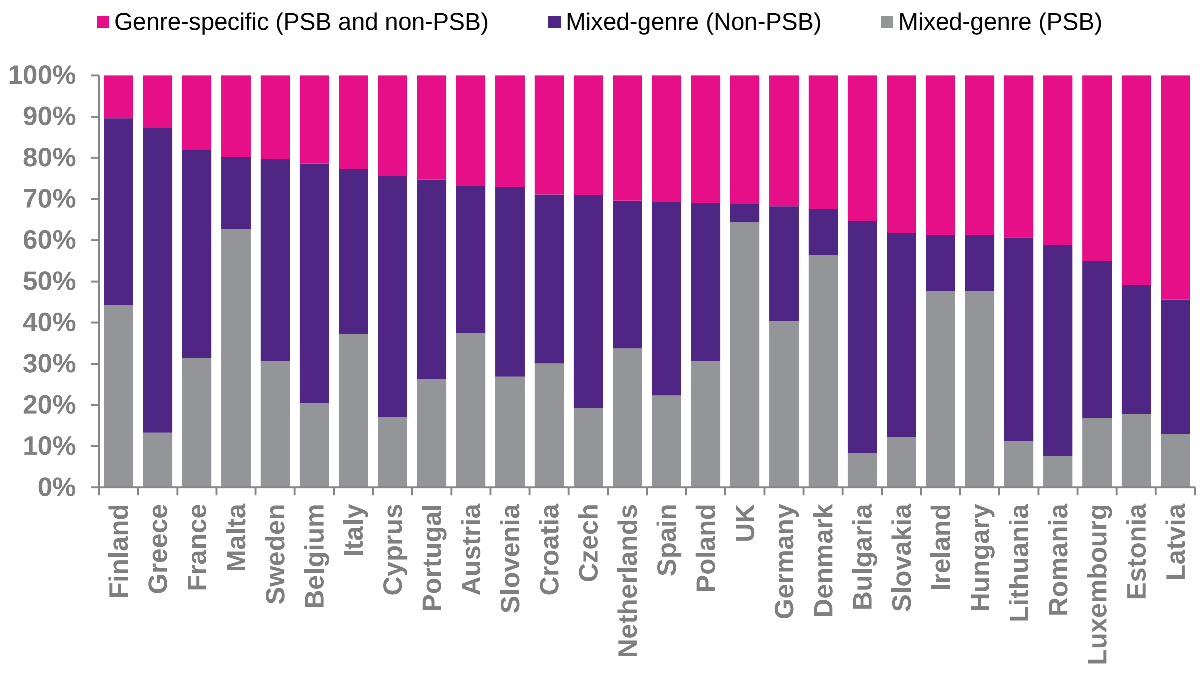
### G.1 Viewing share by channel type

In the old world of analogue terrestrial television, television audiences viewed a small number of channels, each showing a range of content types, usually including news, drama, documentaries, general entertainment shows, sports and many other genres. In most countries, these channels were provided by a combination of Public Service Broadcasters (PSBs) and commercial broadcasters, with some countries more heavily weighted towards one type of broadcaster than the other.

As the TV landscape has shifted towards multichannel platforms, with tens or hundreds of channels, we have seen the majority of viewing staying with these traditional mixed-genre channels, and the remainder of viewing moving to a long-tail consisting of mostly genre-specific channels.

We have divided the existing channels on multi-channel platforms in each EU market into mixed-genre and genre-specific channels, and calculated the viewing share of each channel type, as shown in Figure G-1.

Figure G-1: Percentage of Mixed-Genre and Genre-Specific content watched in EU-28 countries




*Source: EAVO, Farncombe analysis*

As Figure G-1 shows:

- **26** of the EU-28 countries have **>50%** viewing share on mixed-genre channels
- **24** of the EU-28 countries have **>60%** viewing share on mixed-genre channels
- **13** of the EU-28 countries have **>70%** viewing share on mixed-genre channels

We believe that the factors that lead to the share of viewing gained by these mixed-genre channels can be broken down into three groups:

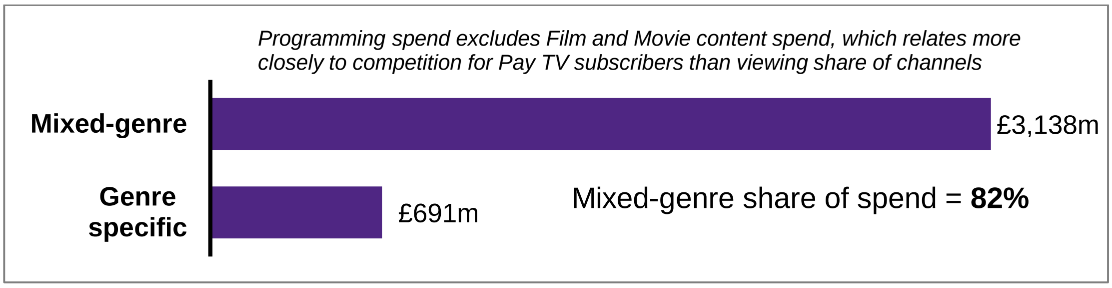
- Right content - High programming spend resulting in large proportion of quality, first-run (new) content
- Right time
  - Mixed-genre linear schedule caters to different viewing needs at different times of day.
  - New content is available first on linear channels.
  - Linear schedule allows sense of communal viewing of “appointment-to-view”[238] programming.
- Right place – a prominent position in EPG ensures high reach of channels.

When examining the viewing shares of these channels it is difficult to separate out the relative impacts of the above factors. We have looked at each of them in the following analysis and tried to provide a qualitative sense of the size of the effect.

## G.2 Right content

Taking the UK as an example, the programming cost on mixed-genre channels was 82% of the total spending on programming in 2012 (including both original and acquired content, but excluding Film and Sport spend). See Figure G-2. This 82% of content spend translates into a viewing share of just under 70% across all platforms. As shown in Figure G-3, first-run content makes up around 49% of total hours for the PSB channels, but only 12% of hours for genre-specific channels.

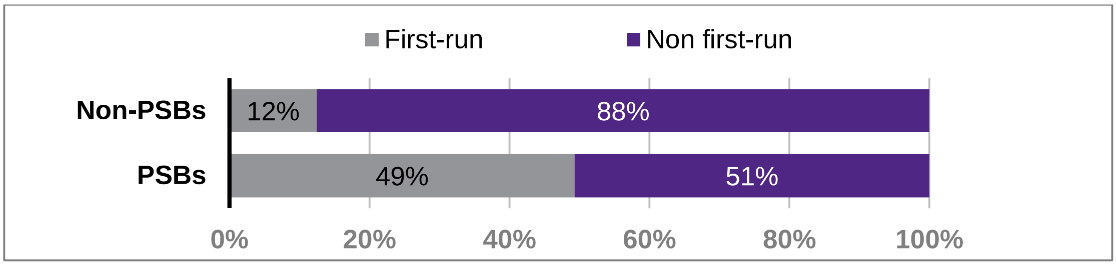
**Figure G-2: Programming cost of UK mixed-genre and genre-specific channels, 2012**




*Source: Ofcom*

[238] Programmes such as live sporting events or new episodes of prime-time drama which tend to be watch as close to live as possible

Figure G-3: First-run content for UK PSBs and non-PSBs (% of total hours)




*Source: Ofcom*

## G.3 Right time

Broadcasters often emphasise the importance of the linear schedule to linear platforms' success, especially in terms of the ability of broadcasters to create a varied schedule of genres and programme types through the day. This schedule, in theory, keeps the viewer interested and meets differing viewing requirements at different times of day (e.g. morning news and breakfast shows, afternoon entertainment, evening soaps and drama, late evening news and current affairs).

We do not have quantitative evidence to support how important this nature of the schedule actually is in terms of viewing share, but we believe that it does contribute to some extent.

The "timing" effects that we believe are *most* important in determining viewing share are:

- First-run programmes can be seen first through the linear schedule
- The linear schedule enables "appointment-to-view" programming

## G.4 Right place

In 2010, Attentional carried out an analysis of the impact on audience of EPG prominence across all TV platforms in the UK (DTT, Cable and Satellite).

A move up the EPG position was found to lead to a rise in audience share, and a move down found to lead to a fall. Of the 33 examples analysed in the study, 28 examples supported the argument that EPG positioning is likely to have a significant impact on a channel's viewing share. Figure G-4 shows some examples from the study.

**Figure G-4: Examples of EPG position from Attentional EPG position study in the UK**

| Platform | Channel Name | Position Change (Channel Rank) | Audience Share Change |
|---|---|---|---|
| DTT | E4 | Down 14 | -15.5% |
| Cable | Lifestyle Channel | Down 42 | -23.8% |
| Cable | Paramount Comedy 2 | Up 27 | +25% |
| DTH | Bravos2 | Down 28 | -36% |
| DTH | Discovery Realtime | Up 13 | +41.1% |
| DTH | G.O.L.D_1 | Down 22 | -21% |
| DTH | Men & Motors | Down 42 | -35.1% |
| DTH | ITV2+1 | Up 42 | +69% |

*Source: Attentional*

# Appendix H: How is content being watched?

## H.1 Introduction

OTT viewing is still in its infancy, as is the measurement of OTT viewing. Most data describing viewing trends in online video have so far been based on surveys (often with self-selecting samples), or on reports from the providers of OTT services. Furthermore, there is little consistency in the presentation of viewing data, meaning that comparisons between different measurements are difficult.

In this appendix we aim to present data with as little ambiguity as possible, in order to enable comparisons among measurements. In order to achieve this, we have set some definitions of viewing types and we examine each in turn:

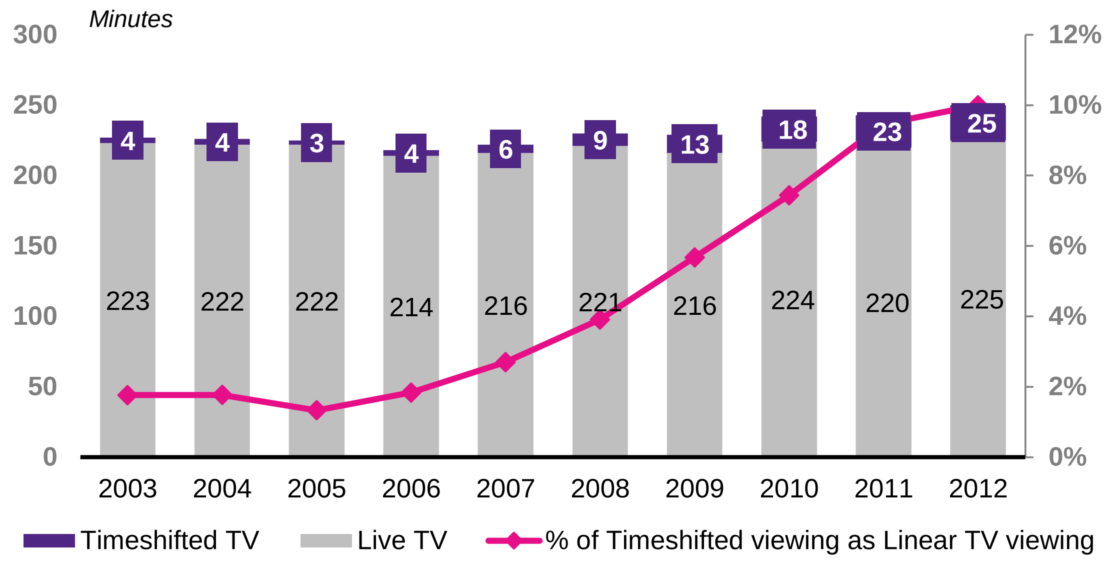
- Broadcast TV: Live TV
  - Video delivered over a broadcast (or IP-multicast) network and viewed live
  - We include viewing of linear OTT services where the content is a simulcast of a broadcast service
- Broadcast TV: Time-shifted
  - Video delivered over a broadcast (or IP-multicast) network and not viewed live
  - This includes paused/delayed broadcast content as well as previously recorded PVR content
- Broadcast TV: Catch Up
  - Video made available by broadcasters for on demand consumption within, usually, 30 days of first broadcast
- Non-broadcast TV
  - On demand content which is not Catch Up plus any live OTT content which is not broadcast
  - Includes archive broadcaster services, Subscription On Demand (SVoD) services and Transactional on Demand (TVoD) services

Where possible, we present data which maps exactly to these categories, though some data may overlap two or more categories.

## H.2 Broadcast TV: Live TV and Time-shifted

BARB data in the UK shows that the overall amount of time-shifted TV viewing is increasing in line with increased penetration of PVRs. See Figure H-1. Time-shifted viewing in households with PVRs has remained stable for several years, at around 15% of Live plus Time-shifted viewing, as can be seen in Figure H-2.

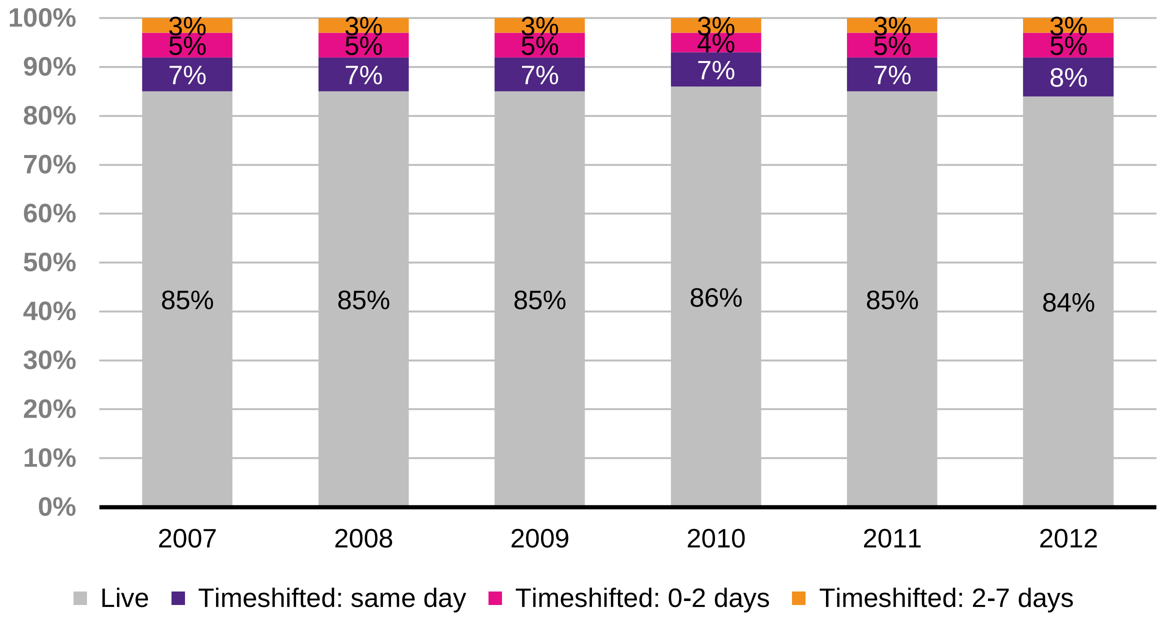
**Figure H-1: Average minutes per day spent viewing Live and Time-shifted content, UK**




*Source: BARB. Time-shifted viewing is defined by BARB as any programmes played back on a PVR within 7 days of first broadcast*

According to BARB, 81% of all time-shifted viewing was watched within two days of recording in 2013, and 47% of time-shifted viewing is seen within 24 hours of it being recorded.

**Figure H-2: Time-shifted viewing in UK PVR Homes**

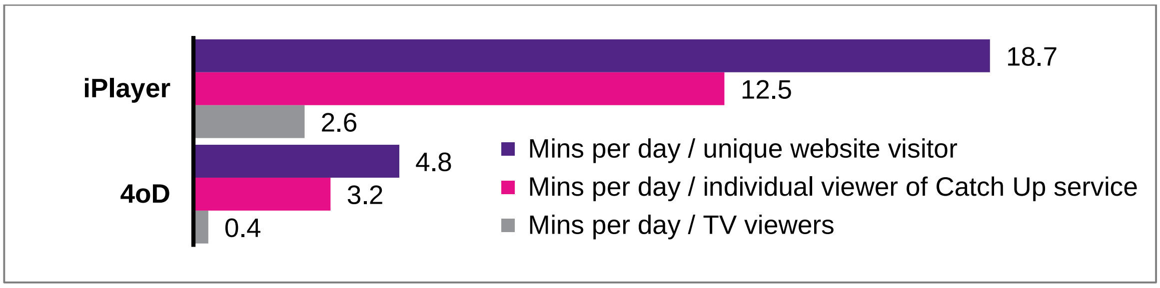


## H.3 Broadcast TV: Catch Up

We have examined reported figures for viewing of catch up services for Channel 4 and the BBC in the UK, as shown in Figure H-3. We have calculated the total minutes of catch up viewing for each service and then divided those minutes as follows:

- Firstly, among unique visitors to the service (as reported by the service) – a unique visitor usually means a unique device (e.g. PC, Connected TV etc.).
- Secondly, among individual viewers – this takes into account that individuals may use multiple devices, or that multiple people may watch an individual stream. We assume that there are 1.5 individual viewers for each unique visitor to the service
- Firstly, among all TV viewers – this allows us to compare viewing to average TV viewing for the population.

**Figure H-3: Viewing of broadcaster catch up services, March-April 2012**




*Total TV viewers = 57m; iPlayer unique visitors = 7.9m; 4oD unique visitors = 4.1m; Farncombe has assumed 1.5 individual viewers per unique website visitor; Source: Comscore, 4oD monthly report, Farncombe analysis*

Taken over all TV viewers, catch up viewing is clearly still low as a percentage of live broadcast viewing – around 1.2% for iPlayer, and 0.2% for 4oD. For users of the services, viewing is much higher (though we cannot say exactly, as average TV viewing will be different for these groups).

These overall figures agrees roughly with European data produced by Screen Digest, which estimates that in 2012, the average person in Western Europe spent 1.7 minutes per day watching on-demand, with 0.96 minutes spent watching TV episodes.

Screen Digest estimated that catch up content viewed *on the main TV set* represented the following percentages of total TV viewing on the main set:

- France: 1.8 per cent
- UK: 1.65 per cent
- Italy: 0.17 per cent
- Germany: 0.15 per cent
- Spain: 0.2 per cent

As Non-Broadcast TV covers so many types of services, some which are clearly complementary to TV and some which may be substitutive, it is the most difficult area in which to create a clear picture of usage.

We have looked at Virgin Media usage in the UK, as well as Netflix usage in the US.

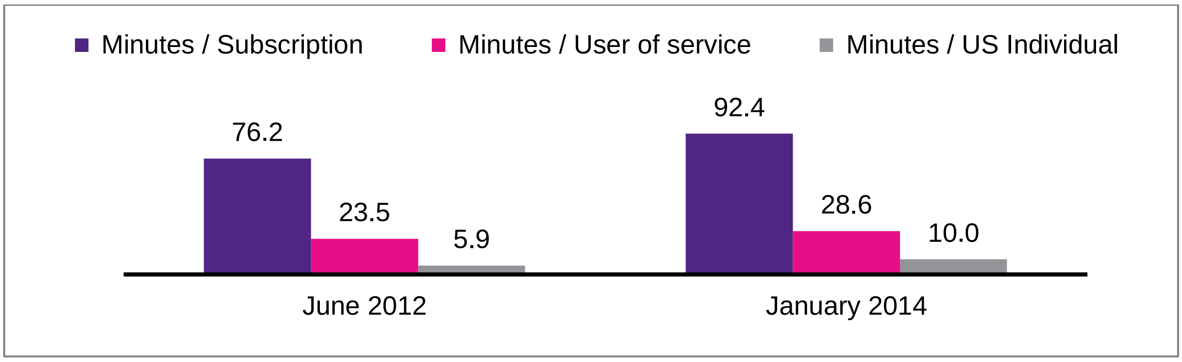
According to a Virgin Press release:

- Total on demand viewing in 2011 was 490 million hours
- Number of on demand subscribers in 2011 was 3.5 million

This implies average viewing for Virgin VoD subscribers of around 30 minutes per day, but will include some iPlayer usage, which was part of Virgin's VoD service in 2011.

Netflix reported in June 2012 that over 1bn minutes had been viewed worldwide during the month; in January 2014, over 2bn minutes was reported for the month. Taking into account the number of subscriptions in the US, and the reported percentage of the population that uses Netflix, we have estimated that Netflix viewing now accounts for nearly 30 minutes per day for people who use the service, and 10 minutes per day across the entire US population.

**Figure H-4: Netflix viewing minutes per day in the US (June 2012 and January 2014)**




*Source: Netflix, GfK, Farncombe analysis*

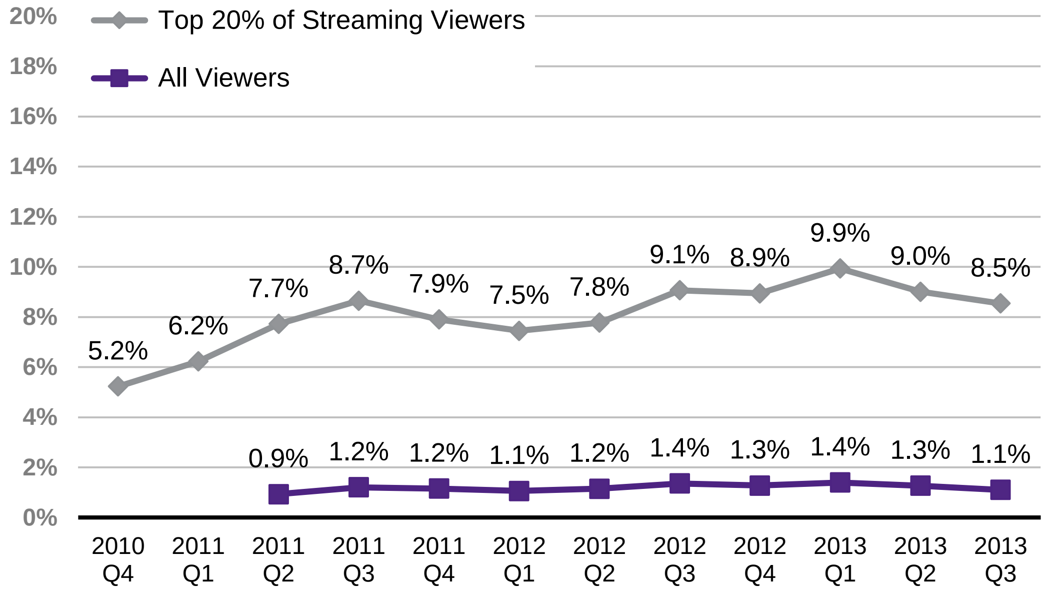
With average daily TV viewing of around 290 minutes per individual in the US, this represents around 10% of viewing for individuals who view Netflix and around 4% of viewing overall. Given that Netflix's content spend in the US is around 12% of the top 12 broadcasters', this is perhaps unsurprising, though significant, demonstrating the effect that a high programming spend can have on viewing levels.

## H.4 Overall streamed usage

Nielsen data indicates overall internet video streaming in the US accounts for just over 1% of all TV viewing minutes, a figure which has remained stable since Q2 2011.

Nielsen also reports streaming usage for the top 20% of streamers – for this segment, streaming accounts for nearly 10% of TV viewing, a figure which has, again, remained stable over the last 2 years.

**Figure H-5: Internet Video minutes viewed as % of Total TV minutes viewed**




*Source: Nielsen, Farncombe analysis*

However, Nielsen's streaming figures do not marry with the reported Netflix streaming volumes described in Section H.4, which suggest a higher percentage of viewing across a greater proportion of the population.

# Appendix I: Where is content being watched?

## I.1 Introduction

In this appendix we distinguish between **in home** viewing and **Out of home** viewing. **In home** viewing is broken down between:

- Viewing on the **Main TV set** and viewing on **Secondary sets**
- Secondary set viewing is broken down further between **Other Fixed TV sets** and **Portable devices**

**Out of home** viewing is broken down between:

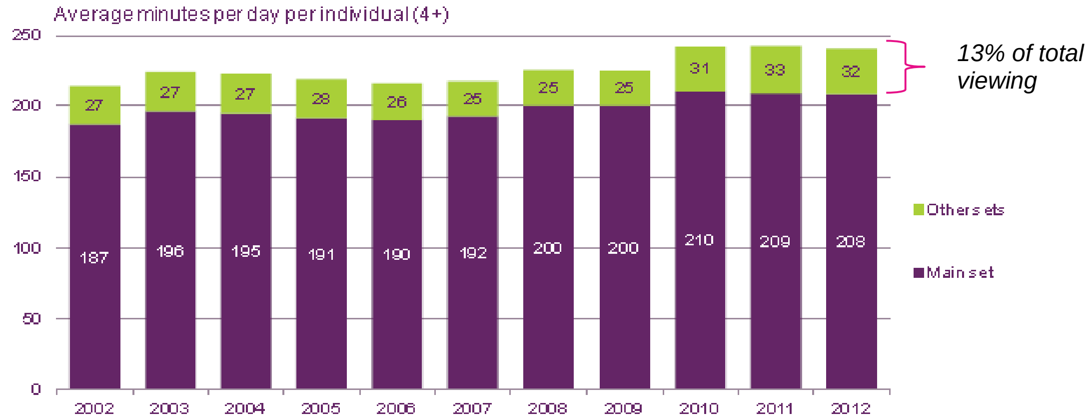
- **Fixed location** viewing (assuming access to fixed broadband, e.g. in an office, library, café etc.)
- **On-the-move** viewing. For our analysis of current consumption we assume that the majority of on-the-move viewing is done via mobile broadband or with pre-loaded content.

For **out of home** viewing we focus on viewing done on portable devices (mainly smartphones and tablets), and ignore other out of home viewing such as viewing on TV sets at work.

## I.2 In home viewing: Main TV sets

As shown in Figure I-1, Main TV set viewing in UK homes accounts for 87% of TV viewing on fixed TV sets – 208 minutes per day per individual in 2012. The ratio of viewing on the Main TV set to viewing on Other Fixed TV sets has remained stable over the last 10 years.  This data does not include viewing on portable devices.

**Figure I-1: Total TV viewing, Main TV set vs. Other Fixed sets, UK**



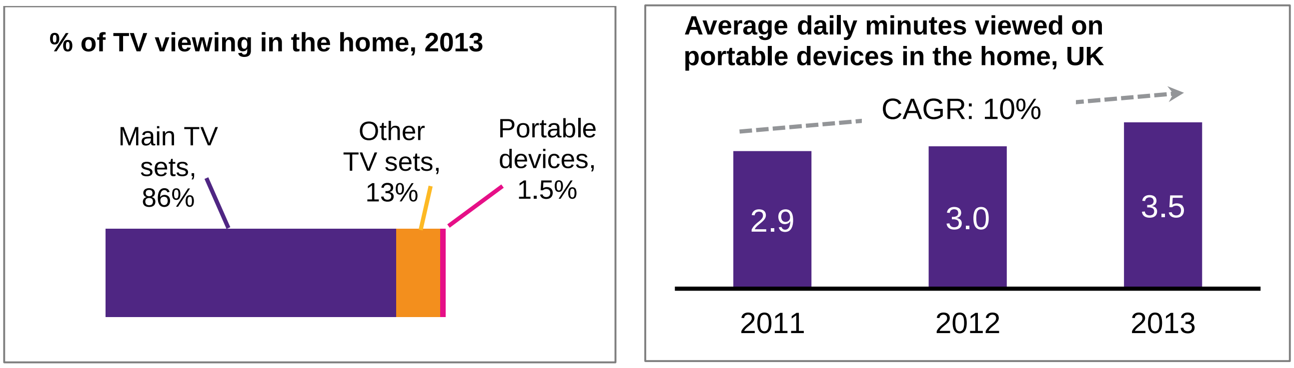

*Source: BARB, all individuals (4+), all homes. BARB Establishment Surveys – Annual Network Q2 reports. Note: i) New BARB panel introduced in 2010. As a result, pre- and post-panel change data must be compared with caution. ii) 'Main set' defined as set located in the living room. 'Other sets' defined as all other TV sets in the home.*

*Source: Ofcom*

# I.3 In home viewing: Other TV sets and Portable devices

Currently, of the TV viewing not done on the main TV set, around 90% is done on fixed TV sets and 10% on portable devices. This portable device viewing represents around 1.5% of total TV viewing, or a total of 3.5 minutes per day per individual (in the UK). It is important to note that these estimates include only TV originated content and do not include other content such as user generated content and content provided by pure OTT players.

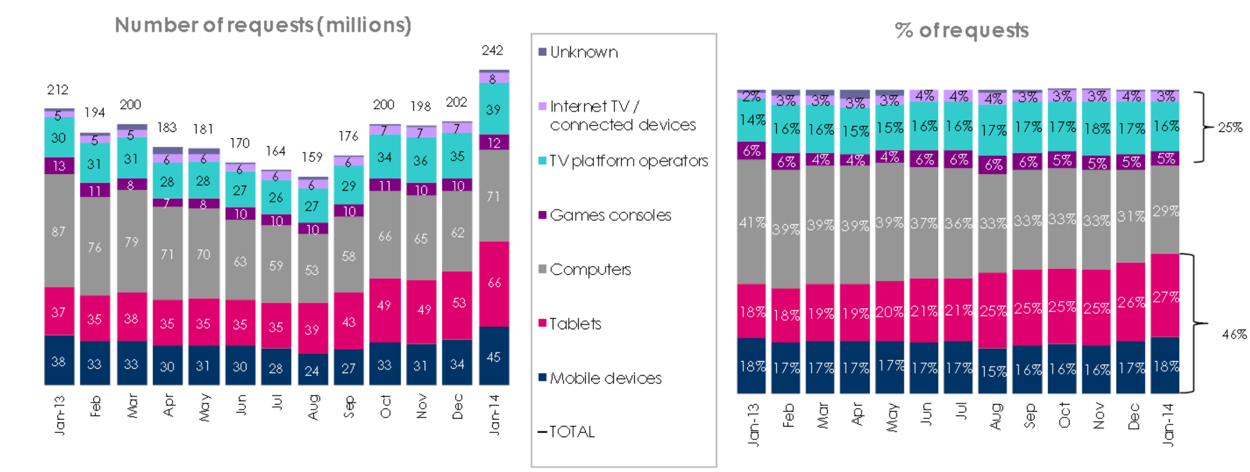
**Figure I-2: Portable device viewing in the UK**




*Source: Thinkbox, Barb, Farncombe analysis*

Growth of viewing on portable devices in the home was around 10% per annum from 2011 to 2013. Considering the low base, this is reasonably slow growth and does not suggest a big switch in viewing to portable devices in the near future. Of portable devices, an increasing amount of viewing is done on tablets, as shown in Figure I-3. Tablet viewing appears to be replacing viewing done on computers - with most other device types experiencing relatively slow growth.

**Figure I-3: BBC iPlayer usage across devices, 2013/2014**




Notes:
Due to a measurement fix, a greater number of tablets are now being correctly identified which caused a step change in tablet requests in August 13.
**Internet TV / connected devices** include Freeview and FreesatsmartTVs, set-top-boxes and devices like Roku and blu-ray DVD players.
**TV platform operators** include Virgin Media, Sky, YouView and BT Vision. **Games consoles** comprise Sony PS3, Nintendo Wii and Microsoft XBox360.
Some stats from PS3 devices were missing between 18 Feb – 21 May 2013.

