Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**EQP Removal**
Date Submitted	**2007-11-01**
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Re:	Letter Ballot 29 Task Group Review of P802.16h/D3
Abstract	Based on simulation results of enhancements added last meeting EQP and aEQP are not necessary.
Purpose	Remove unnecessary features.
Notice	
Release	
Patent Policy and Procedures	

EQP Removal

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1. Overview

EQP and aEQP were originally included in the UCP algorithm to aid coexistence with 802.11y systems. Enhancements were added in Session 51. Based on simulation results in [3], it was determined that the enhancements provided a better mechanism for allowing sharing with 802.11y systems. However, it was not clear at that time whether the hidden node mitigation benefit of EQP/aEQP still warrented its retention so it was not yet removed in the development of [1]. Subsequent simulation results provided in [2] show that the UCP enhancements in [1] do a better job of mitigating the hidden node problem than is done by EQP/aEQP. Therefore, at this time it is prudent to eliminate teh additional complexity of EQP/aEQP.

The Frame maker file is available for the editor.

2. Specific Editing Changes

This document provides changes to IEEE P802.16h/D3 [1].

Blue underlined text represents specific editing changes.

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

Black text is already in the draft.

Bold italics text is editing instructions to the editor.

The following headers are just to get the section numbers correct since I don’t know how to reset the numbers in Frame Maker.

3. Bogus H1

4. Bogus H1

On page 8, line 37, delete the acronym definition for EQP.

5. Bogus H1

6. Bogus H1

6.1

6.2

6.3

6.4 Procedures for uncoordinated coexistence

This sub clause describes enhancements in support of operation in non-exclusively assigned and non-exclusively licensed bands. First, general concepts are described, after which details of support for uncoordinated coexistence mechanisms are presented. The mechanisms detailed are:

— Coexistence with Specific Spectrum Users (SSUs) (*6.4.2.2*) often termed DFS (Dynamic Frequency Selection) **[B52]**.

— Coexistence with non-Specific Spectrum Users (non-SSUs) (*6.4.2.3*). Dynamic Channel Selection (DCS) (*6.4.2.3.2*) is a realization.

— Uncoordinated Coexistence Protocol (UCP) (*6.4.2.3*). UCP ~~uses~~ adds the following techniques:

- ~~Extended Quiet Periods (EQP) (*6.4.2.3.5*).~~
- ~~Adaptive Extended Quiet Periods (aEQP) (*6.4.2.3.6*).~~
- Listen Before Talk (LBT) (*6.4.2.3.7*).

Mechanisms are related to bands containing SSUs and those containing Non-SSUs. It shall be left to regulation to mandate such mechanisms for a particular band.

6.4.1 General concepts

6.4.2 Uncoordinated Coexistence Mechanisms

6.4.2.1 Introduction

6.4.2.2 Uncoordinated Coexistence with *Specific Spectrum Users* (SSUs)

6.4.2.3 Uncoordinated Coexistence with Non-*Specific Spectrum User*s (Non-SSUs)

6.4.2.3.1 Introduction

6.4.2.3.2 Dynamic Channel Selection (DCS)

6.4.2.3.3 Enhanced Measurement and Reporting for Non-Exclusively Assigned or non-exclusively Licensed Bands

6.4.2.3.4 Claiming a Master Frame Sequence

Co-channel coexistence between multiple 802.16 systems is dependent upon synchronization. All BS must be synchronized to GPS or NTP if GPS is not available (see section *15.2.1*). The coexistence frame number is a function of absolute time of day, so not only do all systems have the same DL/UL split (see section *15.7*), but there is a knowledge of absolute time so the functionality or ownership of a particular frame can be agreed upon between different systems regardless of when they actually came on line. This allows sharing in time of the channel by up to three different uncoordinated 802.16 systems using a four frame sequence. It also lays the foundation for supporting the active cognitive radio techniques found in section *15*.

The goal of the four frame repetitive sequence is to allow sharing of a channel by up to 3 different 802.16 systems. When using 5ms frames, this has good synergy with the 20ms packetization of VoIP. While ultimately, the sharing of the channel can be done in both time and power (simultaneous Tx with power level management), only systems communicating via the CXP protocol of section *15.5* have sufficient information available to adjust power or refrain from transmitting when necessary to enable simultaneous transmit. Therefore uncoordinated systems shall only share in time and shall not intentionally attempt to transmit in the same frame at the same time as neighbor systems.

When all systems attempting to coexist on the same channel are 802.16 systems, the end result after all three systems have entered the channel is a four frame sequence of frame usage as shown in *Figure h 1*. This is a simplified version of *Figure h 48* with the simplification being necessary since the uncoordinated systems cannot communicate with each other regarding interference and power levels.

