Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Enhancements to Dynamic Medium Acquisition**
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Re:	Letter Ballot #29a of IEEE P802.16h/D4.
Abstract	To date LBT (Listen Before Talk) as realized by the DMA (Dynamic Medium Acquisition) algorithm provided coexistence between 802.16h and 802.11y. The contribution details enhancements to the DMA algorithm that provides 802.16h to 802.16h coexistence, in addition to 802.16h to 802.11y coexistence.
Purpose	Refine the definition of LBT (Listen Before Talk) and DMA (Dynamic Medium Acquisition) in IEEE P802.16h/D4 based on the latest simulation results.
Notice	
Release	
Patent Policy	

Enhancements to Dynamic Medium Acquisition

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1. Introduction

<*Note*: In order to provide a distinction in terminology within this contribution 802.16 devices compliant to the IEEE P802.16h amendment are referred to as *802.16h* devices. In a similar way 802.11 devices compliant to the IEEE P802.11y amendment are referred to as *802.11y* devices.>

To date LBT (Listen Before Talk) as realized by the DMA (Dynamic Medium Acquisition) algorithm provided coexistence between 802.16h and 802.11y. The contribution details enhancements to the DMA algorithm that provides 802.16h to 802.16h coexistence, in addition to 802.16h to 802.11y coexistence. This contribution covers:

- A summary of benefits.
- Modification to the DMA algorithm.
- Simulation results.
- Editing changes to reflect the modifications in the draft standard [1].

2. The benefits provided by Enhancements to LBT DMA

This section provides a list of enhancements that may be provided by the modifications described in this contribution:

- Removing the fixed allocation for 802.16h systems to frames benefits spatial distribution and permits the use of capacity for partially overlapping deployments. This solution provides a direct solution within the scope of the 802.16h amendment PAR. As a consequence of this proposed enhancement, and the way it's designed, then coexistence for 802.16h-to-802.16h consequently provides coexistence with 802.11y.
- The modification to the DMA algorithm removes uncertainty concerning frame allocation. Fixed frame allocation requires cell planning and can introduce inefficiencies or interference where planning is incorrect. This is a sensing based scheme.
- Setting a *UtilizationGoal* helps, and is required, but if it's incorrectly set then channel sensing provides correction. This provides reasonable flexibility and a dynamic operation where stale information may has been used to set the *UtilizationGoal*.
- This solution resolves the issue of MAP relevance. MAP Relevance of N+1 can be supported. The rule requires that the MAP be used for the next intentionally transmitted frame.

The corollary is that changes enable the WirelessMAN-UCP designation to provide AN OPTION for coexistence with 802.16h-to-802.16h and 802.16h-to-802.11y devices based on the DMA algorithm where no strict frame allocation is required.

3. Modifications to the current DMA algorithm

Changes to the existing DMA algorithm as described in [1] add functionality to enable 802.16h-to-802.16h coexistence. Specific changes in this section provide this support.

- An 802.16h system now uses the 802.11y MA (Medium Acquisition) protocol (at the BS only) to determine if the following frame can be claimed for operation. A given 802.16h BS contends with other 802.16h BS and 802.11y AP and STA devices. As defined previously the DMA algorithm the 802.16h BS is not permitted to begin the MA until the *FRSTn* is passed in a given frame.
- Given that 802.16h Systems may be frame synchronized and in the event the UL subframes finish at the same time then a higher probability for MA clashes exists. To reduce the probability of clashes the DMA should quantize values of *FRSTn* by SIFS intervals.
- Presently the value of *MINFRST* is equal to $T_{CMA} + T_{FRAME\_END\_OFFSET}$. Changes to the DMA algorithm requires a modification to this value. The modifications are required to accommodate a minimum Contention Window (CW) period, therefore:

  $$MINFRST = AIFS[AC] + CW_{min}[AC]*aSlotTime + T_{FRAME\_END\_OFFSET}$$

  Where:

  $AIFS[AC]$, CW_{min} $[AC]$, and *aSlotTime* are configuration dependant.

  $T_{FRAME\_END\_OFFSET}$ = 50µs.

  These parameters and can be configured as required based on the prevailing system configurations. For example providing 1 OFDM symbols (2% capacity penalty) provides a *MINFRST* of 213µs, 2 OFDM symbols (4% capacity penalty) provides a *MINFRST* of 316µs. This assumes a TTG gap of 50µs.
- *UtilizationGoal* can be set to an appropriate value. This is described in detail in the follow subclause.

3.1. Recommended practice on setting UtilizationGoal

Modifications to the DMA algorithm mean that the algorithm ensures systems share frame-on-frame using the 802.11 MA approach. It is still necessary to set the *UtilizationGoal* in some cases. These cases are described below. *n* is the number of 802.16 systems present, and *m* is the number of 802.11 systems present.

For *n>0 and m=0*: *UtilizationGoal*=100% (i.e. not set) works for multiple 802.16 only sharing.

For *n>0 and m>0*: *UtilizationGoal* should to be set based on the number of systems (*n*+*m*) in the general locality. However incorrect setting, or setting to 100%, works and provides a first approximation of fair channel sharing.

