WiMAX/Wi-Fi coexistence in the 3.65GHz band - standardization and simulation

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Abstract

Opening of the 3.65-3.7GHz band in the US has created opportunities to standardize solutions for license-exempt operation of WiMAX systems. This is being realized through the IEEE P802.16h license-exempt amendment. This paper presents a summary of the regulatory requirements of the band, and summarizes efforts within IEEE License-Exempt Task Group in providing a solution for coexistence with 802.11 systems (based on the 802.11y amendment). Some of the technical proposals from the 802.16h draft amendment are presented together with simulation scenarios and accompanying results. Simulation activity is motivated by work within the IEEE 802.19 Coexistence Technical Advisory Group considering WiMAX/Wi-Fi coexistence.

1 Background

The motivation for developing technology solutions for operation in license-exempt (LE) bands is based on the following perceived benefits:

- Provide spectrum depth and add value to existing licensed spectrum holdings by utilizing LE bands.
- Enhance capacity with the off loading of traffic from licensed band macro base stations.
- Enhance coverage to provide infill and hotspot coverage.
- Provide a low cost alternative by using spectrum which requires a lower capital investment.
- Provide low cost deployments derived from a standards based solutions.

The 3.65-3.7GHz band is an emerging LE band which can provide such benefits. The FCC (Federal Communications Commission) rules for operation in this band are contained in 47 CFR (Code of Federal Regulation) Part 90 '*Private Land Mobile Radio Services*' [1]. The band is not truly license-exempt but rather *non-exclusively licensed*, sometimes called *lightly-licensed*. The FCC imposes RF, operational and protocol restrictions for all devices operating in the 3.65-3.7GHz band [1]. Selected restrictions are listed in Table 1:

Table 1 A summary of the FCC regulatory requirements for operation in the 3.65-3.7GHz band.

– *25 Watt EIRP (Effective Isotropic Radiated Power) maximum power in 25MHz bandwidth for Base and Fixed stations (1 W/MHz EIRP maximum Power Spectral Density).*
– *1 Watt EIRP maximum power in 25MHz bandwidth for Mobile and Portable stations (40 mW/MHz EIRP maximum Power Spectral Density).*
– *Mobile and portable stations may only transmit if they can decode an enabling signal from a base station.*
– *Fixed assets must have their location registered.*
– *Exclusion zones: FSS (Fixed Service Satellite) [150km] and Federal radiolocation stations [80km].*

Protocol restrictions are embodied within the definition of a CBP (Contention Based Protocol) [1]

"A protocol that allows multiple users to share the same spectrum by defining the events that must occur when two or more transmitters attempt to simultaneously access the channel and establishing

the rules by which a transmitter provides reasonable opportunities for other transmitters to operate. Such a protocol may consist of procedures for initiating new transmissions, procedures for determining the state of the channel (available or unavailable), and procedures for managing retransmissions in the event of a busy channel."

In order to expedite deployment in the band, the FCC introduced the concept of *Restricted* and *Unrestricted CBPs* in June 2007 [2]. Equipment incorporating an *Unrestricted CBP* is permitted to operate over the whole 50MHz of the band. Equipment incorporating a *Restricted CBP* may operate in the lower 25MHz of the band only. This modification added the following clause to the original CBP definition:

"Contention-based protocols shall fall into one of two categories:
(1) An unrestricted contention-based protocol is one which can avoid co-frequency interference with devices using all other types of contention-based protocols.
(2) A restricted contention-based protocol is one that does not qualify as unrestricted."

2 Standardizing solutions for the 3.65GHz band

Work is being undertaken to standardize an FCC compliant *Unrestricted CBP* for 802.16. This work is being conducted within the License-Exempt Task Group (LE TG) of the IEEE802.16 Working Group. The Task Group is developing the amendment P802.16h to the 802.16 standard to provide '*Improved coexistence mechanisms for license-exempt operation*'. The 802.16 protocol enhancements in the 802.16h amendment aim to facilitate WiMAX operation in the 3.65GHz band. This paper presents some of those proposals where a minimum set of changes to the base standard is intended to retain close alignment to features and parameters defined in the *Mobile WiMAX System Profile* [3]. The IEEE802.11 Working Group is creating an amendment specifically addressing the 3.65GHz band. This is essentially a rebanding exercise for the OFDM (802.11a) air interface. Given 802.11's fundamentally close relationship to the definition of a CBP there are only minor substantive changes to make in the P802.11y amendment.

