Perspectives on the value of shared spectrum access: executive summary

With demands on the radio spectrum becoming more intense, the need to use this resource as efficiently as possible is becoming ever more important. One way forward is to apply innovative and flexible authorization schemes, allowing shared spectrum access using approaches such as collective use and dynamic access. This study[1] is intended, therefore, to contribute to a better understanding of the socio-economic value of shared spectrum access, including its impact on competition, innovation and investment. In doing so, the study is one of several inputs supporting the European Commission's plans to publish a Communication on these issues.

The specific tasks of the study were:

Task 1: Assess in qualitative and if possible quantitative terms the net economic benefit of applying shared spectrum access for wireless broadband, and its socioeconomic impact on traditional mobile services like voice and data transmission, including the take-up of roaming services. Perform these tasks with a focus on the impact in the next 5 years.

Task 2: Review ongoing industry developments as well as projects under the 7th Framework Programme in order to assess:

- if existing frequency allocations for shared spectrum access will be able to satisfy the estimated demand for spectrum resulting from the projects;
- quantify whether technical usage conditions of the existing frequency allocations for shared spectrum access need to be changed, in order to facilitate the use of innovative spectrum sharing techniques and identify which usage conditions, such as "politeness" rules or mitigation techniques, are considered necessary to maximize the socioeconomic value of the applications in the band;
- quantify the need for any additional spectrum for shared spectrum access and the socio-economic value of this spectrum.

Task 3: Gather input from the 27 Member States on current use of shared access frequency allocations for wireless broadband, in particular assess the intensity of Wi-Fi use in the 2.4 GHz and 5 GHz bands. Furthermore provide indications of possible congestion that could hamper the further take-up of wireless

[1] This report was prepared for DG Information Society and Media, Electronic Communications Policy, Radio Spectrum Policy (Unit B4) by a project team led by Simon Forge (SCF Associates Ltd), including Robert Horvitz (Open Spectrum Alliance) and Colin Blackman (Camford Associates) working on behalf of a contractual consortium led by SCF Associates Ltd.

broadband, and possible candidate bands to avoid congestion.

Task 4: Quantify, as far as possible, any administrative cost which would be created or saved if additional spectrum was made available for shared spectrum access based on the findings of Task 2, 3 and 5. Furthermore assess and quantify as far as possible, implementation costs in relation to candidate bands identified under task 3.

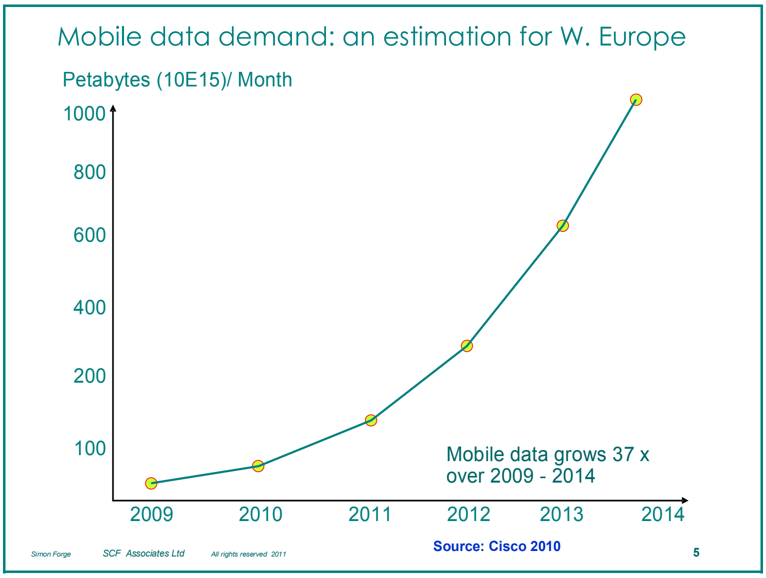
Task 5: Identify key bands targeted by proponents of concepts such as "Authorized Shared Access" (ASA) and "Light Licensing", outline the principal costs and technical challenges to be addressed if those bands were to be allocated for such an approach, and identify the incentives for incumbent users in those bands to agree to the adoption of these concepts.

This executive summary addresses the tasks set for the study by first considering shared spectrum access for wireless broadband (tasks 1, 3 and 5). Next, sharing beyond broadband is discussed (task 2), and then the question of administrative burden is considered (task 4). Finally the results of each task are summarized in a table.

1.1 Maximizing the return on Europe's radio resources

Exploiting the radio spectrum resource is increasingly understood as a fundamental enabler for Europe's economic growth and a key element in achieving the Digital Agenda targets. With the explosive growth in data traffic owing to the rapid take up of smart phones and tablets, the need to relieve pressure on parts of the spectrum is becoming critical. Mobile data traffic is now doubling every six months and Cisco estimate that, by 2014, mobile data traffic will have increased 37 times over the previous five years (see figure below). The next generation of cellular mobile and the shift to cloud computing will place further enormous demands on the spectrum.

