A New Regulatory and Technical Environment for Wireless Broadband: A Primer on the IEEE 802.11y Amendment

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Executive Summary

The addition of the 802.11y amendment[1] to the IEEE 802.11-2007 standard[2] links significant shifts in the regulatory and technical environments for wireless broadband in the United States. The amendment embodies mechanisms that allow cooperative use of the 3650-3700 MHz band (3650 MHz band) and enables a streamlined "light licensing" approach to spectrum management as outlined in the March 2005 3650 MHz Order by the Federal Communications Commission (FCC).[3] The 3650 MHz Order was intended to "create a spectrum environment that will encourage multiple entrants and stimulate the expansion of broadband service"[4] - specifically in underserved areas of rural America. When proven, the technologies developed to meet the requirements for this limited band may make it possible for shared use of a much larger portion of spectrum in the United States and worldwide.

The key elements of this novel regulatory framework are intended to lower cost of entry and compliance while allowing market forces to derive maximum value from the available spectrum through shared use. They include:

- Licensees must not interfere with the operation of existing (grandfathered) satellite earth stations operating in the 3650 MHz band.
    - Base stations must be located outside 150km exclusion zone from an existing primary earth station.
    - Dependent stations are enabled by a licensed base station (enabling station) before transmitting.
- Licensees share responsibility for resolving interference issues.
    - Base stations must be registered and identifiable.
    - Base stations operate using a contention-based protocol (CBP) to prevent interference.
    - Licensees work together to resolve interference issues that cannot be addressed through technical means.
- Non-exclusive 10-year nationwide licenses are available for a low up-front cost with an additional nominal cost per fixed base station.
    - Dependent stations do not require a license.

Wi-Fi technology is especially well suited to meet the requirements for avoiding interference – and builds on that strength with the 802.11y amendment. The 802.11-2007 standard specifies a contention-based protocol that "senses" whether a channel is available before transmitting. The 802.11y amendment improves on that capability with enhancements to carrier sensing and energy detection mechanisms.[5]

- The Extended Channel Switch Announcement (ECSA) mechanism allows access points to notify connected stations of an intention to change channels, operating bandwidth and regulatory classes, allowing the network to dynamically identify and operate on the channel with the least noise.[5]
- The Dynamic Station Enablement (DSE) capability in 802.11y allows a high-powered registered station to enable remote networks that can hear and detect the enabling beacon, which remain under the control of the registered station.[5]

Potential applications of 802.11y include:

- A licensed operator installs a few enabling stations to cover a geographically large oil field, then uses dependent stations at each pump or truck or rig. The enabling stations manage the regulatory aspects of the network(s) with oversight from the information technology department.

- A fire station locates an enabling station on its communications tower, and uses dependent stations on each fire truck and laptop. The incident commander controls the enabling station using a Public Safety band radio.

Technology Enables a Freer Market

The 3650 MHz band provides an opportunity to explore new ways to maximize the value of finite and valuable radio spectrum. The technology can easily be extended to work in other bands, potentially opening vast amounts of underutilized spectrum with low license fees.

The band has been largely vacant due to the range limitations of radio waves and intentional frequency spacing to avoid interference. By making it available for high-powered broadband use, the FCC serves its goal of bringing advanced telecommunications service to all Americans under the Telecommunications Act of 1996.[4] The particular licensing framework adopted by the FCC opens spectrum use to a much larger pool of licensees and uses and demonstrates a management philosophy of maximizing use in a given geographical area (both licensed and unlicensed) without a corresponding increase in regulatory infrastructure. Some key aspects of this move towards a more market-based use of spectrum include:

- A non-exclusive licensing scheme which balances the need for low entry costs and minimal regulatory delay with the benefits of more coordination than a traditional unlicensed approach.[4]
- An environment encouraging innovation. By specifying only the function of contention-based protocol rather than a technology-specific solution, the FCC intends to "facilitate operation of the widest variety of broadband technologies with minimal risk of interference in both the near and long terms."[4]