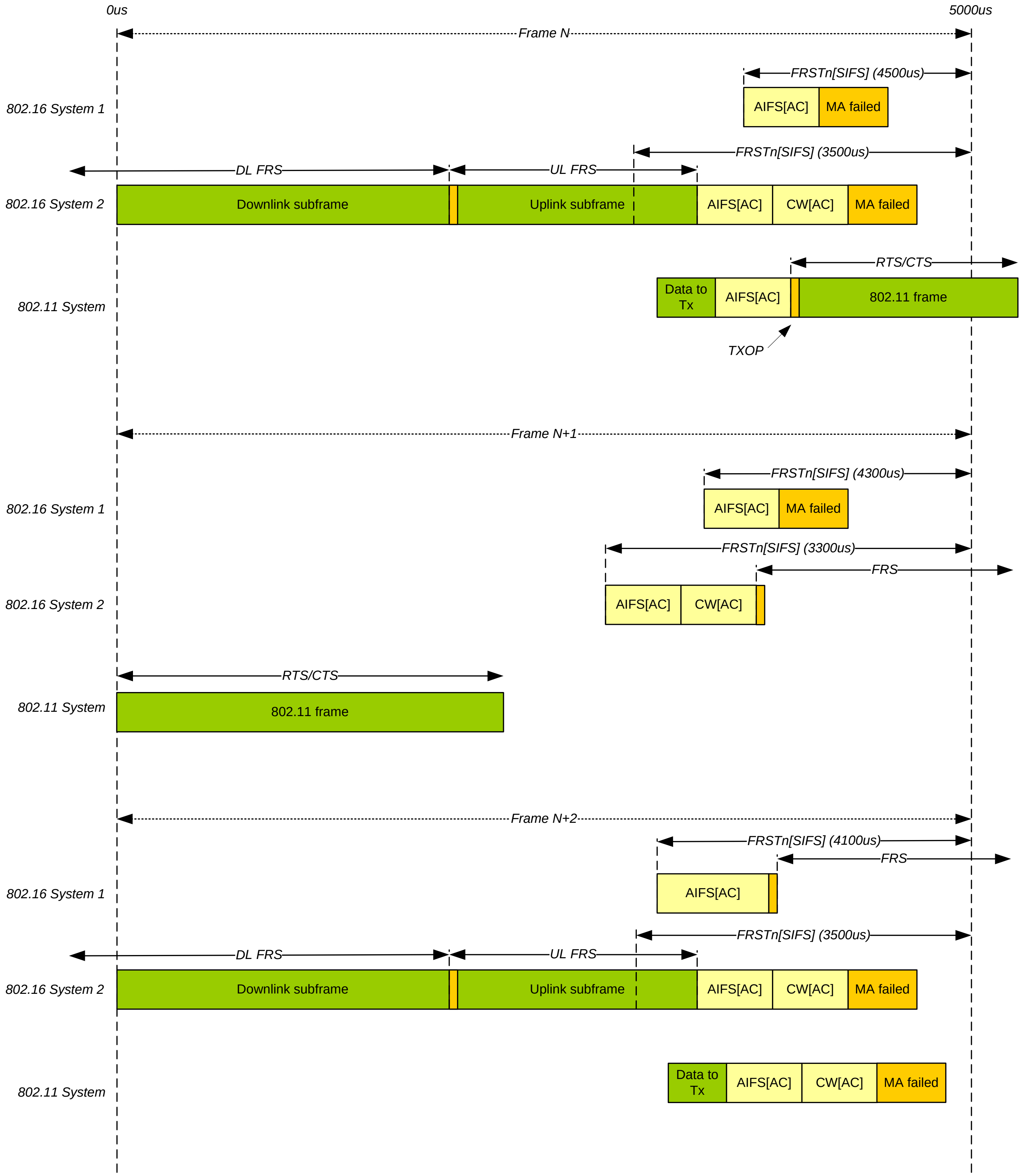

Figure 1 *A detailed example of 2 802.16 and 1 802.11 systems sharing the medium over 3 frame intervals. 802.16 System 2 has Frame N, 802.11 uses Frame N+1, and 802.16 System 2 claims Frame N+2. 802.16 System 1 claims Frame N+3.*

4. Simulation results

The section provides some supporting simulation results for the proposals presented in the preceding sections. The simulation results drawn from the Simulation Parameter specification as defined in [2]; additional configuration parameters are listed as required.

4.1. Collocated case

The *collocated case* provides a 'proof-of-concept' simulation configuration; and provides a time domain assessment of coexistence capabilities. In this configuration many of the variables of a spatially distribution simulation are fixed or removed and so within a well controlled environment provides the ability to analyze the sensitivity of a number of elements and external influences to the DMA scheme. Figure 2 presents an illustration of the collocated simulation configuration. Important simulation values, other than those presented in [2], and unless otherwise stated, are:

- Number of subscribers per base station is one.
- Pathloss between devices is 1dB.
- *Cell extent* is an arbitrary 1m.
- Downlink symbols: 28.
- Uplink symbols: 17.
- Total number of symbols per frame: 45.

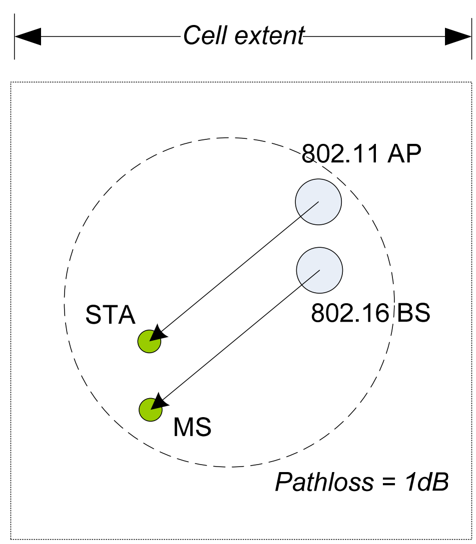

Figure 2 *Collocated simulation configuration.*

Simulation results are presented to demonstrate the following:

- Fair sharing between 802.16h and 802.16h Systems and 802.16h and 802.11y Systems.
- The impact of different settings of the *UtilizationGoal*.
- Demonstrate sensitivity of setting *MINFRST* based on the configuration of the 802.11 system parameters.

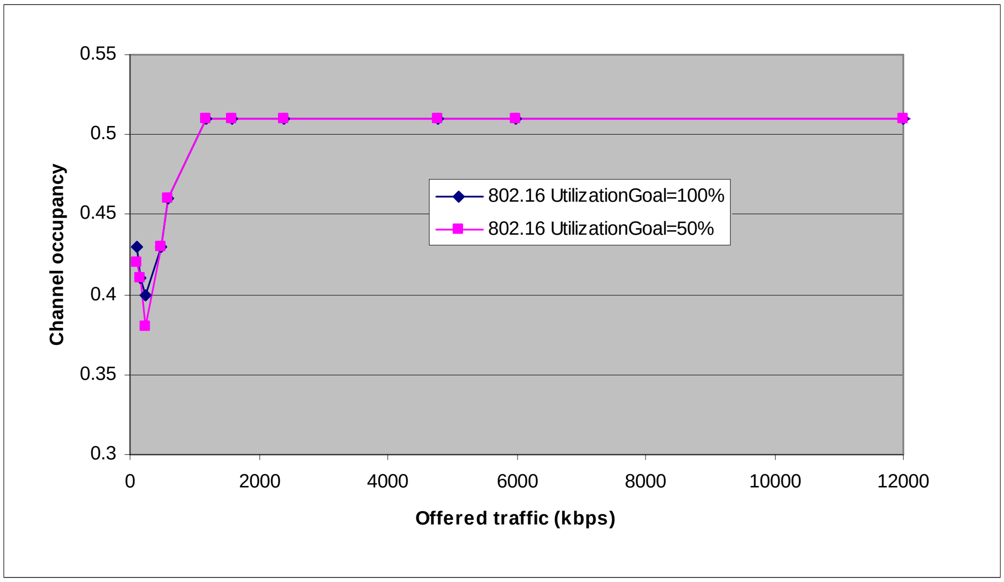

Figure 3 *Collocated simulation configuration – demonstrating fair sharing for 2 802.16 systems. UtilizationGoal=100% (i.e. not set).*