CBP proposals are being considered in the 802.19 Coexistence TAG (Technical Advisory Group). Work has been progressing in this group to define simulation parameters [4], scenarios, and coexistence criteria with the aim of demonstrating coexistence and thereby providing support for the FCC's requirements for an *Unrestricted CBP* at the IEEE802 level. This work takes the form of a *Coexistence Assurance Statement*. The 802.19 simulation parameters document provides a number of options, but a mandatory profile is provided to narrow the simulation configuration and reduce the number of simulation scenarios to assist in the comparison of different simulation approaches.

The 802.19 document covers environmental parameters: large-scale fading (the pathloss model is based on the Stanford University Interim (SUI) model [5]) and small-scale fading (Ricean K factors and fade margins as a function of the MIMO (Multiple Input Multiple Output) structures for both the downlink and uplink). Device parameters are defined such as: channel bandwidth, nominal maximum antenna gains and radiation patterns. Algorithms are provided that specify power control, and link adaptation schemes. The 802.11 and 802.16 specific parameters include receiver sensitivity values and corresponding data rates, medium access timings values for 802.11, 802.16 features as part of the 3.65GHz band solution, and interference detection thresholds. There is definition of external driving parameters which includes a number of traffic models. Coexistence metrics include a specification of channel occupancy and hidden node statistics.

3 Technical solutions

A medium sensing scheme is employed by 802.16, in a similar way to that of 802.11, to determine when the medium is quiet and can be claimed for use. The channel sensing interval is placed at the end of an 802.16 frame thus utilizing the RTG (Receive Transition Gap). Since the *Mobile WiMAX System Profile* [3] dimensions the number of OFDM symbols per frame for macro cellular deployments then for LE band, where cell sizes are likely to be smaller, the RTG offers ample opportunity for other systems to claim the medium. Given the WiMAX frame duration then there is an opportunity to share the medium every 5ms. Furthermore OFDM symbols can be removed from the uplink subframe to accommodate a longer measurement period. The mechanism for reclaiming the medium acts as the interface between the synchronous behavior of 802.16 systems and the asynchronous behavior of 802.11.

The unique requirements of the 3.65GHz band means that since an operator is required to register the location of all fixed stations then it is possible for operators to determine, to a certain accuracy, how many systems are operational in a given area. This knowledge allows 802.16 to set a utilization goal (for example 33% if there is one 802.16 system and two 802.11 systems in the area) to ensure fair sharing of the medium for the deployed systems. An assessment of how much of the 33% is successfully being claimed can be used to modify a Dynamic Medium Acquisition (DMA) algorithm. The DMA algorithm sets intervals when an 802.16 system can begin monitoring and subsequently claim the medium. This interval is based on the past utilization and the utilization goal. As the utilization goal is achieved the opportunities to claim the medium are reduced. 802.16 claims unused frames whenever possible as a means of maximizing the retention of frames for synchronization.

To reduce the uncertainty between 802.11 and 802.16 in claiming the medium, 802.16 claims the medium over an observation period shorter than that used by 802.11. An 802.11 CTS (Clear-To-Send), specifically a *CTS-to-self*, signal (called an FRS (Frame Reservation Signal)) is transmitted by 802.16 to ensure that the TTG (Transmit Transition Gap), RTG (Receive Transition Gap), and frame transmissions are protected from interference by 802.11. CTS transmissions from 802.11 are also detected and obeyed by 802.16 systems. In this way the Frame Error Rate for both systems are much reduced. Figure 1 presents the usage of the DMA algorithm. The figure shows an a priori knowledge of which frames are allocated to which 802.16 systems. The example also shows how 802.16 systems surrender frames due to presence of other systems and how the medium can be subsequently reclaimed by 802.16.