Growth of mobile data, largely broadband to 2014



At the same time, monitoring of the radio spectrum shows that while a few bands are congested, the vast majority of the spectrum is unused or underused most of the time. Spectrum scans made in the centre of Paris, for instance, show average utilization of the 400 MHz to 3 GHz band being 7.7%.

This disconnect arises in large part because spectrum allocations do not adapt quickly to changes in demand. As a result they reflect past practice rather than future needs. Addressing this misallocation so that the potential of the radio spectrum can be maximized will require a radical rethink of spectrum management practices. The key to unlocking that potential is to allow, where possible, shared spectrum access rather than exclusive use.

"Shared spectrum access" includes all situations in which two or more users or wireless applications are authorized to utilize the same range of frequencies on a non-exclusive basis in a defined sharing arrangement, along with any other possibility for multiple users to access the radio spectrum without individual rights.

“Shared access” encompasses licence-exempt bands, bands shared by licensed and licence-exempt applications, and licensed and light-licensed “commons”. Potentially important new kinds of “shared use” are emerging from discussions about “Licensed Shared Access” (LSA) and cognitive access to “white spaces” in the UHF band.

The vast majority of the radio spectrum is actually shared, though not to the full extent indicated by the definition above. Only 11.2% of frequencies below 3GHz are allocated for exclusive use. Those exclusive allocations, of course, tend to be in the most attractive parts of the spectrum – between 300 MHz and 3 GHz, where propagation characteristics are most favourable. Future methods of allocating spectrum need to ensure that licence-based regulatory approaches do not result in artificially generated scarcity. Europe’s economic development could be jeopardized if frequencies for new applications ranging from e-health to payment systems are unavailable.

Europe is trying to solve the problem of band allocations lagging behind shifts in demand for wireless services by gradually replacing rigid, static specifications of band use with flexible, generic, service-neutral allocations. However, any gains from the allocation level will be limited unless methods are also agreed for increasing flexibility and non-exclusivity in the use of frequencies. Solutions to this have been known since the earliest days of radio: channel sharing, in the form of block assignments, and “spectrum commons” in which there are no assigned channels.

1.2 The impact of 4G

However, there is a further complication. While cellular architecture is recognized as a highly efficient way to provide ubiquitous access to mobile communication services, the cellular industry is seeking an enormous increase in its spectrum allocation (1 to 2 GHz) for the roll out of its next generation networks, which the ITU calls IMT-Advanced. IMT-Advanced has evolved into one of the most ambitious and potentially disruptive telecommunications projects ever conceived. It is the largest source of pressure on currently allocated spectrum with effects on other bands identified as targets for service displacements and refarming.

In 2006, when the ITU calculated spectrum requirements for IMT-Advanced, no consideration was given to the cost of build out or affordability to subscribers. The idea was to look at the operators’ need for bandwidth and the subscribers’ desire for data speed and volume as if all resources were free. That may be useful as a way to conjure up an ideal network or to identify ultimate goals, but leaving economics out is unrealistic. So we should not be surprised that the network requirements based on those assumptions are unrealistic, too.

Most European countries currently have 3 or 4 independent mobile networks, Most or all of them will want to upgrade to IMT-Advanced. But when the ITU plugged its market projections into software for calculating spectrum requirements, they found that 3 nationwide networks would need 1560-1980 MHz. Since the recommended frequency range for mobility and good coverage is between 400 MHz and 5 GHz, that amounts to 34-43% of the total range. But it is hard to see how that much spectrum can be made available to IMT-Advanced without severe impact on large numbers of specialized networks and without substantial refarming costs.

Meanwhile it has been realized that the market projections on which the ITU's 2006 spectrum estimates were based are much too conservative. Demand is growing far faster than expected. Early in 2012 we should have new estimates from the ITU about spectrum requirements for IMT-Advanced and they are likely to be even more excessive than the ones of 5 years ago.

So discussion has already shifted to one-network solutions which might "only" require 1280-1720 MHz. However, the European experience has been that competition in telecommunication network services is not just good, it is essential to progress, efficiency and responsiveness to subscriber preferences. So how can competition be preserved in a shared infrastructure? That is a key question and we hope our study will draw attention to the need to discuss appropriate business structures for IMT-Advanced. If the single network solution translates into a single enterprise, it will certainly have significant market power. If it is an organized group, it will have the features of a cartel. In any form, the market consolidation represented by IMT-Advanced poses great challenges for European regulators.

