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Re:	Working Group Review of Working Document IEEE 802.16h-06/015r1
Abstract	This document contains the definition of an Uncoordinated Coexistence Protocol in order to meet the spirit of the FCC and Industry Canada mandates in certain non-exclusively assigned/licensed bands.
Purpose	To provide a mechanism whereby 802.16 transmitters can be expected to provide reasonable opportunities for other transmitters to operate.
Notice	
Release	
Patent Policy and Procedures	

Uncoordinated Coexistence Protocol (UCP)

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Overview

This contribution proposes the addition of new features to the Working Document [1] toward the amendment P802.16h. These features can be used for enhanced uncoordinated coexistence between 802.16 systems operated by different entities or between 802.16 systems and non-802.16 systems, in particular 802.11 systems. These features culminate to form an "Uncoordinated Coexistence Protocol" intended to provide improved coexistence and, in particular, meet the requirements put forth in [3] and [4]. While these references levy requirements for a particular band in the US and Canada, the purpose of their requirements is more far reaching. In particular, they strive quite generally to ensure coexistence of uncoordinated systems of various technologies in the same band. Therefore, a method for coexistence suitable to meet these requirements has applicability that extends to many bands allowing non-exclusive access to the spectrum.

The FCC, in [3], defines a contention based protocol for non-exclusively assigned bands as:

"Contention based protocol: 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."

Industry Canada, in [4], adds a clarifying example based on their interpretation of the FCC's definition:

"Examples of protocols used in existing radio systems that the Department would consider as meeting the requirements of a contention-based system include the Carrier-Sense Multiple-Access with Collision Detection (CSMA/CD) protocol used in Wi-Fi gear or any other form of Dynamic Frequency Selection (DFS) or listen-before-talk approach."

Taking the hint from Industry Canada, in any non-exclusively assigned band, it is obviously best to first use a mechanism like DFS (or Dynamic Channel Selection (DCS), the Working Document [1] term when the detected interferer is not a primary user of the band) to find a vacant channel. If no vacant channel can be found, the 802.16 system must use other measures to coexist with other non-primary users.

To properly coexist with 802.11 systems, it is important to understand how they detect and avoid other users, how they react, and their timing. This is specified primarily by the Clear Channel Assessment (CCA) method and the timing between listening and talking. The algorithms differ depending on the 802.11 PHY mode.

High Rate DSSS (802.11b) in the 2.4 GHz band (Clause 18 of [6])

The current 802.11 revision draft [6] specifies that a High-Rate DSSS ("802.11b") system must use one of 3 CCA modes. In the first mode (CCA Mode 1), the channel is declared busy when any signal is detected above the energy detection (ED) threshold and declared not busy when energy drops below the ED threshold. In the second mode (CCA Mode 4), if a properly formed High Rate DSSS signal is detected, the device declares the channel busy and starts a 3.65 ms timer. When the timer expires, the channel is declared not busy, but only if no High Rate DSSS is detected. The timer duration is based on the transmit time of the longest possible PHY SDU in a 20 MHz channel. The third mode (CCA Mode 5), like CCA Mode 4, only declares the channel busy if a properly formed High Rate DSSS signal is detected, but declares it not busy as soon as energy drops below the ED threshold.

The first mode causes a device to defer transmission if it hears any interferer above threshold. The second mode causes a device to always wait a minimum time after hearing an 802.11b transmission regardless of the true state of the channel, but does not require it to defer transmission if the interferer is not another 802.11b system. The third mode declares the channel not busy more quickly than the second mode but again ignores non-802.11b systems.

In the case a valid signal is detected, the ED threshold ranges from -76 dBm to -70 dBm, depending on the transmit power of the device. There appears to be no specification of the ED threshold in the case of only energy detection (CCA Mode 1).