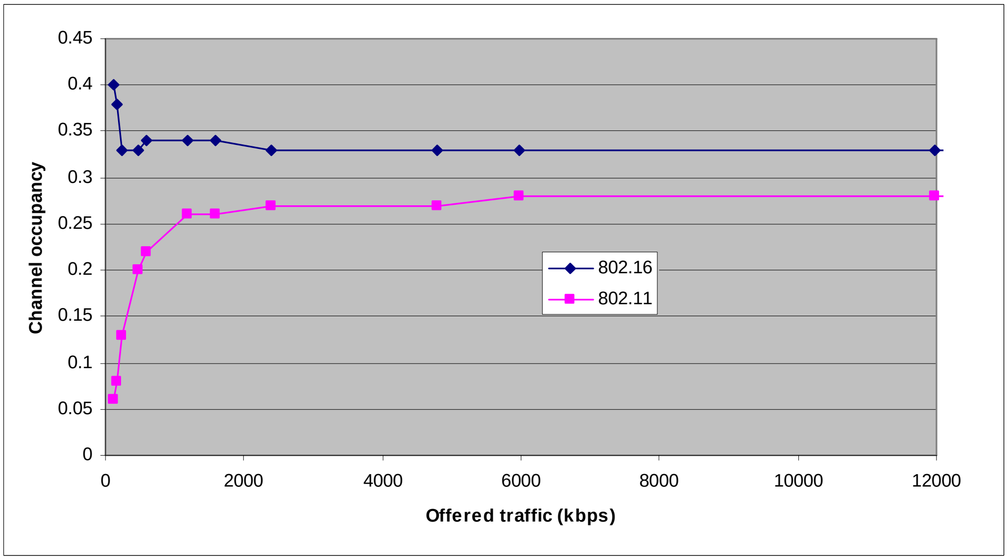

Figure 4 *Collocated simulation configuration – considering fair sharing for 2 802.16 Systems and 1 802.11 System. UtilizationGoal=100% (i.e. not set).*

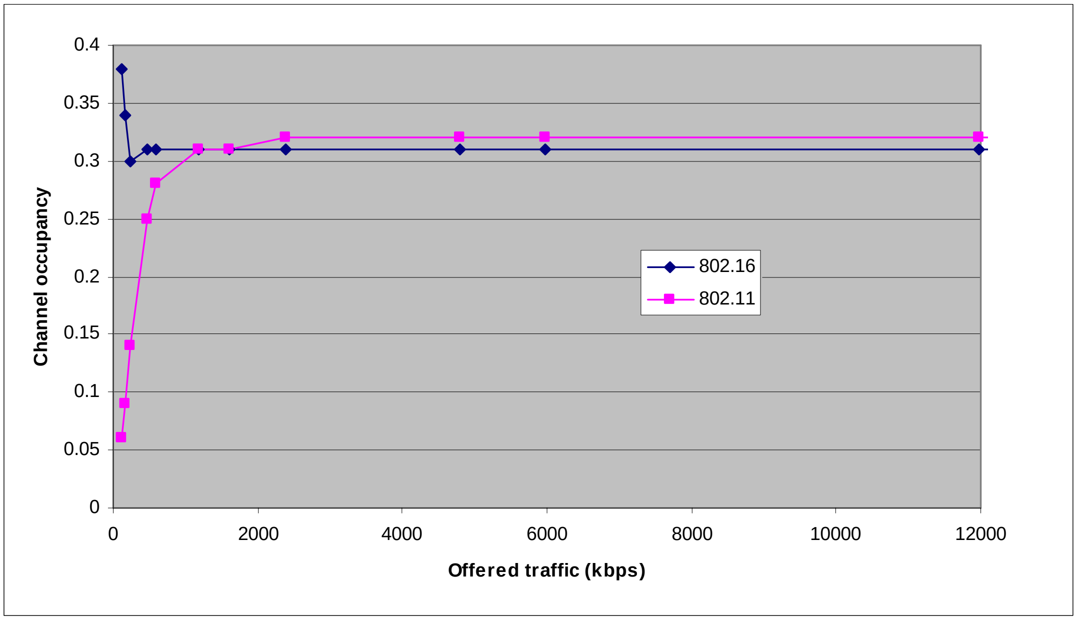

Figure 5 *Collocated simulation configuration – considering fair sharing for 2 802.16 Systems and 1 802.11 System. UtilizationGoal=33%.*

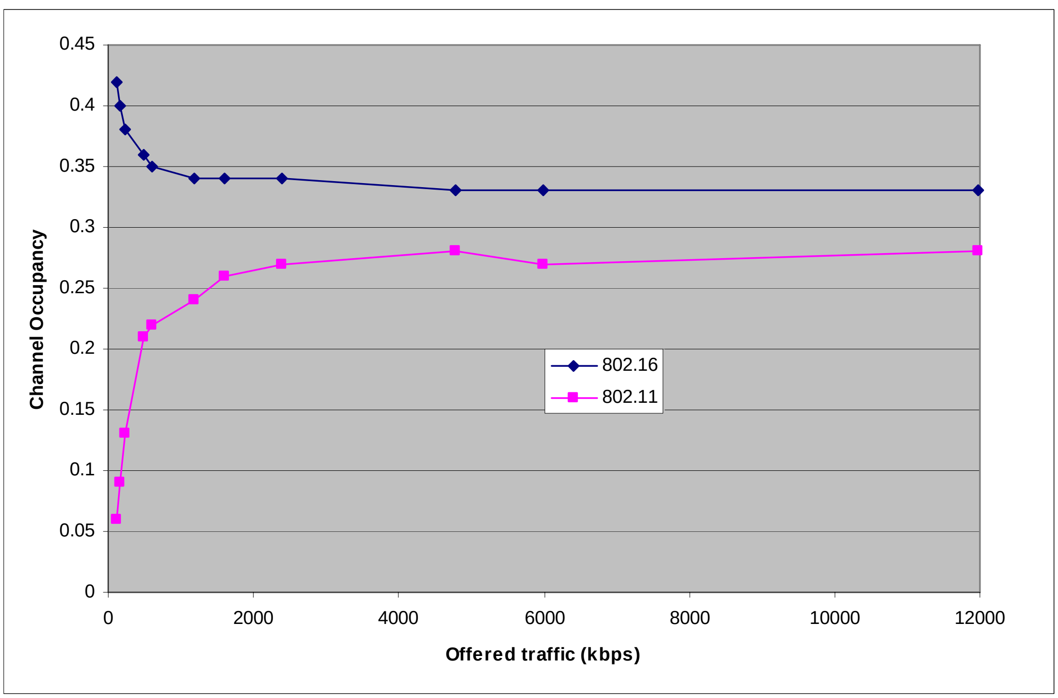

Figure 6 *Collocated simulation configuration – considering fair sharing for 2 802.16 Systems at channel capacity (offered load at 1.5Mbps per link) and 1 802.11 System with varying offered load. UtilizationGoal=100% (i.e. not set)*