Another issue which must be of concern to regulators is the fact that the bandwidth needed to support data offloads to "hotspots" was left out of the ITU's calculation of spectrum requirements for IMT-Advanced. And make no mistake: offloading to "hotspots" will be even more essential in 5 years than it is today. One of the ITU reports mentioned in passing that: "One Administration has made some estimates of nomadic spectrum and has shown that this could be more than 50% of the total spectrum estimate." Since their "total spectrum estimate" at the time was 1280-1720 MHz for a single-network configuration, the bandwidth needed to support data offloads from cellular to radio local area networks (RLANs) in the 2015-2020 timeframe could be more than 640-860 MHz. Unfortunately, there is currently only 538.5 MHz of spectrum for RLANs below 6 GHz.

1.3 Sharing for today and tomorrow

We surveyed the 27 EU regulators to discover their views on congestion in licence-exempt spectrum: is the problem imminent and how can it be detected. We found that with one exception, none had measured occupancy of any of the five bands used by licence-exempt RLANs for wideband data transmission. Only Ofcom, the UK regulator, has tested a method for measuring the deployment density of Wi-Fi nodes and started work on the next step, which is to translate measurable quantities, like packet loss rates, into user perceptions of degraded performance.

A survey commissioned by Ofcom in the UK measured a Wi-Fi node density of 2247 per km^2 in central London in 2008-09. Although it was only in the heart of London that wireless congestion was found to be a significant problem then, recent forecasts of the global growth in Wi-Fi suggest that high-density areas represent a pattern that will become much more widespread in future. The Wireless Broadband Alliance has reported that it expects the number of private Wi-Fi Internet access nodes in homes and offices to increase from 345 million today to 646 million by 2015. During the same period the number of public Wi-Fi hotspots is forecast to grow from 1.3 million to 5.8 million.

However congestion is already spreading in the Wi-Fi band at 2.4 GHz, according to our survey of EU regulators. Yet there is remarkably little agreement among experts on how many Wi-Fi nodes can co-exist in one square kilometre: early estimates of the capacity of the 2.4 GHz band proved much too conservative, varying between 1 and 75 Wi-Fi nodes per square km. WISPs (Wireless ISPs) have successfully rolled out services in various parts of Europe and have, with few exceptions, not encountered interference problems. But future spread may well be limited by band congestion.

In view of the technical challenge of detecting devices with such short ranges, and the length of time it can take to identify a new band for licence-exempt use, there is a clear need for early discovery and assessment of band congestion in licence-exempt spectrum. For greater sharing, new early warning tools for regulators will be needed. CEPT has recognized this requirement for more active monitoring of conditions in licence-exempt bands but so far has not initiated studies. A mandate from the Commission could stimulate activity in this area.

Benefits of shared spectrum access for wireless broadband

Using scenario methods, combined with economic modelling, the study found that increasing shared access for wireless broadband could provide a significant economic stimulus to the EU economy and bring additional social benefits to Europe's citizens. Note that scenarios are not predictions but are plausible projections of possible futures. The assumption made here is that shared access is equivalent to extra spectrum and it is through exploiting this "new" spectrum that the major economic benefits of shared spectrum access accrue. To explore the possibilities, three different scenarios were considered.

Scenario 1: "*No change for the better – a baseline scenario*". The scenario continues today's spectrum conditions forward into the future. There are no changes in regulation to increase sharing so the scenario just extrapolates the costs and benefits of continuing "business as usual" with emphasis on using what is already permitted. The implications of this are saturation of spectrum in around five years due to demand for data traffic at broadband speeds and the entry of LTE. ASA type sharing, in those Member States, where it is permitted, becomes more necessary, especially as LTE enters. The range of frequency bands used for sharing in Scenario 1 is as follows:

Type of sharing	Band position	Spectrum width, MHz	Value
Existing Wi-Fi bands	2.4 and 5 Ghz existing allocations of licence-exempt swathes	Existing allocations (total 538.5 MHz) – no new spectrum	Med/High
ASA sharing (where already used)	GSM and UMTS bands (for MNOs only)	GSM & UMTS standards for channels	Low
Unlicensed bands allocated today	Existing ISM bands	As for existing allocations only	Low
New shared bands, total MHz		0 MHz	

Spectrum saturation implies various negative effects – for instance, auction prices for spectrum rise and this is passed on to the customers in higher tariffs. There is saturation in urban and suburban areas for use of Wi-Fi. Data roaming across the EU does not become viable as a low cost service, while caps on volumes of data are universal, so that even with LTE, wireless broadband has restricted coverage and data rates. Existing mobile services do not have the capacity of delivering the demand for mobile data traffic in Exabytes, the level of pent-up demand by 2015, and Wi-Fi offload has only a limited capability. Elevated data charges are justified by the need to throttle the high volumes of data traffic. The commonest use of wireless for internet access is from picocells in the home or office, supplied via an xDSL copper or direct fibre connection for backhaul. No advance is made by wireless broadband towards comprehensive coverage of the EU to meet the DAE targets of 30 Mbps for all households.