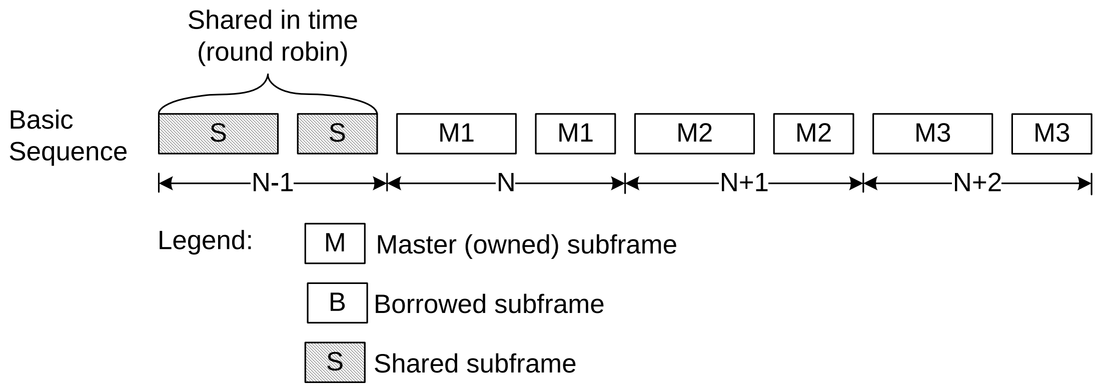


Figure h1—Basic four frame repetitive sequence

Initially when the channel has no occupants, the first system to operate on the channel shall claim a slot within the repetitive sequence as master. While a system may be allowed to borrow unused slots a system shall claim no more than a single slot as master. It does not matter which slot the first system claims although it is highly recommended that all BS on the given channel belonging to the same network operator should claim the same slot as this will reduce the need for operator coordination.

The result of the first system claiming slot 1 of the repetitive sequence is shown in *Figure h 2*.

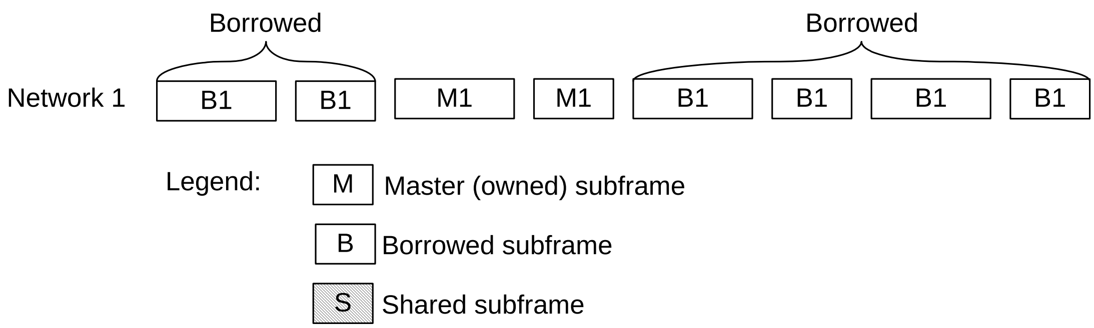


Figure h2—First 802.16 System Claiming Slot 1

The result after a second system has claimed slot 2 is shown in *Figure h 3*.

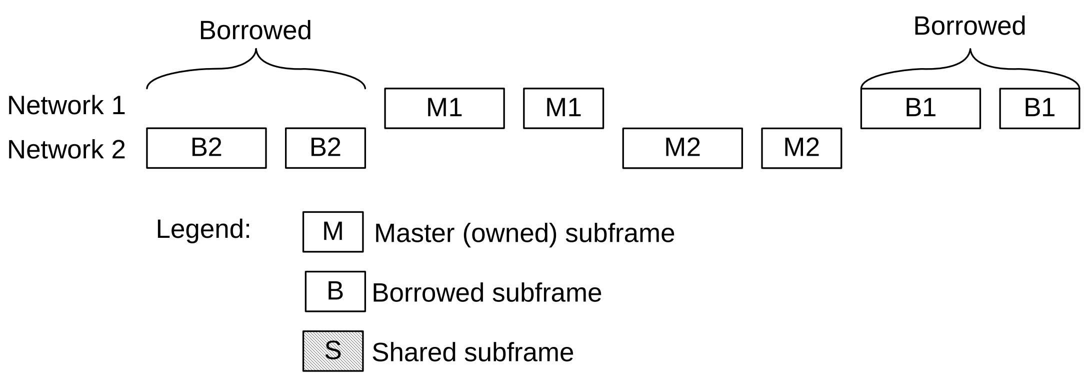


Figure h3—Second 802.16 System Claiming Slot 2

The result after a third system has claimed slot 3 is shown in *Figure h 4*. This creates the basic 4 frame sequence originally described.