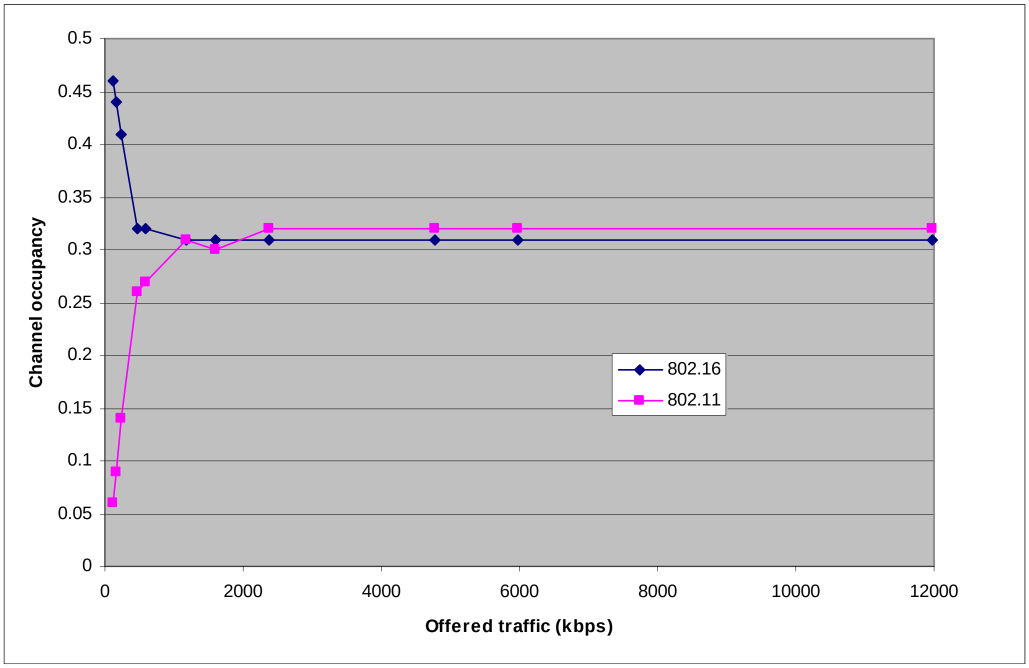

Figure 7 *Collocated simulation configuration – considering fair sharing for 2 802.16 Systems at channel capacity (offered load at 1.5Mbps per link) and 1 802.11 System with varying offered load. UtilizationGoal=33%.*

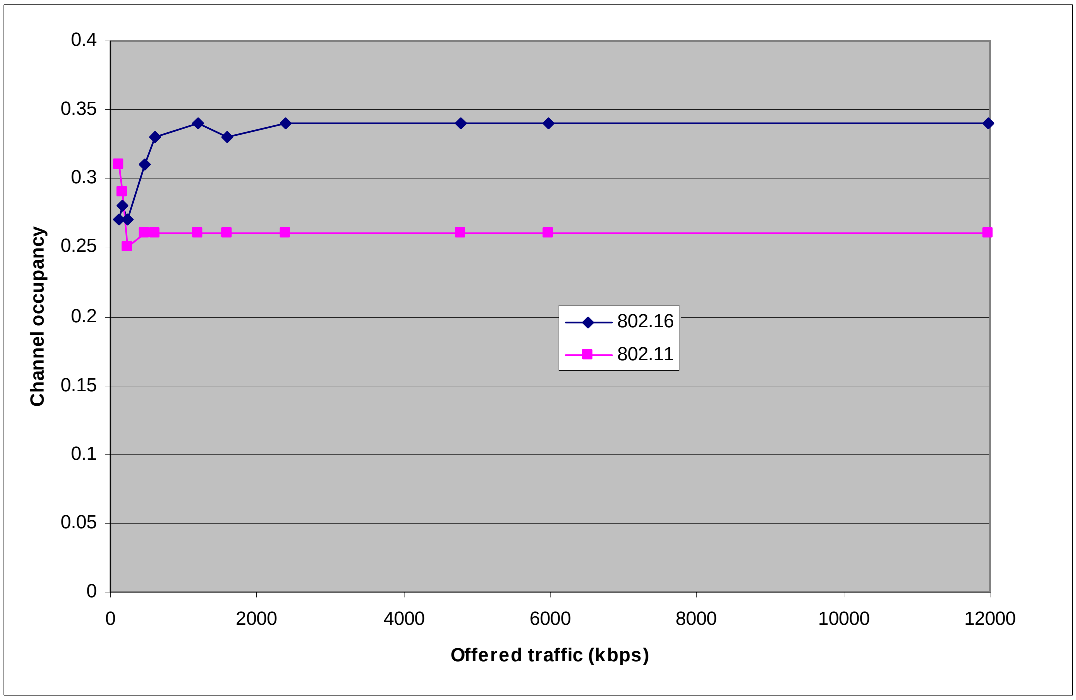

Figure 8 *Collocated simulation configuration – considering fair sharing for 1 802.11 System at channel capacity (offered load at 1.5Mbps per link) and 2 802.16 Systems with varying offered load. UtilizationGoal=100% (i.e. not set)*

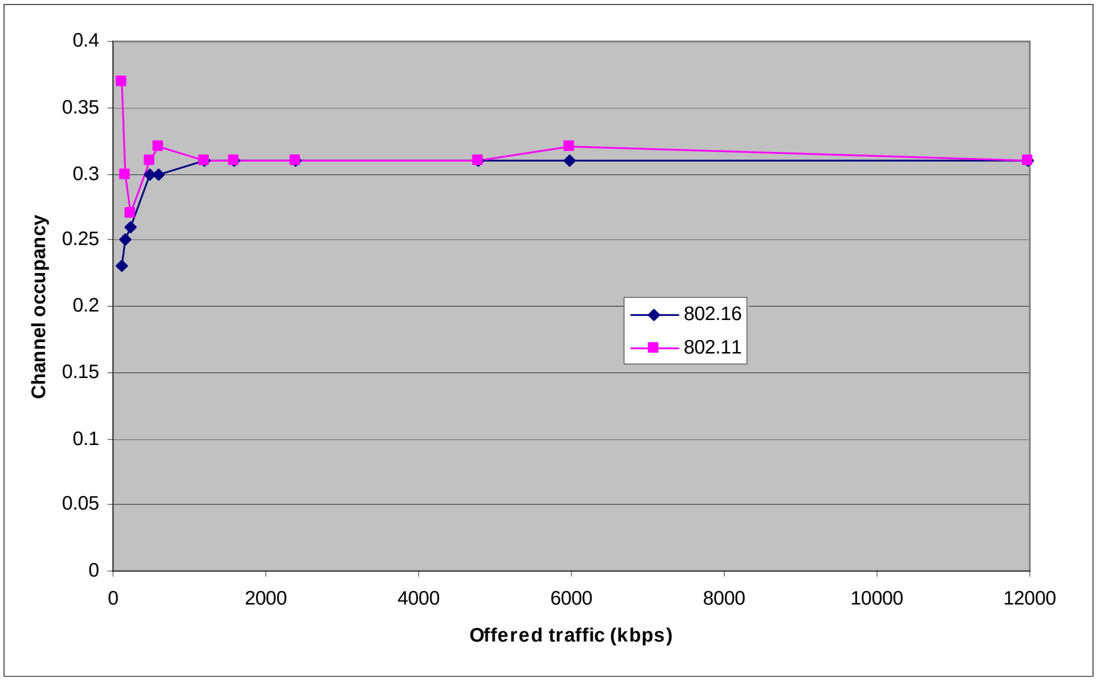

Figure 9 *Collocated simulation configuration – considering fair sharing for 1 802.11 System at channel capacity (offered load at 1.5Mbps per link) and 2 802.16 Systems with varying offered load. UtilizationGoal=33%.*