Scenario 2: "*Something stirring – modest sharing*". In this scenario there is a modest increase in unlicensed spectrum for fixed/nomadic/wireless broadband: overall, some 200 MHz is made available via sharing, through white spaces with cognitive radio, also SRD expansion and light licensing, as shown in the table. This is important for the EU as for the first time coverage universally becomes possible for fairly high speed data rates of the order of several Mbps.

Sharing has a significant economic stimulus for the EU economy, in the range of the low hundreds of billions of Euros when accumulated up to 2020, equivalent to a 10 to 20% increase in broadband penetration. The costs are largely due to the build and operation of a lightweight infrastructure based on Wi-Fi type technologies and WSDs. The order of network costs are estimated to be in the high hundreds of millions of Euros, up to several billions if the cost of additional software and hardware incorporated in the mass market handset device is included. To this should be added the costs of commercial agreements charged per year. Agreements include light licensing and AIP accords with the incumbents, especially the public services and the broadcasters for interleaved and direct spectrum sharing, based on transmission constraints (temporal, power and frequency, etc) for the secondary users. These vary in cost, depending on bandwidth and population coverage, but represent in total several hundred million Euros per year (based on an AIP cost of €300,000 per million population, for sharing of 10 MHz, a price which may well increase with time). That gives an accumulated cost of agreements over ten years of one to five billion Euros.

The result in Scenario 2 is an 'alternative network' as in Catalonia, where Guifi.net's 24,300 km of wireless links serve 15,000 households. The cost to users is around 70 Euros for the customer equipment. This model brings major social benefits, not just for residential communications at low cost and social networking but low speed telemedicine care functions such as home monitoring. The key bands envisaged in Scenario 2 are shown below:

Type of sharing	Band position	Spectrum width, MHz	Value
As for Scenario 1 – Existing Wi-Fi bands 2.4 and 5 GHz licence exempt, ASA sharing, Unlicensed bands allocated today for ISM			
Broadcast sharing using LSA/ ASA	55-68 MHz 174-230 MHz broadcasting	13 MHz 56 MHz	High High High
MNO sharing Using LSA/ASA	862-872 MHz 2100-2120 for SRD only	10 MHz 20 MHz	High/medium (dependent on conditions) High/medium (dependent on conditions)
Military and other public services shared bands - all releases under AIP, for 4 year agreements	870-872 MHz 915-917 MHz 1427-1452 MHz 2025-2070 MHz 4800-4840 MHz 10-10.025 GHz	2 MHz 2 MHz 25 MHz 45 MHz 40 MHz 25 MHz	Low except for RFID or white space 'keyholes' High Medium Low/Medium Low
New shared bands, total MHz		**200 MHz**	Averaged: medium

The light sharing network is based on a layered architecture – firstly a radio access network based on sharing technologies such as cognitive radio and databases of available slots as well as Wi-Fi in licence-exempt bands at 2.4 and 5 GHz. The second layer provides backhaul from the universal access points into internet spines at low cost. This could be via microwave, or directional Wi-Fi, or LEO micro-satellite, HALES or MEO satellites, as appropriate for access, volumes and link delays.

Scenario 3: "*Sharing takes off – and the economy*". Here the net sharing bandwidth doubles to 400 MHz including the establishment of a 100 MHz licence-exempt band in the sub-1 GHz block, usable for both wireless broadband directly and for longer range Wi-Fi (or WiMAX) to offload data from the cellular mobile networks.

Type of sharing	Band position	Spectrum width, MHz	Value
As for Scenario 1 – Existing Wi-Fi bands 2.4 and 5 GHz licence exempt, ASA sharing, bands allocated today for ISM			
As for Scenario 2 – But with variations in width of broadcasting, military and other public services and MNO bands shared under AIP			
Unlicensed bands allocated today	Existing ISM bands	Existing allocations – no new spectrum	Low
Broadcast sharing		Total 111 MHz	Very high/high

MNO sharing		Total 80 MHz	High/medium
Licence-exempt new bands in Digital Dividend	535–585 MHz	50 MHz	Very High
Licence-exempt new bands in upper UHF	1452–1492 MHz	50 MHz	High
Military and other public services		Total 109 MHz	Low except for RFID or white space
New shared bands, total MHz		**400 MHz**	Averaged: medium/high

Our simulations showed that in the third scenario, the most generous and open scenario for shared access, the *net* increase in value to the European economy was of the order of several hundred billion Euros over eight years. This is the net benefit after costs estimated to be of the order of several hundred billion Euros, for introducing sharing with existing users. Refarming for the licence-exempt bands presents a major element, to which must be added the cost of an infrastructure for shared access. However, costs of refarming vary greatly depending on how sharing is implemented. The most expensive is when the incumbent is forced to move frequencies, change equipment and possibly business processes, and perhaps change the equipment of their own end-users with loss of revenues. The least expensive is where pre-programmed channels can be reselected by both emitters and receivers. This is the case for the broadcasters, once digital switchover to digital terrestrial television (DTT) has occurred. Here, the TV broadcasters are able to select new channels on the transmitters, while viewers can rescan the band to find those now carrying programming.