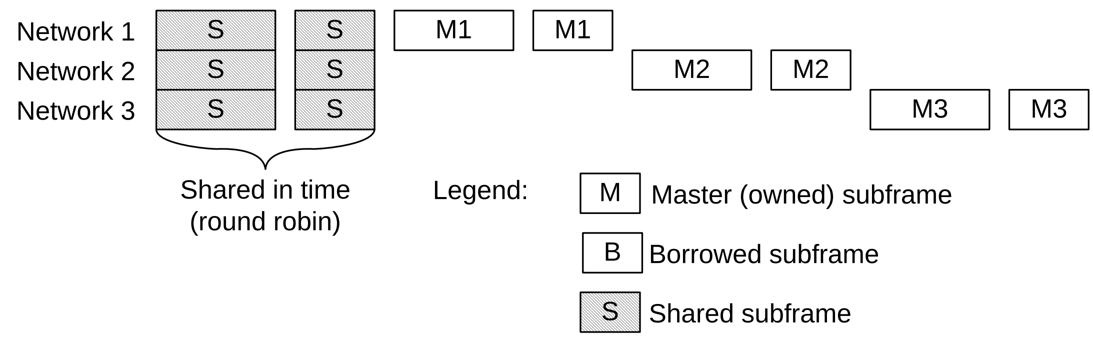
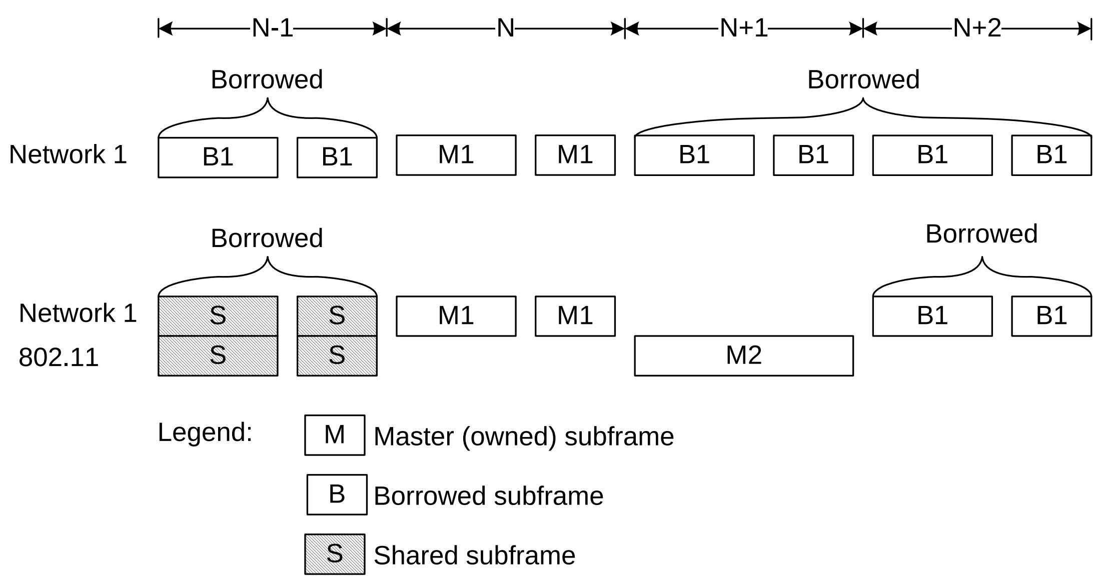


Figure h4—Third 802.16 System Claiming Slot 3

Mechanisms for coexistence with non-802.16 systems are discussed in 6.4.2.3.7.

~~If a single 802.16 system is sharing with a non-802.16 system such as 802.11, the 4 frame sequence would transition from just the 802.16 system to being shared with a non-802.16 system as shown in Figure h 5. If two 802.16 systems were to coexist with a non-802.16 system, the structure would appear as in Figure h 6. In these cases, the attempt is to give the non-802.16 system ample opportunity to transmit while maximizing regularity of the 802.16 system's opportunities. In both cases, the shared frames need not be completely given up to the non-802.16 systems but can be shared through use of the Listen-Before-Talk (LBT) feature described in 6.4.3.5. Attempts to use the shared frames shall be on a round robin basis between 802.16 systems since their synchronization defeats using LBT to avoid each other. Since 802.11 and other non-802.16 technologies do not have a concept of "owned" frames and do not realize they are "master" of certain time periods, there is a possibility of interference even in master frames. Therefore, 802.16 systems shall use the LBT mechanism prior to transmitting in master frames if there is reason to believe a non-802.16 system is co-channel. Additionally, aEQP shall be used to allow entry of the non-802.16 systems.~~



~~**Figure h5—One 802.16 System Coexisting with Non-802.16 Systems**~~

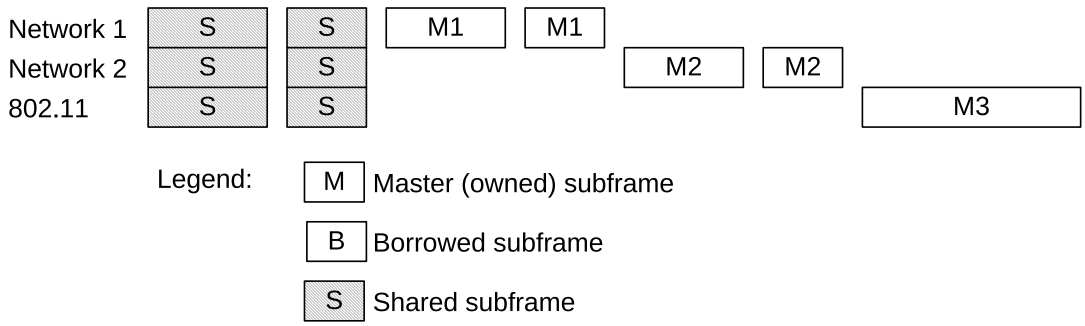


Figure h6—Two 802.16 Systems Coexisting with Non-802.16 Systems

The mechanism for uncoordinated systems claiming a slot within the repetitive 4 frame sequence is the same as it is for coordinated systems described in section *15*. The slot claimed corresponds to a control channel opportunity. In particular, the master frame opportunities of CXCC sub-channels 2 and 4 shall be used to positively claim a slot in the 4 frame sequence. A system shall not borrow a frame during a scheduled CXCC opportunity. It shall only transmit in CXCC opportunities for which it has claimed master status. If a system is borrowing frames, it must monitor the corresponding CXCC opportunities in CXCC sub-channels 2 and 4 to determine if a new system is claiming master status for the corresponding slot.