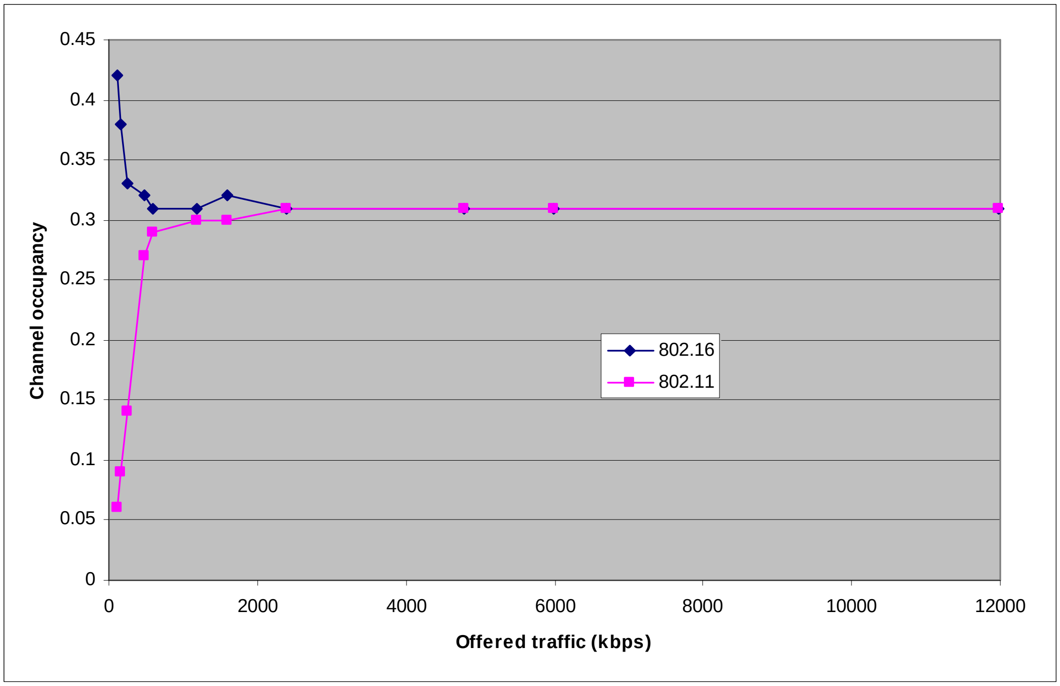

Figure 10 *Collocated simulation configuration – considering fair sharing for 2 802.16 Systems and 1 802.11 System. UtilizationGoal=33%. 46 symbols per frame, downlink=28, uplink=18.*

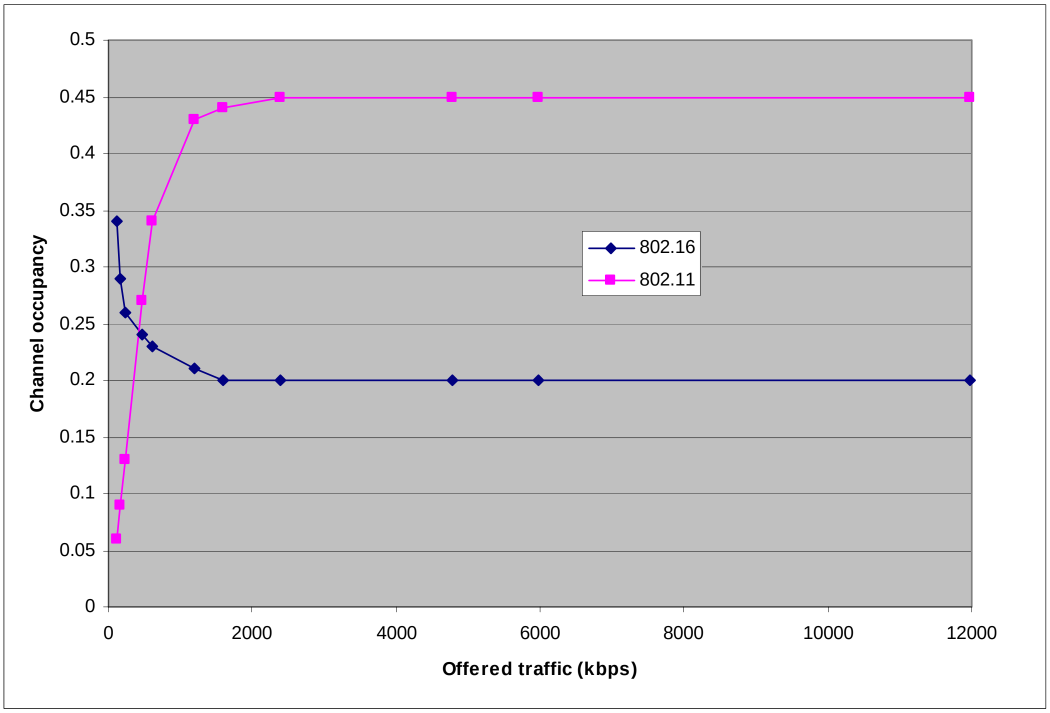

Figure 11 *Collocated simulation configuration – considering fair sharing for 2 802.16 Systems and 1 802.11 System. UtilizationGoal=33%. 47 symbols per frame, downlink=28, uplink=19.*

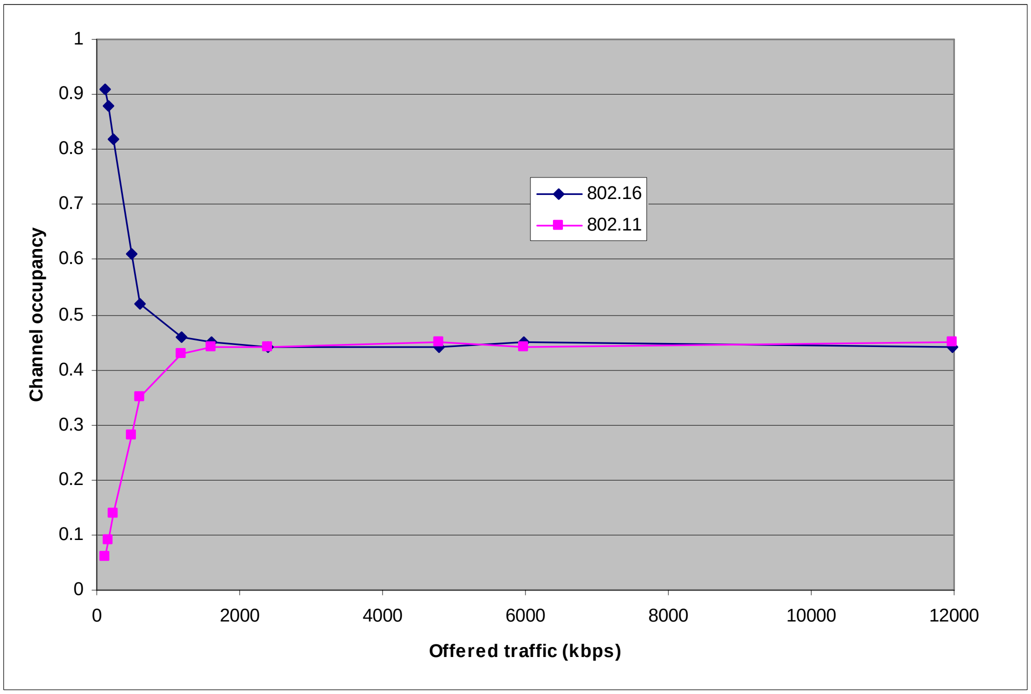

Figure 12 *Collocated simulation configuration – considering fair sharing for 1 802.16 Systems and 1 802.11 System. UtilizationGoal=50%. 46 symbols per frame, downlink=28, uplink=18.*