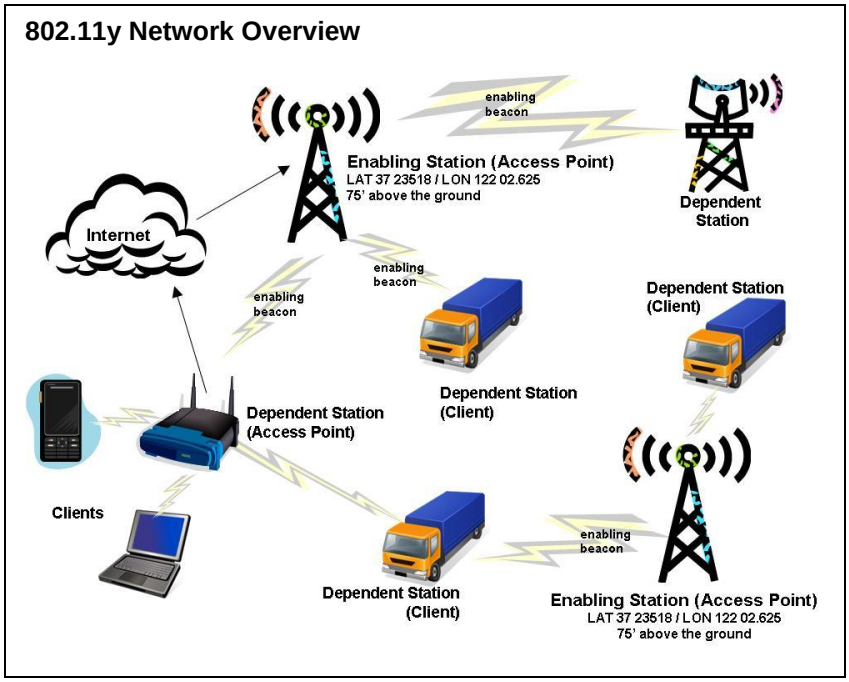
The success of Wi-Fi technology in the unlicensed 2.4 GHz and 5 GHz blocks has been impressive with nearly 5000 devices designated as Wi-Fi CERTIFIED™ since March 2000. The overwhelming market success has driven prices for enabling chipsets to less than $10 – creating a compelling and low cost solution for wireless broadband. Wi-Fi technology also has a great deal of experience with mitigating interference. Because the contention-based protocol used by Wi-Fi technology senses and responds to a broad range of potential technologies (referred to as "unrestricted CBP" under the FCC rules) one hundred percent of the 3650 MHz band is available to networks using the 802.11y protocol. In contrast, technologies that can only mitigate contention with devices using the same protocol ("restricted CBP" under the FCC rules), like IEEE 802.16 (WiMAX), are limited to a 50%, or 25MHz, allocation.[4]

The expectation is that successful deployment of this model in the 3650 MHz band can and should lead to a much broader allocation of spectrum for lightly licensed networks utilizing contention-based protocol mechanism - eventually including most of the known unused or underused radio spectrum. The combination of low cost and robust interference management positions Wi-Fi technology to take full advantage of that opportunity.

Key 802.11y Network Elements

The flexible allocation of radio frequency spectrum supported by the 802.11y amendment has its origins in technology and system concepts contained in a conceptual architecture (XG) developed by the Defense Advanced Research Projects Agency (DARPA). The XG architecture introduced discovery and adaptation in all frequency bands. The logical dispute resolution process in 802.11y builds on that innovation with mechanisms for including regulatory domains (beaconing with the country code and regulatory limits). Below is a brief overview of key elements and enabling mechanisms.

- **Enabling Stations**
  An enabling station is a high-powered fixed station with authority to control when and how a dependent station can operate. An enabling station communicates an initial enabling signal to its dependents over the air. The enabling station may then direct supporting enablement messages to be exchanged over the air, over another dependent station, or by mechanisms that rely on transport via higher layers.



  As with all high-powered stations, GPS coordinates and altitude information of enabling stations are registered in a public database to enable stations experiencing interference to locate interfering stations and seek interference mitigation. Enabling stations must include location information in every beacon.

- **Dependent Stations**
  Dependent stations are devices in the network that are not registered, but instead receive authorization to transmit from a registered enabling station over the air. Failure to receive the enabling beacon at regular, defined intervals requires a dependent station to suspend transmission until it is re-enabled. A dependent station may be fixed or mobile.

- **Regulatory Class Information**
  Each device in a network must be able to operate within regulatory requirements of any channel available to it. Prior to 802.11y, channel switching only occurred within a particular band, where only transmit power limits may have changed. Future implementations will be able to move outside of the original band, complying with the regulatory requirements specified by the regulatory class octet in every beacon.