Extended Rate PHY (802.11g) in the 2.4 GHz band (Clause 19 of [6])

For Extended Rate PHY ("802.11g") systems, the CCA algorithm is very much like CCA Mode 5 of 802.11b except that it must detect both High Rate DSSS and OFDM signals.

In the case a valid signal is detected, the ED threshold is -76 dBm. There is no energy detection only mode, and therefore no threshold for energy detection.

OFDM for the 5 GHz Band (802.11a/802.11j) (Clause 17 of [6])

The 802.11 OFDM mode was originally defined in IEEE 802.11a, which specified 20 MHz channels. IEEE 802.11j extended the frequency range downto 4.9 GHz and added additional specifications, including the option of 10 MHz channelization. The current draft revision of 802.11 [6] would add an option of 5 MHz channelization.

For the OFDM mode, the specification merely says that devices must provide the capability to perform CCA. The details are in the sensitivity section.

When detecting a "valid" signal that it can receive, including the preamble, an 802.11 OFDM device must do so at receive levels equal to or greater than the minimum modulation and coding sensitivity of -82 dBm for 20 MHz channels, -85 dBm for 10 MHz channels, and -88 dBm for 5 MHz channels. If the device cannot receive the signal, it must nevertheless consider the channel busy if it detects the signal at a level 20 dB above the minimum modulation and coding rate sensitivity (-62 dBm, -65 dBm, and -68 dBm for 20 MHz, 10 MHz, and 5 MHz channels, respectively). The detection must occur with 90% probability within 4 μs, 8 μs, or 16 μs for 20 MHz, 10 MHz, and 5 MHz channels, respectively.

The discrimination against non-receivable signals is hopefully overcome by the availability of numerous channels in this band for application of DFS/DCS.

OFDM PHY for the 3650 MHz Band (P802.11y) ([5], modifies Clause 17 of [6])

The IEEE P802.11y project is developing enhancements for the 3.65-3.7 GHz band. One current proposal [5] for the content of the draft bears on the current situation. This proposal would base the 3.65-3.7 operation on the OFDM PHY mode by modifying Clause 17.

First, it introduces CCA/ED Modes 1, 4, and 5 which are patterned after the 802.11b CCA Modes 1, 4, and 5 except that the energy detection mode (CCA/ED Mode 1) must always be used. Additionally, one of the other two modes, timer or energy dropping below threshold, must also be used when the energy is also determined to be a valid 802.11 signal. Second, the wait timer for CCA/ED Mode 4 is made channel bandwidth specific at 3.65 ms, 7.3 ms, or 14.6 ms for 20 MHz, 10 MHz, and 5 MHz channels, respectively. Most importantly, especially when tied with mandatory energy detection, rather than discriminating between 802.11 and non-802.11 signals, the receive sensitivity for any signal must be 0 dBm above the minimum modulation and coding sensitivity of -82 dBm for 20 MHz channels, -85 dBm for 10 MHz channels, and -88 dBm for 5 MHz channels. This appears to have been specifically included for the purpose of enhanced coexistence with non-802.11 systems, given the low number of channels available at 3.65 GHz.

The proposal [5] would not alter the current 802.11 OFDM detection timing requirements.

Relationship of 802.11 methods to 802.16 coexistence

Periodic quiet periods of duration sufficient to allow another system to transmit, coupled with 802.16's current measurement and reporting capabilities, should be sufficient to allow other 802.16 systems to operate in the bands.

However, this is not sufficient for coexistence with 802.11 systems. To properly coexist, a listen-before-talk capability must also be added.

The study group that proposed the 802.11y PAR determined that coordinated negotiation of spectrum usage was not practical. While coordinated methods are occasionally proposed to the P802.11y Task Group, we should assume that the original sentiment still holds and therefore that 802.11y systems, like all other current 802.11 specifications, will not implement any form of coordination that could interact with the method proposed in Clause 15 of the P802.16h Working Document [1].