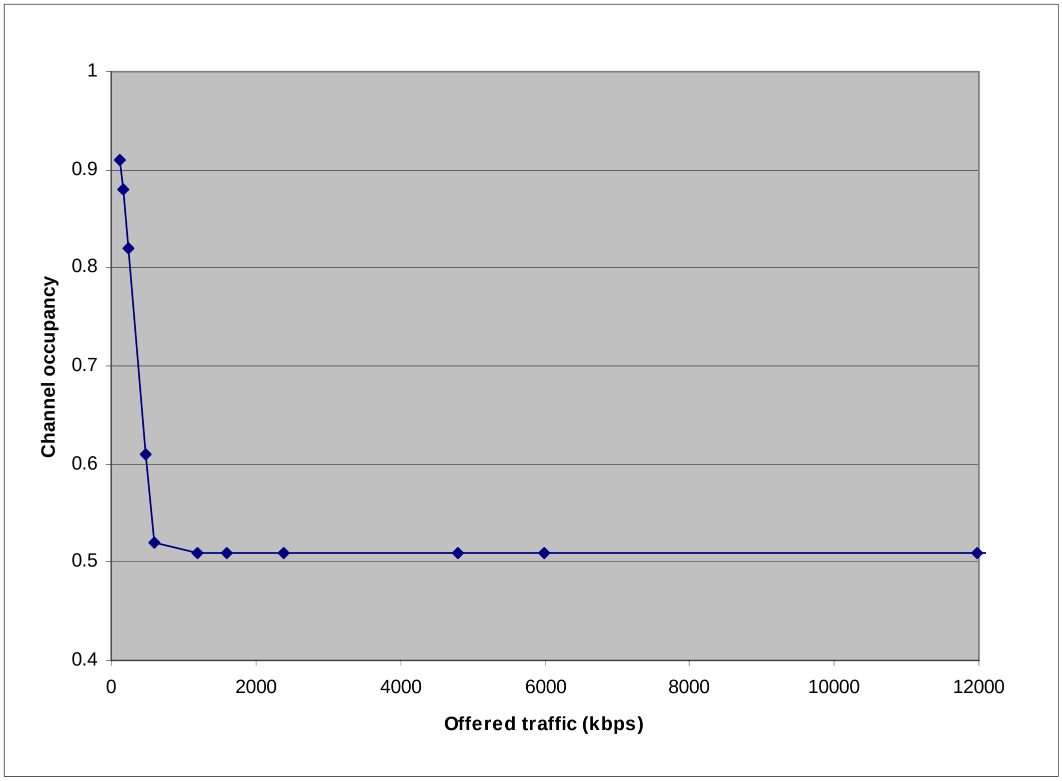

Figure 13 *1 802.16 Systems. UtilizationGoal=100%. 47 symbols per frame, downlink=28, uplink=19. For the case of 46 symbols per frame, downlink=28, uplink=18 channel occupancy is 100% for all offered traffic.*

4.2. Conclusions from collocated simulations

These are the conclusions from simulation results for the collocated configuration case:

- For 802.16h Systems alone it is shown from simulation results that a *UtilizationGoal* does not need to be set (Figure 3).
- When considering a mix of 802.16h and 802.11y Systems then the setting of a *UtilizationGoal* is of benefit for fair sharing of the medium. When a *UtilizationGoal* is not set then a reasonable first approximation to sharing is provided. This is shown in Figure 4 to Figure 9.
- Figure 10 to Figure 13 shows the sensitivity to the number of uplink symbols dedicated to the *DMA Region* and therefore the ability to accommodate the *MINFRST* value. Results in previous figures show fair sharing for a 45 symbol frame with 28 downlink symbols and 17 uplink. Figure 10 and Figure 12 indicates that fair sharing can also be provided with a 46 symbol frame with 28 downlink symbols and 18 uplink symbols. However Figure 11 shows issues of fair sharing for a 47 symbol frame with 28 downlink symbols and 19 uplink symbols.
- Figure 13 provides an interesting result for the case of 19 uplink symbols. Under low traffic loading every frame can be claimed since little data traffic is being transmitted and the 802.11 MA procedure allows for claiming the medium without a CW. However as the loading increases there are more instances of CW and with there being a smaller *DMA Region* then there is no time to complete the MA before the end of the frame. The case of 18 uplink symbols means the occupancy is 100% for all traffic

loadings – there is sufficient time in the *DMA Region* to perform MA.

4.3. Spatially distributed cases

Spatially distributed cases extend the limited configuration of the *collocated case*. This case allows the exploration of the behavior of the DMA solution to cases where a more realistic case of a distributed network is considered. The simulation consideration also allows the investigation of FRS (Frame Reservation Transmissions) and the impact of hidden node problems for both 802.16 and 802.11. Important simulation values, other than those presented in [2], and unless otherwise stated, are:

- Number of subscribers per base station is four.
- *Cell extent* is dependent on the technology and configuration [2].
- *Simulation extent* is 30km.
- Offered traffic load is 1.5Mbps per link.
- Using *Scenario A* and *Scenario C* as indicated [2].
- Downlink symbols: 28.
- Uplink symbols: 17.
- Total number of symbols per frame: 45.

Figure 14 presents an illustration of the spatially distributed simulation configuration representing 1 802.16 System and 1 802.11 System. Figure 15 presents an illustration of the simulation configuration for 3 Systems (any combination of 802.16 and 802.11), and Figure 16 a configuration for 4 Systems (again any combination of 802.16 and 802.11).

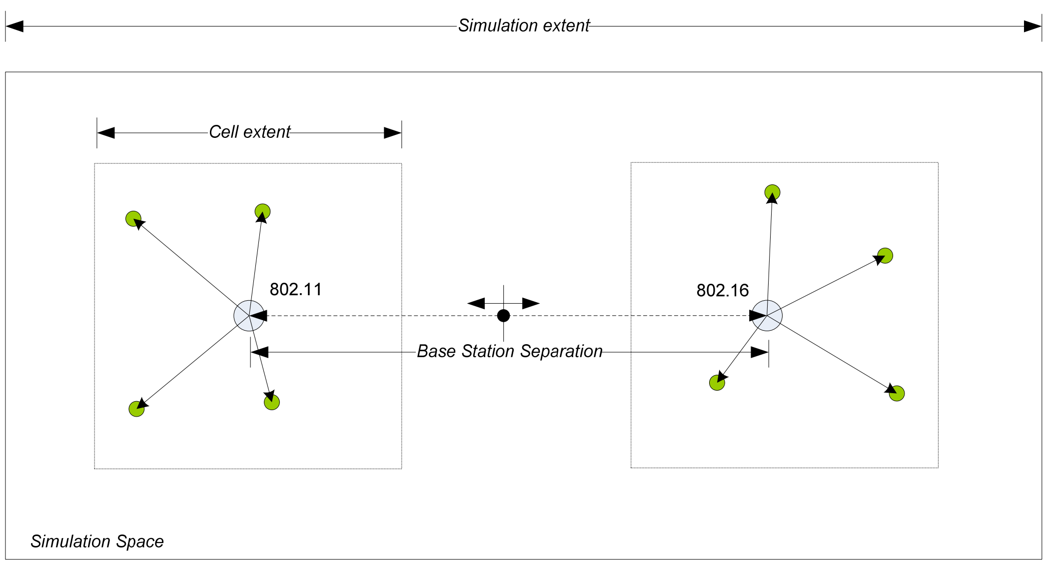

Figure 14 *Collocated simulation configuration: 1 802.16 system and 1 802.11 system.*