*Source: BBC iStats*

## I.4 Out-of-home viewing: Overall

Recent evidence from an Ericsson survey[239] indicates that the portion of occasions on which video is watched is split by location as shown in Figure I-4 below.

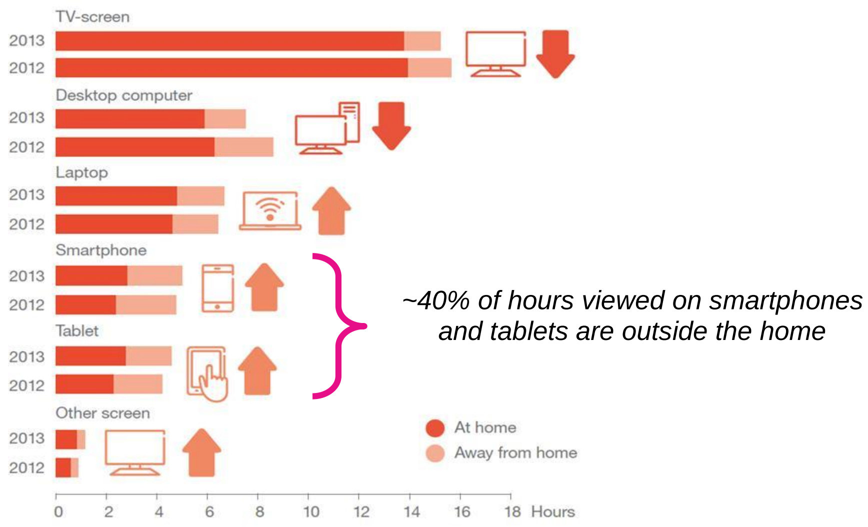
**Figure I-4: Out of home viewing frequency**

| Category | Location | % of viewing occasions | % of viewing time[240] |
|---|---|---|---|
| 1 | At home | 78% | 80.4% |
| 2 | At school/work/friend's house | 16% | 16.5% |
| 3 | Out and about | 2% | 1.0% |
| 4 | When commuting | 4% | 2.1% |
| | Total | 100% | 100.0% |

The table suggests that viewing times outside home and on-the-move (and so requiring nomadic or mobile services) account for around 3% of viewing time or around 7 minutes per day.

Further data from earlier Ericsson's ConsumerLab surveys (worldwide) indicates that, for smartphones and tablets, out of home hours of video viewed make up around 40% of total hours of video viewed on these devices, as shown in Figure I-5. Figure I-6 shows similar data from the US, indicating that, for TV content, 18% of tablet viewing occasions take place out of the home, and 36% of smartphone viewing occasions take place out of the home.

**Figure I-5: Average hours spent watching video per week – In home and Away from home**

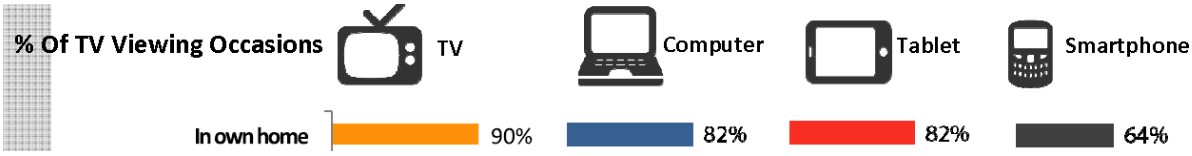



*Source: Ericsson ConsumerLab; Base: US, UK, Germany, Sweden, Spain, Taiwan, China, South Korea and Brazil, those who have and use the device.*

239 *TV and Media 2014*, an Ericsson Insight survey report, September 2014

240 Assuming that the duration of viewing in Categories 3 and 4 is 50% of the duration of viewing in Categories 1 and 2

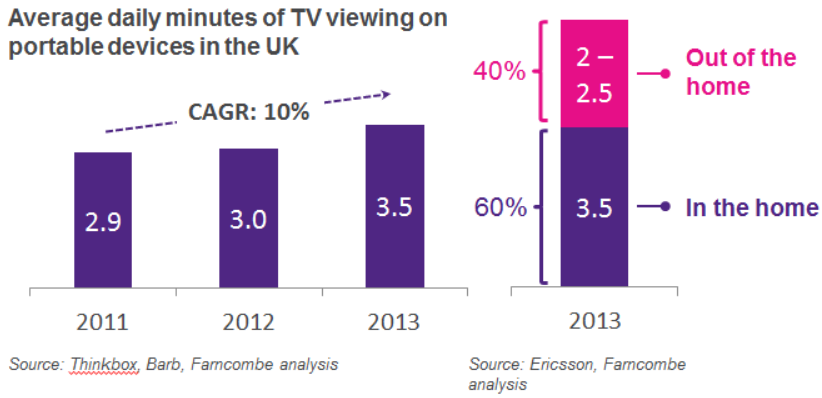
Figure I-6: In home viewing of video by device type, US, 2013




*Source: Council for Research Excellence*

Given the 3.5 minutes of daily portable device viewing that takes place inside the home, as described in Section I-1, we estimate that viewing on portable devices outside the home is the likely to be in the range of 2 to 2.5 minutes, as shown in Figure I-7.

Figure I-7: Out of the home viewing on portable devices




## I.5 Out of home viewing: Fixed location vs. On-the-move

We do not have conclusive data on the proportion of out-of-home viewing that is done on-the-move as opposed to in a fixed location.

In order to obtain an approximate figure for the total amount of video viewing that is done over mobile networks, we have examined Cisco Visual Networking Index data for 2013 and calculated a range of likely daily viewing minutes per member of the population, as shown in Figure I-8. We estimate that individuals watch between 1.5 and 3 minutes of video per day over mobile broadband. This includes both viewing on the move and viewing in static locations.

**Figure I-8: Cisco VNI – video delivered over mobile broadband in Western Europe**

| | 2013 |
|---|---|
| Video as % of mobile traffic: | **53%** |
| Western Europe mobile traffic: | **254** PB / month |
| Western Europe mobile video traffic: | **135** PB / month |
| Mobile video traffic per population: | **0.34** GB / month |
| How many minutes of mobile broadband video per person? | |
| @ 0.5 Mbps average bitrate | **3.0** minutes per day |
| @ 0.8 Mbps | **1.9** minutes per day |
| @ 1.0 Mbps | **1.5** minutes per day |

*Source: Cisco VNI, Farncombe analysis; Western Europe population assumed to be 400m*

In addition we have a recent survey by Quickplay[241] which indicates that 21% of viewing on portable devices is done on-the-move.

Finally we have findings of a survey of German TV viewers (see Figure I-9 below) which indicates that:

- 2.5% of German TV viewers use a portable device for live video streaming over the mobile network
- 2.6% use a portable device for live video streaming via Wi-Fi networks while out of the home
- 2.2% use portable devices with DTT reception while travelling
- 1.7% use portable devices with DTT reception at fixed locations when out of the home.

Based on these sources of evidence, our estimates on viewing via portable devices for 2013 are set out in Figure I-10.

[241] *2012 UK mobile TV/video consumption report*, Quickplay

Figure I-9: Use of portable devices outside the home in Germany

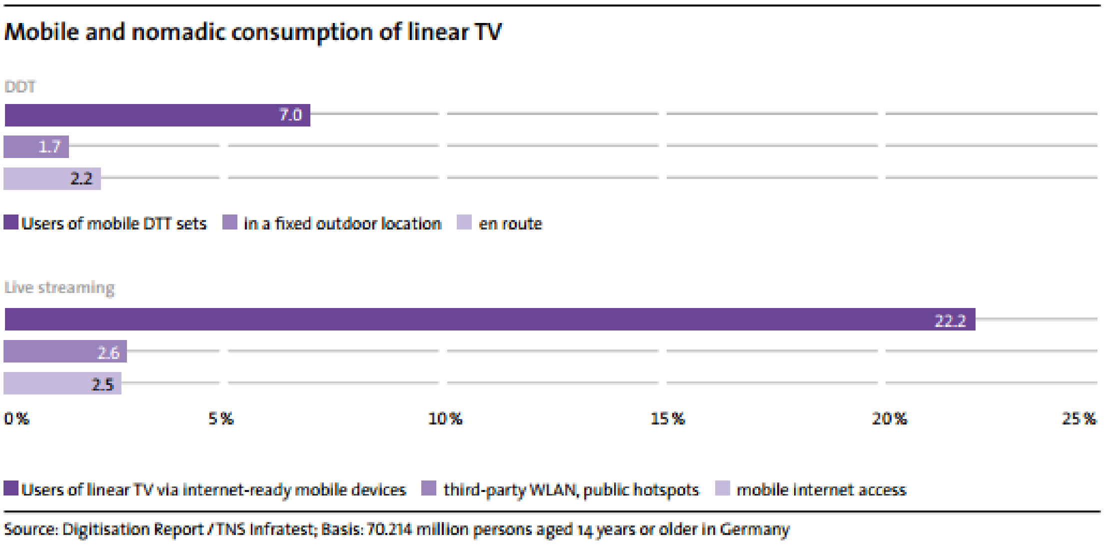



Figure I-10: viewing on portable devices

| Viewing situation | Minutes per person per day | Assumption/comment |
|---|---|---|
| In-house, TV originated content | 4 | See Figure I-2 |
| In-house, non-TV originated content | 4 | Assume as TV-originated |
| In-house total | 8 | Calculated |
| Out-of-home total | 6 | See Figures I-4 and I-5 |
| All portable viewing | 14 | Calculated |
| Out-of-home, all content, on the move | 3 | Quickplay survey – mainly pre-stored and mobile broadband |

We can see from the analysis set out above that:

- Evidence on the current patterns of out-of-home viewing are uncertain
- We need to supplement the available evidence with plausible assumptions about viewing patterns to get estimates
- Whatever plausible assumptions we use, we estimate that out-of-home viewing on the move accounts for no more than a few minutes per day per person
- The estimates of Figure I-10 are broadly consistent with the Cisco VNI estimate of Figure I-8.

# Appendix J: The main standards bodies

This appendix provides a brief description of the main standards bodies which develop AV standards. They are listed in alphabetical order.

**3GPP (www.3gpp.org):** The 3rd Generation Partnership Project (3GPP) unites six telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TTA, TTC), known as "Organizational Partners" and provides their members with an environment to produce the Reports and Specifications that define 3GPP technologies. The project covers cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities - including work on codecs, security, and quality of service - and thus provides complete system specifications. The specifications also provide hooks for non-radio access to the core network, and for interworking with Wi-Fi networks. 3GPP specifications and studies are contribution-driven, by member companies, in Working Groups and at the Technical Specification Group level.

**CELENEC (www.celenec.eu):** CENELEC is the European Committee for Electrotechnical Standardisation and is responsible for standardisation in the electrotechnical engineering field. CENELEC prepares voluntary standards, which help facilitate trade between countries, create new markets, cut compliance costs and support the development of a Single European Market. CENELEC creates market access at European level but also at international level, adopting international standards wherever possible, through its close collaboration with the International Electrotechnical Commission (IEC), under the Dresden Agreement.

**CEN (www.cen.eu)**: CEN, the European Committee for Standardisation, is an association that brings together the National Standardisation Bodies of 33 European countries. CEN is one of three European Standardisation Organizations (together with CENELEC and ETSI) that have been officially recognized by the European Union and by the European Free Trade Association (EFTA) as being responsible for developing and defining voluntary standards at European level. CEN provides a platform for the development of European Standards and other technical documents in relation to various kinds of products, materials, services and processes. CEN supports standardisation activities in relation to a wide range of fields and sectors including: air and space, chemicals, construction, consumer products, defence and security, energy, the environment, food and feed, health and safety, healthcare, ICT, machinery, materials, pressure equipment, services, smart living, transport and packaging.

**DVB Project (www.dvb.org)**: The Digital Video Broadcasting Project (DVB) is an industry-led consortium of over 200 broadcasters, manufacturers, network operators, software developers, regulators and other organisation to design technical standards for the delivery of digital media and broadcast services. The DVB Project develops specifications for digital television systems, which are turned into standards by international standards bodies. It does so through collaboration of its Members in numerous Working Groups. The Steering Board gives the final approval of the specification. It is then offered for standardisation to the relevant international standards body (i.e. ETSI or CENELEC) through the EBU/ETSI/CENELEC Joint Technical Committee.

**ETSI (www.etsi.org):** The European Telecommunications Standards Institute produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies. ETSI is officially recognized by the European Union as a European Standards Organization. ETSI is a not-for-profit organization with more than 700 ETSI member organizations drawn from 62 countries across 5 continents world-wide. ETSI is the recognized regional standards body dealing with telecommunications, broadcasting and other electronic communications networks and services. ETSI produces standards and specifications supporting EU and European Free Trade Association (EFTA) policy issues such as the New Approach, other EU legislation (e.g. Electronic Fee Collection, the interoperability regulation under the Single European Sky (SES) initiative, the Electronic Communication Network and Services Framework Directives), mandated activity and other EU initiatives (e.g. Strategy 2020 and Digital Agenda). ETSI works in close co-operation with the other 2 recognized European Standards Organization, namely CEN and CENELEC in order to co-ordinate activities.

**HbbTV Forum (www.hbbtv.org):** The HbbTV Association is a pan-European initiative aimed at providing an alternative to proprietary technologies and delivering an open platform for broadcasters to deliver value added on-demand services to the end consumer. The founding members of the HbbTV Association consists of both television broadcasters and CE companies, meaning that there is a common goal of creating services that broadcasters wish to offer while meeting the capabilities of today's CE devices. The consortium is open for new members and seeks wide participation in order to foster the market introduction and continued developments.

**ITU (www.itu.int):** The International Telecommunication Union is the United Nations specialized agency for information and communication technologies – ICTs. An organisation of public-private partnership since its inception, ITU currently has a membership of 192 countries and some 700 private-sector entities. ITU is headquartered in Geneva, Switzerland, and has twelve regional and area offices around the world. The ITU is active in areas including broadband Internet, latest-generation wireless technologies, aeronautical and maritime navigation, radio astronomy, satellite-based meteorology, convergence in fixed-mobile phone, Internet access, data, voice, TV broadcasting, and next-generation networks. The ITU comprises three sectors, each managing a different aspect of the matters handled by the Union, as well as ITU Telecom:

- *Radiocommunications (ITU-R)*, managing the international radio-frequency spectrum and satellite orbit resources.
- *Standardization (ITU-T)*, ITU's standards-making sector.
- *Development (ITU-D)*, Established to help spread equitable, sustainable and affordable access to information and communication technologies.

**Open IPTV Forum (www.oipf.tv):** The Open IPTV Forum enables and accelerates creation of a mass market for IPTV by defining and publishing free-of-charge, standards-based specifications for end-end IPTV services of the future. The forum is fully open to participation across the communications and entertainment industries with members including network operators, content providers, service providers, consumer electronics manufacturers and home and network infrastructure providers. In June 2014, the activities of the Open IPTV Forum (OIPF) were transferred to the HbbTV Association.

# Appendix K: DVB-S/S2 standard for satellite TV

In November 1994 DVB-S was recommended by the ITU for satellite use in the 11/12GHz frequency range, and indeed the world's first digital satellite TV services were launched in Thailand and South Africa at the end of 1994 using the newly released system. Over time it has become the most popular system for the delivery of digital satellite television around the world.

Ten years on, the advent of HDTV meant that more efficient satellite delivery systems were required, and in April 2005, DVB announced the ratification of its next-generation satellite standard, DVB-S2, by the European Telecommunications Standards Institute (ETSI). The new standard permits optional backwards-compatible modes; legacy DVB-S receivers can continue operating alongside DVB-S2 ones.

According to DVB, DVB-S2's performance comes close to the Shannon limit, and typically delivers an increase in the useful bit-rate of more than 30% against DVB-S. Comparative bit-rates are shown in the table below for a 27.5MHz transponder broadcasting at two different power-levels, 51 and 53.7 dBW, using typical modulation and FEC schemes. Figure K-1 shows.

**Figure K-1: Comparison table between DVB-S and DVB-S2**

| Satellite EIRP (dBW) | 51 | | 53.7 | |
|---|---|---|---|---|
| System | DVB-S | DVB-S2 | DVB-S | DVB-S2 |
| Modulation and Coding | QPSK 2/3 | QPSK ¾ | QPSK 7/8 | 8PSK 2/3 |
| Useful bit-rate (Mbit/s) | 33.8 | 46 (gain = 36%) | 44.4 | 58.8 (gain = 32%) |
| Number of SDTV programmes | 7 (MPEG-2)<br>15 (H.264) | 10 (MPEG-2)<br>21 (H.264) | 10 (MPEG-2)<br>20 (H.264) | 13 (MPEG-2)<br>26 (H.264) |
| Number of HDTV programmes | 1-2 (MPEG-2)<br>3-4 (H.264) | 2 (MPEG-2)<br>5 (H.264) | 2 (MPEG-2)<br>5 (H.264) | 3 (MPEG-2)<br>6 (H.264) |

*Source: EBU Technical Review (10/04)*

Once published in March 2005, DVB-S2 was rapidly adopted to meet consumer demand for new HD services. In Europe and the USA it is typically used in conjunction with MPEG-4/H.264 advanced video coding. Examples of its use for HD deployment include BSkyB in the UK and Ireland, Sky Deutschland in Germany, Sky Italia in Italy, and DirecTV in the USA). DVB-S2 has also been deployed in the Americas, Asia, the Middle East and Africa. By August 2012, more than 250m DVB-S/S2 receivers had been deployed globally[242].

In early 2014 new extensions to the DVB-S2 specification have been approved. The new enhanced specification, known as DVB-S2X, offers spectral efficiency gains for professional applications by up to 20 -30% and for some scenarios, gains of up to 50% can be achieved. In addition, new operational modes such as channel bonding increase flexibility. The specification will be sent to ETSI for formal standardization and the DVB-S2X BlueBook will be published shortly.

[242] Source: DVB

The key impetus for the new DVB-S2X specification came from the providers of professional services and applications wishing to take advantage of technological advancements and the growing demand for their services. The timely approval of DVB-S2X means it can be implemented with HEVC, the latest video coding scheme (see below). It is anticipated that the volume demand for chip sets and equipment will be driven by consumer internet services and broadcasts of UHDTV with HEVC coding via DTH satellites.

DVB-S2X provides more choices for roll-off factors as well as additional modulation and Forward Error Correction (FEC) options that allow for the more efficient use of satellite transmission channels.

Other key improvements to DVB-S2 include the inclusion of DVB-GSE/GSE-Lite protocols which could facilitate the migration to full IP services in the future – particularly suited for broadcast/broadband service convergence in the home network.

# Appendix L: Ultra High Definition Television

## L.1 Introduction

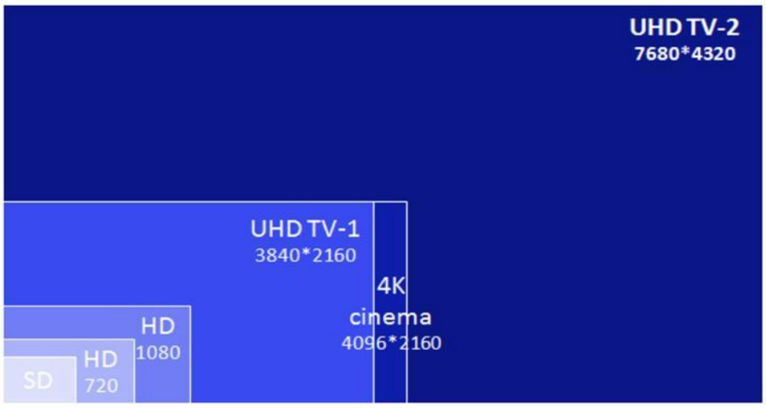
Ultra High Definition Television (UHDTV) is a new standard that represents the next step up from HDTV in terms of quality and immersiveness. Current discussions revolve around two different versions:

- UHD-1, which doubles the HD picture dimensions of 1920 x 1080 pixels to 3849 x 2160
- UHD-2 (based on Japanese broadcaster NHK's Super Hi-Vision (SHV) system), which quadruples them to 7680 x 4320 pixels.

Because UHD-1 uses four times the number of pixels and is nearly 4000 pixels wide, it is sometimes (mistakenly) referred to as '4K' (which is in fact a separate cinema standard[243]). Likewise, UHD-2, by analogy, is often referred to as 8K.

Figure L-1 shows conceptually how the number of pixels per screen has increased from SD to UHDTV.

Figure L-1: Graphical representation of usual video formats from SD to Ultra HD




The starting-point for UHDTV discussions is ITU-R BT 2020, which is a contribution rather than a distribution standard. This is very broad, but its salient characteristics are two different resolution levels, high frame-rates (BT 2020 references 24, 25, 30, 50, 60, and 120 fps), higher bit-depths (up to 12-bit as compared to current HDTV displays' minimum 8-bit RGB specification), a different colourimetry or 'colour space', and a higher dynamic range (e.g. 'blacker' blacks).

Figure L-2 shows the two permitted approaches to UHDTV picture spatial characteristics.

[243] Strictly speaking 4K is the digital cinema's format and uses an image 4096 by 2160 pixels

**Figure L-2: Variants of UHDTV and range of permitted frame rates**

| Parameter | Values | |
|---|---|---|
| Picture aspect ratio | 16:9 | |
| Pixel Count (Horizontal x vertical) | 3840 × 2160 | 7680 × 4320 |
| Sampling lattice | Orthogonal | |
| Pixel aspect ratio | 1:1 (square pixels) | |
| Pixel addressing | Pixel ordering in each row is from left to right, and rows are ordered from top to bottom. | |
| Frame frequency (Hz) | 120, 60, 60/1.001, 50, 30, 30/1.001, 25, 24, 24/1.001 | |
| Scan mode | Progressive | |

*Source: ITU*

## L.2 UHD-1

In the near-term, for all practical purposes, UHD-1 is the focus of industry discussion. Despite the fact that so-called ‘4K’ or ‘UHD’ TV sets are already available at retail, its precise parameters have yet to be agreed, and there is no content commercially available which can therefore be said to meet the standard. ‘4K’ Blu-Ray titles are, nevertheless, routinely bundled with UHD sets, using manufacturers’ own proprietary interpretations.

By implication, the requirement for a more immersive experience demands much better audio, which is not addressed by BT2020. NHK has proposed ’22.2’ surround-sound for 8K, but the likelihood is that to address current living-room technology set-ups, new ‘virtual’ or ‘object-based’ audio systems might have to be created for this purpose to deliver a quality superior to Dolby 5.1, for instance.

In September 2013, Digital Europe, the digital technology industry body that is developing a logo programme for UHD consumer equipment, said its recommended ‘baseline’ capabilities for UHD Consumer Displays were as follows:

- Native Resolution: 3840 x 2160 Pixels
- Aspect Ratio: 16:9
- Colorimetry: ITU-R BT.709
- Colour Bit depth: 8 Bit
- Frame Rate: 24p/25p/30p/50p/60p
- Audio: PCM 2.0 Stereo

Digital Europe defined these as “short-to-medium term UHD Consumer Display capabilities”, saying it did not “want to speculate beyond the baseline UHD characteristics until the consumer uptake of the new UHD products and services is understood”.

Using these minima at a rate of 50 fps implies that a basic UHD-1 picture would generate around four times the raw data-rate of Full HD (1080p/50), viz. around 4.8GBit/s.

However, these minima are well below what European broadcasters imply is needed to generate the desired 'immersive' effect. The consensus appears to be that a colour bit-depth of 10 bits, with a frame-rate of at least 50 fps, is what is required.

Figure L-3 is an example of potential bandwidth requirements for UHD-1 content and the differences between on-demand and linear consumption.

**Figure L-3: Indicative (delivery) bitrate requirements for UHD-1 content**

| | Movie on Demand | Live Sport |
|---|---|---|
| Resolution | 3840 x 2160 | 3840 x 2160 |
| Frame rate | 24 fps | 60 fps |
| Color space | 10 bits | 10 bits |
| 1080i equivalent | 4 x | 10 x |
| HEVC* | 12 Mbps | 25 Mbps |
| Diffusion examples | 11 GB per movie | 2 or 3 channels per DVB-S2 transponder |

*Source: Envivio*

Linear encoding has higher requirements as content is compressed on real-time. On-demand encoding allows for multiple compression iterations reducing the output bitrate required

A wide range of industry bodies are discussing these issues, including DVB, the EBU, MPEG/ITU, the Blu-ray Disc Association, HbbTV, FAME, ATSC, and FoBTV. The standardisation process is mainly being co-ordinated by SMPTE, ITU-R, DVB and Digital Europe.

The industry consensus appears to be that the first commercial UHD-1 services are at least two years away.

## L.3 UHD-2

A DVB-EBU fact-finding meeting convened in July 2013 came to the consensus view that the most likely European parameters for UHD-2 (aka 8K) would be 4320p100 – i.e. 7680 × 4320, with the lines scanned progressively 100 times a second (100 fps). The meeting suggested that commercial deployment was "2020+".

Clearly, UHD-2 is a lot further from commercial deployment than UHD-1. In some ways, this is down to NHK, which has driven the standard. It has had prominent 8K demonstrations at industry exhibitions such as IBC in Amsterdam, and recently sent a small technical team to the Sochi Winter Olympics to test and record events in 8K.

**Figure L-4: 8k SHV video parameters (from Rec, ITU-R BT.2020)**

| Parameter | Value |
|---|---|
| Pixel Count (Horizontal x vertical) | 7,680 x 4,320 |
| Frame frequency (Hz) | 120, 60 |
| Scan format | Progressive |
| Quantization | 12-bit, 10-bit |
| Colour system | Wide gamut RGB |

*Source: NHK*

NHK says it is planning to begin satellite broadcasts of 8K content for 2020, which would align with the Tokyo Olympics in that year. The broadcaster's own definition of 8K (which falls within the BT 2020 standard) is that it should have a frame-rate of 60 fps or 120 fps (due to its NTSC inheritance)[244], use 12-bit or 10-bit quantisation, and that the colour system should be 'wide gamut RGB'. As already mentioned, NHK has also specified 22.1 audio surround-sound for 8K, but outside Japan this is regarded as unrealistic.

Currently its own test implementations only support 60 fps, arguably insufficient for sports coverage – and therefore current research efforts are concentrated on increasing this to 120fps. Ultimately, the parameters for 8K will probably have to involve a compromise between NHK and the rest of the world, or its commercial deployment post-2020 will be slow – if not confined to Japan.

Figure L-5 shows a summary of all the above exposed formats.

**Figure L-5: Summary of video formats, typical encoding and bit-rates**

| Format | Typical bitrate range (Mbit/s) | Resolution | Frame-rate | Typical encoding |
|---|---|---|---|---|
| SD (576i/25) | 2.5 – 5 | up to 768 x 576 | 25 fps | MPEG-2 |
| Legacy HD (720p/50) | 5 – 9 | 1280 x 720p | 50 fps | AVC (H.264) |
| Legacy HD (1080i/25) | 5 – 9 | 1920 x 1080i | 25 fps | AVC (H.264) |
| HD (1080p/50) | 8 – 15 | 1920 x 1080p | 50 fps | AVC (H.264) |
| Ultra HD-1 | 8 – 25 | 3840 x 2160p | 50 fps | HEVC (H.265) |
| Ultra HD-2 | To be defined | 7680 x 4320p | 100 fps | To be defined |

*Source: Harmonic, Farncombe*

[244] In the USA and Japan, 60/120 fps are used as frame rates instead of the 50/100 fps used in the "DVB world"

# Appendix M: Three-dimensional Television

## M.1 Introduction

In April 2010, BSkyB in the UK became the first pay-TV operator outside Japan to launch a 3DTV service with its 3D channel, Sky 3D – a sign of the surge of interest the technology provoked among the broadcasting community at the beginning of the decade.

Sky's channel is still broadcasting, but many other operators who followed suit around the world have closed their 3D channels down, including Foxtel in Australia, ESPN in the USA, and Canal+ in France.

Last summer, the BBC, which had high hopes the London Olympics would spark the same enthusiasm for 3D as the Beijing Games did for HD in 2008, announced it was suspending 3D broadcasts indefinitely, because of a "lack of public appetite" for the technology.

Although it has proven appeal in the cinema for certain genres of movie, 3D has never really taken off on TV. Indeed, one of the reasons why TV set manufacturers are so keen to bring UHDTV sets to market ahead of UHD specifications being pinned down is that 3D capability is no longer a primary selling-point.

Nevertheless, 3DTV still needs to be factored into the standards mix because it may well retain niche appeal as a premium product for certain genres. As screen sizes grow larger, it is arguable that the format will increase its appeal as a more 'cinema-like' experience becomes possible in the home.

There are potentially many different models for delivery of 3DTV. The two principal modes are:

- Capture two HD frames (one for the left eye and one for the right) simultaneously, squeeze them down to fit into one HD frame, and deliver them through existing infrastructure (the current BSkyB model). This is called 'frame-compatible' delivery
- Capture two HD frames (L & R) simultaneously, transmit one of them (e.g. the L frame) as it is, and then add an extra element (the 'delta') containing the difference between the left and right frames. This is called 'service-compatible' delivery, and does not exist commercially yet.

These two models have different implications.

## M.2 Frame-compatible 3DTV delivery

The first re-uses everything in the existing transmissions chain, including the set-top box, but requires an HDTV set with 3D capability. However, the signal cannot be viewed on ordinary 2D HD sets, so this mode implies a requirement for simulcasting (e.g. two separate channels for a sports event, one in 2D, one in 3D).

The bit-rate required is equivalent to a *single* HD transmission with a bit extra (the same coding efficiency cannot be obtained when compressing L and R HD frames into a single HD frame).

Meanwhile, resolution is *half* that of a conventional HD transmission, because this model requires squeezing two HD frames into a single frame: thus half the resolution of each L and R frame is lost.

That said, since the human perception system superimposes the two frames on top of each other to produce a single image, it has been found that there is an additive effect that makes it look better than simple SDTV.

This mode is best suited to a high-bandwidth environment such as satellite or cable because of the need for simulcasting.

## M.3 Service-compatible 3DTV delivery

This requires a new set-top box *and* a 3D-compatible TV set to view in 3D. However, the idea behind this mode is that the 3D transmission *can* be viewed in 2D on ordinary 2D HDTV set using an ordinary 2D set-top box.

This is because all the 2D transmission infrastructure detects are the single (L or R) 2D frames, ignoring the ‘delta’. However, a new 3D set-top box will recognize the ‘delta’ element, add it to the 2D element and create a 3D image from the two sources through a 3DTV display.

This means that simulcasting is *not* necessarily required.

In this case, the bit-rate is also equivalent to a *single* HD transmission (because there is only one HD frame), plus a bit more (the ‘delta’ element).

For this reason, this mode is best-suited to a low-bandwidth environment such as DTT.