The radio infrastructures that can be envisaged for sharing would principally be either those with transmitters that modify their frequency and power characteristics in the presence of other signals or those that are permanently already set up to avoid interference with a primary emitter, by means of geographic, temporal or power limitations. The minimal costs of such an infrastructure based on modifications to base stations, or sales of new types of SDR hubs, for example, were estimated for the scenario conditions to be of the order of a hundred billion Euros but could be less in some circumstances. For instance, there can be re-use of some mobile infrastructure (eg base station site co-location – rental sharing, site facilities for power, cooling and backhaul etc). In Scenario 3, the aim would be to cover a major portion of the EU with wireless broadband. This could be engineered to offer the DAE targets of 30 Mbps for the remaining EU households (about 5% in total and 17.5% of the rural population) who currently cannot connect to a fixed access broadband network.

In the case of radio communications, mobile, or point-to-point, for mobile handsets and tablets, newer models with software defined radios as front-ends will be able to follow frequency changes. This can be the case whether the new handsets are fixed, or opportunistic, for white spaces with cognitive radio type working. For high volume production, the additional software and hardware could be of the order of twenty to thirty Euros per handset at introduction, falling to a fraction of that in two or three years if production volumes are in the hundreds of millions.

But what would be the impact of sharing on existing mobile cellular services? Broadly speaking, increasing shared access would bring increased competition in markets for voice and data with roaming, generally tending to reduce termination charges and, in some Member States, line rentals. This competition from sharing would be increasingly based on provision of internet access, as wireless broadband is rolled out, for VoIP and various forms of video services such as IPTV. Note that in some MS the MNOs could also make arrangements with the large Wi-Fi service providers, possibly limiting competition.

The indirect effects on the economy could also be significant, as existing mobile charges would be progressively reduced. This would drive increased mobile usage, as a 'perception of freeness' arrives for data roaming. Benefits would result for the EU economy as a whole, as in general, greater use of mobile services enhances economic efficiency.

A further consequence is that the mobile industry's business model would move away from simple communications and more in the direction of content delivery and advertising, in order to recoup revenues and margins.

As well as these economic benefits, greater shared spectrum access would bring social benefits. Better wireless broadband coverage and lower prices for communications, internet access with social networking and entertainment should enable a higher proportion of citizens to benefit from the information society. This could, in Scenario 2 and 3, impact the majority of EU citizens, particularly users of mobile services and the internet as wireless broadband becomes more available. Socially valuable services could include health with telemedicine, support for personal aspirations through augmenting education, with vocational training and job search, as well as social support such as dispersed family integration.

1.4 How to orchestrate future spectrum sharing

Our survey of FP-7 projects found that current regulations would not seriously impede the introduction of their new wireless technologies, some of which seem promising for ultra-high speed mobile networking. Many FP-7 projects are working on aspects of dynamic spectrum access and cognitive radio, related concepts which could have a major impact on the way we regulate and use radio as early as next year, if regulators in the Member States open DTT "white spaces" to opportunistic sharing.

In terms of our task of identifying technical usage conditions which need to be changed to facilitate the use of innovative sharing techniques, regulatory approval of the cognitive use of "white spaces" tops the list. Unfortunately, our survey of national regulatory authorities indicates that only a handful plan to authorize white space devices (WSDs) in the near future. Moreover, the rules that may be recommended by CEPT to protect broadcast TV operation could prove to be onerous for WSDs. They might even fail in the marketplace if they are restricted to very limited geographic areas by the protection criteria for DTT, applied even in countries with few over-the-air viewers (eg Netherlands, Belgium, Luxembourg, etc.). That could delay or even derail the commercial development of cognitive radio in Europe, leading to large losses of foreseeable benefits.

A number of FP7 projects recognize a common pattern emerging from their work. It has come into focus as a need to migrate from rigid/static to flexible/dynamic spectrum management. This is our main conclusion as well.

At a more general level, the main change in technical usage conditions which we have identified is for CEPT compatibility and sharing studies to assume a more flexible framework for interference management when evaluating whether two or more systems can co-exist. Given the complementarity of their roles in this crucial work, closer cooperation between ETSI and CEPT is essential.

As to the question of how much additional spectrum is needed for shared spectrum access, we support the Authorization Directive's policy that general authorization should be the "default" option for radio spectrum access, with exceptions justified by necessity and efficient use. So the question should be: how much additional spectrum is needed for *individually authorized* uses? Having reviewed industry trends and developments, including recent ETSI Technical Reports and System Reference Documents as well as ECC Reports, we agree with the RSPG's conclusion that there is no identified need for more dedicated spectrum – with one exception: the case can be made – as we try to make here – for more spectrum dedicated to RLANs giving the public wireless broadband access.