The *DMA Region* is shown in details for *System 2* in Figure 1 and appears at the end of the 802.16 frame. The dynamic boundary is termed the *FRSTn* (Frame Reservation Start Time). This boundary depends on the current channel utilization for a given 802.16 system and defines a logical time when a system can possibly claim the medium for use in the following frame. The values are updated based on the current and past utilization of the channel. *MAXFRST* is the absolute leftmost extreme of the *DMA Region* and is the maximum value (earliest time) of *FRST*. *MINFRST* is the minimum value of *FRST*. *MINFRST* is calculated from the end of the frame and comprises the minimum time for 802.16 to determine the medium is clear and therefore claim the medium.

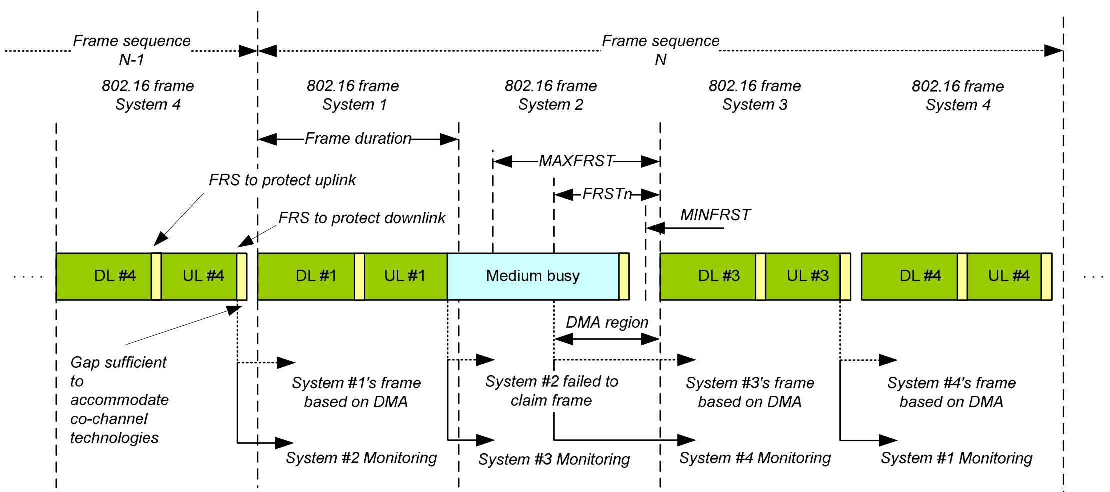
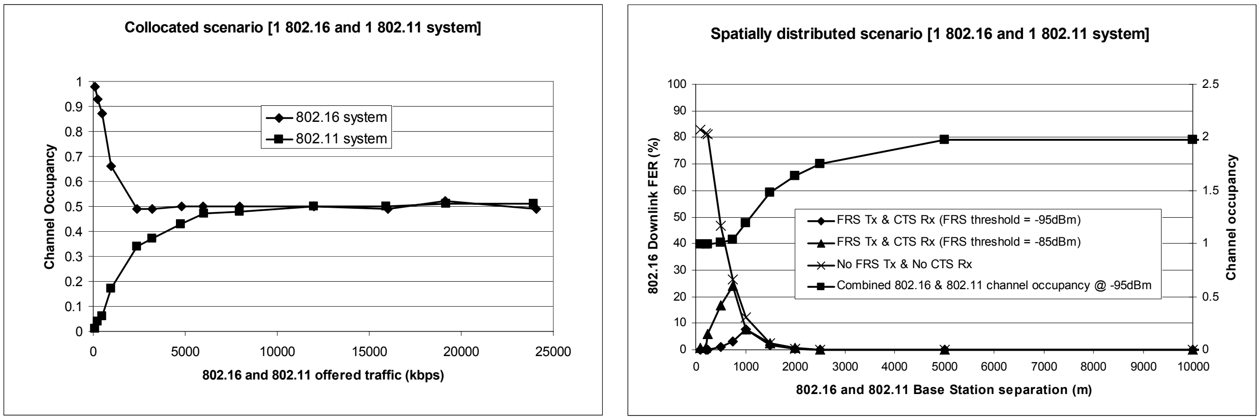


Figure 1 An illustration of the operation of the DMA algorithm and sharing with 802.11. The example shows 4 802.16 systems sharing the medium. *System 2* is unable to use its frame allocation due to a busy medium.