6.4.2.3.5 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 non-exclusively 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, 802.16 systems are expected to coexist with other 802.16 systems and with 802.11 systems.

Since 802.16 systems have the capability to fragment SDUs, EQP duration of a single frame is sufficient for allowing another 802.16 system access to the spectrum. In fact, the synchronized sharing of the channel as described in section *6.4.2.3.4* is a form of synchronized EQP between two or more 802.16 systems. For 802.11 coexistence, the quiet period duration should be chosen to allow the maximum duration 802.11 transmission allowed in the band. For 802.11y, this is 4ms. For 802.11a, b, and g systems the maximum PHY PDU (PPDU) using the 802.11 5.5 Mbit/s PHY modeis used as a reference. 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 h 132g*. The number of integral frames required is a function of the chosen frame duration for the 802.16 system. 802.16 BS and SS shall retain respective DL and UL synchronization over the period of EQP. The use of the EQP protocol shall recognize appropriate use of the Lost DL/UL MAP Interval parameter in table 342.

Table 132g—Minimum EQP Durations for coexistence with 802.11a, b, and g

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

Measurement_Reporting field indicates whether measurement and reporting on the channel should be performed during the EQP. If the Measurement_Reporting bit is set to 0, no automatic measurement and reporting are required. When Measurement_Reporting is set to '1', then all SS shall make measurement in order to create a Report Type 1.1, Bit#0 = 1, type 'Basic Report' in REP-REQ (*11.11*). if so required. An SS will transmit a corresponding REP-RSP message if a measurement detected activity above the *detection threshold* for the frequency band of operation. In such bands with specific requirements for avoidance of SSUs enabling for reporting of prevailing SSUs shall be such so as to comply with the mandated regulatory requirements. 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 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 h 7*. 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. In this case the DL and UL subframes can be more closely associated with each other. This is important for a listen-before-talk capability (*6.4.2.3.7*). The case of EQPs with UL-MAP relevance for the current frame is shown in *Figure h 8*.