1.5 Recommendations on light licensing

The originators of the Authorized Shared Access (ASA) concept proposed the introduction of ASA in the 2300-2400 and 3400-3800 MHz bands, both of which have been identified for IMT cellular mobile networks. However, cellular networks have not yet started deployment in those bands. This could suggest that ASA is intended as a way for cellular operators to protect non-cellular incumbents while activating their networks early. However, ASA's proponents say it is not a temporary stage en route to band clearance. Rather, they seem motivated by the situation where one cellular network agrees to give another cellular network occasional access to their frequencies on negotiated terms and for compensation. We see potential danger in such arrangements.

When regulators establish a sharing arrangement for licensees one presumes they are impartial arbiters serving long-term public interests. When a private licencee sets up a sharing arrangement, one must assume economic motives, ie that it is trying to expand its market share and profit. If a cellular operator with an exclusive authorization or primary status is able to offer or veto access to frequencies for a rival, this is an exercise of significant market power – not in the wireline sense, perhaps, but the power to exclude or enable a rival's access to a bottleneck resource is something regulators must regard with caution and concern. Therefore we would recommend against any ASA-based sharing arrangement between firms competing against each other in the same market.

That said, many of the IMT identified bands have also been designated for WAPECS, the EU's "flexible use" band scheme. WAPECS permits negotiated sharing arrangements between licence holders with rather less regulatory oversight than ASA. ASA is therefore unnecessary in bands identified for IMT when WAPECS already offers cellular networks greater flexibility and freedom. Since WAPECS' rules are already in place, further recommendations appear unnecessary regarding agreements between competitors. However, we would be no less concerned about frequency sharing agreements between rivals operating in the same market under WAPECS than under ASA. But it is up to competition authorities to decide when it is appropriate or inappropriate for business rivals to agree the sharing of access rights to spectrum.

There are other use cases where ASA may have merit, however. Noting that the UK Ministry of Defence has already starting offering access to its frequency bands under a scheme similar to ASA, and in our study we identify access to exclusive bands used by various radars (many of them military) as a potential source of "new" spectrum for sharing, we see ASA as a potentially appropriate method of assuring the current band users a say in who shares spectrum with them, as a way to establish trust, perhaps to develop long-term sharing relationships, and to negotiate compensation for shared access. In general we see ASA – or the variant promoted recently by RSPG, Licensed Spectrum Access – as an appropriate way to encourage new sharing arrangements between governmental primaries and commercial secondaries.

Light licensing has the potential to replace traditional licensing in many bands and services – so much so that it is not easy to list all the contexts where it would be recommended. But for starters, maritime mobile may be an appropriate contender, for pleasure boats, fishing vessels and the like are obvious candidates for light licensing, even for de-licensing – and some Member States have already moved in that direction.

Recognizing that propagation distances above 100 GHz are limited and directional antennae are easily constructed and are very effective at these frequencies, the overall risk of interference in the higher GHz bands is negligible. As a result, several administrations have looked into the option of making licence exemption or light licensing the default authorization schemes above a certain frequency. We support these proposals and believe they are what the Authorization Directive requires.

1.6 Costs and technical challenges

The costs of sharing in the case of light licensing or ASA comprise those associated with the primary or sharing operator and those associated with the secondary sharer. For a primary operator there will be the costs of a licence but this is likely to be much less than the cost of an exclusive licence at auction. The other main cost items are associated with the network equipment and end-user devices. The devices may have some form of cognitive radio to limit interference. These costs would be significant – of the order of many hundreds of millions of Euros – but relatively minor in comparison to the overall economic benefit to the EU economy.

The technical challenges are associated with avoiding interference while maximizing capacity in terms of numbers of simultaneous users. Technical measures may be via frequency and power multiplexing, spatial, or temporal and also by coordinating multiple simultaneous users to avoid interference. The latter may be through databases, cognitive radio technology, or some basic logical alternative. For instance, DTT white space sharing can be an example of uncoordinated sharing among multiple secondary spectrum users, whereby cognitive devices compete via politeness mechanisms to access the white space band (with contention mechanisms similar to Wi-Fi devices). A further key technical challenge is reconfiguration for different (and new) protocols in the same bandwidth, specifically for sharing, for which a software defined radio that can flexibly alter the performance profile of the end-user device or access-unit network equipment may be used.

1.7 Incentives for incumbent users

One of the main barriers to sharing is that the current incumbents seem unwilling to share their spectrum holdings voluntarily as, traditionally, spectrum was assigned with an expectation that it would be effectively held in perpetuity. This has led the major spectrum users such as the MNOs and broadcasters, as well as the major public sector users to similar expectations about the lifecycle of their equipment and business processes. The alternative is to permit incumbent licence holders to participate in the returns from other users if they relinquish control over a swathe of spectrum. This particularly applies to public sector spectrum holders.