Summary of Changes

This contribution adds a number of tools to enhance uncoordinated coexistence in non-exclusively allocated spectrum. These tools may be optional from the point of view of the general standard, but could be required to meet regulatory requirements in certain bands. They can be used together or individually as the requirements of the band dictate. These tools are:

- *Enhanced measurement and reporting* – in particular the suggestion to be able to positively identify a specific spectrum user, another 802.16 system, and 802.11 systems since the actions to be taken may be different with each one.
- *Extended quiet period* – allowing other systems an opportunity to transmit and avoiding unintentional synchronization of measurement period between neighboring systems.
- *Adaptive extended quiet periods* – augmenting the extended quiet period with an algorithm that allows better use of the spectrum when no other users are present and better protection for potentially synchronous users of the channel.
- *Listen-before-talk* – to allow detection of and protection for asynchronous users of the channel.
- *Uncoordinated Coexistence Protocol* – combining the other tools to facilitate operation in bands where the FCC has required a CBP. We believe that the Uncoordinated Coexistence Protocol (UCP) defined here meets the FCC's definition of a CBP.

Specific editorial changes

This section provides a list of changes to the draft document. These changes are in the form of tools added for enhanced *uncoordinated coexistence mechanisms*. These tools are then used to define an Uncoordinated Coexistence Protocol (UCP) for 802.16 for use in bands where the regulatory requirements dictate such a protocol.

Blue text represents specific editorial additions.

~~Red strikethrough~~ text is to be deleted.

Black text is text already in the draft.

Bold italic text is editorial instructions to the editor.

Add the following definition to clause 4: 'Abbreviations and Acronyms'

EQP Extended Quiet Period

UCP Uncoordinated Coexistence Protocol

Add the following subclauses to Clause 6.

6.4.3.2 Enhanced Measurement and Reporting for Non-Exclusively Assigned or Licensed Bands

When operating in non-exclusively assigned or licensed bands, a system compliant to this standard shall be able to detect specific spectrum users (SSU), if any, in their band. Which SSUs and the actions to be taken vary with the regulations for the various bands, but the typical action is the use of DFS and mandatory vacating of the channel.

When operating in non-exclusively assigned or licensed bands, a system compliant to this standard shall be able to detect energy. The required energy detection level is specified by regulations. If the regulations specify SSUs and the 802.16 system is unable to determine specifically that the energy is not from an SSU, the 802.16 system shall take the same action it would upon detection of a SSU.

When operating in non-exclusively assigned or licensed bands, a system compliant to this standard should be able to positively detect other systems compliant to this standard, differentiating them from SSUs, if any, and non-802.16 occupants of the band, such as 802.11 systems. The action taken upon detection may vary based upon the regulations and may include any of the uncoordinated tools in this clause or the coordinated tools in Clause 15.

When operating in non-exclusively assigned or licensed bands where 802.11 systems may also be present, a system compliant to this standard should be able to positively detect 802.11 systems, differentiating them from SSUs, if any, and non-802.11 occupants of the band. The action taken upon detection may vary based upon the regulations of the band and may include any of the uncoordinated tools in this clause.

The reporting mechanisms for an SS informing the BS of the detection of another occupant are described in 6.3.2.3.33 for the REP-REQ/REP-RSP MAC messages. For further detail of message content, see 11.11 and 11.12 respectively).

6.4.3.3 Extended Quiet Periods (EQP)

Extended quiet periods (EQP) are periods of an integer number of frames during which both uplink and downlink transmission is suspended. The primary purpose of the EQPs is to give other uncoordinated users of non-exclusively assigned or licensed bands reasonable opportunity to operate when an alternative channel is not available. While not all future technologies with which 802.16 systems may need to coexist can be identified today, they are expected to coexist with other 802.16 systems and with 802.11 systems.