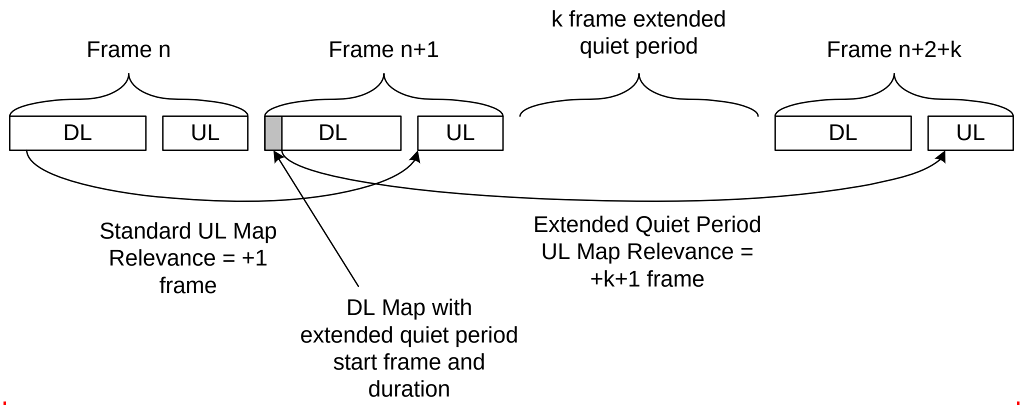


Figure h7—EQPs Map Relevance = n+1

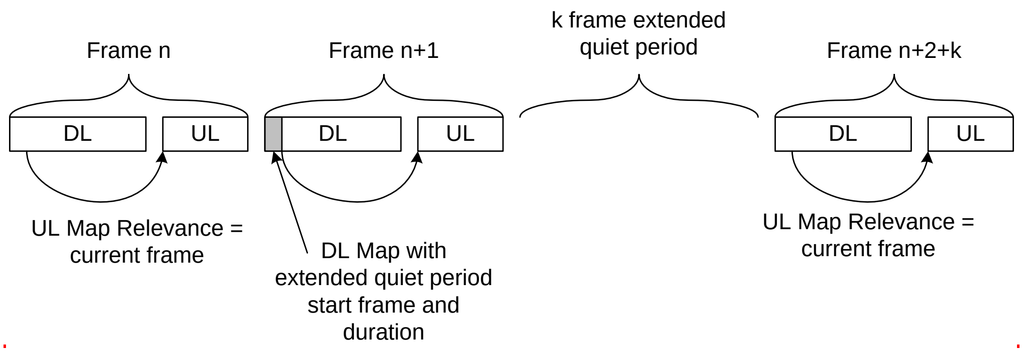


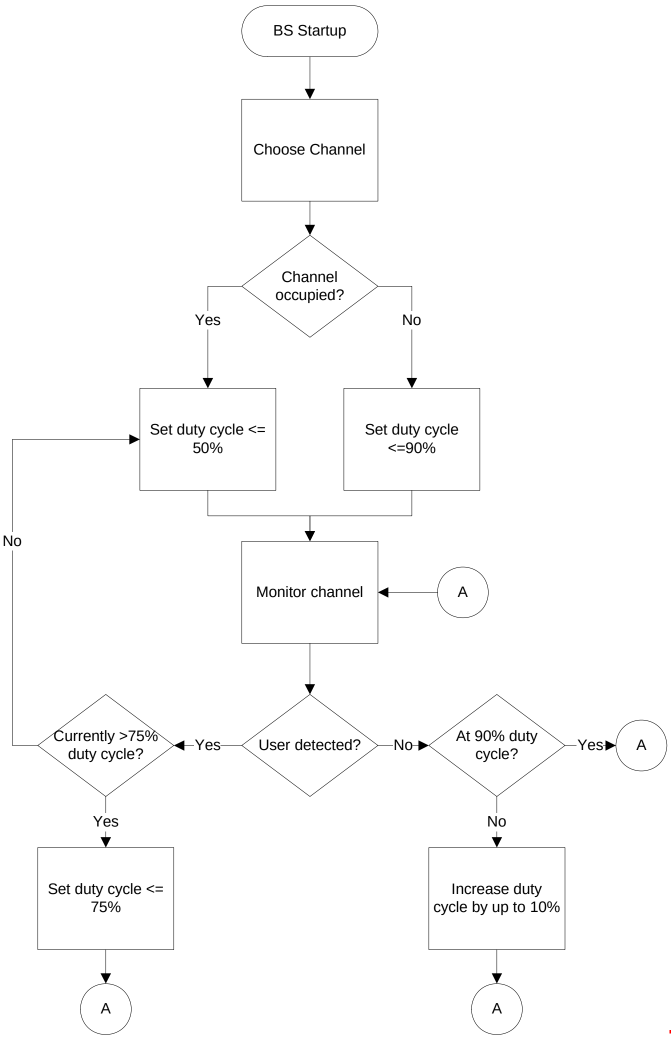
Figure h8—EQPs Map Relevance = n

6.4.2.3.6 Adaptive EQPs (aEQP)

There may be bands where the probability of presence of other users in a specific area is low. This situation may occur where there are very few users present in the band, for example, in a particular rural geographical location. In these cases, it is important to not waste bandwidth catering to non-existent users of the band. When EQPs are used in a non-exclusively assigned or licensed band, a BS initially offering service shall perform an initial (see *6.4.2.3.2*)

~~scan and pick the best channel. (or this may be configured based on measurements made outside the scope of the 802.16 system or based on collaboration between operators). 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 the 802.16 system is already sharing the channel with another 802.16 system as described in section 6.4.3.2 the duty cycle shall be calculated based solely on the master and borrowed frames used by the particular system. Refraining from transmitting during a master or borrowed frame of another system shall not count as having been quiet for the purposes of aEQP.~~

~~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 DCS (see *6.4.2.3.2*) 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 DCS (see *6.4.2.3.2*) mechanism. 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 h 9* using example parameters: share_duty_cycle = 50%, intermediate_duty_cycle = 75%, max_duty_cycle = 90%, and duty_cycle_step = 10%.~~



~~Figure h9 – Adaptive EQP (with example parameter numbers)~~

6.4.2.3.7 Listen-Before-Talk (LBT)

When attempting to coexist with certain asynchronous non-802.16 users of non-exclusively assigned or non-exclusively licensed bands~~, EQPs may not be sufficient. In these cases, a~~ the LBT protocol ~~must~~ shall be used ~~and EQP are optional~~. In such bands, the DL and UL subframes to be logically viewed as a single "packet" of constant duration equal to the frame duration. Steps are taken, as described below to use this concept to minimize interference with co-channel asynchronous systems. The BS shall periodically allocate opportunities for an SS to measure and report on the current state of the channel, and provide input to the LBT protocol. An Extended Channel Measurement IE (see for example sub clause 8.4.5.3.5) may be used, to provide such an opportunity.

In the gap between the UL and DL subframes the BS shall make measurements on the current state of the channel. The general case with three co-channel 802.16 systems is shown in *Figure h 10:*