The UK's audit of spectrum holdings (the Cave review) made wide-ranging recommendations on public sector spectrum use including band sharing between public sector non-governmental radio services. Incentives for sharing such as AIP (Administrative Incentive Pricing) are beginning to yield results, as demonstrated by the UK MoD's scheme.

However, in the commercial markets of broadcasting and mobile cellular, new forces for sharing may become dominant over the next few years. For the broadcasters, wireless broadband will become increasingly attractive for those envisaging an internet play as well as DTT services for delivery of digital content in on a schedule set by the viewer, not by the broadcaster. Thus the broadcasters' willingness to cede spectrum to mobile network operators could grow if current trends toward inter-industry cooperation and broadcast-broadband hybridization continue.

In the cellular mobile industry, MNOs are under pressure to offset declining voice revenue with new cost saving strategies. There are compelling economic arguments for cellular networks to make more use of licence-exempt spectrum – not just for offloading or to capture more of their subscribers' use of Wi-Fi, but to reduce the cost of spectrum for network expansion. The first cellular network established in licence-exempt spectrum is now operating in the US and a field test of LTE in TV white spaces is starting in Europe. We anticipate that techniques for assuring quality of service in licence-exempt spectrum will continue to improve so that MNOs may have no alternative but to follow their customers into shared access spectrum – not just to save money but because sufficient quantities of harmonized spectrum are not available under licence. The ECC's strategic plan for the 2.4 GHz band already warned in 2002 that "Administrations have no legal means to prevent public networks in unlicensed Short Range Device bands including the band 2400-2483.5 MHz."

While there may be commercial reasons for MNOs to consider innovative approaches, it is unlikely that market forces alone will bring about necessary changes. We conclude that regulatory powers might be needed to enable terms and conditions in licences to be renegotiated so that licence holders may forfeit their rights if a case-by-case review finds their use of spectrum falls below a level that justifies their exclusive control of frequencies. We support the "use it or lose it" principle suggested by Vice President Neelie Kroes in her speech to the 2010 Spectrum Summit: "If the potential of a spectrum allocation is not being exploited to its maximum, if the application is not the most efficient way of delivering social, cultural or economic benefits, then it should go to another application or service instead."

1.8 Impact on administrative costs

Increasing shared spectrum use would have some direct impact on the administrative costs of regulatory authorities and spectrum users. The scale of the impact and the issue of who would be responsible for bearing any additional costs are influenced by a number of factors, including:

- How much spectrum is to be shared, and in which bands
- The number of sharers, the amount of traffic generated and the behaviour of sharers.
- The basis for authorization: a licensed, light-licensed or licence-exempt approach
- The basis for sharing, eg "politeness protocol" v spectrum database, or both.

So, for instance, if sharing were performed using politeness techniques, such as "listen before transmit", this could require a small amount of additional hardware and software. If this was applied on a licence-exempt basis, then these additional infrastructure costs would fall on the unlicensed sharer. Conceivably there could be a negligible impact on administrative costs arising to spectrum users and regulators in these circumstances.

If, however, sharing was carried out by means of a spectrum-sharing database and this would be for the regulator to administer, there would be some non-negligible additional costs for the regulator to bear. The basis for a spectrum database is comprehensive spectrum monitoring. We envisage the need for spectrum monitoring regardless of how sharing is done. With less reliance on licensing, the regulator will not know where transmitters are deployed unless they report their location to a database or monitoring detects them. We would hope that the purpose of monitoring would gradually shift from enforcement (catching unlicensed transmitters) to planning and verifying efficient use. Monitoring may also be needed to arbitrate interference disagreements.

A significant question is the scale of the potential enforcement problem in a licence-exempt environment. Under current policies, licence-exempt devices have no right to interference protection. If those sharing abide by the rules and interference mitigation is designed in to their devices, then there will be no basis and no need for regulators to intervene in local conflicts, and no impact on administrative costs.

Given the array of factors that affect the scale of and responsibility for administrative costs arising from shared spectrum access, we have had to make several assumptions so that we can attempt to quantify the impact. We have estimated the administrative burden for scenarios 2 and 3, outlined above; note that for scenario 1 there would be no administrative burden by definition. Thus, contrasting these two scenarios captures the differences in administrative burden between a more moderate scheme with shared spectrum on a light licensed basis, and a more ambitious scheme with sharing in more bands with some being licence exempt, in addition to light licensing.

In theory, an increase in light licensing or licence exemption could imply less traditional authorization, and fewer spectrum licences awarded through auctions. This would mean some savings in administrative costs but also a loss in revenue. Light licensing is still licensing, even though it might mean using the spectrum more efficiently. Thus we have estimated the administrative savings from light licensing at 20% of traditional authorization costs. It is in licence exemption, though, that the potential for savings in administrative costs is greatest. Spectrum licensing, awards, registration and other tasks would drastically reduce administration costs.