Key 802.11y Network Mechanisms

Together these new elements support three significant new mechanisms defined in 802.11y:

- **Dynamic Station Enablement (DSE)**
  Dynamic station enablement is the process by which an enabling station grants permission and dictates operational procedures to dependent stations. The “lightly-licensed” structure of the FCC regulations for 3650 MHz calls for the creation of procedures to govern the use of the band and treatment of violations. DSE supports the “lightly-licensed” regulatory model by empowering the network operator to ensure

appropriate operation of base stations and the dependent stations they enable.

Beyond addressing the regulatory requirements for the 3650 MHz Order, DSE offers the promise of other channel management and coordination benefits.[5] For example, since the enabling station is not required to serve as the access point for each of its dependent stations, DSE can reduce the likelihood of a dependent station contributing to radio interference by allowing the dependent station to complete the enablement process via a geographically closer access point and ultimately through a channel other than the air (e.g. the Internet).[5]

- **Contention-Based Protocol Incorporating Regulatory Class Information**
  802.11y devices can sense both 802.11 and non-802.11 devices and identify available spectrum as small as 5MHz. 802.11y access point beacons identify the country and the regulatory domain for their physical location. By incorporating both channel use and regulatory class information, 802.11y devices can identify available channels and adjust operating parameters to the laws of the country in which the access point resides.

- **Extended Channel Switch Announcement (ESCA)**
  ECSA is a methodology to coordinate a move from one channel to another with less contention or to change channel bandwidth.[5] Specifically, an enabling station can identify the channel with the least aggregate interference to all of the stations that are connected to it on a completely dynamic basis. This capability ensures the best signal to noise ratio and lowest power levels possible.

  ECSA also incorporates regulatory class information – if a channel switch moves the network to a new regulatory domain, the station shifts to the approved frequencies and channels for the new domain.

  ECSA originates in 802.11y, and is now being applied retroactively to 802.11n and the other proposed concepts across 802.11.

Network Operation Overview

The first requirement for establishing an IEEE 802.11y network is determining if the area to be covered is in an exclusion zone. If it is outside of the protected regions, the network operator must file for a license, pay a small fee and register the location of the enabling station in a public database. Dependent stations, fixed and mobile, may then be added to the network based on their ability to receive and decode the enabling beacon.

Once enabled, each dependent station continually tests its ability to receive and decode an enabling beacon. Failing this test, the dependent station attempts to reacquire the beacon, with a finite number of attempts before ceasing trying for a predetermined amount of time. This requirement prevents congestion caused by stations that may be truly out of range of an enabling beacon.

Enabling stations continually tests for interference. If interference is detected, the enabling station must silence the network and search for a clear channel. When a new channel is identified, ECSA directs all of the devices in the network to move to the new channel, which may include a change in regulatory class, as specified by the regulatory class octet.

The Future As We See It

Success for the shared use and “lightly licensed” model in the 3650 MHz band will be defined by network reliability and throughput, minimal interference with networks and devices sharing the

band, and mitigation of any interference that does occur. Wi-Fi technology is a proven winner in the wireless broadband market – it is positioned for successful deployment in the 3650 MHz band and can grow rapidly into subsequent areas that may be made available to cooperative use. Other regulatory domains are already exploring similar spectrum sharing opportunities – for example the European Commission announced a decision in May 2008 to open the 3400-3800 MHz band for non-exclusive licensing.[6]

Low-cost chipsets and the capability to effectively manage interference through contention-based protocols make Wi-Fi technology an excellent fit for applications in this spectrum. The higher-power levels permitted by the 3650 MHz Order combined with enhancements made to the MAC timing in 802.11-2007 extend effective distances to 5 km or more.[5] The improved quality of service (QoS) made possible by higher power levels will make Wi-Fi technology more attractive for intensive applications like Voice over Internet Protocol (VoIP).

802.11y has been structured to facilitate rapid deployment in other bands – any 5, 10 or 20 MHz channel that regulators make available can be incorporated by simply adding entries to the country and regulatory information tables. When the technology in 802.11y delivers compelling performance levels, it is easily transferred to other bands. If licensing in the 3650 MHz band is successful, we believe the FCC will make additional bandwidth allocations available for cooperative use.

NOTE: This document may be updated after the FCC publishes rules for TV White Space, proceeding FCC 04-186.

References

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