## M.4 ‘True’ HD 3DTV

It would be possible to transmit full-resolution HD frames without ‘squeezing’ them, but at double the frame-rate (e.g. 50 fps instead of 25 fps), alternating left and right fields. This mode, which would require twice the bit-rate, could still theoretically re-use the existing transmission infrastructure, but there would be a question as to whether current HD set-top boxes would be able to cope without some sort of upgrade – because of the higher bit-rates required. It would probably also require a different type of display technology.

There is no inherent reason why the human perception system would not perceive this as 3D, since rapid L and R field alternation is one of the techniques used by the 3D glasses required for viewing 3DTV. Clearly, the extra bit-rate requirement would require a satellite or cable variant, most likely using HEVC coding.

## M.5 DVB-3D Standards

DVB has published a Frame-Compatible 3DTV broadcast specification (ETSI TS 101 547-2 V1.2.1 (2012-11) as well as a Service-Compatible one (ETSI TS 101 547-3 V1.1.1 (2012-11). The standards body announced at IBC 2013 that it would introduce a complement to the Frame-Compatible specification in 2014 that allowed higher-resolution L and R images to be broadcast through the use of 1080p50 instead of 1080i25 as the HD ‘frame’.

# Appendix N: The throughput from an LTE FWA network

The table below lists the assumptions and calculations used to assess the likely performance of FWA broadband using 2x20 MHz of 2.6 GHz spectrum and 4x4 MIMO antennae with roof mounted aerials at the end-user premises.

| Variable | Value | Comment |
|---|---|---|
| Rural cell size | 5 km radius | Assumes roof mounted 4x4 MIMO aerial |
| Area overall cell | 78 km$^2$ | Calculated |
| Number of households in a marginal rural cell providing 95% population coverage | 1200 | Based on UK rural population distribution |
| Number of households using FWA | 800 | 67% take-up of FWA given competition from ADSL and satellite |
| Throughput per cell in the busy hour:<br>theoretical<br>Practical | <br><br>480 Mbps<br>336 Mbps | [1] *Infrastructure analysis and solutions for 800 MHz deployment*, KTN, May 2011<br>Assuming 70% utilisation |
| Throughput per user | 29 GB per month[245] | Assuming 20% of AV traffic in the busy hour |
| Typical download speed | 20 Mbps[246] | Assuming a contention ratio of 50:1 |

[245] [336 Mbps x 3600 seconds per hour x 30 days per month]/[20% x 800 HH x 8 bits/byte]

[246] [336 Mbps x 50]/800 HH

# Appendix O: Replication of established AV services by online services

## O.1 Introduction

To replicate existing AV services and, in particular, mixed genre channels, an online service would need to:

- Provide high quality and original content
- Offer varying schedules designed to meet the needs of different audiences throughout the day
- Provide easy methods for viewers to discover content of interest
- Have the potential to reach into a large number of homes.

In this appendix we consider the prospects for such replication and ask:

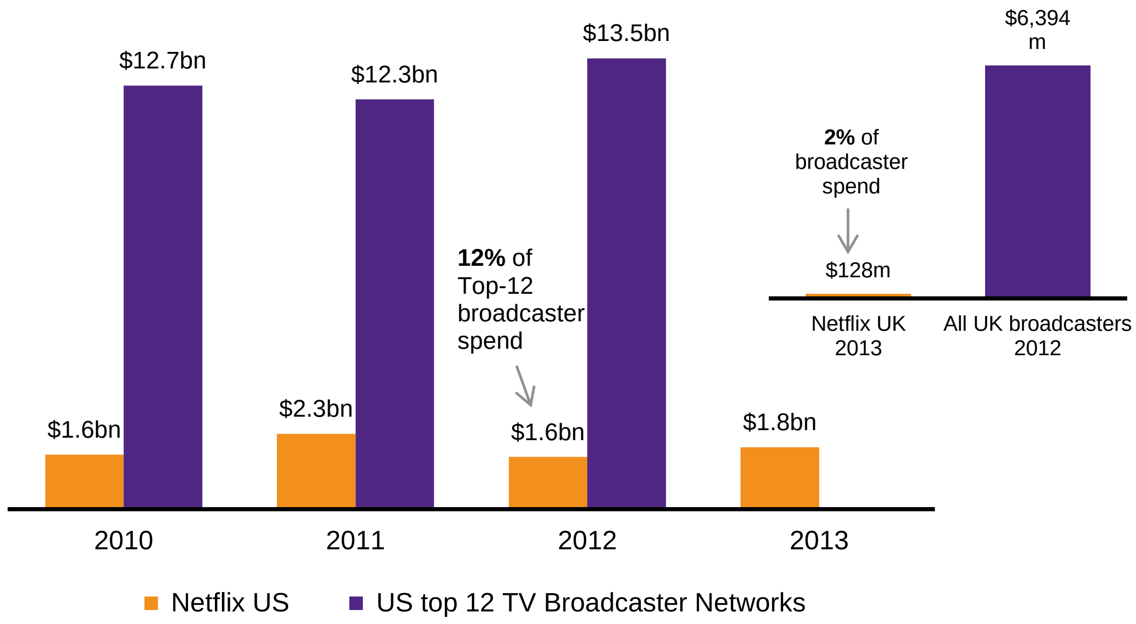
- Will there be changes to the technologies and business models in the delivery of IP content, which will allow IP platforms to accommodate future consumption demands?
- How quickly do we expect new technologies and business models to gain reach in markets across Europe?

## O.2 Original content / Programming spend

Where online services are operated by broadcasters (Catch up, SVoD, Hybrid, or Pure OTT) these services generally have a similar volume of original high quality content to traditional TV broadcasts. For other services (short form, UGC, non-broadcaster SVoD), the volume of original high quality content is significantly lower.

Despite Netflix's large programming spend, as shown in Figure O-1, this spending is small when compared with the broadcasters in its markets. In statements by senior staff, Netflix has indicated that it will continue to increase the amount of original content it creates, which is likely to increase its overall spending on programming, but we consider it unlikely that, in markets outside the US, Netflix spending will be significant compared to broadcasters.

Figure O-1: US and UK Broadcaster Programming Spend vs. Netflix




***US broadcaster spend:*** *SNL Kagan defines the programming spend as the direct cost of creating, acquiring, and distributing content and services; The top 12 US TV broadcaster networks comprise CBS, ABC, NBC, Fox, The CW, Univision, UniMas, Telemundo, ION, MyNetwork TV, Azteca America and Estrella TV*

***UK broadcaster spend f****or all broadcasters but excludes spending on Film and Sports; 1 GBP = 1.67 USD*

***Netflix UK spend:*** *Derived from Netflix reported International content costs and apportioned to UK based on relative number of subscribers in UK as proportion of total International Netflix subscribers*

*Source: Netflix, SNL Kagan, Farncombe analysis*

With non-broadcaster SVoD providers' current business model aimed at securing rights to long-tail archive content, supplemented by a small amount of high quality original programming, they should be limited to addressing some of the genre-specific broadcaster market, which accounts for between 10 and 50% of viewing share in the EU, depending on market. We believe that the remaining 50-90% of viewing share will continue to be addressed by the incumbent (PSB or commercial) mixed-genre broadcasters. Our overall assessment is set out below.

Figure O-2: OTT services' ability to match mixed-genre broadcaster spending on original content

| Spending on original content | OTT services not on hybrid platforms | | | OTT services on hybrid broadcast/OTT platforms | Pure OTT TV platforms |
|---|---|---|---|---|---|
| | Short form / UGC | Broadcaster Catch up / SVoD | Non-broadcaster SVoD | | |
| 2014 | Low | High | Low | High | High |
| 2030 | Low | High | Low-Medium | High | High |

*Source: Farncombe*

## O.3 Mixed genre/Linear schedules

Currently, any sort of on demand content performs poorly when compared to broadcasters in terms of delivering a linear schedule of content with the ability to drive appointment-to-view consumption (i.e. watching at a set time) and provide a range of programming tailored to the time of day.

Developments in recommendation engines for SVoD services, and playlists/channels on UGC sites mean that there is potential for a more linear-like experience to develop with these services.

However, these services (those not provided by broadcasters) are unlikely to have the range of content available (e.g. drama, soaps, news, current affairs, live sports) to create a truly compelling schedule.

By 2030, broadcasters may have developed sophisticated hybrid schedules of linear and on demand content. In March 2014, the BBC announced that it is to close the broadcast version of BBC3 and make programming from the channel available online only. It is possible that future developments of hybrid platforms will allow a mixed schedule of broadcast and online content. These conclusions lead us to the following assessment for 2030.

**Figure O-3: OTT services' ability to provide mixed-genre programming via a linear schedule**

| Mixed-genre programming via linear schedule | OTT services not on hybrid platforms | | | OTT services on hybrid broadcast/OTT platforms | Pure OTT TV platforms |
|---|---|---|---|---|---|
| | Short form / UGC | Broadcaster Catch up / SVoD | Non-broadcaster SVoD | | |
| 2014 | Low | Low | Low | Low | High |
| 2030 | Low-Medium | Medium-High | Low-Medium | Medium-High | High |

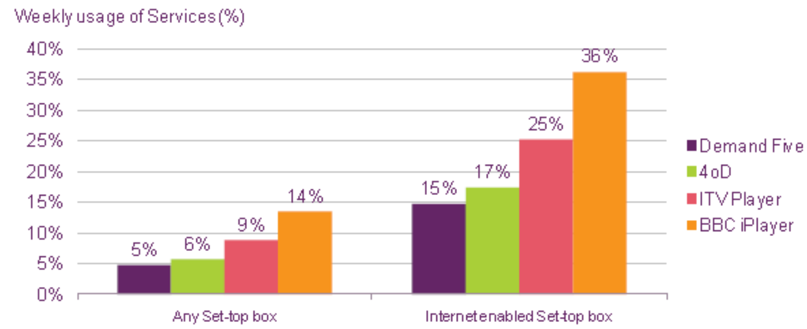
*Source: Farncombe*

## O.4 Ease of discovery

We have seen no evidence that indicates that viewing is going to move away from fixed TV sets in the household to any significant extent and we don't expect any substantial shifts from the TV set in the near future. We also expect the broadcast EPG (hybrid or otherwise) to remain the default point of access to video content on the TV set.

Currently, there is little integration between OTT and broadcast content on EPGs on the main TV set, except for on hybrid platforms with backwards EPGs such as YouView. There is some evidence that usage of on demand services is higher in households with connected set-top-boxes than in households without, as shown in Figure O-4. However, it is not evident from these data that the difference in usage is driven by the connected STB (these households may be more likely to use catch-up services anyway), and we cannot relate these data to overall usage of catch up services in the population, as other, non-STB devices, may also drive the use of catch up services.

**Figure O-4: Claimed weekly use of TV catch-up services via set-top boxes**




*Source: Mediabug Tracker, Decipher, February 2013 All set-top box owners (2805), All internet-enabled set-top box owners (920)*

We expect significant improvements in hybrid user interfaces over the next 15 years, to the extent that on demand services should become much more tightly integrated with the broadcast EPG. Some developments can already be seen in this area:

- YouTube on IPTV
  - YouTube announced in 2014 that it would be working with IPTV operators to make its channels available via their EPGs.
  - YouTube will provide operators with UI and playlist tools that allow the IPTV operator control of which YouTube content appears in viewers' EPGs.
- Netflix
  - In 2013 Netflix reached an agreement with Virgin Media in the UK to integrate its service with the cable operator's TiVo user interface; Netflix content appears alongside broadcast and other catch up content in TiVo searches.

We also expect to see development in the use of second screen (smartphone and tablet) applications for use as the primary user interface for television, which would lead to natural integration between broadcast and on demand content, given that second screens are currently used predominantly for on demand content.

Given this analysis our overall assessment is as follows.

**Figure O-5: OTT services' ability to match mixed-genre broadcaster ease of discovery**

| Ease of discovery | OTT services not on hybrid platforms | | | OTT services on hybrid broadcast/OTT platforms | Pure OTT TV platforms |
|---|---|---|---|---|---|
| | Short form / UGC | Broadcaster Catch up / SVoD | Non-broadcaster SVoD | | |
| 2014 | Low | Low | Low | Medium | High |
| 2030 | Low | Low | Low | High | High |

*Source: Farncombe*

## O.5 Reach of new services

### Introduction

By 2030 we expect short form and catch-up content to have high reach across all markets. Reach of non-broadcaster SVoD services is less predictable: while Netflix has gained high reach rapidly in the US, the success of SVoD platforms in Europe, where the average spend on TV services is much lower than in the US, is uncertain.

Despite the various standards designed to drive uptake of free-to-air hybrid broadcast/OTT platforms, level of uptake is uncertain.

Growth of Pure OTT TV platforms we see as heavily dependent on how technologies and business models develop. There are two key elements to this – the definition and creation of platforms and the availability and cost of devices.

### Definition and creation of Pure OTT TV platforms

As we have seen in the case studies of Pure OTT TV platforms discussed in Appendix B, several variants of this platform type have been launched, and as seen with the Intel On Cue service, we know that advanced user interfaces combining broadcast, catch up, SVoD and recorded content (via network PVR) are possible.

The main barrier to the success of these platforms is to legally obtain the rights to sufficient content to replicate and improve upon the current broadcast experience. The current solution seen with Magine in Sweden and Intel On Cue (regardless of the subsequent sale of On Cue to Verizon) is to pay carriage fees to broadcasters, meaning that a Pay TV business model is required.

In order to match and improve upon functionality of hybrid platforms, Pure OTT TV platforms will also need to provide network PVR services, which currently face resistance by content rights owners in many markets.

There are many ways in which accepted business models in the broadcast ecosystem could change over the next 15 years, and this change will differ among markets. We could see one or several of the following outcomes:

i. No successful Pure OTT TV platforms appear
ii. Successful Free OTT TV platforms appear
iii. Successful Pay OTT TV platforms appear
iv. Both successful Free and Pay OTT TV platforms appear

We believe that Pure OTT platforms will emerge successfully in at least some EU states, though we do not assess in this report where and how this will occur.

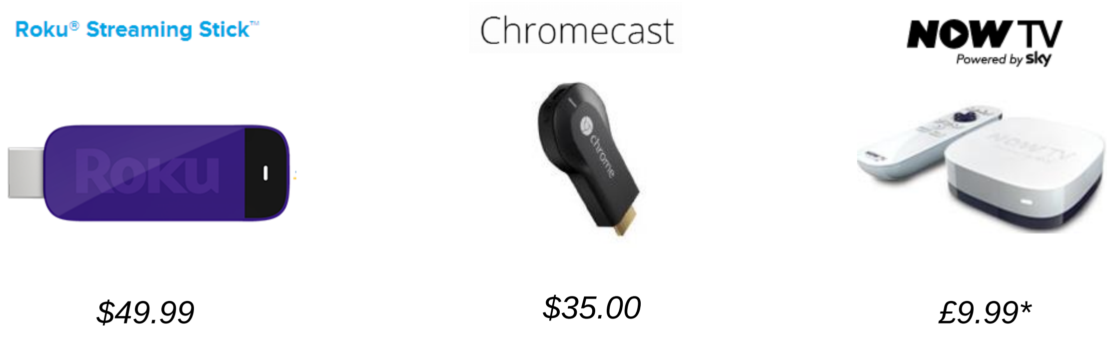
### Availability and cost of Pure OTT devices

By 2030, we believe that devices capable of delivery Pure OTT TV services will be cheaply and widely available.  Consequently, if a free or low-cost Pure OTT TV service is launched in any market over the next 15 years, we expect it to be capable of achieving rapid take up. We base our assumption on several trends relating to streaming OTT devices:

- Rapidly reducing price
- WiFi-enabled by default
- Reducing size; HDMI-dongle form factor.

These trends can all be seen in several recently launched products, as shown in Figure O-6.

**Figure O-6: Sub-€50 streaming devices**




**Now TV box is subsidised – equivalent Roku streaming device is priced at $49.99. Source: Amazon.com, BSkyB*

Google's Chromecast streaming device, which was released in the US in July 2013, reached number one on Amazon's Electronics Best Seller list in October 2013, and was still in the number one position in March 2014.

Given this analysis we summarise our findings below.

**Figure O-7: OTT services' household penetration***

| Household penetration (i.e. % of HHs using service) | OTT services not on hybrid platforms | | | OTT services on hybrid broadcast/OTT platforms | Pure OTT TV platforms |
|---|---|---|---|---|---|
| | Short form / UGC | Broadcaster Catch up / SVoD | Non-broadcaster SVoD | | |
| 2014 | Medium | Medium | Low | Low | Low |
| 2030 | High | High | Low-High | Low-High | Low-High |

*Source: Farncombe *Range of values (e.g. Low-High) indicates possible differences by market, or a range of potential outcomes depending on market developments*

# Appendix P: Out-of-home viewing in 2030

In this appendix we quantify two scenarios out of home viewing of AV content via a mobile network in 2030:

- A low demand scenario
- A high demand scenario

We start by estimating the current position. This is set out in Figure P-1 and derived from the findings of Appendix I – notably Figures I-4 and I-10.

**Figure P-1: Where and how TV consumption is consumed today**

| Mode of consumption | Minutes per day |
|---|---|
| Fixed devices at home | 187 |
| Portable devices at home | 8 |
| Fixed devices at school/work/friends' house | 36 |
| Portable devices at school/work/friends' house | 4 |
| Portable devices when out and about | 6 |
| Of which when commuting | 4 |

The main indicator of future growth in demand for out-of-home AV consumption comes from Cisco VNI. This suggests that:

- There is currently 3 minutes per day per person of mobile video consumption (assuming a bit rate of 0.5 Mbps)
- Demand will grow eight-fold over the next five years to 24 min per day per person
- Using curve fitting techniques to extrapolate forward to 2025 for mobile video might indicate over 100 min per day of AV consumption per person!

But such long term projections do not take account of time budgets. People like to watch at home and the time they spend on the move is limited. It is difficult to quantify the impact of such constraints. But we note that:

- A high % of on-the-move viewing will be when commuting
- Around 50% of people commute to work[247]
- Around 50% of these are in a position to view video (car drivers are excluded)
- The average commuting time in the EU is 50 minutes per day[248]

With these assumptions the time available per person per day for video consumption while commuting is 50 minutes x 0.5 x 0.5 = 12.5 minutes per day with some (significant) % of this time used in viewing downloaded video on a portable device.

[247] Assuming that 60% of the population work and 10% do not commute

[248] See for example http://www.oecd.org/els/family/43199696.pdf

Based on this analysis we estimate the time spent per day per person on out-of-home AV consumption using a mobile device is as shown in Figure P2.

**Figure P-2: Out-of-home viewing using portable devices in 2030**

| Measure | Low demand scenario | High demand scenario | Comment |
|---|---|---|---|
| Minutes per day per person on AV viewing while commuting | 12 | 12 | See text |
| Mark up for other use of portable devices for out-of-home AV viewing[249] | x1.5 | x3 | Scenario assumption |
| Total out-of-home AV consumption via portable devices in minutes per day per person | 18 | 36 | Calculated |

[249] We assume that the bulk of out-of-home viewing will be done while commuting. This multiplier adjusts for other out-of-home viewing when not commuting using plausible assumptions

# Appendix Q: Using sub-700 MHz spectrum for mobile devices

## Q.1 Introduction

There are particular device challenges associated with using the UHF spectrum. Adding additional frequency bands to any device is challenging, although becoming commonplace for handset designers. But the UHF band brings particular problems due to:

- Antennas need to be long – 25cm or more for optimal performance. This is typically not possible in a hand-portable causing reduced performance and making antennas susceptible to "detuning" when held in the hand
- Most RF arrangements have a tuning range of around 4% of the centre frequency. At high frequencies such as 2GHz this leads to 80MHz bandwidth – more than adequate for the 3G band. But at UHF this might only be 24MHz, only about 10% of the total bandwidth. Working outside of this reduces sensitivity and leads to interference issues
- Man-made noise becomes more problematic as frequencies reduce, limiting the signal-to-noise ratio that can be achieved in the lower part of the UHF band.

These problems have not been particularly severe to date in the UHF band because fixed TV reception can accommodate large roof-mounted antenna which are well separated from the man-made noise and in receive-only devices tuning over 10% or more of the centre frequency can be achieved.

For scenarios where eMBMS is broadcast to fixed receivers with rooftop antennas, the issues may remain manageable. However, the band is highly likely to be used for portable devices – either for some form of DTT reception or because spectrum is liberated from DTT and re-purposed to mobile usage.

## Q.2 Mobile TV reception

Because of the issues listed above, mobile devices will have limited sensitivity. A portable device, for example a tablet computer will have an antenna with a negative gain of typically -7 dBi. An additional 12 dB of height loss, additional building penetration loss of 7 dB and location variation due to standing waves (signal phase cancellation) of 14 dB means that the received signal is up to 52 dB lower than the value planned for fixed rooftop reception. This will prevent reliable reception unless a LPLT approach is adopted where the base station locations are designed to achieve hand-portable coverage.

Even where a LPLT transmission scheme is adopted a mobile device may have reduced ability to tune across the band. We estimate elsewhere that a minimum of 80MHz would be needed for a downlink eMBMS system that replicated the current DVB-T channel transmission. Even if this was at a consistent frequency across regions and countries it might require complex receivers with multiple overlapping filters. If this eMBMS band could occur anywhere within the UHF band then it would be very challenging to design a handset capable of working well. At the least this would add significant cost to the handset, but possibly also size, battery drain and reduced sensitivity across other nearby bands. Again this raises the issue of whether EU coordination would be helpful.

## Q.3 Mixed HPHT and LPLT issues

Problems occur in all devices (TV receivers and handsets) when there are highly unequal signal levels on two or more transmissions that are close in frequency. This might occur, for example, when a device was some distance from a HPHT TV transmitter (and so receiving a weak signal) but close to an LTE base station (and so seeing a very strong signal on a neighbouring channel). Such a mismatch in power can cause problems because:

- The receiver may not be able to adequate filter the strong unwanted transmission
- Out-of-band emissions from the strong interferer may be sufficiently strong in the wanted signal band to reduce the SNR
- The RF front-end may be overloaded by the strong signal resulting in non-linear behaviour which will distort the wanted signal.

Of these, the second can be ameliorated by better transmitters with tighter roll-off characteristics. To date, most LTE base stations in the 800MHz band have had sufficiently good roll-off that this issue is not dominant, but it cannot be guaranteed that this will continue to be the case. In particular, LTE specifications are not sufficient stringent to ensure this but most manufacturers exceed the specification.

The receiver issues can be overcome by better receiver design – typically using improved filtering in the receiver. However, tighter filters generally have a reduced bandwidth, exacerbating the problems noted earlier of insufficient tuning range. These are already sufficiently limiting to suggest that further changes in this area are unhelpful.

A more radical solution is to simply avoid having large differences in signal levels. This can be achieved if there is no HPHT transmission with both broadcast and cellular transmissions both coming from the same masts and at similar power levels. This is an advantage of a converged platform (or of removing broadcasting from the UHF band altogether).

## Q.4 Trade-offs

Various approaches could be adopted to ease the handset design problems:

- Sub-bands could be identified such that devices needed only a limited tuning range within each band
- TV and mobile signals could be well separated in frequency making any filtering problems simpler
- Hand portable operation could be restricted to the upper part of the UHF band (eg >600MHz) where tuning ranges are larger and economies of scale more likely.

It would be theoretically possible to divide the UHF band into (for example) five by 70 MHz sub bands coupled to a variable switchable antenna (an antenna that switches in additional lengths of antenna as frequency deceases) but the cost and complexity would be disproportionate. The switch would introduce additional insertion loss and antenna matching would be problematic. The normal response would be to assume that a technology solution will be found but at present there is no indication of a viable alternative to duplex filters and the bandwidth limitations of other resonant components including antennas and resonators. Improvements in these components tend to occur only slowly.

There are adaptive techniques that can be used to stretch the bandwidth over which devices will operate but they all trade off a performance improvement in one area with a performance loss in another.

The notion of a low cost efficient software radio that can tune across the UHF band and ideally include all other bands up to 1 GHz therefore remains a remote prospect. This does not preclude an integrated broadcast broadband device in the UHF band but does imply that such a device will need to segregate different functions into discrete (70 MHz receive only or 30 MHz RX/TX) sub bands.

The other approaches such as band separation make the use of the UHF spectrum less efficient. This may reduce its value, making the business case for convergence with subsequent spectrum savings less attractive. Nevertheless, some combination of all of these approaches is likely to be required.

## Q.5 Summary

There are multiple potential device issues. The most significant occur when handsets are required to cover large parts of the UHF frequency band. This leads to both more expensive and less sensitive devices. This can be partly resolved by restricting operation to parts of the band but only if these are kept quite small – negating spectrum efficiency gains and potentially creating roaming / economies of scale problems. For receive-only devices such as an LTE-eMBMS receiver built into a TV set these issues are less problematic although still not entirely trivial.

The scale of the issues, and the costs and reduced sensitivity as a result, are very hard to predict because they depend on the device form factor, the other bands and technologies it is aiming to support, the network topography and the restrictions that can be tolerated. At the worst case the increase in cost could be sufficiently material to make the band uneconomic or the decrease in sensitivity sufficient to offset the benefits of additional spectrum. Alternatively, it may be necessary to make the band below 700MHz downlink only to remove the need for transmitters in handsets in this band.

Our best estimate at this early stage is that:

- Portable devices will not be able to work reliably from HPHT configurations
- No portable device will be able to span the entire UHF band and devices are likely to concentrate on the upper part
- UHF support both for cellular ***and*** broadcast operation will not be built into handsets unless there is strong global or regional demand from operators, possibly driven by what happens in the US and elsewhere
- There will be much support for downlink-only use of the UHF band below 700MHz, simplifying devices. While this reduces the flexibility of the spectrum released, most estimates suggest much more downlink than uplink spectrum will be needed so this may not be a material constraint in practice
- Improvements in this area cannot be assumed and may take decades to materialise.

# Appendix R: Supporting detail on spectrum issues

## R.1 Proposals for use of the 700MHz band

At WRC-12 it was agreed that 694-790 MHz (700 MHz band) would be allocated to mobile on a co-primary basis with broadcasting services after WRC-15. Since then there have been national and Europe-wide discussions about the future use of the 700MHz band in Europe. These activities are on-going. However it seems likely that the 700MHz band will be vacated by DTT and other existing services (e.g. PMSE) in a 2017-2025 timeframe and reallocated primarily for use by mobile services.

The key European level initiatives include:

- The European Commission issued a mandate to CEPT in February 2013[250] to develop least restrictive harmonised technical conditions for the use of the 700MHz band by wireless broadband[251] and to identify suitable spectrum to accommodate incumbent users of the band (e.g. PMSE). Interim outputs are given in CEPT Report 53 which is to be finalised by the end of 2014[252].
- An RSPG report examining the approach which could be considered for spectrum coordination between EU countries, in case of use of the 700 MHz frequency band for wireless broadband communications, and the related timeline.[253]
- The Lamy Report on the Future Use of the UHF band (470-790 MHz) which has proposed co-ordinated repurposing of the 700MHz band to mobile services (possibly by 2020 +/-2 years), safeguards for continued broadcasting use of spectrum below 700MHz until 2030 - notably no co-primary mobile allocation as of 2015 - and a stock-taking exercise no later than 2025[254].

The preferred channelling arrangement for the 700MHz band proposed in draft CEPT Report 53 is as follows[255]:

- Paired arrangement (FDD) – 2x30 MHz (703-733/758-788 MHz) for mobile use in line with the lower duplexer of the APT 700 MHz band plan
- Unpaired arrangement in the centre gap – four lots of unpaired 5 MHz from 738-758 MHz for supplemental downlink. In general, the use of this centre gap spectrum and the guard band 694-703MHz is a national matter subject to a few options and could include mobile supplemental downlinks, PMSE and (paired) PPDR mobile broadband (e.g. using 698-703MHz paired with 753-758 MHz subject to compatibility with DTT below 694 MHz).

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[250] The work on the mandate is being undertaken by several CEPT working groups including PT1 (IMT matters) and PT D (WRC-15 agenda item 1.2).

[251] RSC Mandate to CEPT to develop harmonised technical conditions for the 694-790 MHz frequency band in the EU for the provision of wireless broadband electronic communications services and other uses in support of EU spectrum policy priorities, 11 March 2013. https://ec.europa.eu/digital-agenda/sites/digital-agenda/files/Mandate_CEPT_700_MHz%20.doc.pdf

[252] At the time of writing Draft CEPT Report 53, http://www.cept.org/ecc/tools-and-services/ecc-consultation#CEPT%20Reports

[253] RSPG. 1st Progress Report on the future of the UHF band. 12 June 2014. https://circabc.europa.eu/sd/a/3ebde24c-f5f8-4b69-8d7c-897fca8ca9a1/RSPG14-570_%201st%20Progress-Report_on_the_future_of_the_UHF_band.doc

[254] Results of the Work of the High level Group on the Future Use of the UHF Band (470-790 MHz), Report to the European Commission, Pascal Lamy1 September 2014, http://ec.europa.eu/digital-agenda/en/news/report-results-work-high-level-group-future-use-uhf-band

[255] Summary of ECC PT1 #46 meeting (28 April – 2 May 2014) http://www.cept.org/ecc/groups/ecc/ecc-pt1/page/ecc-pt146-meeting-%2828-april-02-may-2014,-luxembourg%29

There are numerous national initiatives examining the possibilities for reallocating the 700MHz band from broadcasting to mobile use. For example:

- In Belgium, the regulator BIPT has issued a consultation on the release of a number of frequency bands including the 700MHz band[256].
- In Denmark[257], the government is consulting on proposals to end use of the 700MHz band after 2020. A supporting consultancy report estimates a positive net present value for releasing the 700 MHz band for mobile.[258]
- In France, the President announced in October that the process of auctioning frequencies in the 700 MHz band for use for electronic communications services will get under way in 2015[259].
- In Finland[260] and Sweden[261] there are proposals to end TV use of the 700MHz band in 2017 so the band can be used for mobile broadband
- In Germany, the 700MHz band is expected to be auctioned in the second quarter of 2015 together with several other bands. BNetza has published a draft decision for consultation concerning the auctioning of spectrum in the 700 MHz, 900 MHz, 1800 MHz and 1.5GHz bands for electronic communications services (mobile broadband)[262]. This followed the publication of the German government's digital agenda strategy[263] in August 2014 which referred to the release of the 700MHz band for mobile broadband.
- The Irish regulator ComReg is consulting on the possible award of a number of frequency bands for wireless broadband including the 700MHz band.[264]
- The Netherlands government has initiated an enquiry into the future use of the 700MHz band as 15 year TV licences will expire in 2017[265]. The aim is to have certainty over the future of 700 MHz as early as possible in 2015.