Since 802.16 systems have the capability to fragment SDUs, an EQP duration of a single frame is sufficient for allowing another 802.16 system access to the spectrum. For 802.11 coexistence, the quiet period duration should be chosen to allow transmission of an entire maximum length 802.11 PHY PDU (PPDU) using the 802.11 5.5 Mbit/s PHY mode. 802.11 systems can operate with one of three channel bandwidths – 20 MHz, 10 MHz, or 5 MHz. This bandwidth affects the transmission duration of a maximum length 802.11 PPDU. The minimum EQP durations for various channel bandwidths are shown in Table x. The number of integral frames required is a function of the chosen frame duration for the 802.16 system.

Table x: Minimum EQP Durations

Channel Bandwidth	Minimum EQP Duration
20 MHz	3.65 ms
10 MHz	7.3 ms
5 MHz	14.6 ms

The duration, in frames, of the EQP is signaled in the DL-MAP using the EQP_IE defined in 8.4.5.3.29. The EQP always starts in the frame following the DL-MAP containing the EQP_IE. In addition to the duration of the EQP, the report_requested field indicates whether measurement and reporting on the channel should be performed during the EQP. If the report_requested bit is set to 0, no automatic measurement and reporting is requested. When it is set to '1', then all SS will make measurements as if commanded to create a *Basic Report* in REP-REQ

(11.11). They will transmit a corresponding REP-RSP message if a measurement detected activity above the threshold for the frequency band of operation. The need for bandwidth to transmit a report may be signaled through any of the standard methods for signaling a need for UL bandwidth. When the UL-MAP relevance is the next frame as it is for WirelessMAN-OFDMA based systems, the UL-MAP transmitted in the last DL subframe before an EQP describes the allocations for the first UL subframe after the EQP. This is shown in Figure x. The periodicity of EQP is described in the next sub clause. This discontinuity of the UL-MAP relevance does not exist in the case where the UL-MAP describes the allocations for the current UL subframe as is possible in some WirelessMAN modes. In this case the DL and UL subframes can be more closely associated with each other. This will be important for a listen-before-talk capability. The case of EQPs with UL-MAP relevance for the current frame is shown in Figure x2.