4 Simulation results

This section provides some interesting and representative simulation results of channel sharing based on the DMA algorithm as described previously. Figure 2 (a) provides channel occupancy results for the simulation scenario in which all devices are *collocated*. This is a baseline scenario to demonstrate the expected behavior of the algorithm. The results show fair sharing of the channel by DMA. As the two systems' offered traffic load increases 50% channel occupancy for each system is achieved, note that under low loading 802.16 claims the unused frames as a means of maximizing synchronization retention. Figure 3 provides the illustration of a simulation scenario to provide a *spatially distributed* configuration; results are presented in Figure 2 (b). This scenario analyzes the impact of hidden nodes and the resulting FER (Frame Error Rate). This figure demonstrates lower FER for 802.16 systems that support the transmission and reception of FRS signals; furthermore careful selection of FRS detection thresholds can be used to optimize coexistence. As would be expected the total channel occupancy approaches 2 as the base station separation increases to a point where there is no interaction between 802.16 and 802.11 systems.



(a) (b)

Figure 2 Example simulation results for the 802.16 DMA algorithm for: (a) a *collocated* simulation scenario, and (b) a *spatially distributed* simulation scenario.

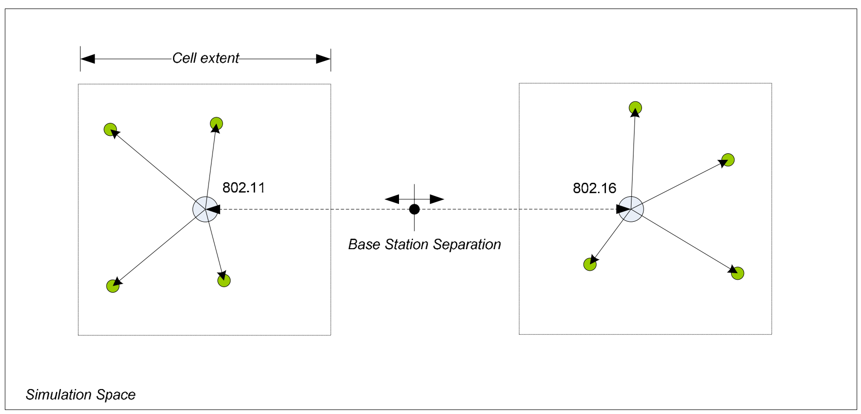


Figure 3 Simulation configuration to provide a *spatially distributed* scenario.

5 Summary

The paper has described the IEEE standardization activities for operation in the 3.65-3.7GHz band and the regulatory requirements for operation. Simulation results have been presented to demonstrate some proposals for 802.16 coexistence with 802.11 where both systems are designed to meet the requirements of the FCC's CBP.

6 Reference

[1] Title 47 – Telecommunication, Part 90 – Private Land Mobile Radio Services: Subpart Z - Wireless Broadband Services in the 3650-3700 MHz Band, Part 90.1301 - 90.1337, Federal Communications Commission.
[2] FCC Memorandum, 060707 3650-3700MHz MO&O, FCC 07-99, June 7, 2007.
[3] WiMAX Forum Mobile System Profile Release 1.0 Approved Specification (Revision 1.2.2: 2006-11-17).
[4] Paul Piggin (Editor), *Parameters for simulation of Wireless Coexistence in the US 3.65GHz band,* IEEE 802.19-07/11, 802.19 Coexistence TAG Technical Memo, November 2007.
[5] IEEE 802.16.3c-01/29r4: Channel Models for Fixed Wireless Applications, Erceg et al., IEEE 802.16 Broadband Wireless Access Working Group, January 2001.