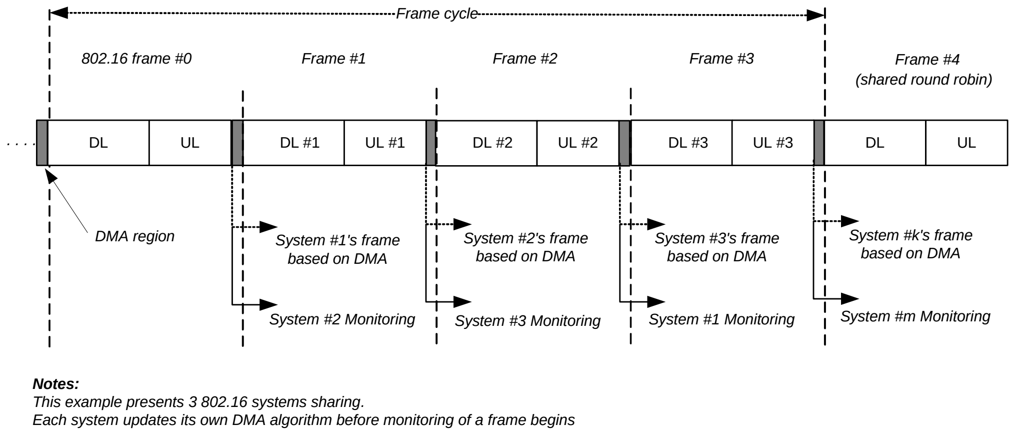


Figure h10—Basic LBT Opportunities

The gap between the end of the UL and the start of the DL in which Clear Medium Assessment (CMA) is performed must be of sufficient length to allow an asynchronous system to claim the channel if necessary. For instance if the asynchronous system is an 802.11 system, the gap must be at least the duration of the 802.11 AIFS in the band of interest. CMA is similar to the Clear Channel Assessment (CCA) of 802.11 based systems. In this way CMA is a measurement based report that provides an indication (to a certain probability and to a certain threshold level) of whether or not the medium is quiet and therefore available for use.

Given that the LBT protocol detects energy above the defined threshold then no transmission will take place in the succeeding subframe. The use of the LBT protocol shall recognize appropriate use of the Lost DL/UL MAP Interval parameter in table 342. Transmission may recommence per the dynamic medium access (DMA) protocol when energy levels drop below the threshold level. Due to the fact that there would be no time to signal an energy detection event then a BS or SS shall reliably handle the absence of a subframe where it was previously scheduled by the DL or UL-MAP. ~~Similar to the case with EQP, when~~ When a DL is not transmitted due to LBT, the UL MAP is for the next frame in which there is a DL. An example of this arrangement is given in *Figure h 11*. for systems with UL MAP relevance of N and in *Figure h 12* for systems with UL MAP relevance of N+1. The frame in which the system refrained from transmitting shall be used to sense other non-802.16 systems. The minimum duration is 4 us. Use of LBT shall not eliminate any requirements for other measurement and reporting that may be required for operation in a particular mode or band. ~~Refraining from transmitting during a frame due to energy detection during the LBT "listen" period shall count towards fulfilling the quite percentage of the aEQP duty cycle.~~

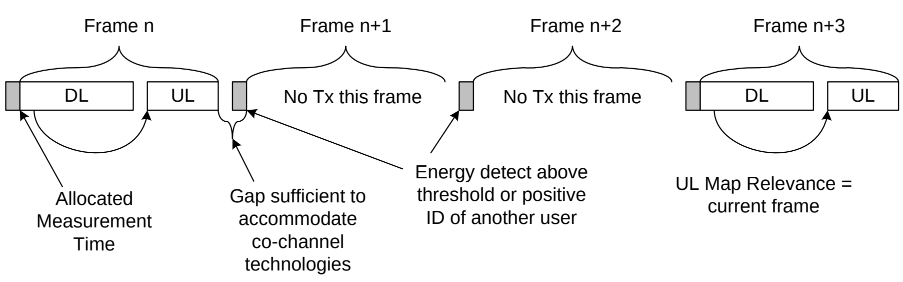


Figure h11—LBT-UL MAP Relevance N

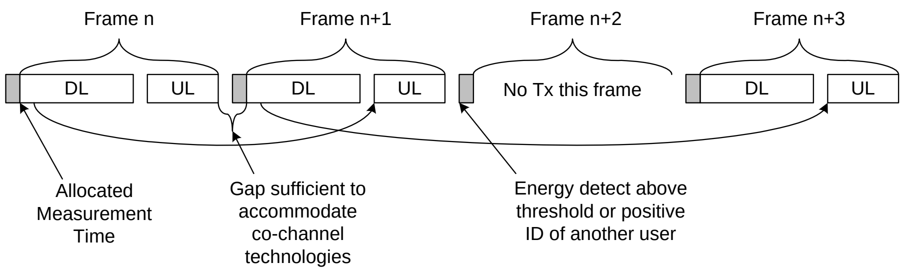


Figure h12—LBT - UL MAP Relevance N+1

In cases of high traffic volume for both co-channel asynchronous and WirelessMAN-CX systems, the synchronous nature of WirelessMAN-CX systems disadvantage them relative to asynchronous systems. Generally, an asynchronous system will access the medium very soon after it has become free while an WirelessMAN-CX system waits until the frame boundary (typically 5 ms) to reclaim the medium. The Dynamic Medium Access (DMA) protocol enables an WirelessMAN-CX system to determine that it is not receiving its fair share of the channel occupancy relative to other co-channel systems an regain the medium.

The DMA protocol consists of determining a time in advance of the start of the DL subframe at which the BS desires to transmit a Frame Reservation Signal (FRS) to reserve the downlink. In general, this FRS only need be sent when the BS has had difficulty reacquiring the channel after it was acquired by an asynchronous system. Additionally, how far in advance of the frame boundary the FRS may be sent must be strictly controlled and be based on the concept of fairness of occupancy of the channel.