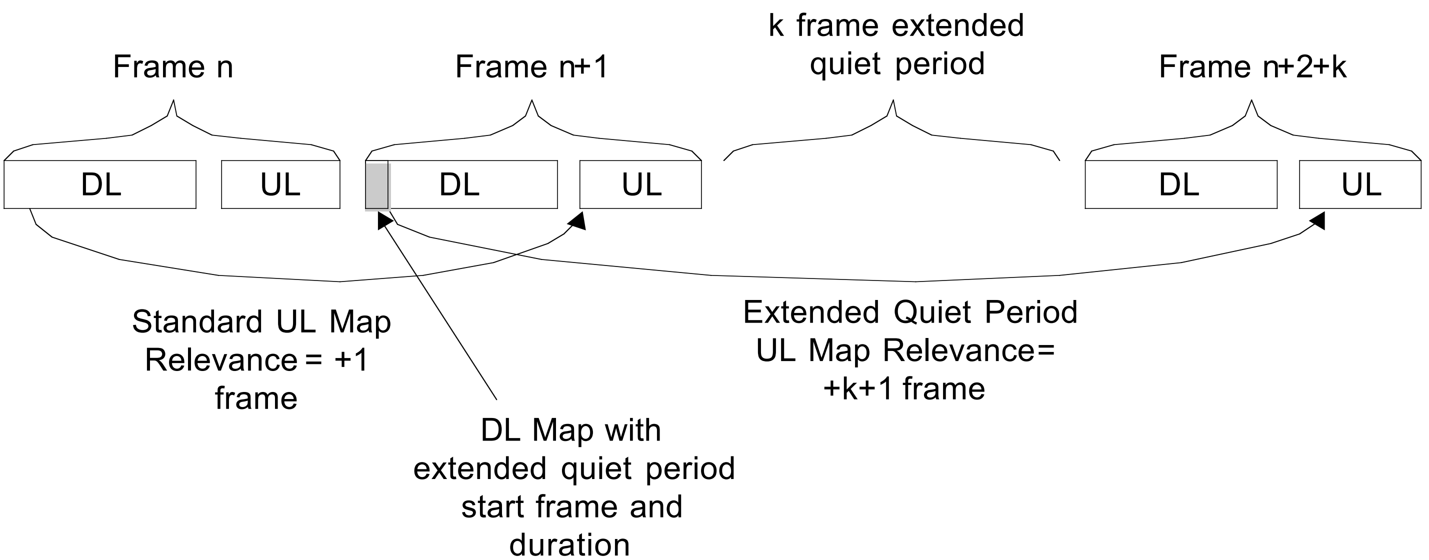

Figure x: EQPs Map Relevance = n+1

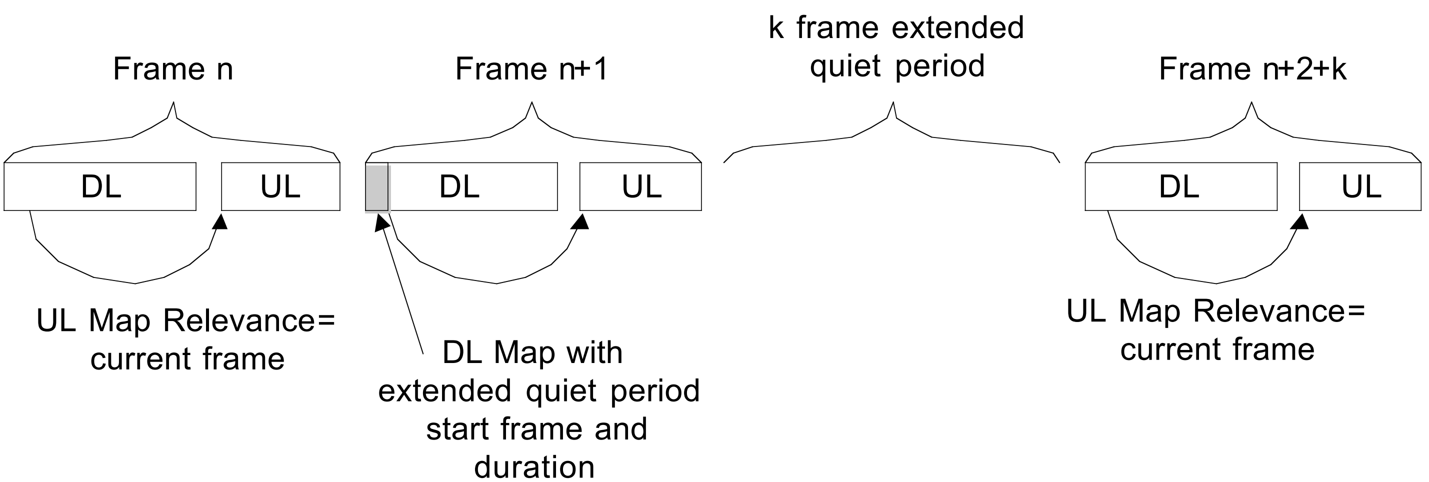

Figure x2: EQPs Map Relevance = n

6.4.3.4 Adaptive EQPs

There may be bands where there is a possibility of other users, but the probability is low. In these cases, it is important to not waste bandwidth catering to non-existent user of the band. When EQPs are used in a non-exclusively assigned or licensed band, a BS initially offering service shall perform an initial (DFS/DCS) scan and pick the *best* channel. Based on this choice, if the channel is thought to be free of other users, the BS shall set the initial duty cycle to no more than *max_duty_cycle*. If another user was detected, the BS shall initially operate a duty cycle of no more than *share_duty_cycle*. Duty cycles are measured over a 1 second period. This duty cycle can be achieved a number of ways. For instance a 50% duty cycle can be achieved: with the use of every other frame, *n* frames on and *n* frames off, or operate in *n*/2 of *n* frames, etc. The method of achieving the duty cycle shall be left for vender differentiation which increases the likelihood of randomization of the algorithm of two different BS from two different operators which in turn increases the likelihood of their ability to eventually detect each other or an SS associated with the other BS.