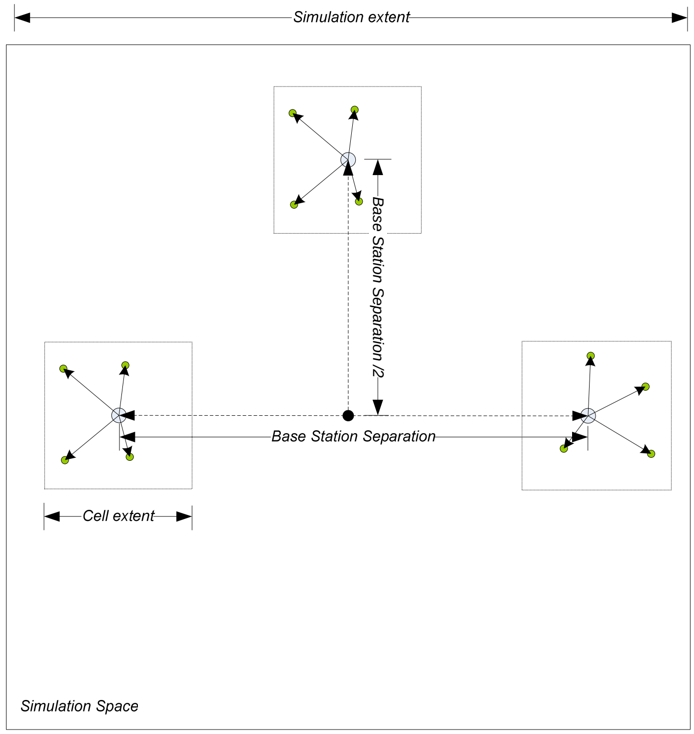

Figure 15 *Collocated simulation configuration: 3 systems.*

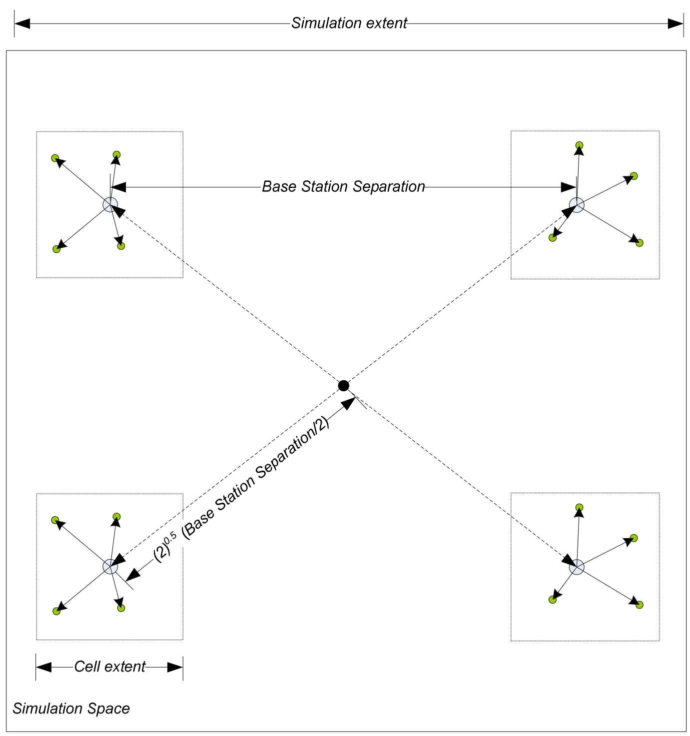

Figure 16 *Collocated simulation configuration: 4 Systems.*

Simulation results are presented to demonstrate the following:

- FER (Frame Error Rate) as a function of BS/AP separation. Considering 802.11y Systems alone, 802.16h Systems alone, and a combination of the two Systems.
- Simulation results for *Scenario C* [2] and configuration for the specific number of Systems.
- Demonstrate the optimized usage of unused capacity in the spatially separated case.
- Sensitivity to Pathloss Standard Deviation [2].

5. Scope of editing changes

Based on the simulation results presented in the preceding sections the modifications to the existing text related to LBT w/DMA in [1] include:

- Add language that provides an option to provide an 802.11 MA event at the start of a valid DMA region.
- Language to provide an option to quantize *FRSTn* in SIFS intervals.
- Add the expression for $MINFRST = T_{CMA} + T_{FRAME\_END\_OFFSET}$ in the text, and the subsequent modification to *MINFRST*.
- Remove all language mandating DMA to work within a frame structure. New language should be added making this an optional mode of operation.
- Statement on MAP relevance.

6. Specific editing changes

All the following editing changes apply to IEEE P802.16h/D4 [1].

Blue underlined 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'.

AC	Access Category
AIFS	Arbitration Interframe Space
AIFSN	Arbitration Interframe Space Number

CW	Contention Window
MA	Medium Acquisition

Add the following paragraph to line 48, page 34.

A discovery protocol may be used for coexistence between 802.16-based systems, asynchronous non-802.16 systems or a mixture of the two. Such a discovery protocol shall be based on the 802.11 Medium Acquisition procedure. This type of discovery protocol is described in subclause 6.4.2.3.5.2.

Add the following expression and definitions to clarify the use of MINFRST in subclause 6.4.2.3.5.1 at line 5, page 39.

$$MINFRST = T_{CMA} + T_{FRAME\_END\_OFFSET} \quad [x1]$$

Where T_{CMA} is the time to perform a CMA, and $T_{FRAME\_END\_OFFSET}$ is the time to switch RX/TX and transmit an FRS.

Add a new subclause 6.4.2.3.5.2 'Dynamic Medium Acquisition discovery protocol' at line 28, page 42.

6.4.2.3.5.2 Dynamic Medium Acquisition discovery protocol

The DMA protocol described in subclause 6.4.2.3.5.1 may be used as a discovery protocol for coexistence with 802.16-based systems in addition to coexistence with asynchronous non-802.16 systems. DMA as a discovery protocol for coexistence with 802.16-based systems shall use the algorithm described in 6.4.2.3.5.1 but may use different default configuration parameters. In addition the BS shall use the 802.11 Medium Acquisition (MA) algorithm [B28] as a means of accessing the medium, and as a means of providing fair sharing of 802.16 frames between 802.16 and 802.11 Systems. In a similar way to the method described in subclause 6.4.2.3.5.1 the MA procedure is triggered once *FRSTn* has been exceeded in a given frame.

The DMA protocol allows the following interpretation of MAP relevance. A MAP relevance of N can be supported since if the downlink is transmitted the uplink will follow in the same frame. A MAP relevance of N+1 can be supported where the interpretation applies the MAP referencing the uplink in the next intentionally transmitted frame, i.e. where the downlink is received.