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[256] http://bipt.be/public/files/fr/21385/20141107114102_Consultatie_ECS_Spectrum-FR.pdf

[257] Danish Business Authority. Undersøgelse af frekvensbehov til antenne-tv og mulighederne for at frigøre 700 MHz-frekvensbåndet til mobilt bredbånd efter 2020. June 2014 http://erhvervsstyrelsen.dk/file/486941/ERST_KUM_700_MHz_rapport.pdf

[258] This is estimated to be between DKK 2.5bn and DKK 4bn (excluding positive and negative externalities) for the period 2013-2030. http://erhvervsstyrelsen.dk/700mhz-frekvensbaandet

[259] http://www.arcep.fr/index.php?id=8653&L=1

[260] Ministry of Transport and Communications (Finland). Terrestrial television: the next technology transition. Working Group Interim Report, March 2014. http://www.lvm.fi/publication/4381823/terrestrial-television-the-next-technology-transition-working-group-interim-report

[261] Ministry of Culture (Sweden). Sändningsutrymme för tv-sändningar, 17 February 2014 http://www.radioochtv.se/Documents/Tillst%C3%A5ndsprocesser/Marks%C3%A4nd%20tv%202014/sandningsutrymme%20f%C3%B6r%20sandningar.pdf; Swedish Broadcasting Authority. Spectrum allocated for terrestrial television broadcasting, 27 February 2014 http://www.radioochtv.se/en/About-us/News1/2014/Spectrum-allocated-for-terrestrial-television-broadcasting/

[262] http://www.bundesnetzagentur.de/cln_1431/EN/Areas/Telecommunications/Companies/FrequencyManagement/ElectronicCommunicationsServices/MobileBroadbandProject2016/project2016_node.html

[263] http://www.digitale-agenda.de/DA/Redaktion/DE/Publikation/digitale-agenda.pdf?__blob=publicationFile&v=8

[264] http://www.comreg.ie/publications/spectrum_award_-_2_6_ghz_band_with_possible_inclusion_of_700_mhz__1_4__2_3_and_3_6_ghz_bands.583.104700.p.html

[265] Ministry of Economic Affairs (Netherlands). Toekomst DVB-T. Consultation, 7 July 2014 http://www.internetconsultatie.nl/toekomstdvbt

- In the UK, Ofcom carried out and consulted on a cost-benefit analysis of reallocating the 700MHz band from TV to mobile use in a 2018-2022 timeframe[266]. The analysis shows there are net economic and social benefits from this change. Subsequently Ofcom issued a decision to reallocate the 700MHz band from TV to mobile use by the start of 2022 at the latest[267].

These European and national initiatives together suggest that the 700MHz band is likely to be reallocated to use by mobile broadband in a 2017-2025 timeframe.

## R.2 Migration to DVB-T2

The adoption of more efficient DTT technology, namely DVB-T2, is an important enabler of this change in use of the 700MHz band as it helps maintain the capacity of the DTT platform. DVB-T2 offers significant efficiency gains compared with DVB-T transmission. In comparable transmission conditions, the gain of channel capacity between DVB-T and DVB-T2 is most often estimated at around 50%[268]. DVB-T2 is being used to enable HD services over the DTT network and to support more SD services. These features provide an incentive to consumers to replace their DVB-T terminals with DVB-T2 (HD compatible) receivers. This is essential as a DVB-T terminal cannot process a DVB-T2 signal.

**Figure R-1: EU-28 DTT evolution stage[269]**

| Expanding DTT / No concrete plans for T2 (5) | Mature DTT / No current commitment for T2 (11) | Introduced / Planning for T2 (12) |
|---|---|---|
| Bulgaria | Croatia | Austria |
| Estonia | Cyprus | Belgium |
| Greece | Ireland | Czech Republic |
| Hungary | Latvia | Denmark |
| Slovakia | Lithuania | Finland |
| | Luxembourg | France |
| | Malta | Germany |
| | Netherlands | Italy |
| | Poland | Romania |
| | Portugal | Slovenia |
| | Spain | Sweden |
| | | UK |

*Source: Results from the questionnaire to member states on digital broadcasting, COCOM 13-11 FINAL, 8 January 2014, Farncombe analysis*

[266] Ofcom. Consultation on future use of the 700 MHz band – cost-benefit analysis of changing its use to mobile services, May 2014. http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/summary/main.pdf

[267] http://stakeholders.ofcom.org.uk/consultations/700MHz/statement/?utm_source=updates&utm_medium=email&utm_campaign=700-mhz-statement.

[268] In a typical European deployment, a DVB-T2 signal in a 8-MHz channel will carry between 30 and 40 Mbit/s, resulting in a typical Spectral Efficiency of ca. 4.5 bit/s/Hz (bit per second per Hertz).

[269] We have used COCOM's questionnaire as an input to this table. But the table also takes account of other DTT evolution plans which a member state may have (e.g. launch of new services, new MUXs, etc.). It is not solely related to DVB-T2 plans

Figure R-1 shows the status of DTT in the EU as of January 2014. 12 countries have firm plans to move to DVB-T2. This includes France and Germany, which have delayed the rollout of DVB-T2 to await the widespread availability of cheap HEVC chipsets. Other countries have not yet opted to migrate to DVB-T2, mainly due to the cost for viewers to replace their receivers and also because some countries

In Italy the government has approved legislation obliging manufacturers to include T2 and MPEG-4 in all DTT receivers in 2015. The French regulator CSA has recommended adoption of a similar measure requiring T2 receivers but for 2020[270]. In Finland there is a 10 year plan for technology migration from DVB-T to DVB-T2 (or newer) technology over a 10 year switchover period (2017-2026)[271].

Whether T2 receiver sales are mandated or not, it will be sometime before the primary TV set in most EU DTT households has a T2 receiver. The main incentive to upgrade to T2 is to view HD services. Most DTT services are still in SD and upgrade incentives are weak. However, sales of large TV screens are growing and these generally have T2 receivers. Hence as consumers upgrade their primary sets, either to take advantage of larger screens and advanced formats or as part of the natural replacement cycle, the proportion of T2 enabled households will grow. For example, in the UK it is forecast that around 80% of TV sets will be T2 enabled by 2025[272].

## R.3 Potential for use of the VHF broadcasting band

We have considered whether the VHF band could be used for either the converged platform or for simulcasting DTT services in the transition to a converged platform.

The VHF band 174-230 MHz is allocated to broadcasting services and has historically been used for analogue TV transmission. As part of the GE-06 Agreement the band was planned for T-DAB and DVB-T services. Under the plan all countries except Luxembourg, Malta and the UK have allotments for DVB-T at VHF. However, according to a 2012 RSPG survey only four countries stated they were using VHF for DTT[273]. In a more recent review 2014 the EBU reports that Finland, Italy, Norway, Poland, Russia and Sweden either have or plan to have use of the VHF band by one or more DTT multiplexes[274]. In these and other countries there is or are plans for DAB services and use of a variety of other applications including PMR, defence, PMSE and aeronautical communication.

In addition to fragmented use of the band across Europe and the relatively small amounts of spectrum available, households in some countries do not have aerials that could receive VHF TV services. There is no comprehensive source of information on this issue, though we understand from e-mail correspondence with the EBU that this is the case in Germany, Spain and the UK. The installation of new household VHF aerials in these countries would be very costly.

In summary there is not sufficient spectrum available on an EU-wide basis at VHF that could be used for either the converged platform or for simulcasting in the transition to a converged platform.

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[270] Digitag. Launching DVB-T2 in Europe, March 2013 http://www.digitag.org/WebLetters/2013/External-Mar2013.html

[271] In Finland the VHF band will also be used for DTT services. See Ministry of Transport and Communications (Finland), March 2014.

[272] See Figure 6.2. Ofcom. The Future of Free to View TV. Discussion document, May 2014 http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/discussion/ftv.pdf

[273] http://rspg-spectrum.eu/consultations/responses_questionnaire_dtt/dtt_questionnaire_responses.zip

[274] The Use of Band III in Europe, EBU Technology Factsheet, 1 September 2014.

## R.4 Timing of a move

It appears likely the 700 MHz band will be vacated by DTT in a 2017-2025 timeframe and this will be facilitated by either a market or government driven move to DVB-T2 over the same (or longer) timeframe. These changes require complex (and potentially costly) changes to UHF spectrum use (nationally and across Europe) and changes to consumer equipment. Experience with digital switchover suggests the release of the 700MHz band will require extensive bilateral co-operation between countries on the timing of changes in spectrum use and communication plans aimed at informing consumers of the changes at national level.

Introducing a converged platform at UHF in parallel with the refarming of the 700MHz band and DVB-T2 migration would be problematic, both in terms of achieving the necessary changes in spectrum use at a European level and in gaining consumer (and political) support for the changes. There is a risk that some consumers could end up having to make two changes to their DTT reception equipment in quick succession and incur extra costs. There could also be misunderstanding and confusion among consumers on the changes that are required.

Hence we conclude that introducing a converged platform at UHF in parallel with the release of 700MHz would not be practical. This means we assume that a converged platform is implemented in 2025 or later.

## R.5 Impacts on incumbent services

### R.5.1 Cable networks

There is potential for interference from a converged platform in relation to cable networks. This issue has been raised in the discussion over the future use of the 700 MHz band[275]. CEPT has noted that its review will be able to be used by the standards bodies (ETSI and CENELEC) to undertake activities to address cable industry concerns and that CEPT will not be addressing compatibility studies for cable networks[276]. We assume the same arrangements would apply were 470-694 MHz to be used for a converged platform.

### R.5.2 Wireless audio PMSE systems

Wireless audio systems (i.e. microphones, in ear monitors[277] and talkback[278]) make extensive use, in specific locations and often on a temporary basis, of frequencies in the 470-790MHz range that are not used for TV broadcasting. This use occurs both indoors (e.g. theatres and production studios) and

[275] Cable Europe. Contributing to Draft ECC Mandate to develop harmonised technical conditions for the 694–790 MHz frequency band. Presentation, April 2014 http://www.cept.org/Documents/ecc-pt1/17760/ECC-PT1(14)INFO-06_Contributing-to-Draft-ECC-Mandate-to-Develop-Harmonised-Technical-Conditions-for-the-694-%E2%80%93-790-MHz-Frequency-Band

[276] ECC. Response to Cable Europe, 14 March 2014 http://www.cept.org/Documents/ecc-pt1/16581/ECC-PT1(14)INFO-03_ECC-response-to-Cable-Europe

[277] These are body worn miniature receivers with earpieces used for personal monitoring of a sound track.

[278] Talkback is a voice communication used to relay instructions (one way or two way) amongst those involved in the production of a programme material or an event.

outdoors (e.g. at outdoor sporting or musical events) and forms an essential input to the creation of much of the audio-visual content distributed over TV broadcast networks.

The 470-790 MHz is the main band used by wireless audio systems in Europe[279] and the re-allocation of the 800MHz band to mobile (and now probably the 700 MHz band) has reduced the spectrum available for wireless audio systems. Most studies point to increasing demand for spectrum for wireless audio applications[280] and CEPT and the European Commission have produced a number of reports addressing the future spectrum requirements of PMSE, technical conditions for use of specific bands, and the socio-economic benefits from harmonisation of spectrum allocations[281] [282] [283].

The Commission has issued a decision on harmonised technical conditions for spectrum use by wireless audio PMSE applications[284]. This proposes that a minimum of 60MHz is made available for basic daily needs as follows:

- The duplex gaps at 800 MHz and 1800MHz (i.e. 821-832MHz and 1785-1805 MHz) are designated and made available to PMSE on a non-exclusive basis, based on technical conditions given in the decision. (Although the amount of spectrum that is usable by PMSE depends on the proximity of PMSE devices to mobile transmitters and devices[285].)
- Member states guarantee on request that a further 30MHz of spectrum be made available for prospective users of wireless audio PMSE equipment on a non-interference and non-protection basis with regard to licensed users of such spectrum. This spectrum would be selected from tuning ranges decided by the Member States, preferably in the 470-790 MHz range. Member states may go beyond the minimum 30MHz.

The industry body APWPT has stated that at least 96 MHz of UHF spectrum is required for wireless audio applications. This is based on the daily requirement in Berlin[286], and APWPT considers that the

[279] Other bands include 863-865 MHz, 1785-1800 MHz, 1492-1518 MHz (indoor only) and the range 1800-1804.8 MHz (in addition to 1785-1800 MHz though this is not widely used because it is allocated to digital wireless microphones and there are latency problems with this equipment). ERC Recommendation 70-03 http://www.erodocdb.dk/docs/doc98/official/pdf/rec7003e.pdf

[280] See VVA Consulting presentation on the socio-economic aspects of spectrum harmonisation for PMSE equipment. May 2013 http://ec.europa.eu/digital-agenda/en/news/public-workshop-socio-economic-aspects-spectrum-harmonization-pmse-equipment Plum, Aegis, Whatif and Quotient. Entertainment in the UK in 2028. Report for Ofcom, 2009 http://www.plumconsulting.co.uk/pdfs/Plum_July09_Entertainment_UK_2028.pdf

[281] ECC. CEPT Report 32 on a "Recommendation on the best approach to ensure the continuation of existing Program Making and Special Events (PMSE) services operating in the UHF (470-862 MHz), including the assessment of the advantage of an EU-level approach", 30 October 2009 http://www.erodocdb.dk/docs/doc98/official/pdf/CEPTRep032.pdf

[282] ECC. CEPT Report 50 (and its addendum) Technical conditions regarding spectrum harmonisation options for wireless radio microphones and cordless video-cameras http://www.erodocdb.dk/doks/doccategory.aspx?doccatid=16; VVA Consulting. Assessment of socio-economic aspects of spectrum harmonisation regarding wireless microphones and cordless video-cameras (PMSE equipment), Report for the European Commission, September 2013 http://ec.europa.eu/digital-agenda/en/news/report-assessment-socio-economic-aspects-spectrum-harmonisation-regarding-wireless-microphones

[283] ECC. Spectrum use and future requirements for PMSE. Report 204, February 2014 http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP204.PDF

[284] Commission Implementing Decision of 1 September 2014 on harmonised technical conditions of radio spectrum use by wireless audio programme making and special events equipment in the Union (notified under document C(2014) 6011) (2014/641/EU). https://ec.europa.eu/digital-agenda/en/news/commission-implementing-decision-01092014-spectrum-use-wireless-audio-pmse

[285] http://www.apwpt.org/downloads/using-mobile-duplex-gaps-and-guard-bands-for-a.pdf

[286] Institut für Hochfrequenztechnik und Funksysteme. Report on the frequency resource requirements of Professional Wireless Microphone Systems in urban areas with respect to changing broadcasting allocation concepts. 29 October 2008 http://apwpt.org/downloads/reportonthefrequencyresourcerequirementsofpwms.pdf

Commission's proposals are insufficient to compensate for the loss of spectrum access at 700MHz and 800MHz.

The UK regulator Ofcom has assessed the potential impact on wireless audio applications of the loss of access to the 700MHz band in 2022 (i.e. a 30% reduction in available spectrum)[287]. Some users would need to upgrade their equipment and the net present value (NPV) of this cost is estimated to be between £6 million to £18million. In addition, the loss of the 700 MHz band would mean events with very high use of wireless audio applications (there are 10-20 of these, typically high profile, events in the UK each year) would not have access to sufficient spectrum and a larger number of other users would have to significantly change their equipment and/or working practices to support the events in their current form. Furthermore there would be no scope to increase the use of wireless audio applications in future.

While there may be opportunities to improve the efficiency of spectrum use by wireless audio systems (e.g. through better management and new technology)[288] [289] such innovations are not considered to be sufficient to meet future requirements for wireless audio applications. Current proposals to deal with the anticipated shortage of spectrum for PMSE audio systems include the following:

- Ofcom has proposed shared use of 960-1350 MHz and 1525-1710 MHz as priorities for investigation. In addition Ofcom proposes to investigate possibilities for use of bands in the 1427-1518 MHz range as some of this spectrum is available in Germany for wireless microphones on a non-interference, non-protection basis.
- BNetza has proposed that wireless audio applications might in future use frequencies in and around 1452-1525 MHz [290].
- ECC Report 204 indicates that CEPT is exploring greater access to L band – in particular it noted that it may be beneficial to explore sharing opportunities in the 1200-1650 MHz range (which includes L band) as proposed in the ITU working group JTG 4-5-6-7. More recently CEPT has stated that it is considering 1350-1400 MHz as a potential tuning range for wireless microphones[291].
- Spectrum sharing between PMSE and the downlink frequency ranges of mobile systems[292]. In principle, the situation is similar to sharing with TV (TV transmissions being 'downlink only') though mobile downlink frequencies may change from time to time. The PMSE user would have to scan the available frequencies and choose one that is not in use by nearby base stations –the interference is likely to be experienced by the wireless microphone and not the mobile transmitter[293]. If all downlink frequencies are in use at all base stations (e.g. as might be the case in areas of high mobile use) then this approach clearly will not work.

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[287] See Section 7. Ofcom. Consultation on the future use of the 700MHz band. Consultation document, 28 May 2014.

[288] Aegis, Cobham. Spectrum efficiency of wireless microphones. Report for Ofcom, 30 June 2010 http://stakeholders.ofcom.org.uk/binaries/research/technology-research/sewm/finalreport.pdf;

[289] European Commission. PMSE Stakeholders' Workshop 2014, 18 February 2014 http://www.apwpt.org/regional-information/europe/index.php

[290] Bundesnetzagentur. Strategic aspects of the availability of spectrum for broadband rollout in Germany. June 2013

[291] Draft Minutes, CPG-PTD #7, CEPT Doc. CPG-PTD(14)223, 15 September 2014

[292] ECC Newsletter April 2014 http://www.cept.org/ecc/news/ecc-newsletter-april-2014

[293] The PMSE user therefore needs flexible equipment (that can tune across the downlink range and avoid the local downlink(s)) or have access in advance to information on the downlink frequencies and then plan its use to avoid them.

- Possible use of the 700MHz centre gap on a national basis, although there has been a proposal from Germany to use the centre gap for PPDR broadband services[294].

At present, it is thought that any new frequency bands for wireless audio applications would need to be below 2 GHz and it is argued by some in industry that frequencies below 1 GHz are required because of body absorption and increased free-space propagation loss above 1 GHz.[295]. Given spectrum bands below 2GHz are all allocated finding replacement spectrum for PMSE could take many years, not least because PMSE services may need to share spectrum with uses that require considerable protection from interference (e.g. aeronautical services). In addition existing users will incur some costs of equipment replacement. We make an estimate of this cost, assuming alternative spectrum can be found, in the text panel below. If sufficient spectrum to support PMSE applications cannot be found then clearly much higher costs would be incurred.

In a study for the European Commission, the consultancy VVA identified three levels at which use of PMSE equipment creates socio-economic value[296]:

- Equipment production which generates economic benefits and costs for equipment manufacturers and PMSE users.
- Equipment use which enhances event quality and frequency to the benefit of PMSE audiences
- Indirect impacts on those not using the equipment or attending events e.g. impacts on tourism, wider societal benefits of cultural events.

VVA were only able to quantify aspects of the first level, namely equipment production. They estimate that the wireless microphone and in-ear monitor market in the EU generates an annual turnover of €170m (260,000 units/systems sold each year with around 2m units in operation at any point in time) and VVA estimates the average lifetime of equipment is 8 years[297]. This data includes both professional and consumer equipment some of which uses the licence exempt 863-865 MHz band.

We estimate that, using the VVA data on equipment numbers and costs, at worst, the one-off cost of bringing forward equipment purchases, should the industry have to move from the UHF band, would be €700m (= 2m x €650 x0.5). This estimate assumes that equipment is on average half way through its 8 year life[298]. Alternatively, using data from Ofcom's 700MHz consultation we obtain a lower value of €130-162m for the EU.[299]

### R.5.3 Wind profilers

Wind profilers are radars that operate in a number of frequency ranges (e.g. around 50MHz, 400MHz and 1 GHz) with lower frequency ranges being used to observe atmospheric processes at greater

[294] http://www.cept.org/ecc/groups/ecc/wg-se/se-7/page/overview-of-the-latest-se7-meeting,-eco,-copenhagen

[295] Pages 45-46, http://stakeholders.ofcom.org.uk/binaries/consultations/pssr-2014/statement/cambridge-main-report.pdf; http://www.apwpt.org/terminologies-a--i/body-loss-effect/index.html

[296] VVA (2013). Assessment of socio-economic aspects of spectrum harmonisation regarding wireless microphones and cordless video-cameras (PMSE equipment).

[297] VVA (2013) op.cit., pp.17-18,

[298] Total full replacement cost would be 8x170m = 1,360m. We take 50% of this value.

[299] Ofcom's analysis given in Appendix 12 of their consultation found that

- there are approximately 27,000 pieces of wireless audio equipment at UHF
- the cost of early replacement of a piece of equipment is £400-540 per unit or €480-600 per unit.

This implies a total replacement cost for the UK of €13-6.2m. If we multiply by 10 to get an EU value then the implied replacement cost would be €130-162m.

heights[300]. Currently, in Europe, there are four operational systems at 482 MHz (requiring around 5 MHz in the 470-494 MHz band) in Germany and another to start soon in the Czech Republic[301]. Several other European meteorological services (in particular Switzerland, Croatia and Ireland) are also currently considering use of this band[302].

If in the worst case the 470-494 MHz frequency range could not be used by wind profilers then in theory other frequencies around 400-470 MHz might be used, though finding sufficient bandwidth could be challenging given heavy use of these frequencies by mobile, fixed and military applications. Even if other frequencies could be made available there would be costs associated with new equipment purchases[303]. Estimates of equipment costs for a 400 MHz installation indicate these can be of the order of €1-2m and there would also be costs associated with decommissioning existing systems. If new frequencies were not made available there would be a loss of meteorological information that would adversely affect weather forecasting across Europe as the information that is gathered is shared with other countries[304]. There is a literature on the economic benefits of meteorology.[305] However it is not possible to apportion these benefits to the use of specific frequency bands for wind profilers.

In summary it is not certain whether wind profilers could easily share spectrum with a converged platform. But, as there are relatively few installations across Europe and they use small amounts of spectrum, some geographic sharing should be possible.

### R.5.4 Radio astronomy

The 608-614 MHz frequency range is used by the radio astronomy service for pulsar observations and very long baseline interferometry (VLBI) measurements[306]. VLBI also uses a number of other frequency ranges and provides a tool to gather data on the detailed structure and positions of astronomical sources. It also has applications in many other fields of research including global climate, positioning and geodetic research[307].

Like the situation with wind profilers there are relatively few locations in Europe where channel 38 is used for radio astronomy[308] and the amounts of spectrum required are not large. Hence countries with radio telescopes using this frequency range may choose to accommodate the service. In this regard

[300] See background on European co-operation in the field of scientific and technical research (COST) at http://www.metoffice.gov.uk/research/weather/ewinprof/background

[301] Most deployments are in rural or sometimes sub-urban areas. Source: Correspondence with EUMETNET.

[302] There is a secondary allocation for the service in in Germany, Austria, Denmark, Estonia, Finland, Liechtenstein, Norway, Netherlands, the Czech Republic and Switzerland in accordance with Resolution 217 (WRC-97). European table of frequency allocations, ERC Report 25, October 2013, http://www.erodocdb.dk/docs/doc98/official/pdf/ERCRep025.pdf

[303] Equipment costs are discussed in J. Dibbern et al. (2003) Operational aspects of wind profiler radars. WMO Instruments and Observing Methods Report no.79 https://www.wmo.int/pages/prog/www/IMOP/publications/IOM-79/WindProfilers.pdf

[304] ECC. Compatibility of wind profiler radars in the radiolocation service (RLS) with the radionavigation satellite service (RNSS) in the band 1270-1295 MHz. ECC Report 90, September 2006. http://www.erodocdb.dk/docs/doc98/official/pdf/ECCRep090.pdf

[305] The economic benefits of Met Office activity in the UK are estimated in this study. Met Office. The public weather service's contribution to the UK economy. May 2007 http://www.metoffice.gov.uk/media/pdf/h/o/PWSCG_benefits_report.pdf; See also T Frei (2009) Economic and social benefits of meteorology and climatology in Switzerland. Meteorological Applications (2009), http://www.wmo.int/pages/prog/amp/pwsp/documents/MetAppl_Frei_MeteoSwiss.pdf

[306] Radio astronomy requires access to 608-614 MHz

[307] RSPG Report and opinion on "A coordinated EU spectrum approach for scientific use of radio spectrum", October 2006;

[308] The European VLBI Network http://www.evlbi.org/

we note that in the UK Radio Astronomy has already given up its use of the band[309] while in the US the FCC's 600MHz band plans protect the radio astronomy service[310].

## R.6 Impacts on possible future uses of 470-694 MHz

There are industry and regulatory initiatives examining the proposals for:

- Use of parts of the 700MHz band for dedicated mobile broadband networks for public protection and disaster relief (PPDR) services and machine to machine services. As discussed below PPDR is likely to be accommodated mainly in the 700MHz band or other spectrum and so is unlikely to be impacted by a converged platform
- Shared unlicensed use of 470-790 MHz in the UHF band by White Space devices[311]. A converged platform seems likely to reduce the spectrum available for white space devices. However, there is commercial uncertainty as to how much (if any) spectrum will be demanded by these applications in the 470-694 MHz range.

We did not identify any other potential future uses of the 470-694 MHz band in the course of our work.

### R.6.1 PPDR mobile broadband

Requirements for PPDR at 700MHz might be accommodated within the 694-790MHz frequency range, either with a dedicated PDDR network and/or some use of commercial LTE networks. A European Commission study on mission critical infrastructure has found that commercial MNO networks are a feasible option for PPDR mobile broadband only if a specific regulatory structure is developed to ensure a given service level commitment with cost based pricing[312].

Alternatively, there are a number of ways a dedicated network might be accommodated although there are issues with each option that would need to be resolved:

- 2x5 MHz in the centre gap and the lower guard band might be used for the service (assuming suitable interference protection is given to TV services)
- If 2x10 MHz was required then a further 8 MHz TV channel could be required[313].
- In addition there is a proposal to accommodate 2x10MHz for PPDR in the 700MHz centre gap[314],

In summary, an allocation to PPDR mobile broadband at 700MHz on a converged platform would be at most a small reduction (up to 10 MHz) in the spectrum available for the converged platform. It

309 See para 4.25. Ofcom. Digital Dividend Review: 550-630 and 790-862 MHz. Consultation document, June 2008 http://stakeholders.ofcom.org.uk/binaries/consultations/clearedaward/summary/condoc.pdf

310 FCC. Staff summary of incentive auction report and order, 15 May 2014 http://www.fcc.gov/document/staff-summary-incentive-auction-report-and-order

311 Van de Beek et al (2011). UHF white space in Europe – a quantitative study into the potential of the 470-790 MHz band. IEEE International Symposium on Dynamic Spectrum Access Networks http://www.inets.rwth-aachen.de/fileadmin/templates/images/PublicationPdfs/2011/DySPAN2011-TV-White-Spaces.pdf

312 Study on use of commercial mobile networks and equipment for mission-critical high-speed broadband communications in specific sectors, SCF Associates, Final Workshop slides October 2014.

313 See ECC Report 199, User requirements and spectrum needs for future European broadband PPDR systems (Wide Area Networks), May 2013. http://www.erodocdb.dk/Docs/doc98/official/Word/ECCREP199.DOCX

314 http://www.cept.org/ecc/groups/ecc/wg-se/se-7/page/overview-of-the-latest-se7-meeting,-eco,-copenhagen

appears more likely that there will be no impact as it now seems probable that member states will not adopt a single EU approach to meeting their needs for mobile broadband for PPDR[315]. The bands used may differ (400 MHz, 700 MHz and a mix of the two) as may the delivery platform – a dedicated network, commercial networks or a mix of the two.

### R.6.2 White space devices (WSD) at UHF

There are a number of European initiatives aimed at developing a regulatory framework for white space devices in the 470-790 MHz band, where these devices would be used on an unlicensed basis and controlled by a geo-location database. For example:

- RSPG has published an opinion on Cognitive Technologies, 10 February 2011, RSPG10-348.
- The European Commission has published a communication on shared spectrum use that supports dynamic sharing approaches[316] and has issued a standardisation mandate to harmonise access to location-based information for these technologies through geo-location databases[317].
- ETSI has published a technical feasibility study on Radio Frequency (RF) performance for Cognitive Radio Systems operating in UHF TV band White Spaces[318]
- In CEPT FM53 has produced 3 ECC reports providing inputs to a regulatory framework: ECC Reports 159, 185 and 186. It is also working on producing a further Report titled "*Overall regulatory framework for TV WSD using geolocation database and guidance for national implementation*".
- ETSI has published the document "Harmonised European Standard for white space devices (EN 301 598)".
- ETSI is working on two further technical specifications addressing system architecture issues and a European standard aimed at defining parameters and procedures for information exchange between geo-location databases.

At a national level WSD trials have taken place in some countries (e.g. Germany, Finland[319], Slovakia and the UK[320]) and in the UK is there a regulatory framework in place. Whether these trials/pilots will proceed to commercial deployment and the necessary regulatory frameworks implemented is uncertain and will depend in part on the extent of available spectrum at UHF. In the US where there is a regulatory framework in place and some niche commercial applications have been developed (e.g.

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[315] FM49 is developing a European harmonised regulatory framework to achieve the necessary level of interoperability for the 400MHz and 700MHz two candidate bands. The results from this work will be delivered in early 2015.

[316] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Promoting the shared use of radio spectrum resources in the internal market, COM(2012) 478, September 2012

[317] Standardisation mandate to CEN, CENELEC and ETSI for Reconfigurable Radio Systems (RRS).

[318] Information on ETSI's work on reconfigurable radio systems is accessible at http://www.etsi.org/index.php/technologies-clusters/technologies/radio/reconfigurable-radio; ETSI's technical report on TV White spaces is ETSI TR 103 067 V1.1.1 (2013-05) http://www.etsi.org/deliver/etsi_tr/103000_103099/103067/01.01.01_60/tr_103067v010101p.pdf

[319] See Core+ project http://core.willab.fi/; PR Newswire. Fairspectrum provides TV white space database for Europe's first geolocation radio license, 27 August 2012 http://www.prnewswire.com/news-releases/fairspectrum-provides-tv-white-space-database-for-europes-first-geolocation-radio-license-167517285.html

[320] Ofcom. Ofcom unveils participants in wireless innovation trial. News release, 2 October 2013 http://media.ofcom.org.uk/2013/10/02/ofcom-unveils-participants-in-wireless-innovation-trial/

agricultural services, rural broadband, sensors). However, the planned auction of the 600MHz band could significantly reduce spectrum access for WSD in the US[321].

If a converged platform deployed using supplemental downlinks were implemented below 700MHz some but not all white spaces could be removed[322]. Co-existence of white space devices with a mobile SDL could therefore be a possibility (as described for PMSE above) and so we do not count any impacts on this service in the cost benefit analysis.

[321] J Schmidt. Five years of CR policy development: lesson learned and the road ahead. Presentation, 29 April 2014 http://www.cost-terra.org/uploads/TERRA%20web%20content%20files/2014-04%20meeting%20Vilnius/2-1%20-%20GDB.pdf

[322] Not all mobile downlink frequencies would be used in all locations

# Appendix S: The economic value of sub-1 GHz spectrum

## S.1 Value of UHF spectrum

This appendix discusses possible estimates for the value of UHF spectrum that could be released for mobile use from the move to a converged broadcast-broadband platform. The following approaches considered are:

- Market benchmarks based on 800 MHz and 2.6 GHz auctions in Europe
- Estimates of avoided costs and additional benefits for 700 MHz spectrum based on Analysys Mason's May 2014 study for Ofcom[323]
- Two previous studies commissioned by Ofcom which also provide estimates of the value of the 700 MHz band.