For the two options the net costs of implementation and the ongoing administrative burden can be estimated through the following main cost items:

1. Spectrum monitoring and database
2. The regulatory process
3. Enforcement and administration

In compiling these estimates, we have modelled the costs for a typical large regulator. We have then used a scaling factor of 10 to reach a figure for the EU-27 as a whole. Therefore, our estimate for the annual administrative burden to NRAs for increased spectrum sharing is very similar for both options, ranging from about €28.8 to €30.3 million. The implementation costs for increased shared spectrum access ranges from €31.6 to €35.5 million.

1.9 The need for flexibility and cooperation

Using the most valuable parts of the radio spectrum as efficiently as possible is key to Europe's future economic prosperity. As Europe seeks ways to maximize the return on its radio resources, by escaping from older systems of administration, industry structures and technologies, legislators and regulators need new principles for apportioning spectrum.

The case for a more flexible approach to spectrum management is compelling, but the change required is significant and the difficulties facing regulators and users should not be underestimated. NRAs have a great many pressures to deal with and, not unsurprisingly, their focus is on present day issues rather than those that will become urgent over the coming years.

NRAs have a duty to serve the public and that, we believe, will require them to keep an open mind about the economic and social case in favour of making more spectrum available for shared access. European cooperation will be required if regulators are to embrace the more flexible strategic role that we expect to be necessary in the future.

1.10 In summary

The table below briefly summarizes the findings of the study by task:

Task 1	• Estimates from the scenario simulations of net economic benefit of applying sharing for wireless broadband show significant returns, considering the range of uncertainties of such modelling. • Benefits from driving the EU economy vary by scenario. Total net increases in GDP over eight years to 2020 was estimated at approximately €200 to 500 billion but with proportionately less impact in the first five years. • Variations are due to the form of sharing, the bandwidth made available and the costs of sharing including, in one scenario, refarming of some incumbents. • Social benefits are significant as wireless broadband can offer households and individuals internet access in rural, suburban and urban settings varying from several Mbps up to 30 Mbps, depending on the implementation scenario.

Task 2	• Industry trends and developments most relevant to shared spectrum access are:
	    • Accelerating growth in wireless data traffic generated by smart phones, tablets, and other portable Internet access devices.
	    • The resulting need to expand cellular mobile networks rapidly, including backhaul, and to accommodate an "exaflood" of offloads into licence-exempt spectrum below 6 GHz.
	    • The proliferation of SRDs and the growth of M2M communication.
	    • Tentative movement toward a "strategic partnership" between the broadcast industry and wireless broadband providers.
	    • Interest among regulators in exploiting "white spaces" as a way to increase spectrum utilization in predominantly licensed bands.
	• Few FP7 projects see any need to change "shared access" allocations in order for their technology to enter the marketplace. But "white space" projects favour rule changes to enable the deployment of their technology. A general pattern emerging from the FP7 radio projects is the urgent need to replace static/rigid forms of spectrum management with dynamic/flexible ones.
	• "Politeness" rules enable more sharing but can be a source of inefficiency in channel use. Better coordination is needed between standards groups to improve compatibility between different new radio technologies.
	• On the need for more "shared access spectrum" we estimate 320-450 MHz is needed for more wireless broadband access (WAS/RLANs).

Task 3	• NRA knowledge of use of shared access bands for wireless broadband, congestion and interference is mainly anecdotal. Only one has measured occupancy of any of the five bands used by licence-exempt RLANs. • Congestion at 2.4 GHz is becoming more widespread in dense urban areas. The rate of traffic growth means problems will increase, although there is no consensus on the upper limits of Wi-Fi density. • To relieve congestion, we propose the bands in Scenario 2, as given in the table above, and for Scenario 3 we also propose an additional licence-exempt band in the 500-600 MHz region as well as one at around 1400 MHz, each of 50 MHz.
Task 4	• The annual administrative burden to NRAs for increased spectrum sharing is about €28.8 million for scenario 2 and about €30.3 million for scenario 3. • The implementation cost is about €35.5 million for scenario 2 and €31.6 million for scenario 3.
Task 5	• The ASA and light licensing bands suggested are given in the tables above. • ASA's proponents envision it applying to the 2300-2400 MHz and 3400-3800 MHz bands for rival cellular operators to transfer unneeded channels to each other for compensation. It raises questions about fair competition and market power. We do not support arrangements where one licensee makes a sharing arrangement with a competitor operating in the same market. • ASA is potentially most useful where a public sector primary might be induced to share with a commercial secondary. Modelling shows that the spectrum efficiency gain could be significant, and the technical challenges minor. • Light licensing is such a flexible authorization regime that it could be applied in many bands, first among them being maritime mobile.