The remainder of this subclause discusses appropriate parameter configuration for the DMA discovery protocol.

It may be the case that 802.16 Systems are frame synchronized and UL subframes finish at similar times. In order to reduce the probability of MA clashes *FRSTn* should be quantized by SIFS intervals to reduce this probability given the higher likelihood of detecting other devices. Therefore after updated *FRSTn* then the resulting value should be further processed accordingly:

If $\mathrm{mod}\left(\frac{FRSTn}{SIFS}\right) > SIFS/2$:

$$FRSTn = ceiling\left(\frac{FRSTn}{SIFS}\right).SIFS \qquad [x2]$$

Otherwise $$FRSTn = floor\left(\frac{FRSTn}{SIFS}\right).SIFS$$

The value of *MINFRST* is calculated according to the following equation:

$$MINFRST = AIFS[AC] + CW[AC]*aSlotTime + T_{FRAME\_END\_OFFSET} \qquad [x3]$$

These parameters can be configured as required based on prevailing system configurations. The configuration is dependant on channel bandwidth of operation, cell size (time of flight impact on the calculation of MA parameters), and the expected operational parameters of any 802.11 systems. Example parameters for calculating MINFRST are given in table h200803-01 [B28] [B29].

Table h200803-01 – Example values for calculating *MINFRST*

Parameter	**Example value**
AC (Access Category)	AC_VO (Voice Only)
Channel bandwidth	5MHz
Cell radius	1.4km
SIFS	64µs
AIFSN[*AC*]	2
aSlotTime	32µs
AIFS[*AC*] = *SIFS* + *AIFSN*[*AC*].*aSlotTime*	128µs
$CW_{min}[AC]$	3
$T_{FRAME\_END\_OFFSET}$	50µs
MINFRST	**274µs**

The *UtilizationGoal* should be set as described in subclause 6.4.2.3.5.1 however the behavior of the DMA discovery protocol means that a *UtilizationGoal* of 100% (i.e. unset) provides a reasonable first approximation to fair channel sharing in areas where uncertainty exists about the presence of other 802.16 and 802.11 Systems.

An example of the usage of the DMA discovery protocol is given in figures h200803-01.

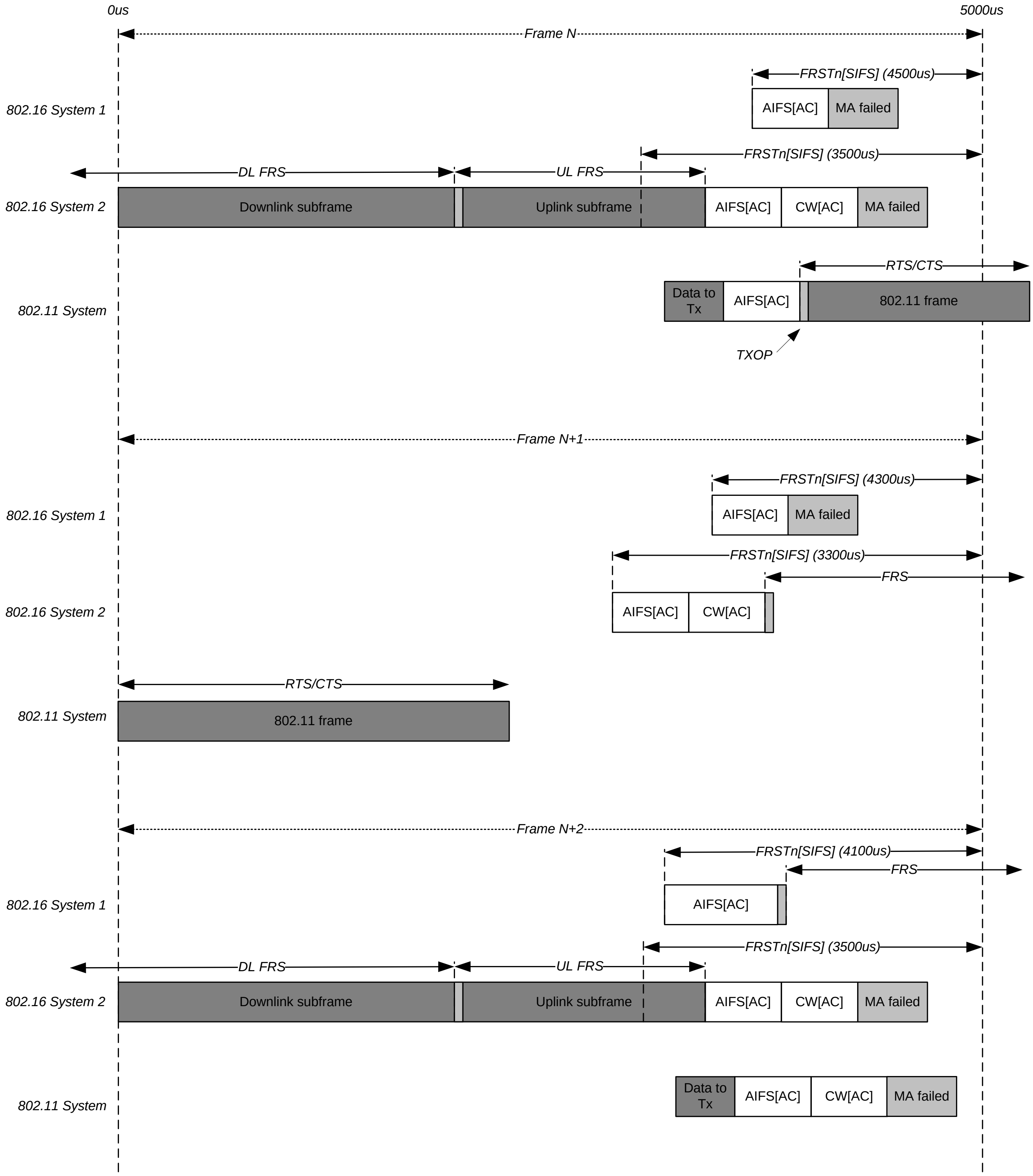

Figure h200803-01 – A detailed example of 2 802.16 and 1 802.11 systems sharing the medium over 3 frame intervals. 802.16 System 2 has Frame N, 802.11 uses Frame N+1, and 802.16 System 2 claims Frame N+2. 802.16 System 1 claims Frame N+3.

Add the following reference to Annex A at line 10, page 177.

[B28] Standard for Information Technology— Telecommunications and information exchange between systems— Local and metropolitan area networks— Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications.

[B29] IEEE 802.19-07/11: *Parameters for simulation of Wireless Coexistence in the US 3.65GHz band*. 802.19 Coexistence Technical Advisory Group, Paul Piggin (editor).

7. References

[1] IEEE P802.16h/D4: *Air Interface for Fixed Broadband Wireless Access Systems Improved Coexistence Mechanisms for License-Exempt Operation*, Draft Standard.

[2] IEEE 802.19-07/11: *Parameters for simulation of Wireless Coexistence in the US 3.65GHz band*. 802.19 Coexistence Technical Advisory Group, Paul Piggin (editor).