To ensure fairness, the BS is assigned a utilization goal that is based on the number of co-channel systems. For instance, if an WirelessMAN-CX system is sharing the channel with one other system, it's utilization goal would be 50%. If it is sharing the channel with another WirelessMAN-CX system and an 802.11 system, its utilization ratio would be 33%. Determination of the number of co-channel systems may be accomplished via sensing or may be determined by administrative means (database of registered systems, etc.). The method is immaterial to the protocol.

If the BS's current utilization of the channel (measured over time) is at or above its utilization goal, the BS does not exert extra effort to reclaim the channel because it is receiving fair occupancy. In this case the BS merely performs LBT sufficiently ahead of transmitting the downlink to sense the medium is free and start transmitting.

If the BS's current utilization of the channel is less than its utilization goal, the BS exerts extra effort to reclaim the medium by assessing the channel conditions increasingly earlier before the start of the DL subframe up to a point in time, *MINFRST*, described below. When the BS detects the medium is available, it transmits an FRS to claim the downlink subframe. The protocol has the following terms and equations:

$FRST_n$ - Frame Reservation Start Time. This defines the time before the start of frame n at which the BS starts sensing whether the channel is free and prepares to send an FRS.

MAXFRST - the maximum value of FRST. Band dependent. For example, in the 3.65 GHz band in the US 4 ms is a reasonable value since any 802.11 burst in this band would be shorter and could fit before the start of the 802.16 frame.

MINFRST - the minimum value of FRST. Implementation dependant. This is the minimum value the FRST can take based on the ability of the BS to sense and claim the channel. It must be smaller than the gap between the end of one UL subframe and the start of the subsequent DL subframe.

UtilizationGoal - the "fair" channel occupancy for this system, based on number of co-channel systems as described above.

CurrentUtilization - the currently achieved channel occupancy for this system. To ensure that the 802.16 system does not attempt to claim the channel excessively when the 802.16 system has little or no demand, CurrentUtilization is only calculated over frames when the 802.16 system has data to transmit. It is calculated using a sliding window or exponential decay to represent a reasonable period in the immediate past.

UtilizationRatio - the metric indicating the level to which the UtilizationGoal has been achieved.

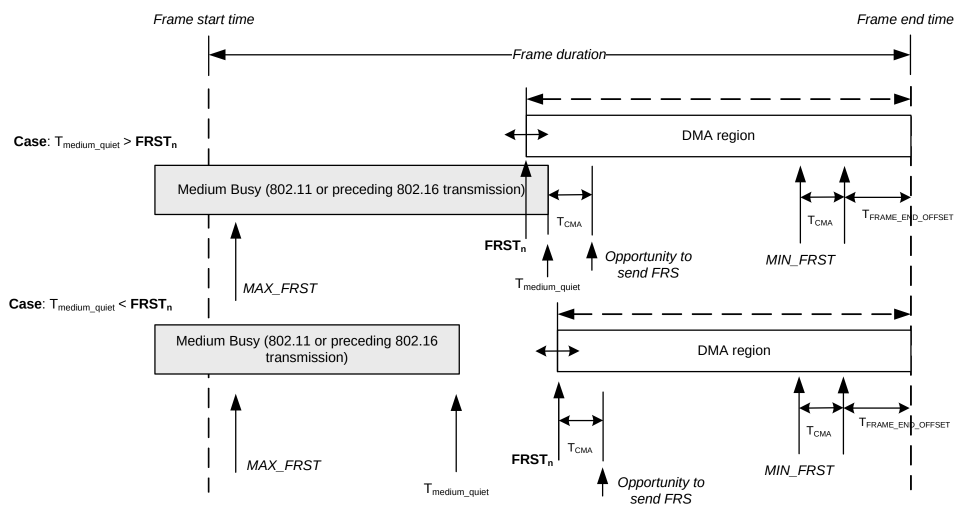
The *UtilizationRatio* is calculated according to the following formula, where K is an aggressiveness factor to be determined by simulation. *(So far, simulation results show very little difference between k = 1, 2, 4, etc.)*

$$UtilizationRatio = (UtilizationGoal/CurrentUtilization)^K$$

$FRST_n$ is calculated according to the following formula. It may be modified to be more aggressive when necessary to maintain synchronization.

$$FRST_n = MIN(\ MAXFRST,\ MAX(UtilizationRatio*FRST_{n-1},\ MINFRST\ )\ )$$

The parameters are applied as shown in *Figure h 13.*



$MIN\_FRST=T_{CMA} + T_{FRAME\_END\_OFFSET}$
$T_{FRAME\_END\_OFFSET}$ = 50µs (minimum time to Rx/Tx and send FRS)
T_{CCA} = 4/8/16µs (20MHz/10MHz/5MHz channels) – aligned with 802.11 values
MIN_FRST=54/58/66µs
MAX_FRST=4000µs
802.16 parameters
5ms 802.16 frame duration
47 symbols per frame [DL=28, UL=19] symbol duration ~102µs
TTG = 5µs

Figure h13—Reclaiming the Medium

The BS SDL for the DMA protocol for reclaiming the medium is shown in *Figure h 14*.