If after a prolonged period which is band specific in duration, the BS and its associated SSs have not detected other users in the band through measurement and reporting during EQPs coupled with measurement and reporting as performed for DFS/DCS then the BS may increase its duty cycle by *duty_cycle_step*. The duty cycle shall not increase above *max_duty_cycle* as measured over a 1 second period. The BS shall continue to measure and shall continue to instruct SSs to measure and report using the EQPs and the DFS/DCS mechanisms. If a SSU is detected, the band specific regulations shall be followed. If another user that is not a SSU is detected the BS shall reduce its duty cycle to at most *intermediate_duty_cycle* within 10 frames of the BS becoming aware of the detection. If the detected user persists, the BS shall reduce the duty cycle to at most *share_duty_cycle*. The flow is shown in Figure x3 using example parameters: *share_duty_cycle* = 50%, *intermediate_duty_cycle* = 75%, *max_duty_cycle* = 90%, and *duty_cycle_step* = 10%.

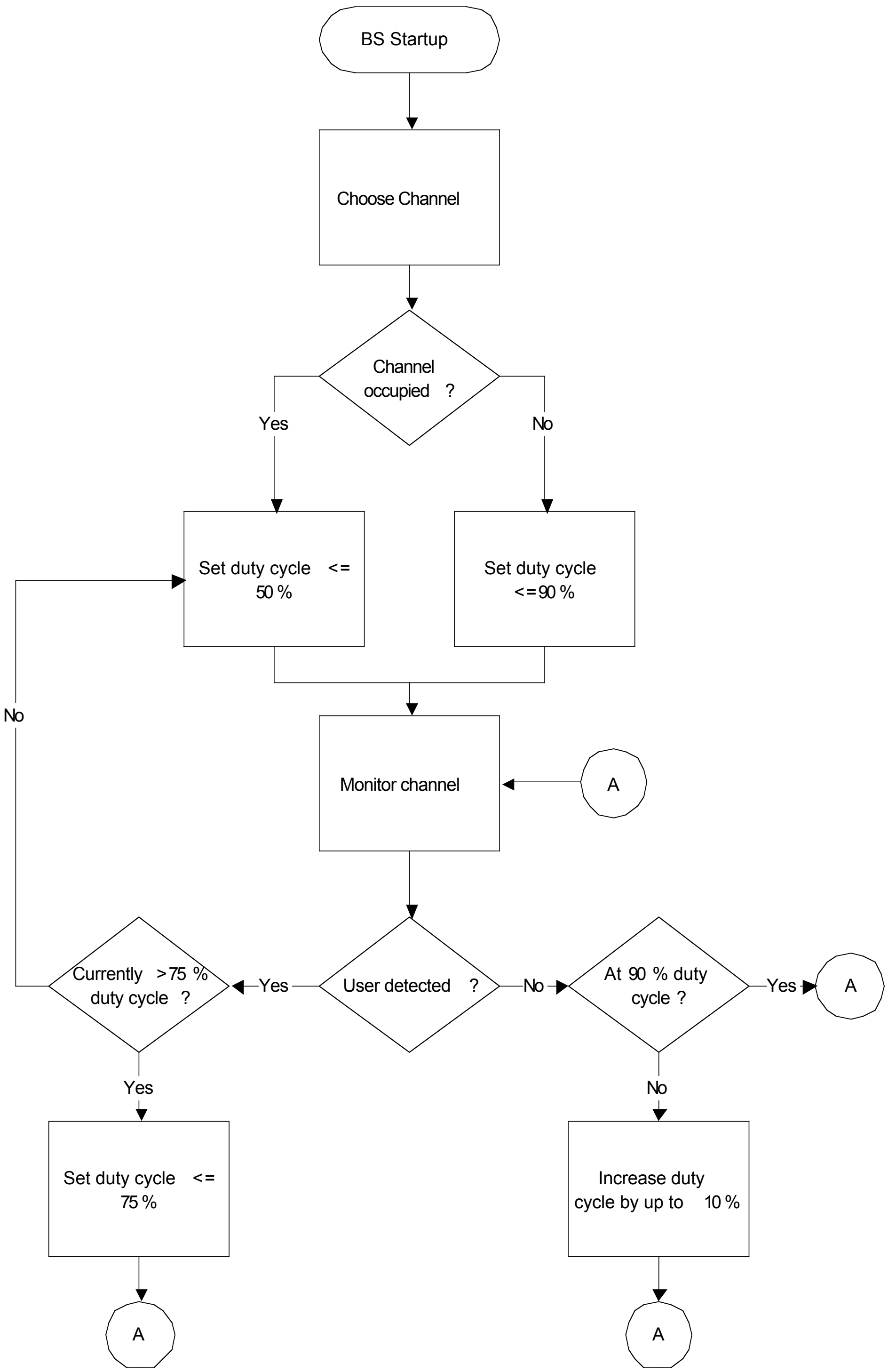

Figure x3: Adaptive EQP (with example parameter numbers)

6.4.3.5 Listen-Before-Talk