## S.2 Auction benchmarks

Recent auctions for 800 MHz and 2.6 GHz in Europe[324] represent possible market benchmarks for the value of UHF spectrum released by the move to a converged platform. Both the 800 MHz and 2.6 GHz bands are harmonised for LTE in Europe and it is expected that the UHF spectrum released will be deployed for similar use.

To enable comparisons across countries, we make the following adjustments to the auction results:

- Normalise to a 20-year licence duration using a 10% discount rate
- Apply a purchasing power parity (PPP) adjustment factor to account for cost of living differences across the countries[325]
- Convert values in international dollars to euros (in March 2014 real terms).

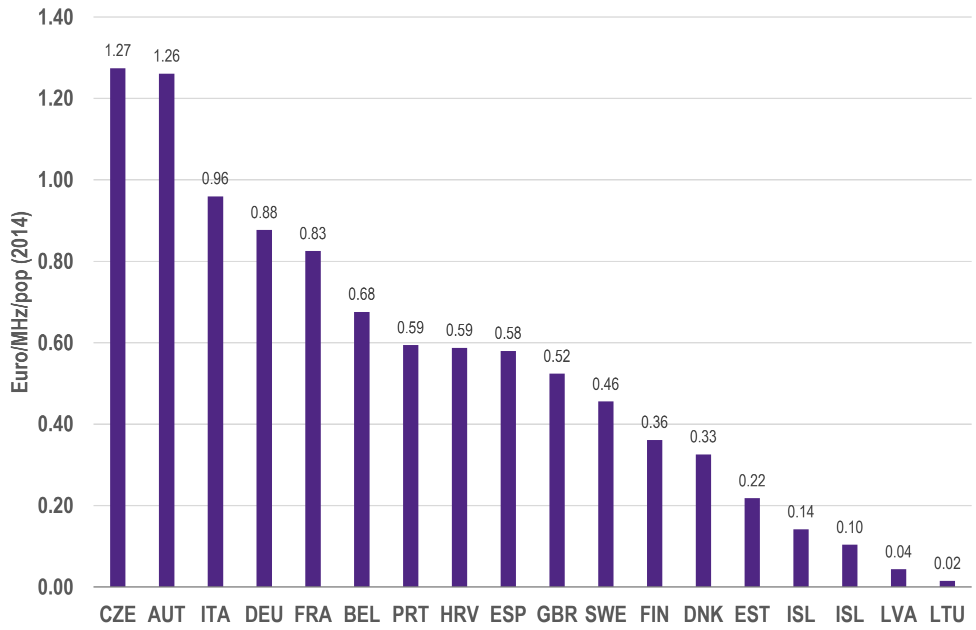
Figures S-1 and S-2 show the 800 MHz and 2.6 GHz FDD auction results for Europe expressed in EUR/MHz/pop. Note that we only report results from auctions where disaggregated results by band are available.

[323] Assessment of the benefits of a change of use of the 700 MHz band to mobile, Analysys Mason, May 2014 http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/annexes/benefits_700MHz.pdf

[324] We include results for countries in the European Free Trade Association (EFTA).

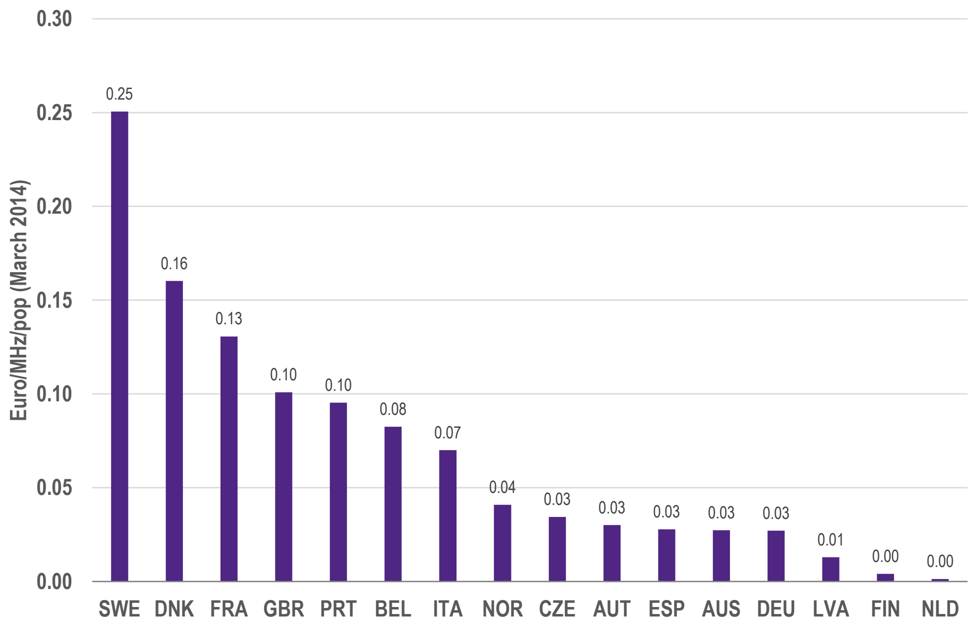
[325] This step involves a conversion of the auction results in local currency into the international dollar and an adjustment for inflation.

Figure S-1: European 800 MHz benchmarks




Source: Plum analysis based on data from national regulators

Figure S-2: European 2.6 GHz FDD benchmarks




Source: Plum analysis based on data from national regulators

Figure S3 summarises the benchmark data for the 800 MHz and 2.6 GHz auctions.

Figure S-3: Summary of market benchmarks (EUR PPP/MHz/pop, March 2014)

| | 800 MHz | 2.6 GHz FDD |
|---|---|---|
| Mean | 0.53 | 0.07 |
| Maximum | 1.27 (Czech Republic) | 0.25 (Sweden) |
| Minimum | 0.02 (Lithuania) | 0.001 (Netherlands) |
| Sample size | 21 | 16 |
| Standard deviation | 0.37 | 0.07 |
| 95% confidence interval | 0.36 – 0.70 | 0.03 – 0.10 |

## S.3 Ofcom 700 MHz consultation

In May 2014 Ofcom published a consultation document on the future use of the 700 MHz band which outlined its cost-benefit analysis (CBA) of changing its use to mobile.[326] In the assessment of the benefits Ofcom refer to the Analysys Mason study (May 2014) which used a network cost savings model from 2018-2041 to estimate the NPV of 700 MHz to a generic operator with 2x10 MHz holding.

In the study four scenarios are considered with varying input assumptions for traffic forecast, offloading, spectral efficiency forecast, spectrum availability, number of new build sites, type and cost of sites, site sharing, traffic distribution and traffic served by sub-1 GHz spectrum. The release of 700 MHz for mobile use is assumed to be take place in 2022 (Ofcom's base case for analysis) so the NPV calculated is for a 20-year period.

Figure S4 shows the results. The values reported are expressed in 2014 real terms and the NPV are calculated using a Spackman approach – annualising capital costs incurred by private firms using weighted average cost of capital (WACC) (6.2%) and discounting back to 2014 using the social discount rate of 3.5%.

Figure S-4: Network cost savings of the 700 MHz band (£ millions, 2014 real terms)

| | PV of network cost savings of 2x10 MHz to generic operator | PV of network cost savings of 2x30 MHz of 700 MHz |
|---|---|---|
| Wide range, low scenario | 65 | 195 |
| Central range, low scenario | **162** | **485** |
| Central range, high scenario | **255** | **766** |
| Wide range, high scenario | 309 | 927 |

Ofcom assessed the benefits of 700 MHz for mobile to be between £480m and £770m, noting that the wide range estimates by Analysys Mason are less plausible as they are based on factors which are particularly unlikely in combination. To compare these values to the auction benchmarks we make the following adjustments:

[326] http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/summary/main.pdf

- Adjust the NPV of cost savings using a 10% discount rate
- Apply a PPP adjustment factor to convert from GBP to EUR PPP
- Derive a EUR/MHz/pop based on UK population

The results are shown in Figure S5. They suggest that the value of the 700 MHz band could be closer to 2.6 GHz FDD than 800 MHz.

**Figure S-5: Network cost savings of 700 MHz, EUR PPP**

| | PV of network cost savings of 2x30 MHz of 700 MHz | Value/MHz/pop |
|---|---|---|
| Central range, low scenario | 370m | 0.0963 |
| Central range, high scenario | 582m | 0.1516 |

The Analysys Mason study also estimated the additional benefits of the 700 MHz band in terms of improved coverage, capacity and performance by estimating the additional sites required to provide the same capacity and performance (single user throughput) as could be achieved if the 700 MHz were available on all sites. The central range for these estimates is between £390 million and £480 million. It should be noted that these estimates are subject to greater uncertainty than cost savings calculations which Analysys Mason acknowledge in their report. Figure S6 shows the value of 700 MHz including the additional benefits. The inclusion of the additional benefits pushes the values up by 60%-80% but this is still 60% below the UK value of the 800 MHz spectrum.

**Figure S-6: Benefits of 700 MHz (including additional benefits), EUR PPP**

| | PV of network cost savings of 2x30 MHz of 700 MHz | PV of additional benefits | Value/MHz/pop |
|---|---|---|---|
| Central range, low scenario | 370m | 294m | 0.1729 |
| Central range, high scenario | 582m | 367m | 0.2472 |

## S.4 Previous Ofcom studies

Prior to its 700 MHz CBA Ofcom published two other studies which estimate the economic value of the 700 MHz – one by Real Wireless (2012) [327] and another by Analysys Mason and Aegis Systems (2013)[328]. We summarise their very different findings below for the sake of completeness

[327] Real Wireless. Techniques for increasing the capacity of wireless broadband networks: UK, 2012-2030, April 2012 http://www.ofcom.org.uk/static/uhf/real-wireless-report.pdf

[328] Analysys Mason and Aegis Systems. Opportunity cost of the spectrum used by digital terrestrial TV and digital audio broadcasting. March 2013. http://stakeholders.ofcom.org.uk/binaries/consultations/aip13/annexes/report.pdf

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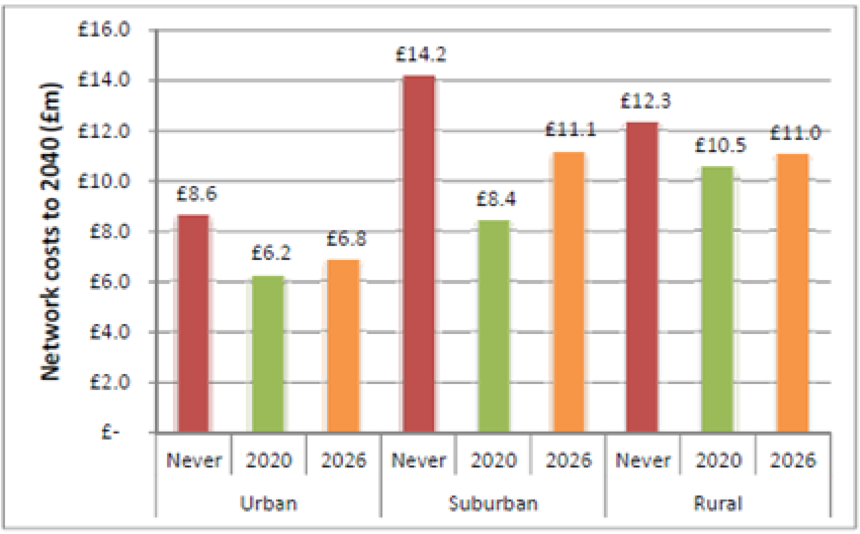
### S.4.1 Real Wireless (2012)

Real Wireless's study is based on analysis of 6% of the UK population divided into urban, suburban and rural categories, with the avoided cost estimates shown below (for the 'mid' case scenario). The NPV of avoided costs are calculated on the basis of incremental expenses from 2012 to 2040 (with the network size remaining constant from 2030-2040). The analysis is based on 700 MHz (2x40 MHz) being made available in 2020 and 2026 and the avoided cost estimates in 2012 values based on a social discount rate of 3.5% are shown below.

**Figure S-7: Impact of 700 MHz timing on network cost (mid demand and mid capacity scenarios)**




*Source: Real Wireless*

Based on Figure S-7, we calculate the incremental avoided cost for each of the areas as shown in Figure S8.

**Figure S-8: Incremental avoided cost for each area (£m, 2012), 3.5% discount**

| | Urban | Suburban | Rural |
|---|---|---|---|
| Weight | 3% | 2% | 1% |
| No 700 MHz | £8.6m | £14.2m | £12.3m |
| 700 MHz in 2020 | £6.2m | £8.4m | £10.5m |
| 700 MHz in 2026 | £6.8m | £11.1m | £11m |
| 2020 cost saving | £2.4m | £5.8m | £1.8m |
| 2026 cost saving | £1.8m | £3.1m | £1.3m |

Next we scale up to the UK on the basis of the weighted sum for the different areas and assuming each area individually is representative of the whole country as shown in Figure S9.  This gives us a mid-point estimate and upper and lower bounds.

**Figure S-9: Scaling to whole UK (£m, 2012), 3.5%discount**

| | 100% Urban | 100% Suburban | 100% Rural | Weighted |
|---|---|---|---|---|
| No 700 MHz | £287m | £710m | £1230m | £585m |
| 700 MHz in 2020 | £207m | £420m | £1050m | £418m |
| 700 MHz in 2026 | £227m | £555m | £1100m | £482m |
| 2020 cost saving | £80m | £290m | £180m | £167m |
| 2026 cost saving | £60m | £155m | £130m | £103m |

To ensure that these cost savings are comparable to the auction benchmarks we make the following adjustments:

- Adjust the NPV of cost savings using a 10% discount rate
- Apply a PPP adjustment factor to convert from GBP to EUR PPP
- Adjust for inflation to euros (in March 2014 real terms)
- Derive a EUR/MHz/pop based on UK population
- Adjust to reflect a 20-year NPV using a 10% discount rate

The final step is necessary because the 2020 and 2026 cost savings reported by Real Wireless reflect the value of 700 MHz for 21 and 15 years respectively. Putting them on a 20-year basis allows comparisons with the auction benchmarks. The results are shown in Figure S10.

**Figure S-10: Real Wireless NPV estimates for 700 MHz, EUR PPP/MHz/pop (March 2014)**

| Timing of 700 MHz availability | 100% urban | 100% suburban | 100% rural | weighted |
|---|---|---|---|---|
| 2020 cost saving | 0.0118 | 0.0428 | 0.0266 | 0.0246 |
| 2026 cost saving | 0.0101 | 0.0260 | 0.0218 | 0.0174 |

*Notes: NPV are for a 20-year duration, 10% discount rate used*

### S.4.2 The Analysys Mason-Aegis study (2013)

In the Analysys Mason-Aegis work a network cost model for a 20-year period from 2015-2034 is used to estimate the NPV of 700 MHz spectrum in the UK. The market is divided among four equally sized 'generic' operators with 25% market share each, and various scenarios in which an operator wins a varying amount of spectrum are considered (p86).

The results in below are taken from the scenario where the operator wins 2x10 MHz[329]. Since the result represents the NPV for a single operator, we scaled the results by a factor of four to represent the total market as shown in Figure S11.

**Figure S-11: AM-Aegis net present value of 700 MHz (2015 real terms), 6.2% discount**

| 700 MHz availability | Avoided cost of 700 MHz to generic operator | Factor by 4 to get total savings |
|---|---|---|
| 2x10 MHz of 700 MHz in 2020 | £539m | £2.156bn |
| 2x10 MHz of 700 MHz in 2026 | £350m | £1.4bn |

As with the Real Wireless cost saving values, we make the similar adjustments to put these values on the same basis to enable comparisons. The results are significantly higher than the Real Wireless calculations and suggest that 700 MHz is similar in value to the 800 MHz.

**Figure S-12: AM-Aegis NPV of 700 MHz, EUR PPP/MHz/pop (March 2014)**

| EUR/MHz/pop (2014) | Avoided cost of 700 MHz to generic operator | Factor by 4 to get total savings |
|---|---|---|
| 2x10 MHz of 700 MHz in 2020 | 0.1135 | 0.4538 |
| 2x10 MHz of 700 MHz in 2026 | 0.0973 | 0.3892 |

*Notes: NPV are for a 20-year duration, 10% discount rate used*

[329] Note that Analysys Mason produce a bar chart illustrating the NPV of costs for different spectrum holding scenarios, but that the figures in the graph do not match the figures in the table (p89) – we do not know the reason for this discrepancy. For this analysis the figure reported in the table has been used.

# Appendix T: The cost of upgrading a mobile network to provide an LPLT DTT network

## T.1 Introduction

This appendix sets out how we derive the cost of upgrading a mobile network to provide an LPLT DTT network in terms of:

- The number of base stations which need upgrading
- The capital costs required
- The likely operating costs
- The % of aerial realignments needed.

The assumptions used are based on:

- Plum and Farncombe estimates of unit costs derived from previous relevant consulting studies
- Discussion with key stakeholders and, in particular, Arqiva, IRT, NSN and Qualcomm
- Recent reports and presentations by IRT[330], Ofcom[331], and NSN (confidential).

## T.2 The number of base stations requiring an upgrade

There are 5000 macro-cell BTSs in a network in the 20 million population case study country[332]. This is similar to the position in Germany and the UK where there are roughly 15,000 BTS per operator serving a population of 60 to 80 million.

The population density is 250 people per square kilometres (like the UK and Germany)

The area of the country is 80,000 km² i.e. 20 million/250,000 people per square kilometres

The suburban and rural area is 95% of the total and the urban area 5%. This assumption is based on previous consulting studies by Plum to consider future mobile demand for spectrum which required estimates of the distribution of the population between rural and urban areas in Western Europe

ISDs in suburban and rural areas are 10 km giving cell sizes of 77 km²[333] but (say) 50 km² after allowing for terrain and overlap effects

ISDs in urban areas are 3 km giving a cell size of 7 km²[334] but (say) 5 km² after allowing for clutter effects etc

The number of rural sites = 0.95 x 80,000/50 = 1520

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[330] *Costs of hypothetical TV distribution via small cell networks – why there is no way out of the dilemma*, Alexander Schertz, IRT, July 2014

[331] *The Future of Free to View TV*, Ofcom, May 2014

[332] This estimate reflects conditions in our hypothetical member state. We considered the effects of lower population density in Section 10 of the main report

[333] 5km x 5km x π

[334] 1.5km x 1.5 km x π

The number of urban sites = 0.05 x 80,000/5 = 800

The total number of sites = 2320 (1520 + 800)

## T.3 Upgrade costs – capex

An upgrade at a site with spare mast space and electronic housing space costs €40,000. This estimate is based on discussions with Arqiva and NSN.

A major site upgrade costs €120,000. This estimate is based on discussions with Arqiva and figures published by Ofcom[335].

We assume 25% of sites need a major site upgrade in both urban and rural areas on the grounds that:

- Sites in rural areas likely to have the necessary capacity
- Urban areas offer more choice of sites but sites are less likely to have than the necessary capacity

So the average upgrade costs per site = €40000 x 0.75 + €120000 x 0.25 = €60,000

For the DVB option we add €4000 per site for additional electronics (based on discussions with Arqiva and NSN).

## T.4 Upgrade costs – opex

Maintenance and running costs are 20% pa of capex. This is an NSN estimate. 15% is a more normal industry figure. But we have used this conservative estimate after consultation with stakeholders.

25% of sites have opex = €120000 x 0.20 + €10000 for additional site rental = €34000 pa. Site upgrade costs come from D3 above. Site rentals are based on previous cost modelling work for EU mobile operators by Plum

75% of sites have opex = €40000 x 0.20 = €8000 pa

Average opex = €8000 x 0.75 + €34000 x 0.25 = €14,500 pa

For the DVB option we add 20% of €4000 = €800 pa

The total opex for an LPLT network in the case study country would be €14,500 x 2320 sites = €34 million pa for the LTE option and €36 million pa for the DVB option.

## T.5 Aerial reorientation

50% of households are in urban areas. This assumption is based on previous consulting studies by Plum to consider future mobile demand for spectrum which required estimates of the distribution of the population between rural and urban areas in Western Europe

[335] *The Future of Free to View TV*, Ofcom, May 2014

10% of these need reorientation. This assumption is based on discussions with Arqiva and Qualcomm. In urban areas ISDs are short and this substantially reduces requirements for aerial reorientation

50% of households are in suburban and rural areas

50% of these need reorientation. This assumption is based on discussions with Arqiva and Qualcomm

So overall the proportion of households requiring aerial reorientation = 50% x 10% + 50% x 50% = 30%

# Appendix U: The main sources for our assumptions

The table below lists the main sources for our assumptions.

| Assumption | Source |
|---|---|
| 2,320 base station sites to be upgraded | Estimated in Appendix T with its assumptions based on discussions with mobile equipment vendors and DTT network operators and on previous confidential Plum and Farncombe studies |
| €60,000 per site upgrade cost for the LTE-B option | Estimated in Appendix T with its assumptions based on discussions with mobile equipment vendors and DTT network operators and on previous confidential Plum and Farncombe studies |
| €4,000 more for the DVB option | Discussions with DTT network operators |
| €14,500 per year per site operating costs for the LTE-B (NSN) | Estimated in Appendix T with its assumptions based on discussions with mobile equipment vendors and DTT network operators and on previous confidential Plum and Farncombe studies |
| €45 million pa operating costs for existing HPHT DTT platform | Based on average operating costs of HPHT DTT networks in Spain, UK and Germany scaled pro rata to population of the case study country |
| €45 million for new platform development and implementation | Study assumption (costs include specifications, "EPG" management, certification, branding, marketing, regulatory and market structure related changes) based on confidential Farncombe studies |
| 5 year simulcast period for HPHT and LPLT with 20% pa upgrades | Study assumption for duration of simulcast period and network roll-out |
| €70 per DTT household per TV set for LTE broadcast option and €0 per TV set for DVB option | Based on cost of DTT set-top boxes with additional €20 for value of end user time |
| 30% of households require aerial reorientation at €70 per household | Estimated in Appendix T with its assumptions based on discussions with mobile equipment vendors and DTT network operators; study assumption for average cost of engineer visit for aerial re-alignment and/or new aerial structure |
| €40 million or €100 million for transition management costs | Based on average costs of managing digital switchover in Sweden and the UK (includes PMO setup and related activities, consumer helpline/support) |
| Average of €10 million per country for replanning spectrum to avoid cross border interference | Based on estimates by Analysys Mason for UK DSO spectrum planning and previous Farncombe studies |
| Average of €70 million for retuning of national HPHT DTT networks | Based on Arqiva estimates of the clearance costs of 700 MHz spectrum in the UK of £300 million – adjusted for the population in the case study country and assuming that 60% of high towers are affected (those in the border areas). |
| 5% new high discrimination aerials at €200 per aerial installed to enable regional SFNs can | Study assumption for new aerial and new aerial structure; assumes that 10% of households are unable to receive TV broadcasts based on regional SFNs[336] and that 50% of these require high discrimination aerials |

[336] *Frequency reuse of one for broadcast networks*. BBC for ECC TG6 TG6(14)064

# Appendix V: DTH satellite costs

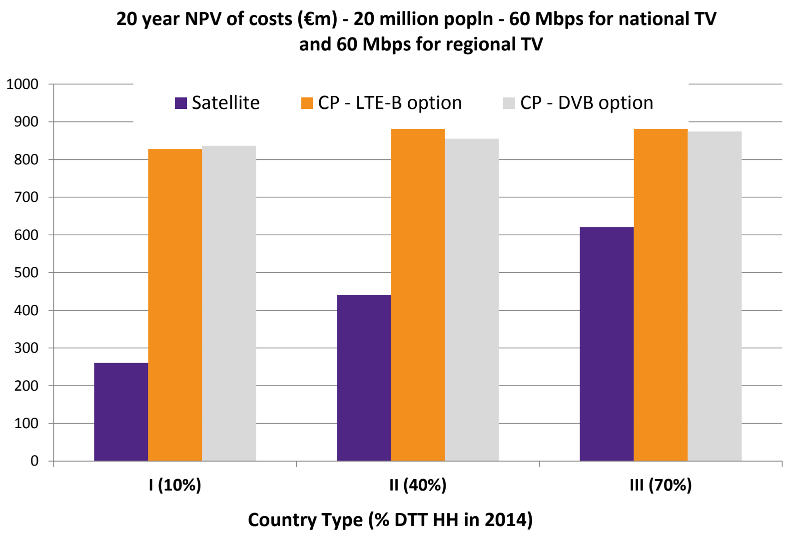
In this appendix we compare the costs of using DTH satellite with the costs of an LPLT converged platform under various circumstances. In all cases we assume the high impact scenario. To make our estimates we use the assumptions listed in Figure V1 for DTH satellite and the assumptions listed in Chapter 10 for the converged platform. In two cases we have a range of estimates for our unit costs. In both these cases the lower end of the range represents the view of key satellite suppliers on long-term future unit costs, while the upper end of the range represents the study team's view on current unit costs. We have used the midpoint of these ranges in making the estimate set out below.

**Figure V-1: Assumptions for DTH satellite costs for Figure V2**

| Parameter | Value |
|---|---|
| Satellite capacity required for national free to view channels (Mbps) | 60 |
| Satellite capacity required for regional free to view service (Mbps) | 60 |
| Cost of managing the transition €m) | 40 |
| Operating cost per Mbps for the satellite service (€000 pa) | 40 to 120 |
| Cost of upgrading each DTT household to receive the satellite service (€) | 150 to 250 |
| Average cost of developing and implementing new platform software for free to view satellite service (€m)[337] | 25 |

Based on these assumptions Figure V2 then compares the NPV of the costs of using DTH satellite and a converged platform for delivering 60 Mbps of national TV services and 60 Mbps of regional channels to DTT households in a country with 20 million people

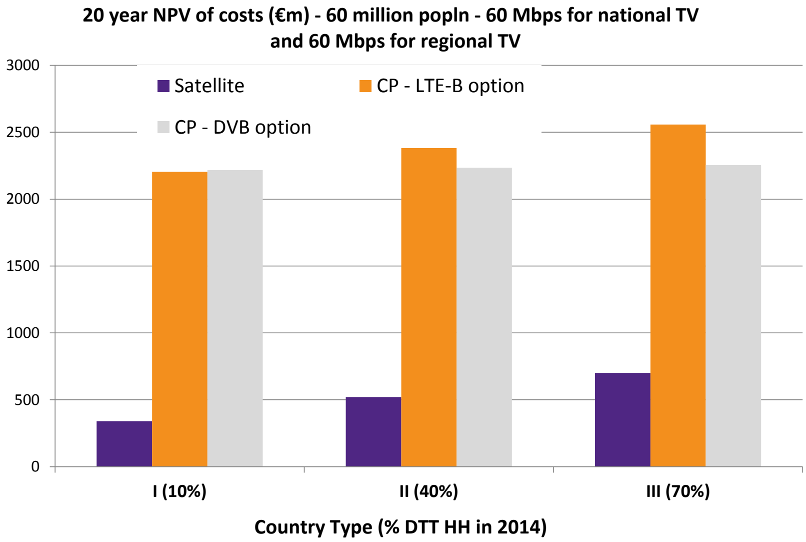
**Figure V-2: Cost comparison 1**




337 Assuming a 50% discount to reflect the fact that these platforms already exist in many member states

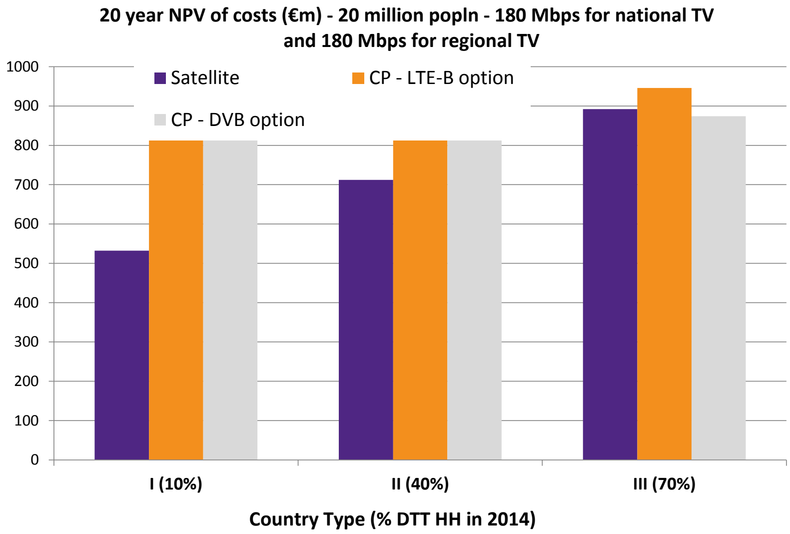
Figure V3 then compares costs for delivering the same TV payload to a country with a population of 60 million.

### Figure V-3: Cost comparison 2




Finally Figure V4 compares costs for delivering a payload of 180 Mbps of national TV channels and 180 Mbps of regional channels in a country with 20 million people.

### Figure V-4: Cost comparison 3



# Appendix W: Network reliability

## W.1 Introduction

This appendix summarises the key findings from our research on the reliability standards for broadcast and mobile networks set by regulators and the levels of reliability achieved by operators. Such standards and levels are typically measured in terms of availability or uptime requirements over a specified period of time.

In many cases mobile network operators and broadcasters tend to be vertically integrated (i.e. the same entity operates the network and provides the service). Where mobile operators or broadcasters enter into wholesale or sharing arrangements, these are usually private contract arrangements between network operators and service providers. Therefore information on network reliability is often not publicly available unless there is some regulatory requirement (e.g. in the UK where Arqiva is required by Ofcom to publish a national DTT reference offer).

In a few countries regulators have imposed general guidelines on technical standards for broadcasting and mobile networks. Most regulators however do not stipulate minimum reliability standards, especially where services are competitively provided. Instead, a self-regulatory approach, based on monitoring and publishing of quality of service indicators, is usually preferred (e.g. France, UK). These indicators cover various aspects such as call handling and performance, download speeds, network latency, service coverage and complaints handling.

## W.2 Broadcast network reliability

The typical uptime for broadcast networks ranges between 99.7% and 99.99%. Depending on the structure of the broadcasting sector, reliability measures sometimes distinguish between transmitter and backhaul network requirements. Examples of reliability measures in EU countries are:

- Denmark – 99.8% for PSB services, no information on commercial broadcasting
- Germany – 99.7% for transmitters; 99.9% for backhaul
- Spain – 99.8% for main transmitters; 99% for the rest

These measures are minimum contractual requirements on DTT network operator rather than regulatory requirements.

In the UK, Arqiva, the broadcast transmission operator, is required by Ofcom to publish reference offers for the provision of network access. In Arqiva's reference offer for national high power TV multiplex services[338], network access availability for each station calculated for preceding 12 months is calculated based on the following formula:

$$Network\ Access\ Availability\ (Station) = \frac{A - B}{A} \times 100\%$$

Where:

[338] http://www.arqiva.com/documentation/reference-offers/other-national-dtt-reference-offers/arqiva_reference_offer_version_3.pdf

A = Total number of minutes in the relevant 12 month period

B = Total minutes in the relevant 12 month period during which network access was not available at the relevant station, other than where such non-availability is attributable to an excluded event.