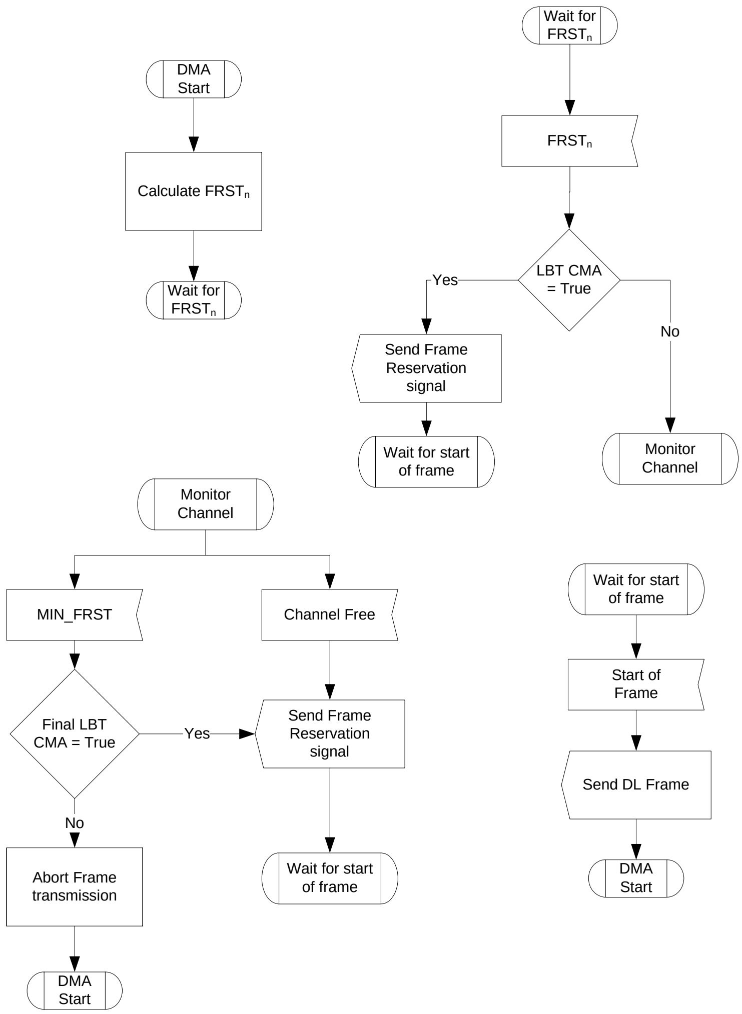


Figure h14—BS Dynamic Medium Access Protocol

When using any carrier sense protocol, such as LBT, in a wireless environment the hidden node problem cannot be 100% avoided. It can only be mitigated. Additionally, in bands such as 3.65 GHz in the US, there is an aggravated hidden node problem due to the distinctly lower transmit power allowed for mobile devices compared to fixed, registered devices. The mobiles are more often geographically disadvantaged due to this transmit power disparity. Fixed, registered client devices can also be geographically disadvantaged (the classical hidden node problem), although not as often. To remedy this the BS transmits a Frame Reservation Signal (FRS) at the end of the DL subframe to reserve the subsequent UL subframe (or used portion, thereof) for the subscriber stations. The form of the FRS is band dependent and should be structured to be receivable by other technologies that may be co-channel. For instance, in bands where 802.11 would be a typical co-channel asynchronous system, the 802.11 CTS transmitted using the appropriate 802.11 burst structure would suffice. The reservation of the UL subframe by the BTS precludes the need for the SS to also perform LBT. The use of the FRS to protect the UL is shown in *Figure h 15*.

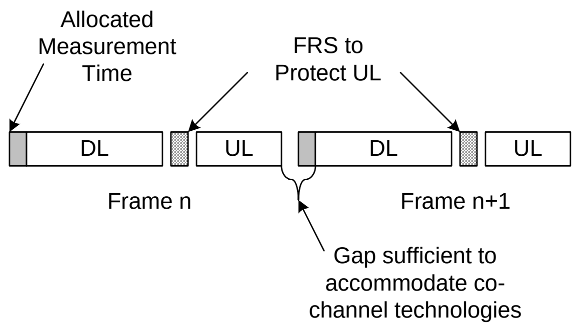


Figure h15—UL FRS

On page 46, line 6 remove the EQP_IE from table 277a, and on page 46, delete section 8.4.5.3.29 (or if the new resolution to comment 30 in [4] is accepted, replace these with that resolution).

7. References

[1] IEEE P802.16h/D3: *Air Interface for Fixed Broadband Wireless Access Systems Improved Coexistence Mechanisms for Licensed Exempt Operation*, Working Group Draft, 1 Oct 2007.

[2] IEEE C80216h-07_095, *"Uncoordinated Coexistence Protocol (UCP) Coexistence Assurance statement for the 3.65GHz band in the US and Canada"*, Paul Piggin, Nov. 2007.

[3] IEEE C80216h-07_082, *"Enhancements to UCP LBT: Supporting Simulation results"*, Paul Piggin, 7 Sept. 2007.

[4] IEEE 80216h-07_20r3, "Comments in Task Group Review of Working Group Draft P802.16h/D2c", 4 Oct 2007