When attempting to coexist with certain non-802.16 users of non-exclusively assigned or licensed bands, EQPs may not be sufficient. In these cases, a listen-before-talk protocol must be used. In such bands, the BS shall operate with a UL-MAP relevance of the current frame. This allows the DL and UL subframes to be logically viewed as a single “packet” of constant duration equal to the frame duration. The BS shall allocate the UL subframe such that a time period is reserved between the end of UL allocations and the start of the frame preamble for the next DL subframe as shown in Figure x4. This time period shall be used to sense other non-802.16 systems and shall have at least the durations specified in Table x2. Use of listen-before-talk shall not eliminate any requirements for other measurement and reporting that may be required for operation in a particular mode or band. Use of listen-before-talk shall not eliminate any requirement for use of EQPs.

Table x2: Minimum Listening Intervals

Channel Bandwidth	Minimum Listen-Before-Talk Duration
20 MHz	4 μs
10 MHz	8 μs
5 MHz	16 μs

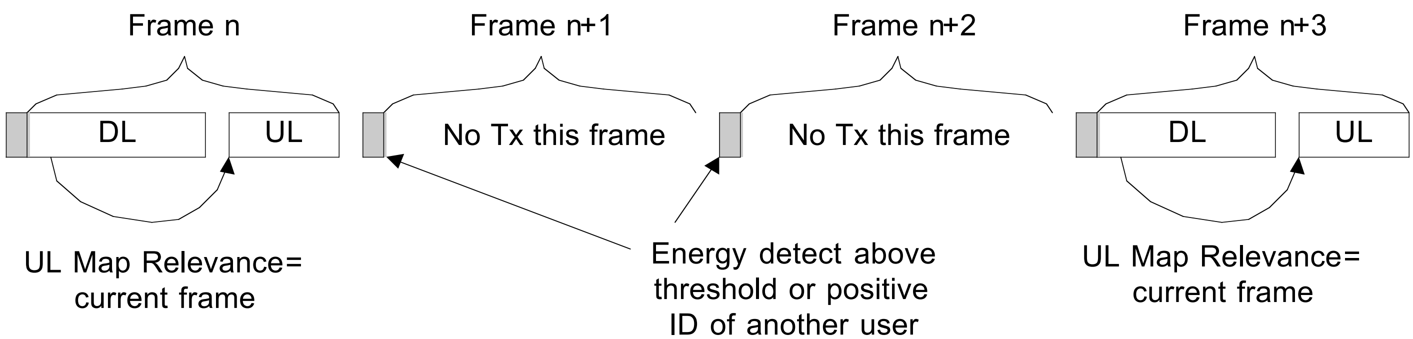

Figure x4: Listen-Before Talk

6.4.2.4 Uncoordinated Coexistence Protocol (UCP)

The clause describes the use of an Uncoordinated Coexistence Protocol (UCP).