Network access levels for three categories of stations are specified as follows:

**Figure W-1: Arqiva's network access availability**

| Category | Antenna Configuration | Mains Electricity Supply Configuration | Structure Height | Network Access Level |
|---|---|---|---|---|
| Alpha | Main and Reserve | Duplicated | >50m | 99.95% |
| Beta | Split | Single | >50m | 99.90% |
| Gamma | Single | Single | <50m* | 99.50% |

These reliability levels are well in excess of regulatory requirements. Ofcom requires availability of 99.8% for reference transmitters (similar to Arqiva's Alpha category) and 99.0% for other transmitters.

## W.3 Mobile network reliability

There is little data in the public domain on the reliability standards for mobile networks. In some countries regulators require mobile network operators to monitor and submit reports on quality of service indicators but these tend to be related to voice rather than data services (e.g. call success rate, call drop rate, call set up time).

Some regulators (e.g. Singapore[339], UAE[340]) also require mobile operators to report performance indicators for their networks including core and access network availability. Core network availability is calculated as:

$$1 - \frac{\sum_{i=1}^{i=n} Ti * N_i}{Total\ time * T_n}$$

Where:

*Ti* = duration of outage in seconds

$N_i$ = number of affected subscribers during outage

*Total time* = time in seconds for specified period (e.g. one month)

$T_n$ = total number of subscribers for the mobile network

Access network availability is measured in terms of the total uptime of the radio network controller (RNC) and base station controller (BSC) for a specified period and is calculated as:

$$1 - \frac{\sum_{i=1}^{i=n} Bi * Cells_i}{Total\ time * Cells_n}$$

Where:

[339] http://www.ida.gov.sg/~/media/Files/PCDG/Licensees/StandardsQoS/QualityofService/MobileQoSFramework3Gnew.pdf

[340] http://www.tra.gov.ae/download.php?filename=policies_regulations/Reporting-Spec-V1.3-Annex%201-2-28-Sep-10.pdf

$B_i$ = duration of BSC/RNC outage in seconds

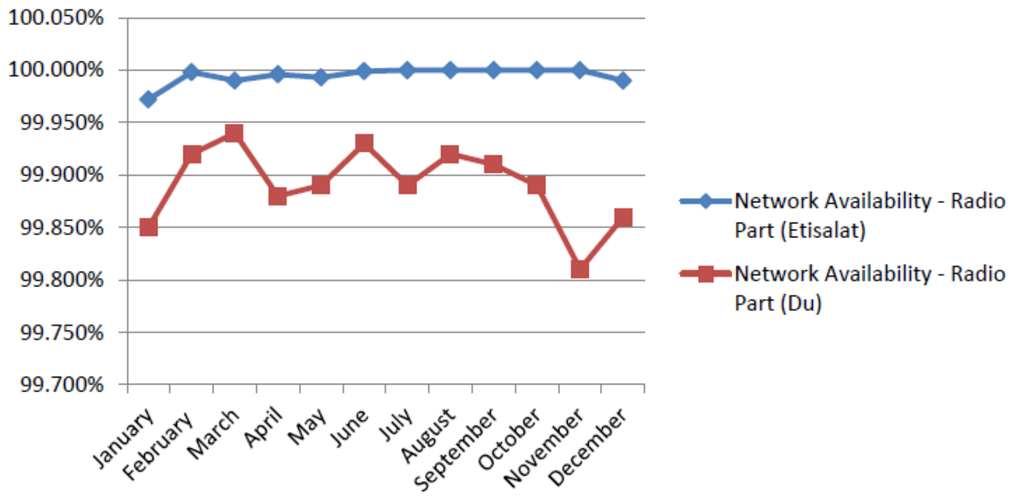
$Cells_i$ = number of cells connected to $BSC_i/RNC_i$

*Total time* = time in seconds for specified period (e.g. one month)

$Cells_n$ = total number of cells for the mobile network

According to figures published by the UAE telecoms regulatory authority (TRA) the core network availability for the two main operators DU and Etisalat is 100% for 2013 while the radio access network availability ranges between 99.8% and 100% as shown in Figure W2 below. In Hong Kong all five mobile operators report network availability in excess of 99.99%[341].

**Figure W2: Access network availability**




Source: UAE TRA

In March 2014 ictQatar published a consultation on a quality of service regulatory framework for telecoms services.[342] Among the requirements is a radio network unavailability of less than 1% (i.e. availability of above 99.0%). Radio network unavailability is measured in terms of the probing attempts with mobile services unavailable as a proportion of all probing attempts within a declared coverage area.

## W.4 Summary

Network reliability for broadcasting in terms of minimum uptime varies between 99.7% and 99.99% for main transmitters where there is redundancy provision and backup power supply. The reliability for secondary transmitters varies from 99% to 99.5%.

[341] http://www.ofca.gov.hk/en/consumer_focus/mobile_telecom/performance_pledges/index.html

[342] http://www.ictqatar.qa/en/documents/document/consultation-document-draft-qos-policy-and-regulatory-framework-annex-2-draft

For mobile network information on network reliability is not widely available.  For example we have not been able to get any information on reliability in EU member states.  Operators tell us that such information is commercially confidential.  In addition the contended nature of mobile services means that assessment of reliability is different to that for broadcast services. Regulators tend to focus on aspects such as call handling and performance, download speeds, network congestion in assessing quality of service or reliability of mobile networks.  Based on statistics published by the UAE and HK regulators, the typically uptime of radio access networks lies between 99.8% and 99.99%.

# Appendix X: The market for radio services

## X.1 Overview

Broadcast radio has been around since the later 1920s; like broadcast television the advent of digital technology and the internet are transforming the radio industry and the way radio is consumed. In this Appendix we discuss radio technology standards, recent EU market trends and radio consumption, and relevant policy developments around digital radio.

Radio listening is a key activity in the EU with 50% of EU citizens tuning in on a daily basis and 74% listening at least once a week. While digital radio has been around since the late 1990s, the migration to digital broadcast radio has been slow. FM radio continues to be the dominant platform and growth of digital radio penetration and market share has been slow. Even in the UK, which is the most mature DAB market in the EU, take-up of digital radio sets is at 35% (as of 2013) and weekly audience share of digital radio (DAB) is 24% compared to 58% for analogue (as of Q1 2014). By comparison online listening (6%) is still low while listening through digital TV is 5%.[343]

Possible factors contributing to the slow progress of developments around digital broadcast radio (DAB) in Europe so far:

- Fragmentation of standards and lack of devices – competing digital radio standards mean EU countries have not been able to fully agree on common standards which has hampered the development of receivers and compatible devices; although DAB is now widely implemented in Europe, it is not a global standard unlike FM
- Lack of economic incentives – for radio stations digital transmission is a significant additional cost offering little additional benefit and the possibility of additional competition for revenues. Also DAB is less well suited to local delivery, as most local radio markets (outside the main cities) cannot support the number of services (up to 10) carried on a digital multiplex. Hence commercial interest in digital radio is the additional capacity offered by digital radio. Also digital radio switchover does not release valuable spectrum for mobile services unlike TV; this means there is a lack of political support and public funds to help accelerate migration
- Strength of FM radio – FM remains the dominant radio platform audience and is likely to continue in most countries; the large base of low cost FM compatible devices and the absence of an obligatory switch-off date means listeners are not compelled to migrate to digital; consumer interest in DAB across Europe is low in general.
- Emergence of internet radio – as broadband penetration and take-up of internet-connected devices (smartphones, tablets) increase, internet radio provides a substitute to FM and DAB with the advantages of digital radio (e.g. choice, interaction) and at a lower cost for broadcasters.

In terms of spectrum policy, there is little activity or interest in VHF Band I while the status of DAB deployment in Band III varies across EU countries. There are plans in a few countries (Denmark, UK) for a digital radio switchover to address congestion in Band II but these are contingent on digital radio take-up and market developments. No firm deadlines for analogue radio switch-off have been confirmed – although Denmark is looking at end-2019. In recent years online radio services have

[343] Remaining 7% of radio listening unspecified (respondent unsure).

grown significantly and there is evidence of increasing online radio use among listeners, particularly younger listeners. This suggests that broadband platforms are likely to have an expanding role in the future delivery of radio services.

## X.2 Radio technology standards

There are multiple delivery platforms for radio services today – these comprise both analogue and digital technologies as well as dedicated (e.g. AM, FM) and complementary platforms (e.g. DTT, broadband). In general these are two fundamental approaches for distributing radio content – broadcast and broadband. There are various standards under each of these approaches and Table X-1 describes their common features and characteristics.

**Table X-1: Key features of broadcast and broadband radio distribution technologies**

| Broadcast distribution | Internet/broadband distribution |
|---|---|
| • Analogue and digital<br>• Broadcast/one to many delivery mechanism<br>• Unmediated/direct access to listeners<br>• Free to air reception<br>• Existing regulatory framework on content and network access<br>• Defined quality of service<br>• Access to spectrum crucial | • Digital only<br>• Unicast and multicast delivery via internet<br>• Potential for global coverage<br>• Require internet access subscription (fixed or mobile) for reception<br>• Gatekeeper element<br>• Greater scope for flexibility and interactivity<br>• Best effort delivery (OTT)<br>• No need for dedicated spectrum access |

*Source: Adapted from ECC Report 177*[344]

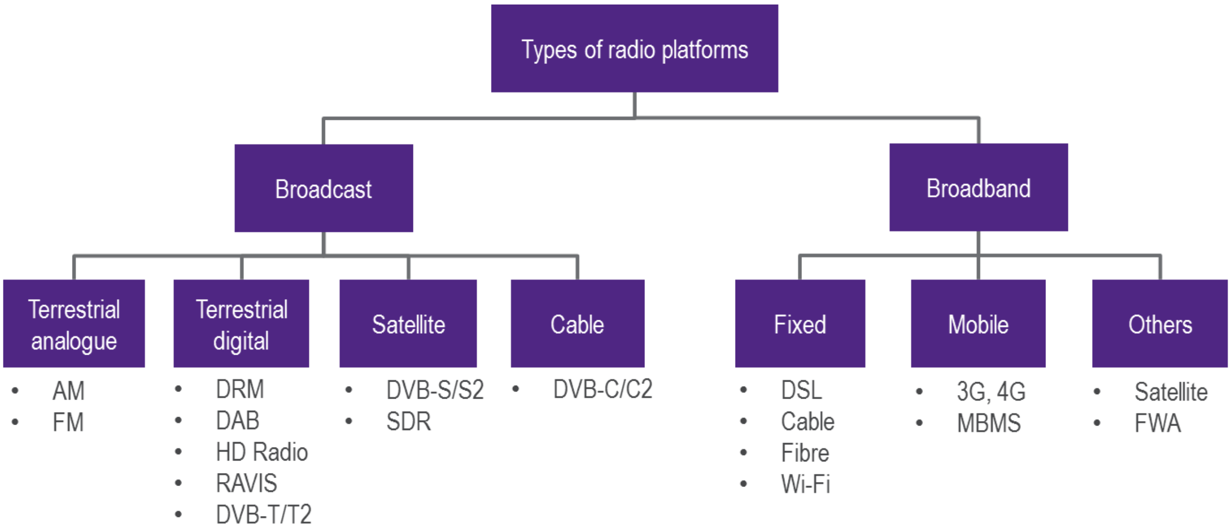
For consumers there are various advantages which digital broadcast radio and online radio offer over analogue platforms. These include:

- Better navigation between stations
- Ability to pause and rewind live radio
- Catch-up services (e.g. podcasts) and ability to download these to personal players
- Personalisation and interactive services (e.g. programmes, playlists, recommendations)
- Access to supplementary data regarding the current track or programme.

Figure X-1 provides an overview of the types of technologies or platforms for radio distribution.

[344] ECC Report 177. Possibilities for future terrestrial delivery of audio broadcasting services, April 2012.

**Figure X-1: Types of radio platforms**




## X.2.1 Broadcast platforms

**AM (amplitude modulation)** radio is first radio technology developed in the early 1900s and is still used today. AM radio stations operate in the low frequency (30–300 kHz), medium frequency (300–3000 kHz) and high frequency (1.6-30 MHz) bands with a carrier channel of 5 kHz or 9 kHz. Due to the higher levels of interference at these lower frequencies AM radio is usually used for news and talk radio rather than music.

**FM (frequency modulation)** radio provides sound broadcasting using VHF Band II (87.5-108 MHz) with carrier channels of 100 kHz. It is the most widely used radio platform with significant advantages including wide coverage, superior sound quality (compared to AM) and low cost in terms of current networks available and receivers in the market. FM radio is well suited to local, regional and national programming and FM is also a common feature in car radio and mobile phones.

Digital radio emerged in the 1990s with the introduction of **Digital Audio Broadcasting (DAB)** standard initially using MPEG Audio Layer II encoding and then MP3. The emergence of the more efficient MPEG-4 AAC compression standard has been incorporated into the next generation standard **DAB+** which can accommodate about twice the number of services of its predecessor. The carrier channels for DAB/DAB+ are 1.75 MHz and the number of programme streams that a single channel can carry depends on the desired audio quality; typically one DAB multiplex can support about 10 programme streams. Compared to AM and FM, DAB offers features such as programme guides and real-time information (e.g. song titles, news and traffic updates).

DAB/DAB+ is the most widely adopted digital broadcast radio platform and regular services are being provided in 13 of EU28 countries according to WorldDMB, with 11 other EU28 countries having held DAB/DAB+ trials at various times.[345] DAB/DAB+ is mainly deployed in the VHF Band III (174-230 MHz); while the L-band (1452-1492 MHz) has also been allocated for terrestrial and satellite DAB,

[345] WorldDMB. http://www.worlddab.org/country-information (Accessed 7 August 2014)

there have been few actual DAB deployments in this band in Europe and this band has since been the subject of an ECC Decision on harmonisation for wireless broadband use.[346]

**Digital Radio Mondiale (DRM)** is another digital radio standard developed for use in the current AM bands to complement DAB. It has been standardised in Europe and trials have been held in at least 8 countries.[347] The current status of DRM in those countries is unclear. The extension **DRM+** is designed to work in the VHF bands I, II and III has also been mooted as a possible long term replacement for FM radio. DRM+ is a spectrum efficient system with a bit rate capacity up to 186 kbps at only 96 kHz bandwidth.

**HD Radio** was selected by the FCC in 2002 as the digital radio standard for the United States. It is a proprietary standard, unlike DAB and DRM which are open standards, and uses the VHF Band II while supporting simultaneous operation of legacy AM and FM services.[348] Another digital radio standard is **RAVIS** which is intended to deliver audio and multimedia content through narrowband channels (100, 200, 250 kHz) for VHF bands I and II, has been trialled in Russia.

Satellite is another delivery platform for radio and ETSI has developed the **Satellite Digital Radio (SDR)** for direct broadcasts to mobile and handheld receivers in the L-band (1479.5-1492 MHz) and S-band (2-4 GHz). The main advantage of satellite radio is coverage due to its ability to reach remote areas. However with the wide coverage of terrestrial radio platforms SDR has not been deployed in Europe. Unlike the US and China where satellite radio has had some success, the different languages, national regulations and market conditions across Europe pose considerable challenges for establishing satellite radio services.

**Table X-2: Comparison of different broadcast radio standards**

| Standard | Multiplex bandwidth | Suitable bands | Channel raster (ITU Region 1) |
|---|---|---|---|
| AM | NA | LF, MF, HF | 9 kHz<br>5 kHz |
| DRM30 (DRM Mode A-D) | 4.5 – 20 kHz | LF, MF, HF | 9 kHz<br>5 kHz |
| HD Radio AM | 10 – 30 kHz | MF | 9 kHz |
| FM | NA | VHF II | 100 kHz |
| DAB | 1.5 MHz | VHF III, L-band | 1.75 MHz |
| DAB+ | 1.5 MHz | VHF III, L-band | 1.75 MHz |
| DRM+ (DRM Mode E) | 96 kHz | VHF I, II, III | 100 kHz |
| HD Radio FM | 70 – 200 kHz | VHF II | 100 kHz |
| RAVIS | 100 kHz, 200 kHz, 250 kHz | VHF I, II | 30 kHz (Russia) |

*Source: ECC Report 177*

[346] ECC Decision ECCDEC(13)03, 8 November 2013. http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCDEC1303.PDF

[347] Belgium, Bulgaria, Denmark, France, Germany, Italy, Luxembourg, Spain and the UK

[348] http://www.ibiquity.com/hd_radio

Besides the radio-specific platforms discussed above, broadcast TV platforms (DTT, DTH satellite cable) are often used to deliver radio services as well. In many EU countries both free and pay TV platforms typically provide a selection of free-to-air radio channels alongside TV channels.

### X.2.2 Broadband platforms

Just like television digital technology has enabled the delivery of radio over IP platforms. Today Internet radio can be accessed over any broadband platform (fixed, mobile, satellite) and increasing broadband penetration coupled with the proliferation of connected devices means the Internet is becoming a key way for many to access radio services.

Internet radio services comprise both conventional linear radio as well as on-demand radio services (i.e. podcasts). These can be delivered via streaming or downloads (for on-demand services). Quality of service for streaming may be variable because of most radio services are delivered using unmanaged broadband Internet (i.e. over the top); however this is less of an issue for radio than video because the bitrate requirements for audio services are around 128 kbps (although higher quality streaming may take up to 320 kbps) compared to around 1500 kbps for a SD video stream. As bandwidth constraints are not as acute for Internet radio, most services are provided in unicast mode although multicast technology has also been implemented to help improve quality of experience for listeners.[349]

Internet radio offers opportunities for new forms of interaction with listeners (e.g. audience feedback, participation, social networking, sharing) and improved features (e.g. playlists, links to information, podcasts). Unlike broadcast radio which is inherently national or regional, the global nature of the internet infrastructure means internet radio is potentially accessible by a worldwide audience. Another key difference with broadcast radio is that internet radio does not require access to dedicated spectrum.

## X.3 Market trends for radio

The market trends reported in this section are based on desk research and our analysis of publicly available data. Data on the radio industry in Europe is not as comprehensive as for TV and thus it is not possible in most cases to present data for all EU28 member states. Historic data is not available in many cases as well. We have focussed our research on the main EU countries (i.e. France, Germany, Italy, Spain, UK) and also report information for any other EU country for which there is data available.

### X.3.1 Industry revenue

On the whole, annual radio industry revenues in Europe have remained fairly constant between 2008 and 2012 as shown in Table X-3. Germany has by far the big radio market in terms of revenue – €3.5 billion (2013 prices) followed by the UK (€1.5 billion) and France (€1.2 billion) as shown in Table G-3. For other EU countries radio industry revenues tend to be than €500 million per annum. The German

[349] http://www.bbc.co.uk/multicast/radio/

radio industry is about a quarter the size of the TV industry; in most other EU countries radio revenues typically range from 5-10% of TV revenues.[350]

In general overall industry revenues have either remained constant or fallen from 2009-2012. Revenue in real terms has fallen by 50% or more in Ireland, Netherlands and Sweden over this period.

**Table X-3: Total radio industry revenue (€bn, 2013 prices)**

| | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|
| Germany | 3.56 | 3.66 | 3.61 | 3.47 | 3.50 |
| UK | 1.78 | 1.46 | 1.37 | 1.44 | 1.50 |
| France | 1.64 | 1.58 | 1.62 | 1.80 | 1.25 |
| Spain | | 0.61 | 0.62 | 0.60 | 0.50 |
| Netherlands | | 0.49 | 0.50 | 0.36 | 0.25 |
| Italy | | 0.47 | 0.50 | 0.60 | 0.50 |
| Sweden | | 0.37 | 0.37 | 0.36 | 0.12 |
| Ireland | | 0.24 | 0.25 | 0.12 | 0.12 |
| Poland | | 0.12 | 0.12 | 0.24 | 0.12 |

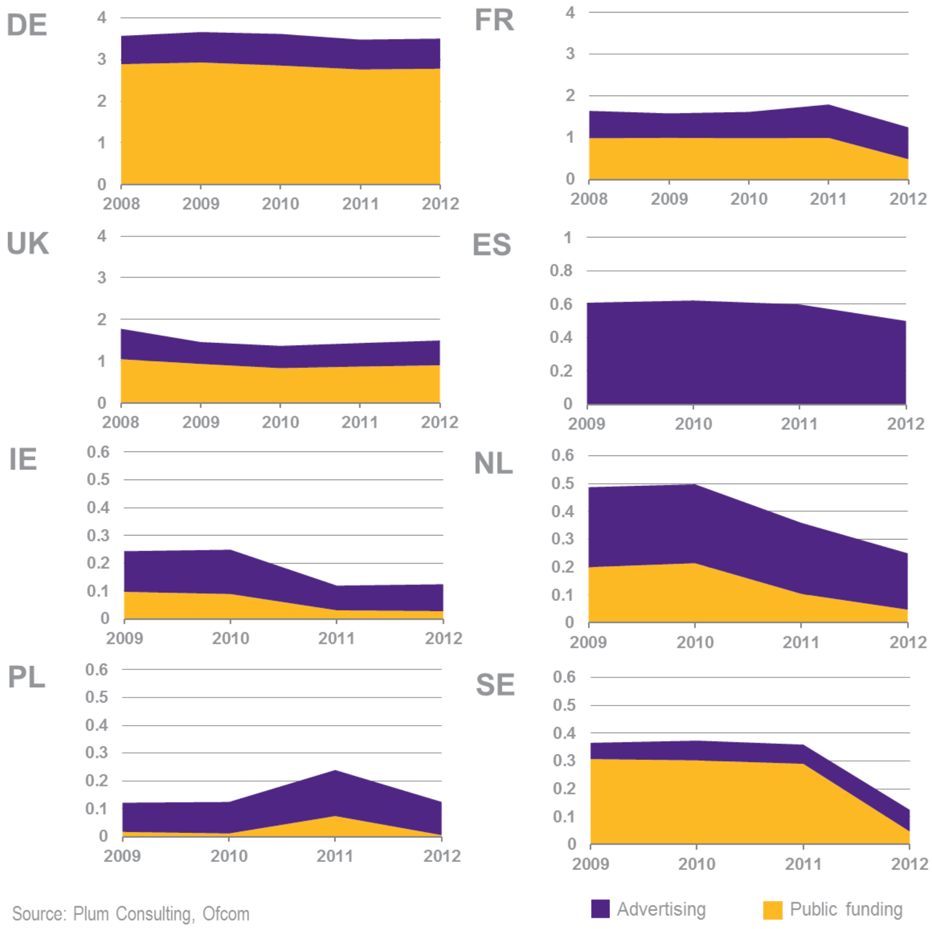
*Source: Plum Consulting, Ofcom ICMR*

The two principal sources of revenue for radio broadcasters in Europe are advertising and licence fees although the ratio differs greatly between countries as illustrated in Figure X-2. The proportion of advertising revenues ranges from 100% (Spain) to 21% (Germany). With the exception of Germany and the UK, licence fee revenues have fallen from 2009-2012 in real terms with significant decline in a number of countries (France, Netherlands, Sweden, Ireland). In comparison variations in advertising revenues have been smaller with either a slight decline or increase.

Figure X-3 then compares radio revenue per capita in 2012.  Public funding is significant in Germany, France, UK and Sweden and sector revenues per capita vary greatly.

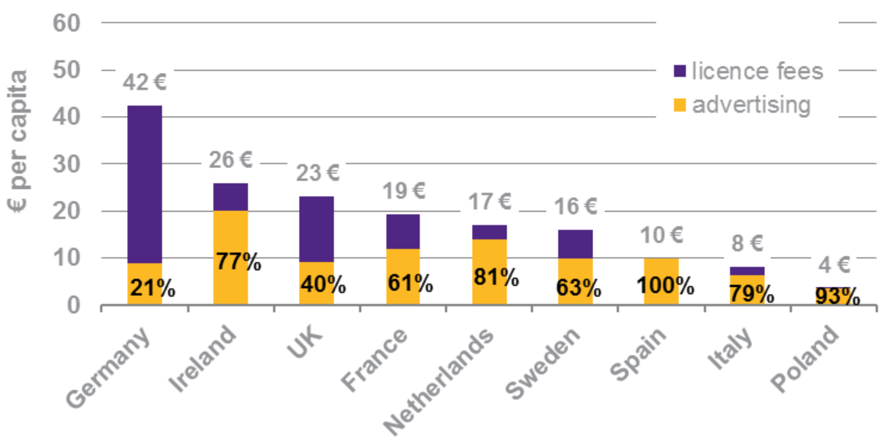
[350] According to data from Ofcom's International Communications Market Report (2013)

**Figure X-2: Radio industry revenues by source, 2008-2012 (€ bn, 2013 prices)**




Source: Plum Consulting, Ofcom

**Figure X-3: Radio industry revenue per capita in 2012 (€, 2013 prices)**




Source: Plum Consulting, Ofcom

## X.3.2 Analogue radio

Data on the number of AM and FM stations in EU countries is patchy but it is clear that analogue radio is firmly established in across all countries. Table X-4 shows the estimated number of FM radio stations in selected EU countries in 2013.

**Table X-4: Approximate number of FM stations**

| Country | Number of FM radio stations | Source |
|---|---|---|
| Belgium | FM radio stations are divided by language in Belgium. Regarding Flemish, there are 2 national, 5 regional and 293 local broadcasters. For French, there are 11 national, 5 provincial and 84 local broadcasters. Regarding German, there are 3 national, 2 regional and 4 local broadcasters. | ECC Report 141[351] |
| Czech Rep. | There are 3 national PSB FM radio networks and 2 national commercial FM radio networks. | ECC Report 141 |
| France | There are nearly 900 private FM radio broadcasters in France. | CSA[352] |
| Germany | There are approximately 390 FM radio stations in Germany | Wikipedia[353] |
| Hungary | There are 3 national PSB FM radio networks and 2 national commercial FM radio networks. | ECC Report 141 |
| Ireland | There are 4 PSB national FM radio stations. There are also 57 commercial radio stations with the following breakdown; 1 national; 1 quasi-national; 1 multi-city; 4 regional; 26 local; 1 special interest; 18 community and 5 institutional FM radio stations. | ECC Report 141 |
| Latvia | There are about 140 FM radio stations forming 8 ‘nationwide networks’. | RSPG[354] |
| Lithuania | There are 10 national FM radio networks (7 of which are commercial). There are 42 regional and local radio stations. | ECC Report 141, RSPG |
| Netherlands | There are over 300 FM radio stations, with the following breakdown; 4 national PSB; 12 regional PSB; 4 local minority PSB; about 300 local PSB; 9 nearly national commercial; 38 regional commercial; and 3 local military FM radio stations. | ECC Report 141 |
| Portugal | There are 6 national and 2 regional FM networks, and over 300 local FM radio stations. | COCOM[355] |
| Romania | There are 4 national FM radio networks (2 of which are PSB). | ECC Report 141 |
| Slovakia | There are 4 national PSB FM radio services. There are also 9 multi-regional, 15 regional and 9 local commercial FM radio broadcasters. | ECC Report 141 |
| Sweden | Regarding analogue radio stations (FM and AM) there are 4 national stations; 27 regional stations; 103 commercial stations; 831 community radio associations and 151 community radio transmit areas. | Sweden Broadcasting Authority[356] |
| UK | There are 490 FM radio stations in total. The breakdown is 4 PSB national; 1 commercial national; 238 local commercial; 46 PSB local; and 201 community FM radio stations. | Ofcom[357] |

351 ECC Report 141. Future possibilities for the digitalisation of Band II (87.5-108 MHz). May 2010

352 http://www.csa.fr/Radio

353 http://en.wikipedia.org/wiki/List_of_radio_stations_in_Germany

354 RSPG. The future of radio broadcasting in Europe: identified needs, opportunities and possible ways forward. October 2010.

355 COCOM. Results from the questionnaire to Member States on digital broadcasting, 8 January 2014.

356 http://www.radioochtv.se/om-mediebranschen/mediestatistik/

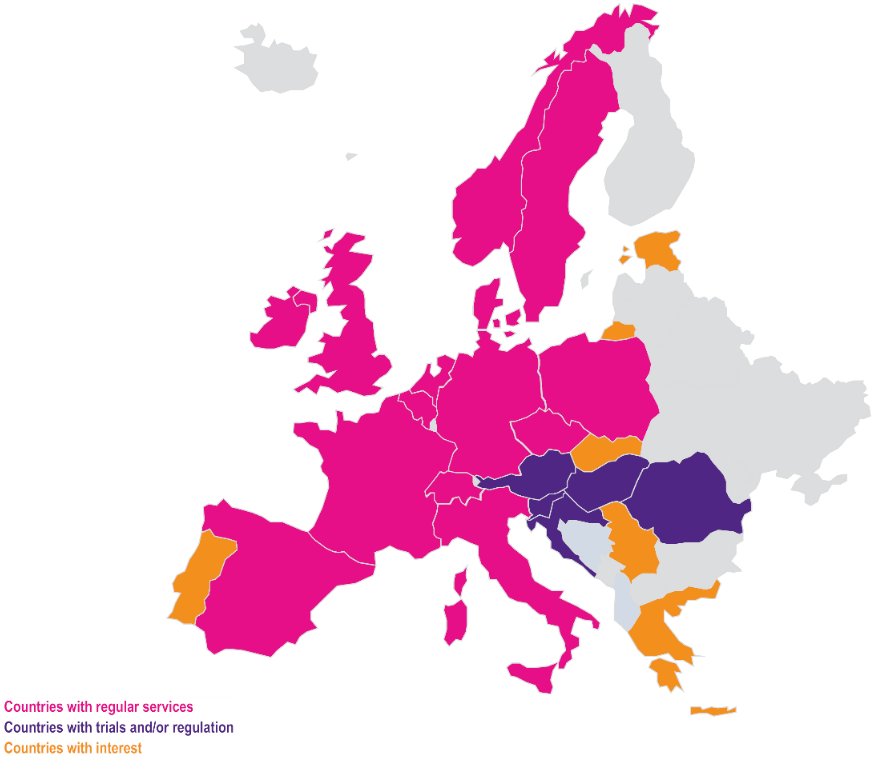
357 http://stakeholders.ofcom.org.uk/binaries/research/radio-research/drr-13/2013_DRR.pdf

The majority of radio stations for each country are regional, local or community stations. The FM radio industry is typically highly localised, often with only a few national stations in a country. The EU5 countries each have between 10 and 20 national FM radio stations.

### X.3.3 Digital radio (DAB)

Broadcast digital radio in Europe is predominantly in the form of DAB/DAB+ which operates mainly in VHF Band III. While there have been some DRM trials, there are few actual services – a joint BBC-Deutsche Welle service at transmitting at 1296 kHz is one of the few DRM services launched in Europe.[358] Figure X-4 shows the deployment of DAB/DAB+ in Europe as of September 2014. Of the countries with regular services most - except Ireland, Spain and the UK - have launched DAB+ services.