Upon system startup, the BS shall perform DFS/DCS to choose the channel on which to operate. If the band has SSUs, the BS shall use DFS to find a channel free of SSUs. DCS shall be used to choose the *best* channel that not occupied by a SSU. The definition of *best* for this purpose shall be left for vendor differentiation.

The BS shall implement adaptive EQPs as described in clause 6.4.3.3 to ensure other systems have an opportunity to transmit. The BS shall require measurement and reporting from the SSs per the DFS/DCS protocol, and move to a better channel should one come available.

If systems other than other 802.16 systems and SSUs may be present in the channel, the BS shall use the listen-before-talk protocol of 6.4.3.5 to avoid scheduling a frame when another system is transmitting on the channel.

Further modify table 277a, subclause 8.4.5.3.2.1

Extended DIUC (hexadecimal)	Usage
09	CXZ_DL_IE
~~09~~ 0A	~~*reserved*~~ EQP_IE

Insert a new subclause 8.4.5.3.29

8.4.5.3.29 Extended Quiet Period (EQP) IE format

The start, on the next frame boundary, of an extended quiet period is signaled by using the extended DIUC=15 with the EQP_IE (0x09) in the extended DIUC field. The EQP_IE indicates that there will be no transmissions in either the DL or the UL, starting in the next frame and continuing for the specified number of frames after which normal transmission shall resume. When used, the CID in the DL-MAP_IE() shall be set to the broadcast CID.

Table 286ab – EQP IE

Syntax	Size	Notes
EQP_IE() {		
Extended DIUC	4 bits	EQP_IE = 0x0A
Length	4 bits	Length = 0x01
Report requested	1 bit	0 = no measurement report required 1 = measurement report required on detection
Duration	7 bits	1-127 frames, 0 not valid
}		

Add the following new rows to the non-collaborative mechanism section of table h1 in sub clause 15.1.2

	Extended quiet periods (EQP) 6.4.3.3	✓	✓	✓	✓	✓	✓	✓	✓
	Adaptive EQP 6.4.3.4	✓	✓	✓	✓	✓	✓	✓	✓
	Listen before talk 6.4.3.5	✓	✓	✓	✓	✓	✓	✓	✓
	Uncoordinated Coexistence Protocol (UCP) 6.4.2.4	✓	✓	✓	✓	✓	✓	✓	✓

References

[1] IEEE 802.16h-06/015r1: *Air Interface for Fixed Broadband Wireless Access Systems: Amendment for Improved Coexistence Mechanisms for License-Exempt Operation*, Working Document.

[2] IEEE 802.16h-06/012r1: *Comments received in Working Group Review of Working Document IEEE 802.16h-06/010.*

[3] (US) Federal Communications Commission, *FCC-05-56, Report and Order and Memorandum Opinion and Order In the matter of Wireless Operations in the 3650-3700 Band*, March 2005 <http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-05-56A1.pdf,>.

[4] Industry Canada, DGTP-006-06, Proposed Spectrum Utilization Policy, Technical Licensing Requirements for Wireless Broadband Services (WBS) in the Band 3650-3700 MHz, August 2006.

[5] Peter Ecclesine, IEEE 802.11-06/0955r1: *IEEE P802.11 Wireless LANs OFDM PHY 3650 MHz Band*, July 2006.

[6] P802.11-REVma/D8.0, *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications*, (Draft Revision of IEEE Std 802.11), Sept. 2006.