**Figure X-4: Status of DAB/DAB+ deployment in Europe (2014)**



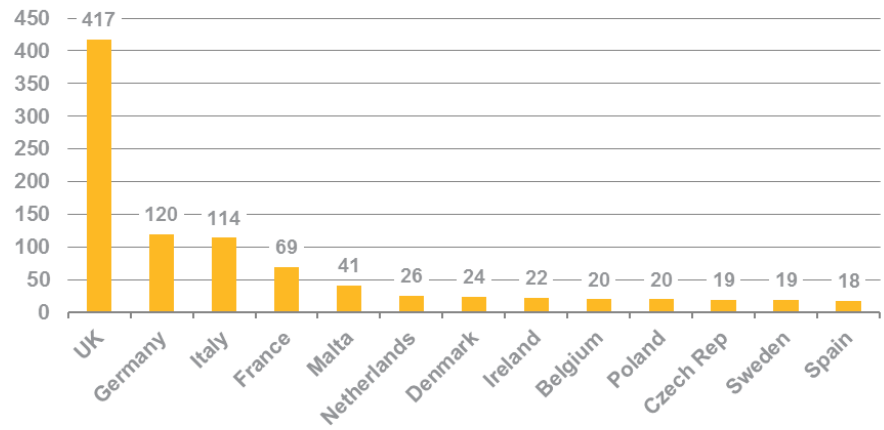

Source: Plum Consulting, WorldDMB

The number of DAB/DAB+ stations in Europe is shown in Figure X-5. These consist of national, regional and local/community stations and include both simulcast and digital only stations. DAB/DAB+ is most common in the UK, Germany and Italy – DAB+ services have been launched in Germany and Italy while the UK is using DAB. In June 2014 France launched DAB+ with a total of 69 stations on air

[358] http://www.bbc.co.uk/pressoffice/pressreleases/stories/2008/09_september/16/drm.shtml

in Paris, Marseille and Nice.[359] In most other countries where DAB/DAB+ has been launched, there are typically around 20 stations.

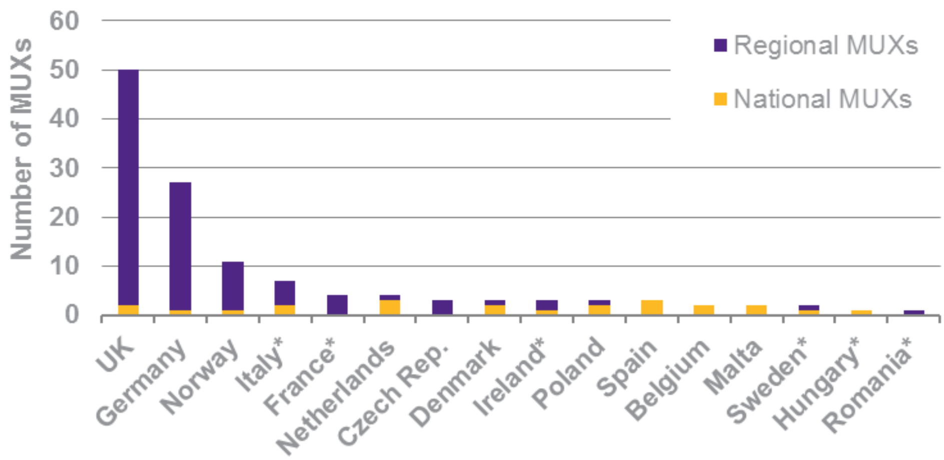
Figure X-5: Number of DAB/DAB+ stations (2014)[360]




Source: Plum Consutling, WorldDMB

Figure X-6 and Figure X-7 give the number of digital radio multiplexes (muxes) and population coverage of DAB/DAB+ by country. Most countries have deployed one to three national muxes while the number of regional muxes differs greatly with the UK and Germany having a significant number of regional muxes. DAB/DAB+ services have not been launched in about half of the EU28 countries.[361]

Figure X-6: Number of DAB/DAB+ multiplexes (2014)



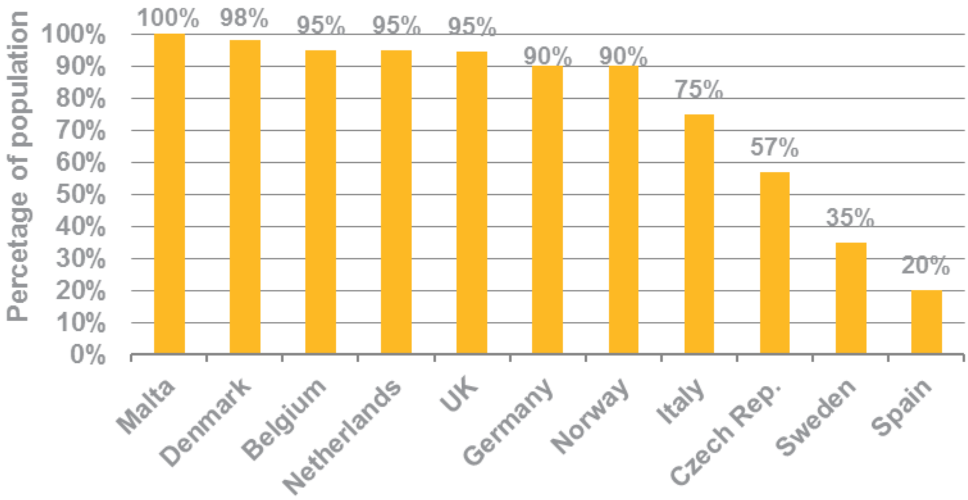

*Including MUXs on trial
Source: Plum Consulting, WorldDMB

[359] World DMB Global Update. September 2014 http://www.worlddab.org/public_document/file/493/WorldDMB-Country_Update-web.pdf?1410172799

[360] http://www.worlddab.org/country-information

[361] Austria, Bulgaria, Croatia, Cyprus, Denmark, Estonia, Finland, Greece, Lithuania, Luxembourg, Portugal, Slovakia, Slovenia.

Figure X-7: Population coverage of DAB/DAB+ services (2014)




Source: Plum Consutling, WorldDMB

Compared to FM, DAB is much less established in Europe. In countries which have launched DAB services there are typically fewer DAB than FM stations; many other countries are either still at a trial stage or do not have any firm plans for DAB.

### X.3.4 Internet radio

Internet radio services have proliferated in recent years and along with the devices and applications through which radio can be accessed over the Internet. While early internet streaming radio was mainly accessed through a web browser on PCs and laptops, radio services are now available through various online portals across multiple devices such as smartphones, smart TVs, tablets and gaming consoles. These include services providing streaming versions of broadcast radio stations (e.g. Radioplayer[362], TuneIn[363]) as well as on-demand audio streaming services (e.g. Rdio[364], Spotify[365])

We estimate that there are over 4,000 EU radio stations available through online streaming[366], with a breakdown by country given in Figure X-8. Globally there are some 100,000 radio stations from more than 200 countries according to online radio portal TuneIn.

362 http://www.radioplayer.co.uk/

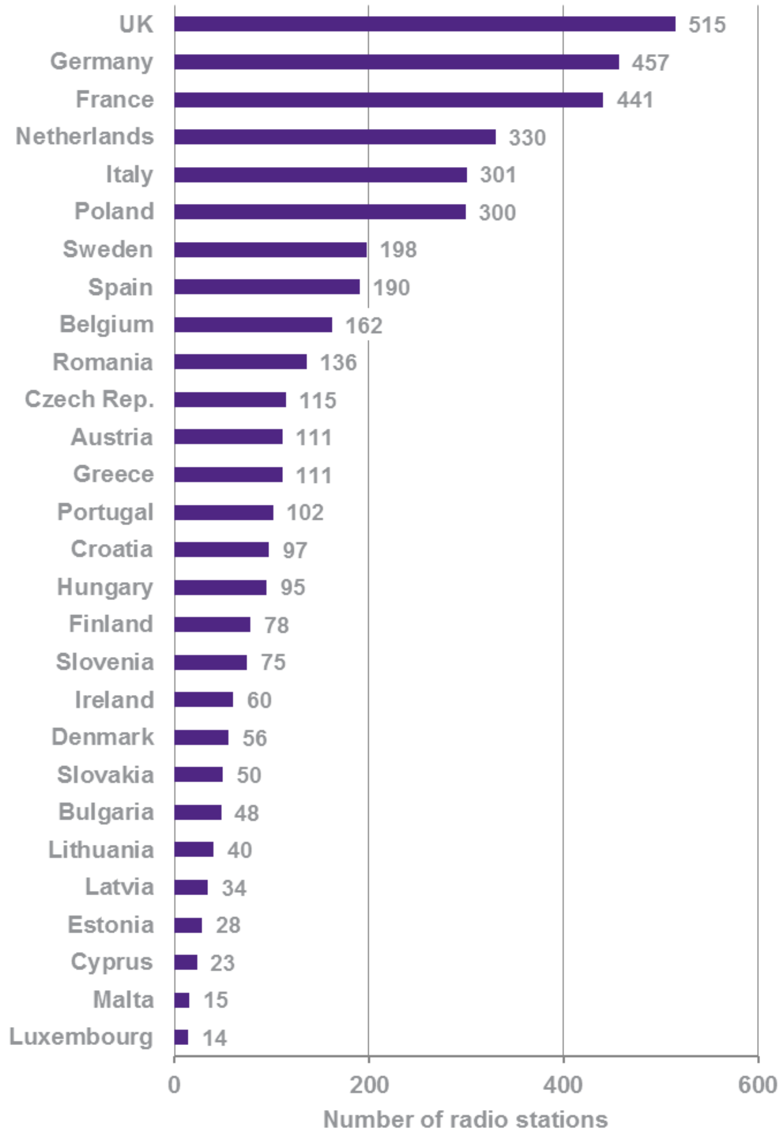
363 http://tunein.com/

364 http://www.rdio.com/

365 https://www.spotify.com/

366 This is based on the radio stations listed on www.listenlive.eu (accessed 27 May 2014).

Figure X-8: Number of online radio stations (by country of origin)




Source: Plum Consulting, listenlive.eu*
*Accessed 27th May 2014

## X.4 Radio listening

### X.4.1 Listening hours

On the whole, 74% of EU citizens listen to radio at least once a week with 50% tuning in on a daily basis in 2013.[367] In terms of reach, radio is only second to television among the different forms of media – 97% watch TV at least once a week. As shown in Table X-5 listening levels have remained

[367] European Commission. Media use in the European Union. Standard Eurobarometer 80, November 2013.

fairly constant since 2010 reflecting radio's position as a well-established form of entertainment for most people. The reach of radio in the EU is around 90% which is second only to television.

**Table X-5: Frequency of radio listening in the EU**

| | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| Every day/almost everyday | 56% | 51% | 53% | 50% |
| At least once a week | 23% | 25% | 24% | 24% |
| Less than once a week | 11% | 12% | 11% | 13% |
| Never | 10% | 11% | 12% | 12% |

*Source: Eurobarometer*

There are pronounced differences in radio listening across the EU28 countries as illustrated in Figure X-9. EU citizens in Germany, Ireland and Austria are most likely to listen to the radio every day (all 70%). Conversely, less than one-third of respondents say they listen to the radio every day in Bulgaria (22%) and Romania (31%).

Data on the number of listening hours is not available across all EU countries; however national survey data from several countries indicate that radio listening hours are similar to TV viewing (228 minutes per day[368]). In Finland, radio audiences spent an average of almost 4 hours (236 minutes) per day listening to radio for February-April 2014.[369] In Malta, radio audiences listen to an average of 3.34 hours (200 minutes) in February 2014.[370] Irish audiences also listen to a similar amount of radio daily in 2013 (234 minutes, 7am-7pm).[371] In the UK average weekly listening among radio audiences is 22.0 hours, 3.14 hours (189 minutes) in 2013.[372]

[368] Average for 43 European countries in 2011. Source: Eurodata

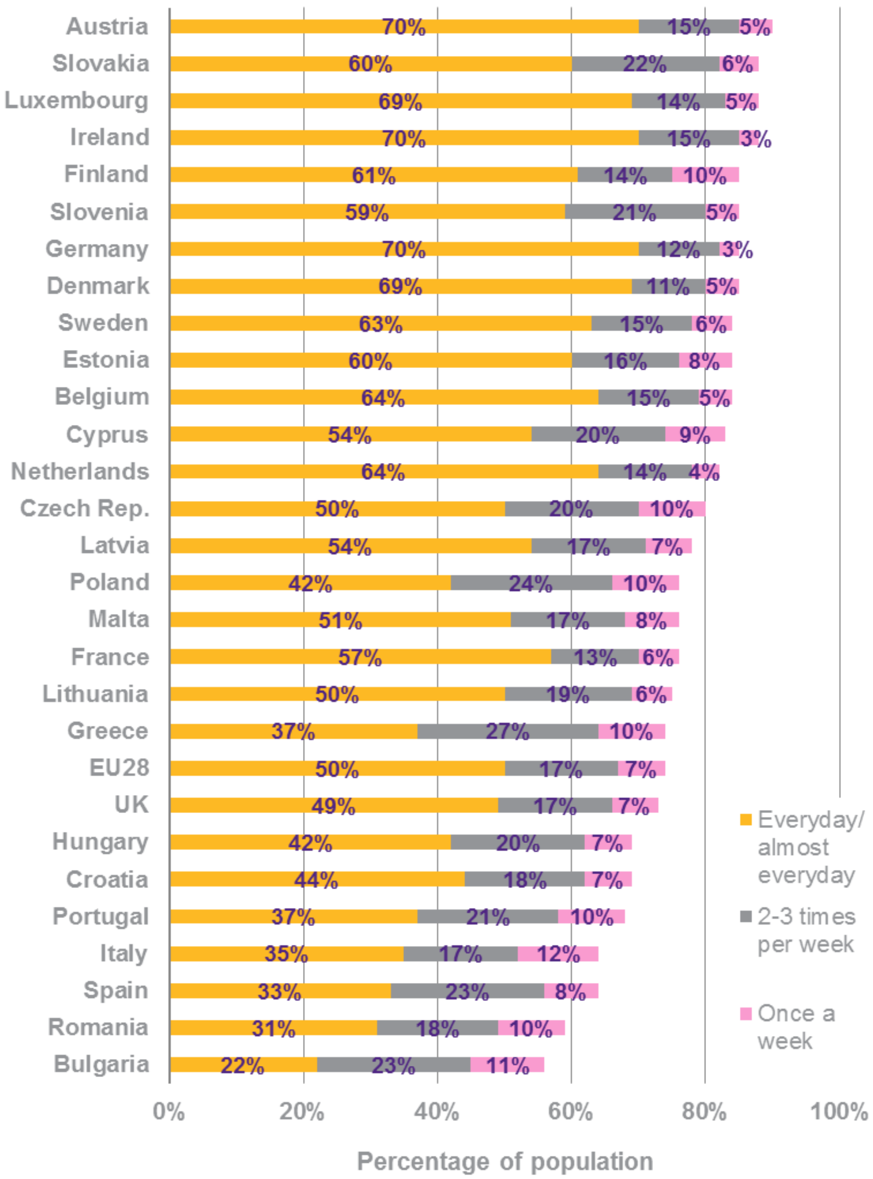
[369] Finnpanel. Results from the National Radio Survey. http://www.finnpanel.fi/en/tulokset/radio/krt/viimeisin/tavoittavuus.html

[370] Broadcasting Authority Malta. Radio and Television Audiences, April 2014.

[371] Broadcasting Authority of Ireland. JNLR/Ipsos MRBI April 2013-March 2014. http://www.bai.ie/?page_id=142

[372] Ofcom. Communications Market Report 2013.

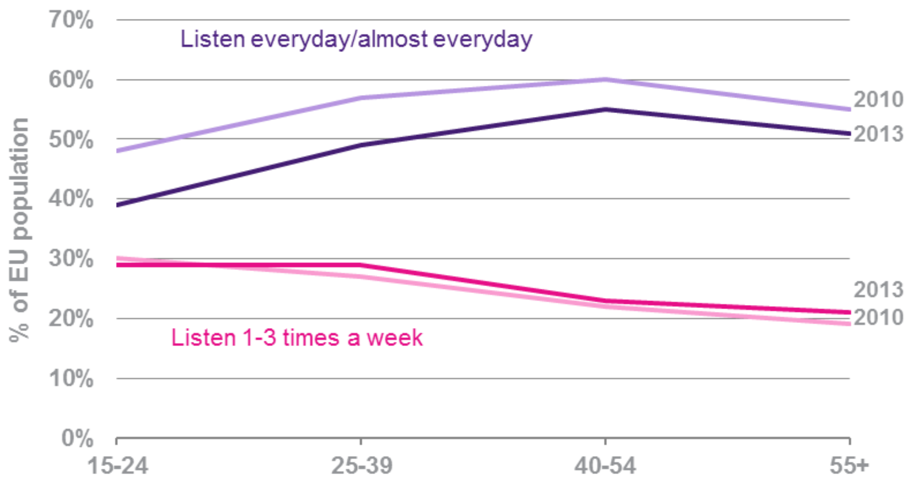
Figure X-9: Radio listening by country (2013)




Source: Plum Consulting, Eurobarometer

In general radio audiences tend to be older and older audiences tend to listen more frequently than their younger counterparts as shown in Figure X-10. The proportion of frequent listeners (everyday/almost everyday) has declined between 2010 and 2013 with a bigger decrease among young listeners.

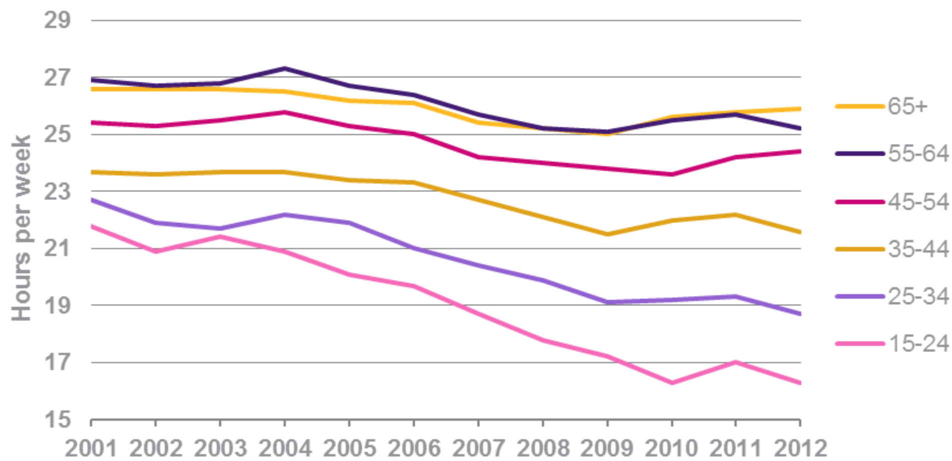
Figure X-10: Percentage of European citizens who listen to radio almost every day and once or several times a week, by age group (2010, 2013)




Source: Plum Consulting, Eurobarometer

The total number of radio listening hours appears to have fallen over a longer time scale. In the UK average weekly listening has decreased from 24.4 hours to 22.2 from 2001 to 2012 with steeper declines among younger listeners as shown in Figure X-11.

Figure X-11: Average weekly radio listening hours by age group in the UK



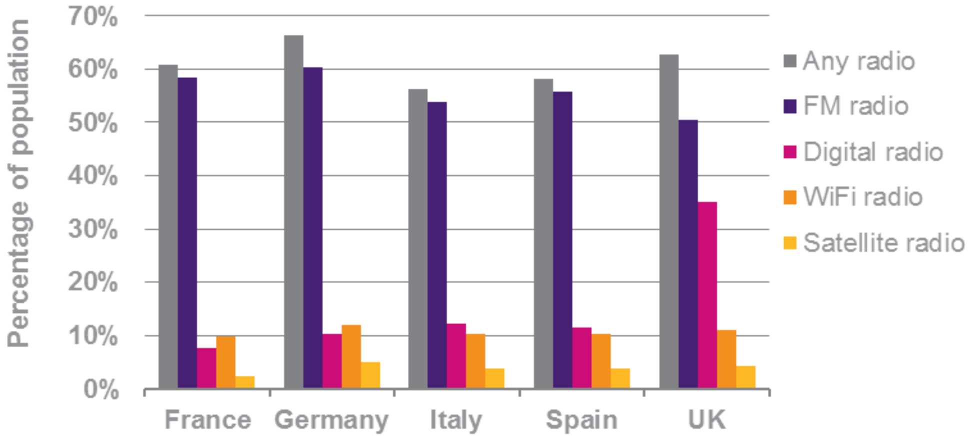

Source: Plum Consulting, Ofcom

## X.4.2 Mode of consumption

Take-up in terms of ownership by type of radio set among the EU5 countries is around 60% on average with FM radio having the highest ownership.

Figure X-12: shows the take-up of different radio platforms in the EU5 countries in 2013. FM radio take-up is lowest in the UK with 50% of the population owning one although take-up of digital radio sets is highest in the UK (35%). Take-up of other radio platforms (digital, satellite, WiFi[373]) is still significantly lower than FM radio.

**Figure X-12: Take-up by type of radio sets (2013)**

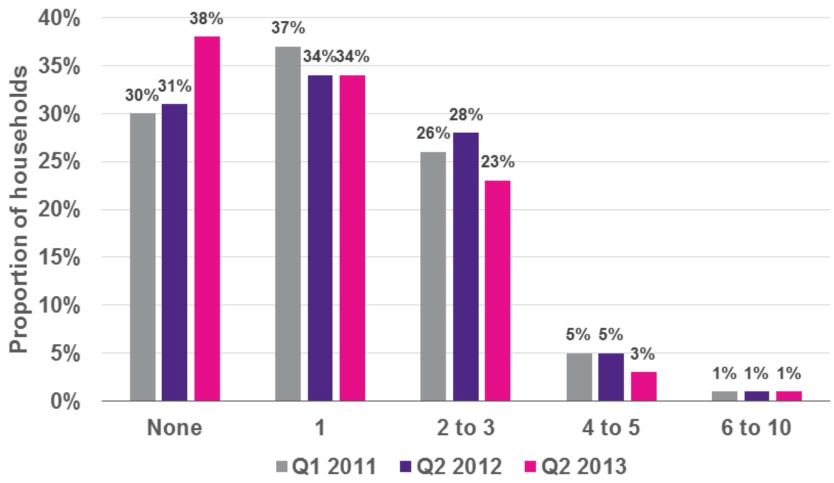



Source: Plum Consulting analysis of Ofcom data

In the UK Ofcom estimates that in 2013 there are between 101 million and 117 million radio sets in the home (consisting of portable sets, hi-fi equipment and clock radios) and in cars/commercial vehicles.[374] This is equivalent to 1.6 to 1.9 radio sets per head or 3.8 to 4.5 per household. In terms of usage most households either use none or just one radio set regularly as shown in Figure X-13.

Note that these figures exclude other media devices which also provide access to radio such as mobile phones/smartphones, MP3 players, DTV decoders, PCs and other digital devices with a WiFi connection.

**Figure X-13: Number of radio sets in the home that consumers listen to in 'most weeks' - UK**



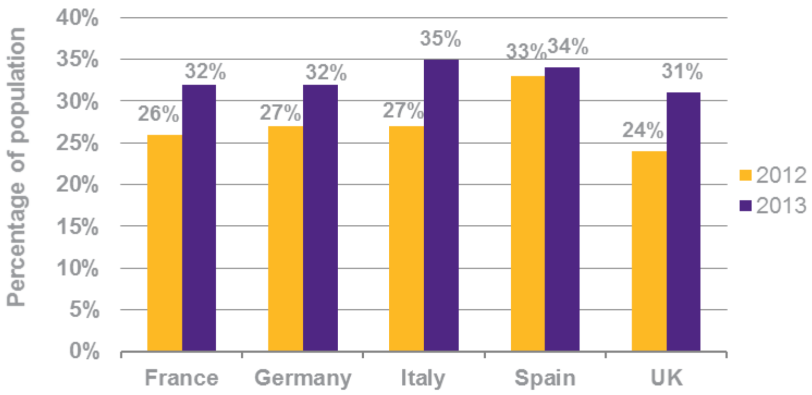

Source: Plum Consulting, Ofcom

[373] Use of home internet connection to listen to audio content

[374] Ofcom. Digital Radio Report 2013, September 2013.

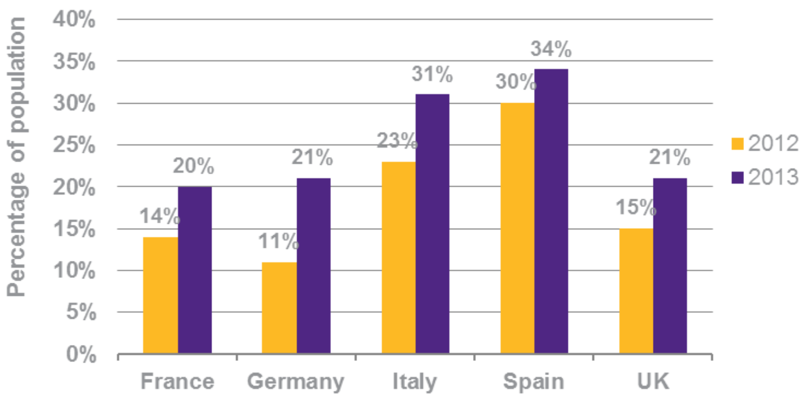
Other means of accessing radio are likely to be significant and increasing. The use of online radio via personal computers at home or mobile phones appears to be a growing trend as shown in Figure X-14 and Figure X-15. In 2013 approximately a third of EU5 citizens have used their home internet connection to listen to radio online while approximately a quarter have used their smartphone or mobile phone to listen to radio.[375]

Figure X-14: Use of home internet connection to listen to radio online




Source: Plum Consulting, Ofcom

Figure X-15: Use of smartphone/mobile phone to listen to radio*



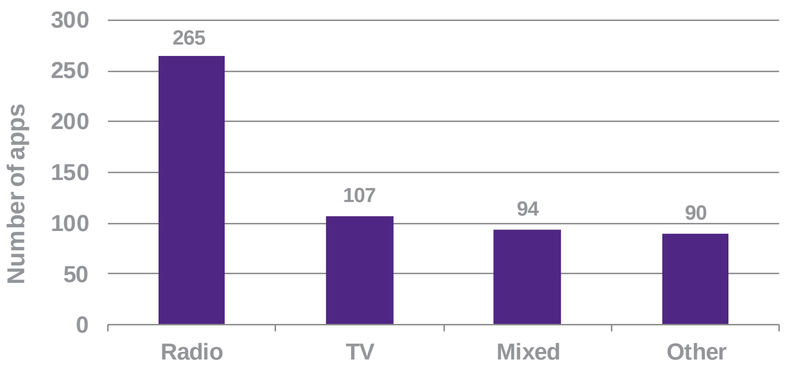

Source: Plum Consulting, Ofcom

One way that radio broadcasters are responding to the changing digital media environment is by increasing their provision of radio apps. While online radio can be streamed to mobile phones using standard mobile web browsers, mobile apps provide a more user friendly interface and a new way for broadcasters to reach new audiences especially younger audiences who are less likely to adopt traditional analogue platforms. Figure X-16 gives the number of apps run by public sector

[375] No distinction made between online radio and FM radio on mobile/smartphone.

broadcasters in the EU. As of October 2013, of 71 public sector broadcasters, 91% offered at least one app that has live radio streaming.[376]

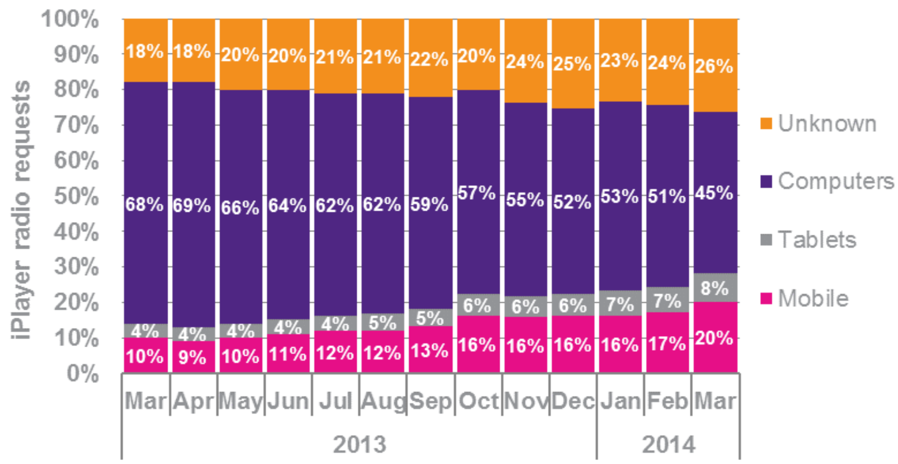
**Figure X-16: Public sector broadcasters' apps in the EU (2013)**




Source: Plum Consulting, EBU

Data from the BBC on iPlayer consumption indicates that the use of mobile devices to listen to radio is growing rapidly – more than a quarter of iPlayer radio requests are via tablets and mobile phones (Figure X-17). This proportion is likely to be higher still considering that the unknown category involves mostly requests from online radio services (e.g. TuneIn radio) for which the BBC is unable to distinguish between device types.

**Figure X-17: BBC iPlayer radio requests**




Source: Plum Consulting, BBC

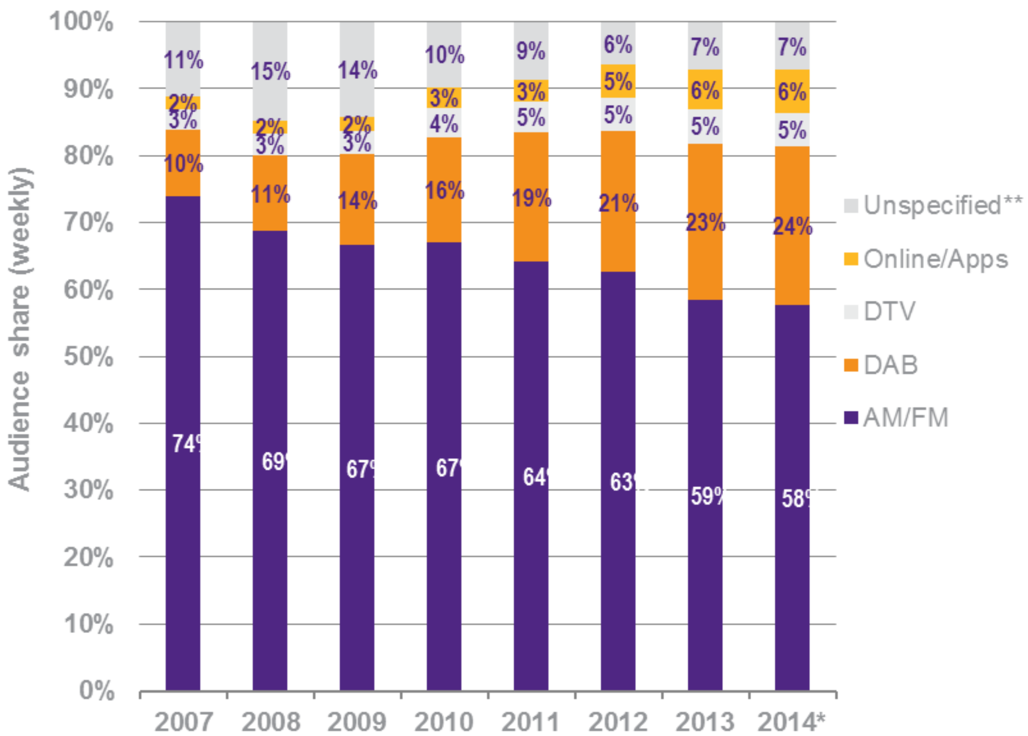
Both digital and online radio listening have had an effect on the audience share of analogue radio as indicated in Figure X-18. In the UK, the share of analogue radio has fallen from 74% in 2007 to 58% in 2014 while the combined share of digital listening (DAB, DTV, online) has increased from 15% to

376 http://www3.ebu.ch/files/live/sites/ebu/files/Knowledge/Publication%20Library/EURORADIO-Planet_Of_The_Apps-Report_2013.pdf

35%. These figures are likely to be on the high side among among EU28 countries given that the UK is among the earliest to adopt digital radio (DAB). Similar data for other EU countries is not available.

It is possible that there may be less of a decline in FM radio listening in other EU countries as digital radio penetration in the UK is particularly high (Figure X-12). Considering that online radio is becoming more accessible as internet take-up grows, it is likely that EU citizens will also gradually migrate away from FM radio towards digital platforms including online radio.

Figure X-18: Percentage of UK radio listening by platform[377]




Notes: *First quarter; **Respondent unsure
Source: Plum Consulting, RAJAR

Radio listening in cars is a common activity as almost all vehicles are equipped with a radio whether analogue or digital. While most in-car radio sets tend to be FM, new vehicles increasingly come equipped with DAB or internet radio (LTE-connected cars). In the UK Ofcom estimates there are some 35 million vehicle radios of which 5-9% are digital and 92% of vehicle radios are used at least weekly.

Radio audience figures for the UK[378] indicate that people are almost as likely to listen to radio at home (75% weekly reach[379]) as in a vehicle (62%) while listening at work or elsewhere is significantly lower (24%). However most listening takes place in the home (63% weekly share) compared to vehicles (21%) and work/elsewhere (16%) as shown in Figure X-19.

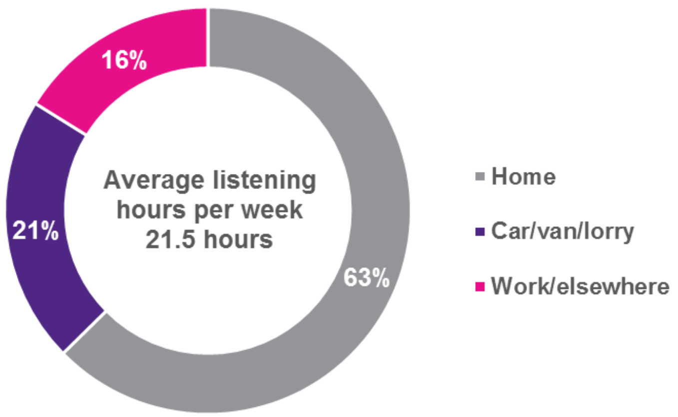
[377] http://www.rajar.co.uk/content.php?page=listen_market_trends

[378] RAJAR Data release, Quarter 1 2014. http://www.rajar.co.uk/docs/news/RAJAR_DataRelease_InfographicQ12014.pdf

[379] Weekly reach is the number of people (adults 15+) in the UK who listened to a radio station for at least five minutes in the course of an average week during the quarter.

It is not possible to infer from UK data the amount or the mode of access of out-of-home listening while on-the-move although this could be as high as 38% (8.2 hours) of average weekly listening. This would be considerably higher compared to TV but not a surprise as people tend to multi-task while listening to radio (e.g. working, travelling, and exercising).

Figure X-19: UK radio listening – weekly share by location, 2014 Q1




Source: Plum Consulting, RAJAR

## X.5 Policy and regulatory developments

Spectrum allocation and technical regulation for broadcast radio services stem from the Radio Regulations and regional agreements (e.g. Geneva 1984). Regulatory processes in Europe mean that national administrations have to coordinate with neighbouring countries in their licensing decisions. Unlike for television, there have been relatively fewer policy and regulatory developments around switchover to digital radio and spectrum release.

In a 2010 report on the future of radio broadcasting in Europe[380] the RSPG noted a general lack of progress to cease analogue radio and that FM radio remains the dominant revenue source for commercial radio and the major source of listening among all radio services despite digital radio becoming more widespread. The deployment of DAB radio in Europe is shown in Table X-6: All of these services are in VHF Band III.

The lack of digital radio deployment in the L-band is a main reason for the recent regulatory activities at the CEPT on harmonised technical conditions for wireless broadband use in the L-band (1452-1492 MHz).[381] This band is being supported by CEPT for allocation to mobile at WRC-15 under agenda item 1.1. It is also the subject of an EC Mandate to CEPT to develop harmonised technical conditions wireless broadband electronic communications services in the 1452-1492 MHz frequency band taking into account, if necessary, sharing conditions with incumbent services.[382]

Table X-6 provides a summary of the status of the various radio bands in Europe.

[380] RSPG. The future of radio broadcasting in Europe: identified needs, opportunities and possible ways forward. October 2010.

[381] ECC Decision ECCDEC(13)03, 8 November 2013.

[382] RSC. Mandate to CEPT to perform technical studies in the 1452-1492 MHz frequency band for its use for wireless broadband electronic communications services in the EU, 19 March 2014.

Table X-6: Overview of main radio bands in Europe

| Band (frequency) | Licensed services | Non-licensed services | Possible future use | Comments |
|---|---|---|---|---|
| LF<br>148.5-255 kHz | AM broadcast | | AM broadcasting DRM | Some AM radio assignments but mainly unused across Europe<br>DRM trials conducted, no plans in many countries |
| LF<br>255.0-283.5 kHz | AM broadcast, aeronautical radar | Short range devices on non-interference basis (medical applications) | AM broadcasting DRM | DRM trials conducted but no plans in most countries |
| MF<br>526.5-1606.5 kHz | AM broadcasting | Short range devices on non-interference basis (medical applications) | AM broadcasting DRM | Mainly used for AM broadcasting<br>Some DRM services (e.g. BBC/DW service at 1296 kHz) but no plans in most countries |
| HF<br>1.6-30 MHz | AM broadcasting (SW radio) | | AM broadcasting DRM | Some use for SW radio<br>Some DRM trials but no plans in most countries |
| VHF Band I<br>47-68 MHz | Analogue TV broadcast, land mobile, wind profiling radar, military services | Amateur radio | Analogue broadcasting, DRM+, military services, auction for alternative technologies | Low utilisation partially because of its highly variable propagation characteristics |
| VHF Band II<br>87.5-108 MHz | FM broadcast services | Short range devices, short range communications | Analogue broadcasting, DRM+, HD Radio | Highly congested by FM broadcasting services |
| VHF Band III<br>174-230 MHz | Analogue TV, T-DAB, land mobile | Radio microphones, PMSE, telemetry | DVB-T, DAB, DRM+, radio microphones, land mobile | Already used for T-DAB; analogue TV services to leave the band to allow widespread implementation of DAB and DVB-T services |
| L-band<br>1452-1479.5 MHz | T-DAB, auctioned for commercial use | PMSE | Mobile supplemental downlink | ECC Decision adopted; EU harmonisation expected by end 2014; deployment likely to be post WRC-15 |

*Source: Plum Consulting, ECC Report 117, ECC Report 141*

There are analogue AM broadcasting services in several EU countries mainly in the MF band with the LF and HF band mostly unused. DRM trials have been conducted in several countries but there are few actual services – a joint BBC-Deutsche Welle Europe-wide service at transmitting at 1296 kHz is one of the few DRM services launched in Europe.[383] Most countries indicate there are no future plans for usage in the LF/MF/HF bands.

For the VHF bands most EU countries do not have any concrete plans for Band I (although there have been some DRM trials). Band I is mostly used for analogue TV and there is little FM broadcasting in

[383] http://www.bbc.co.uk/pressoffice/pressreleases/stories/2008/09_september/16/drm.shtml

this band due to variable propagation characteristics. Band II is fully occupied by FM radio in most some countries especially in densely populated regions. In the replies to RSPG's 2010 questionnaire most administrations indicated that FM radio is likely to continue in this band.

Band III is the main digital radio (DAB) band and is generally supported by broadcasters and industry although there is also interest in using the band for DTT in some countries. Some countries have indicated their intention to migrate FM radio to DAB:[384]

- In Denmark the government has recently adopted a digital radio strategy with a view to switching off FM radio by the end of 2019 although this is condition on digital radio listening reaching 50%.[385]
- Norway has also indicated that the FM network may be partially shut down by 2017 provided digital radio coverage requirements are met.[386]
- In December 2013 the UK government announced in its Digital Radio Action Plan[387] that it was not ready to commit to a switchover. The UK had earlier planned to implement a migration plan to move all FM radio services to DAB by 2015 to make Band II available for the expansion of local and community radio services.

## X.6 Digital switchover and implications of a converged platform

Switching off analogue radio broadcasting is a possibility. But our analysis, set out below, suggests that this is unlikely before 2030.

Digital radio switchover is a possibility if migration towards DAB and internet radio gathers pace over the next decade. However the lack of economic incentives and the continued prevalence of FM radio are challenges that need to be addressed if analogue switch off is to be achieved. The possibility of a converged broadcast-broadcast platform in the UHF band provides another migration path for the transition to digital radio. An LTE-broadcast radio option might be more a more attractive option than DAB especially in countries which have yet to implement DAB.

The possible future scenarios for analogue radio broadcasting include:

- No analogue switch off – continuation of current status with FM radio remaining in VHF Band II
- Analogue switch off with migration of FM radio to:
  - DAB
  - Internet radio
  - Converged platform

In terms of a migration to DAB, the key issue is the lack of DAB implementation in half of Europe. Experiences of countries with DAB deployment suggest that voluntary migration by consumers is likely to be a long process which means this scenario may not materialise before 2030 given so many countries have not yet commenced DAB network or service deployment.

[384] RSPG. The future of radio broadcasting in Europe. Replies to questionnaires. 23 September 2013.

[385] http://www.kulturstyrelsen.dk/fileadmin/user_upload/dokumenter/medier/radio_og_tv/Digital_radio/Justeret_koereplan_for_udbygning_af_digital_radio_i_Danmark.pdf

[386] http://eng.npt.no/technical/broadcast/digital-radio/digital-radio-in-norway

[387] https://www.gov.uk/government/publications/digital-radio-action-plan

A migration to internet radio would depend on the pace of take-up of online radio listening. Online radio services are already widely available and there is some evidence of increasing internet radio use but FM radio remains firmly established across the EU. Furthermore while fixed and mobile broadband coverage across Europe is improving, they cannot yet match the universal coverage of FM although this could change by 2030.

A converged platform using the UHF band is another option for digital radio switchover. If a LPLT LTE network is implemented for broadcast TV, it is possible to allocate some bandwidth for radio. Given that the capacity requirements for audio transmission are much smaller than for video, digital radio via LTE broadcast could easily be accommodated on the converged platform. The bitrates for a single TV channel in standard definition could support an equivalent of around 20 radio programme streams. A converged platform would be able to provide the key features of public broadcasting – universal coverage and free-to-air reception. Regional radio broadcasting is also possible with a converged platform although there are technical issues which need to be addressed. However a converged platform may not be implemented across the EU before 2030.

In summary, digital radio may in future be implemented on a number of platforms, including a converged broadband/broadcast network at UHF; however, our analysis suggests it is unlikely any one of these platforms will provide an EU-wide replacement for FM radio before 2030. Switching off analogue radio broadcasting is a possibility. But our analysis, set out below, suggests that this is unlikely before 2030.

# Appendix Y: Relevant developments in other world regions

## Y.1 Introduction

The technical specification for the study suggests profiles of relevant developments in Australia, China and the US. But on further investigation we have found that only developments in the US are relevant to the central purpose of this study while there are useful indicators of demand for mobile TV in Japan and South Korea. In particular:

- Recent delays with the Australian government's NBN mean that there is little to be learnt about AV delivery and consumption over wireline broadband in Australia
- Research into activities in China suggests that the current focus there is on the development of smart TVs, while the schedule for digital switchover is still uncertain in China.

Given this analysis we have focused our reviews of relevant developments in other world regions on the US in the Americas and Korea and Japan in the Asia Pacific region. The review focuses on standards, experience with mobile TV, and attitudes towards a converged platform.

## Y.2 The USA

### Attitudes towards a converged platform

US audio-visual policy is based on letting market forces determine outcomes as far as possible. As part of this market-led approach the FCC has scheduled incentive auctions for mid-2015 in which broadcasters offer UHF spectrum for release which is then auctioned to mobile operators. This implies that UHF spectrum will remain partitioned between broadcasters and mobile operators rather than being used for a converged platform but that the 600 MHz band might be used for mobile services rather than DTT. The FCC and others have developed possible band plans for use of UHF spectrum in this way. We will consider these further in Phase 2 of the study.

There is also the some uncertainty over a common ITU Region 2 position on the UHF band for WRC-15. The US and Canada are pushing for 470-698 MHz to be allocated for mobile on a co-primary basis while Latin America are taking the opposite position that the band should not be identified for mobile services.[388]

### Development of standards

The Advanced Television Systems Committee (ATSC), which develops technical standards for digital television, is currently in the early stages of establishing a next generation ATSC 3.0 standard to replace the current digital broadcasting systems used in the US. [389] The timetable for the ATSC 3.0 is not confirmed although 2016 has been mentioned as a possible date for finalisation. If so this would

[388] http://apps.fcc.gov/ecfs/document/view?id=7521067444

[389] http://www.atsc.org/cms/index.php/communications/press-releases/315-advanced-television-systems-committee-invites-proposals-for-next-generation-tv-broadcasting-technologies

happen after the FCC's rearrangement of the 600 MHz through the incentive auction scheduled for mid-2015. This could mean a further reassignment of the UHF band from broadcasting to mobile before ATSC 3.0 is finalised. Whatever the outcome of the incentive auction, the spectrum will continue to be used on a partitioned basis across broadcasting and mobile.

The key objectives of ATSC 3.0 are to provide TV services to both fixed and mobile devices, including fixed devices (such as traditional living room and bedroom TV sets), handheld devices, vehicular screens and portable receivers. According to the ATSC, the new ATSC 3.0 broadcast TV standard will provide higher capacity to deliver UHD services, robust reception on mobile devices, improved spectrum efficiency, interactive and personalised services.

So far the ATSC has called for proposals for both the technical 'physical layer' and watermarking technologies for ATSC 3.0. Numerous proposals on the 'physical layer' have been received[390]. There is considerable debate within the broadcasting industry on what the new standard would mean for broadcasting's future, in particular how the mobile TV element is addressed.[391] It is as yet unclear what the standard could look like – DVB has pitched DVB-T2 and DVB-NGH; Qualcomm-Ericsson are advocating all-IP LTE Broadcast; NHK is pushing its 8K Super Hi-Vision standard based on ultra-multilevel OFDM technology. Should the Qualcomm-Ericsson proposal be chosen by ATSC, a rethink on a converged broadcast-broadband network solution may be necessary.

## Mobile TV experience

In the US, DVB-H services were short-lived. Wireless tower company Crown Castle and private firm Aloha were both unsuccessful in their attempts to launch mobile TV services using DVB-H.[392] Qualcomm's MediaFLO TV service, considered to be the strongest competitor, also struggled to attract subscribers despite both AT&T and Verizon selling devices compatible with MediaFLO. Barely two years after its nationwide launch in 2009 Qualcomm announced that it was ending the service and promptly sold its spectrum to AT&T.[393]

The reasons cited for MediaFLO's struggles were similar and in particular the high costs for operators in terms spectrum, network and content investment which meant high prices for consumers at a time when media companies were starting to provide their own online streaming services.[394] On top of the device cost, the service was priced at US$10-15 per month (€7-11) for about 20 basic and on-demand channels. It managed about 1 million subscribers before the service was discontinued in early 2011.[395]

While the trend for mobile TV in the US has been towards IP delivery, some advances have been made using ATSC Mobile/Handheld ("ATSC M/H").[396] ATSC M/H receivers are appearing in the market, mostly in the form of USB tuner peripherals and specialty receivers that connect to personal computers and mobile devices. In August 2012 Dyle Mobile DTV service was launched in 35 markets reaching more than 55 percent of the US population.

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390 http://www.atsc.org/cms/index.php/the-news/327-summaries-of-responses-to-atsc-30-physical-layer-call-for-proposals

391 http://www.tvnewscheck.com/article/74466/top-techs-have-no-desire-to-lose-spectrum/page/2

392 http://gigaom.com/2007/07/24/crown-castle-turns-off-mobile-tv/; http://www.engadget.com/2008/02/05/fcc-blesses-sale-of-alohas-700mhz-spectrum-to-atandt/

393 http://www.qualcomm.eu/news/releases/2010/12/20/qualcomm-announces-agreement-sale-700-mhz-spectrum-licenses

394 http://gigaom.com/2010/12/20/flo-tv-fail/

395 http://www.multichannel.com/mobile/att-buy-qualcomms-flo-tv-spectrum-19-billion/125619

396 http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-13-99A1.pdf

## Y.3 The Asian Pacific region

### Attitudes towards a converged platform

Under the Asia Pacific Telecommunity (APT) Wireless Group, there is a working group on service and applications (WG S&A) which has set up a task group to study issues related to radio communication convergence.[397] The task group published a report on "telecommunication broadcast convergence" in September 2012[398], which covers:

- Motivation for telecommunication broadcast convergence – increase in Internet penetration, improving user experience, enhancing service efficiency, minimising number of infrastructure, network and service nodes
- Current state of telecommunications and broadcasting services
- Examples and implementation cases of telecommunications and broadcasting convergence services
- Roadmap of telecommunication and broadcasting convergence services

The report discusses various forms of radio access technologies (RAT) and TV services – both broadcast (e.g. DVB-H and T-DMB) and IP-based (e.g. DAB-IP, IPTV, HbbTV and OTT). In terms of network convergence, five types of RAT are described, with the first three considered the main technologies for convergence:

- RAT1: Cellular Mobile (2G, 3G, E3G, 4G etc.)
- RAT2: WLAN/WMAN (WiFi, WiMAX etc.)
- RAT3: Broadcast (CMMB, DVB-H etc.)
- RAT4: Global coverage (Satellite, HAPS etc.)
- RAT5: Short Range Device (Zigbee, Bluetooth etc.)

Several implementation scenarios are considered in the report as set out below in Figure Y-1. There has not been any significant policy and regulatory development at the APT level since the publication of the report. Like other regions of the world, the policy focus in the Asia Pacific has been on national broadband networks rather than hybrid broadband-broadcast networks. While more developed countries such as Japan, Korea and Australia have completed digital TV switchover, the process is slow most of Asia Pacific with 2020 as the targeted completion in many countries. Most of these countries have adopted existing DTT standards (e.g. DVB-T2, ISDB-T) and are not actively considering converged broadcast-broadband solutions.

[397] http://www.aptsec.org/AWG-ServiceApplication-TG#RC

[398] http://www.aptsec.org/sites/default/files/Upload-files/AWG/APT-AWG-REP-30_APT_Report_Telecom-Broadcasting_Convergence.doc

Figure Y-1: Scenarios considered in the APT report on convergence

| Scenario | Technology used |
|---|---|
| Inter RAT1 | i. CDMA + LTE<br>ii. HetNet |
| RAT1 and RAT2 | iii. CDMA + WLAN (+ LTE moving forward)<br>iv. DPI analysis to address unbalanced growth of signalling and user traffic of different services |
| RAT1 and RAT3 | v. High power nodes + low power nodes + interworking (high power on carrier 1, low power on carrier 2, broadcast service continuity guaranteed by interworking between CMMB/T-DMB/ISDB-T and eMBMS)<br>vi. Convergence of unicast and broadcast in RAT (no high power transmitters, low power cells to carry both unicast and broadcast by carrier aggregation) |
| RAT1 and RAT4 | vii. Cellular coverage enhancement using satellite backhaul, terminals could be multi-mode or not while RAN should be independent |
| RAT1 and RAT5 | viii. Converged terminal in mobile applications (multimode phone with SRD module necessary for this scenario) |

## Standards development

There are activities in China to develop smart TV standards[399] while the focus in Japan and Korea seems to be on ultra HD TV. In Japan the Ministry of Internal Affairs and Communications recently published a consultation on the technical conditions for ultra HD TV although the focus appears to be on cable, IPTV and satellite rather than terrestrial delivery[400]. In Korea the future of the 700 MHz is still undecided – the broadcasters have been calling for the government to assign the band for broadcasting to facilitate delivery of UHD TV while mobile industry is warning that failure to assign 700 MHz for mobile will mean missing out on the benefits of harmonisation with the rest of the global community.[401]

## Mobile TV experience

Unlike the EU and the US, there has been some success with mobile TV in Korea, Japan and China.

**South Korea** was the first country to launch mobile TV services commercially in 2005 and has been relatively more successful in terms of adoption, helped by the widespread availability of compatible handsets and a free-to-air advertising-funded service.

Two forms of DMB were launched in 2005 – satellite-DMB and terrestrial-DMB. SK Telecom offered a pay satellite-DMB service (TU-Media) with about 20 channels for a monthly fee of KRW11,000 (€6).

[399] http://www.usito.org/news/miit-and-sapprft-set-joint-working-group-smart-tv-standards

[400] http://www.soumu.go.jp/menu_news/s-news/01ryutsu08_02000093.html

[401] http://www.koreaherald.com/view.php?ud=20140219000756&mod=skb

The number of S-DMB subscribers reached about 2 million in 2009 although by the time SKT ended the service in 2012 it had dropped to 38,000.[402]

T-DMB was a free-to-air service with 7-9 channels (retransmissions of terrestrial channels from the three main broadcasters KBS, SBS and MBC, and several DMB-only channels). Sales of T-DMB receivers were rapid and it was estimated that T-DMB viewers exceeded 20 million in May 2009.[403] As of 2012, T-DMB was available via more than 40 million mobile phones in use.[404]

Despite the high adoption rates, T-DMB has struggled to find a profitable business model. Advertising revenues alone were insufficient to cover network and content investment costs. As a result the DMB-only service providers have yet to make any profit. Competition from video services delivered using smartphone applications also increased the pressure on T-DMB to explore new revenue models. In 2013 smart DMB which has VOD capability and better picture quality was launched.[405]

In **Japan**, the mobile TV standard “1-seg” ISDB-T was launched in 2006 offering seven free-to-air channels. By 2012 more than 80% of mobile phones have “1-seg” capability and all TV stations transmitted their channels in this format, enabling users to watch terrestrial broadcast TV for free – although research by Docomo found that only 1 in 5 mobile users actually use 1-seg.[406]

In April 2012, a new service NOTTV which was based on ISDB-Tmm was launched by mmbi – a joint venture between NTT Docomo, Dentsu and several private broadcasters.[407] The service is priced at JPY420 (€3) per month and offers original content. NOTTV had 1 million subscribers as of June 2013.[408]

**China’s** mobile TV standard CMMB (China Mobile Multimedia Broadcasting) was launched in 2010 with the network covering over 300 cities with 900 high power sites and 2000 low power sites. The basic subscription package offered by China Mobile and China Broadcasting Corporation costs RMB6 per month (€0.12) and has 10 million users[409] (compared with 1.23 billion mobile subscribers in China[410]).

In **Hong Kong** a CMMB service was launched by China Mobile in December 2012 with users having to use a dongle to access the service.[411] The service was priced at HKD58 (EUR 5.50) per month for eight channels. However the service was discontinued after a year with China Mobile selling their licence to Hong Kong Television Network.[412] The service is due to be relaunched in late 2014.

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[402] http://www.rapidtvnews.com/index.php/200906294150/dmb-mobile-tv-widespread-in-korea.html

[403] Kyung et al (2009). The status and revenue models of T-DMB in Korea. Proceedings of 46th ABU General Assembly.

[404] Sohn, S (2013). How some regulatory policies can undermine the success of a new technology: a case study of digital multimedia broadcasting in South Korea. Keio Communication Review, 35, 51-66.

[405] http://www.arirang.co.kr/News/News_View.asp?nseq=153920

[406] http://www.japantimes.co.jp/life/2013/04/17/digital/shows-on-the-road-mobile-on-demand-tv-a-hit-in-japan/

[407] http://asiajin.com/blog/2012/02/17/nottv-japan/; http://www.theverge.com/2012/2/19/2808389/ntt-docomo-nottv-mobile-tv

[408] http://thebridge.jp/en/2013/06/nottv-hits-a-million-paid-subscribers

[409] http://www.itu.int/ITU-D/asp/CMS/Events/2011/DigitalBroadcast-May2011/S3_China.pdf

[410] http://www.reuters.com/article/2014/01/20/china-mobilesubscribers-idUSL3N0KU1JC20140120

[411] http://www.telegeography.com/products/commsupdate/articles/2012/12/11/china-mobile-hong-kong-launches-carrier-independent-mobile-tv-network/

[412] http://www.bloomberg.com/news/2014-01-06/china-mobile-to-start-internal-probe-of-hong-kong-unit-sale.html

## Y.4 Other regions

Other countries have generally been followers rather than leaders in terms of technology and policy initiatives around new broadcast-broadband convergence. Most of the developments involve the adoption of the various existing mobile broadcast standards (e.g. T-DMB, ISDB-T and DVB-H).

In Africa, DVB-H and DMB services have been launched while most countries in South America have opted for the Japanese ISDB-T standard. In Brazil the government has attempted to impose a quota of 5% on all mobile handsets to be equipped with ISDB-T receivers but this was contested by manufacturers.[413] Governments in Argentina and Venezuela have also been pushing for DTT-compatible handsets to be made available.

[413] http://www.analysysmason.com/About-Us/News/Newsletter/Botswana-switches-to-ISDB-T-for-digital-TV/

# Appendix Z: Possible band plan for a converged platform

## Z.1 Introduction

In this appendix we set out proposals for a band plan for a converged platform on the assumption that converged platform is the best option. We take as a starting point that the 700MHz band will have been allocated to mobile based on the band plan currently being developed at European level. This leaves the question of what band plan might be implemented at 470-694MHz. Any final band plans will need to be developed and agreed through the normal European and international processes. We discuss only the final band plan for when all HPHT transmission has ceased. Interim band plans, such as those required to create simulcast spectrum at a national level, would need to be developed on a country-by-country basis.

## Z.2 Downlink only operation

There are various options for the provision of uplink and downlink. These include:

- A paired (FDD) downlink and uplink allocation as is used in 800MHz in Europe and is proposed for 600MHz in the US.
- An unpaired downlink-uplink allocation using TDD technology as, for example, used in the central part of the 2.6GHz band.
- A downlink-only allocation, often termed supplemental downlink (SDL) where uplink channels in other bands such as 800MHz are used.

We recommend that the 470-694 MHz is configured as downlink only - a position which is supported by the mobile community. We make this recommendation because:

- Downlink only operation substantially eases handset design, removing the need for power amplifiers, duplexers and some of the filters in this band. There is currently some doubt as to whether it would be possible to design a practical and cost-effective handset with uplink capability across this band because of the breadth of the band relative to its centre frequency which makes component design more challenging than in other bands.
- It eases compatibility with existing broadcasting use during any transition process since the interference from downlink use is generally less problematic and more predictable than interference from the mobile uplink.
- It fits well with anticipated traffic patterns. The broadcast service will clearly be downlink only, and traffic patterns on unicast mobile services typically show there is 5 to 10 times more traffic in the downlink as the uplink[414]. This asymmetry is expected to either continue or grow further as users consume increasing amounts of downloaded unicast video.
- It avoids the need for a duplex band spacing which can be wasteful of spectrum as it is often difficult to find a use for the centre gap, because of either the small amount of spectrum available and/or the limitations placed by interference from the mobile service. This issue is illustrated by the current discussions around the 700MHz and 800MHz duplex centre bands.

[414] See for example *Economic benefits of 1.4 GHz spectrum for multimedia services*, Plum for Qualcomm, June 2011

This downlink only approach is different from the current approach proposed in the US where the 600MHz band plan has both paired frequencies and possibly additional downlink (depending on how much spectrum is sold at auction)[415]. The reasons for the difference are:

- The bands likely to be released in the US are narrower (likely only circa 584-698MHz) and so the equipment issues are less problematic.
- A converged platform is not proposed in the US and so the flexibility conferred by a downlink only approach (see below) is not important.
- Competition issues in the US, partly arising from sub-optimal band plans at 700MHz, mean that it is possible that not all operators can use a nearby uplink.

A downlink-only approach simplifies the band plan since there are no questions around duplex spacing and pairing arrangements. The questions that then need to be addressed are:

- How much of the band should be devoted to LPLT broadcasting operation?
- Where the LPLT broadcasting should be located within the band?
- What bandwidth should be adopted for a channel?
- How might the spectrum be assigned?

## Z.3 Amount of spectrum used for LPLT broadcasting

The amount of spectrum required for LPLT broadcasting is difficult to determine with certainty. As discussed elsewhere in this report it depends on:

- The number of channels to be broadcast and the level of definition to be used.
- The technology adopted (DVB or LTE).
- The extent of regional broadcasting
- Whether SFNs are used within a country.
- The extent of additional spectrum requirements at border areas.

Depending on these factors spectrum requirements could vary between member states from a minimum of around 24MHz (three multiplexes each using a national SFN) to a maximum of the entire band. This suggests that it would be valuable to have flexibility in the designation of the part of the band used for broadcasting versus that used for mobile SDL. Indeed, this flexibility is one of the advantages of a converged platform based on one technology (LTE) and of a downlink-only band plan, allowing the balance of spectrum to change over time as modes of viewing evolve. Hence, we do not recommend a single unified boundary.

## Z.4 Location of broadcasting in the band

The LPLT broadcasting downlink usage should be placed at the bottom of the band. This is because the freed spectrum (which will then be at the top of the band) will likely be used for mobile applications where proximity to bands already used for mobile will ease handset design. We expect the broadcast

[415] Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, FCC Report and Order, May 15, 2014 https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-50A1.pdf

channels to be predominantly received by fixed TV systems which can already operate throughout the band. Hence there is no penalty from being at the bottom of the band.

## Z.5 Bandwidth

It is not obvious what minimum channel bandwidth should be specified. Mobile technologies tend to work on 5MHz channel bandwidths or multiples of 5MHz. Broadcasting TV channels are 8MHz wide. If LPLT-DVB were adopted there would be an argument for the bottom of the band remaining on an 8MHz channel spacing while the top would be changed to a 5MHz spacing. This would facilitate the use of existing TV receiving equipment which would be an important benefit. But if LPLT-LTE were adopted for broadcasting then the entire band could be moved to 5MHz spacing since receiving equipment will need to be changed in any case.

## Z.6 Licensing

We propose that the services are licensed rather than being licence exempt in order to provide regulatory certainty with regard to the interference environment and the extent of spectrum access. Meeting both of these requirements is important if mobile operators and broadcasters are to make the necessary investment in a converged network. The precise design of the licences and the assignment process (e.g. auction, beauty contest, direct award) would be country-specific and take into account factors such as public service broadcasting obligations, coverage obligations and national competition objectives as well as being consistent with the European regulatory framework – and particularly the Framework Directive, the Authorisation Directive, the Radio Spectrum Decision, the Radio Spectrum Policy Program as well as relevant state aid rules.

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