Enhancements to UCP LBT: Supporting simulation results

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Venue:

IEEE 802.16h-07/019 Task Group Review of P802.16h/D2c.

Base Contribution:

IEEE C802.16h-07/082

Purpose:

Simulation results in support of enhancements to UCP LBT.

Notice:

Release:

Patent Policy:

Enhancements to UCP LBT: Supporting simulation results

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Content

- Setting the scene
- Background
- The DMA (Dynamic Medium Acquisition) algorithm as an enhancement to LBT (Listen Before Talk)
- What is and where does the DMA feature fit into the current document structure
- Initial simulation results to prove the concept
- Simulation results for the spatially distributed case and the use of FRS (Frame Reservation Signal)
- Conclusions

Setting the scene

- The purpose of the UCP in section 6.4 of [Ref 1] is to allow synchronous 802.16 systems to coexist on a co-channel basis with asynchronous systems.
- The primary asynchronous system of interest is 802.11. Additionally, the features are structured to meet the requirements of the 3.65 GHz band in the US as regulated by the FCC.
- As we continue to refine the simulations and analysis, enhancements come to light that can improve coexistence.

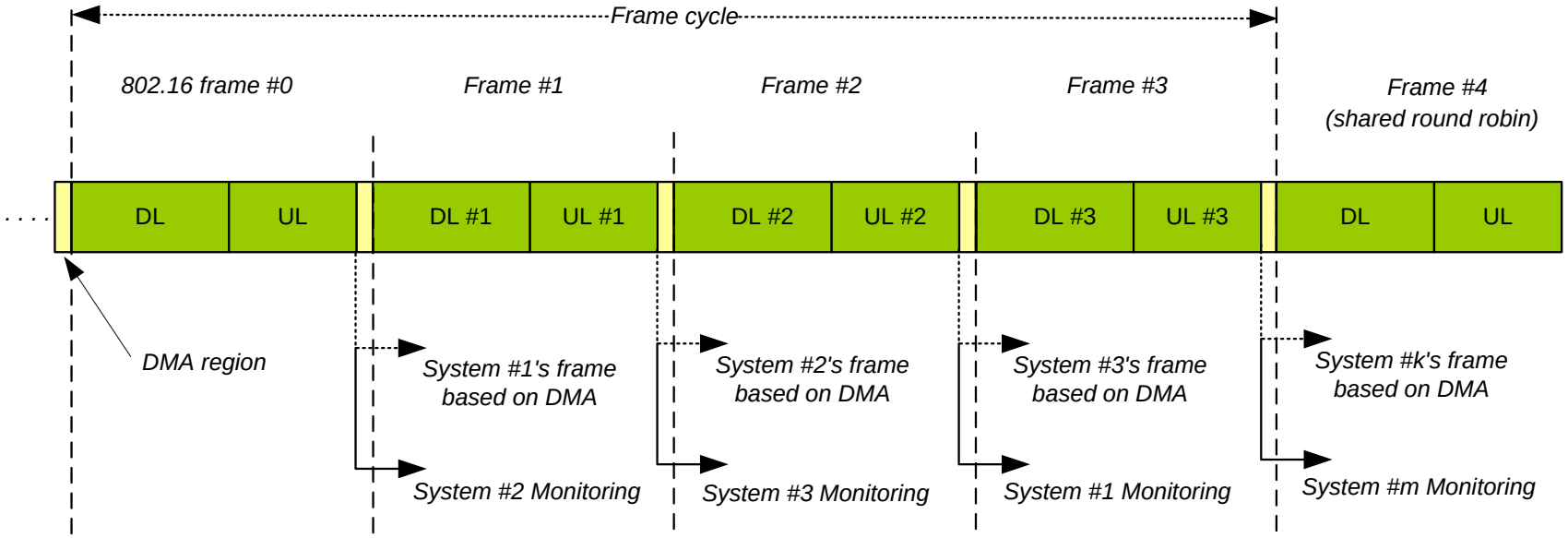
Background

- Only systems communicating via the CXP protocol of section *15.5* [Ref 1] 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 neighboring systems.

What DMA seeks to address

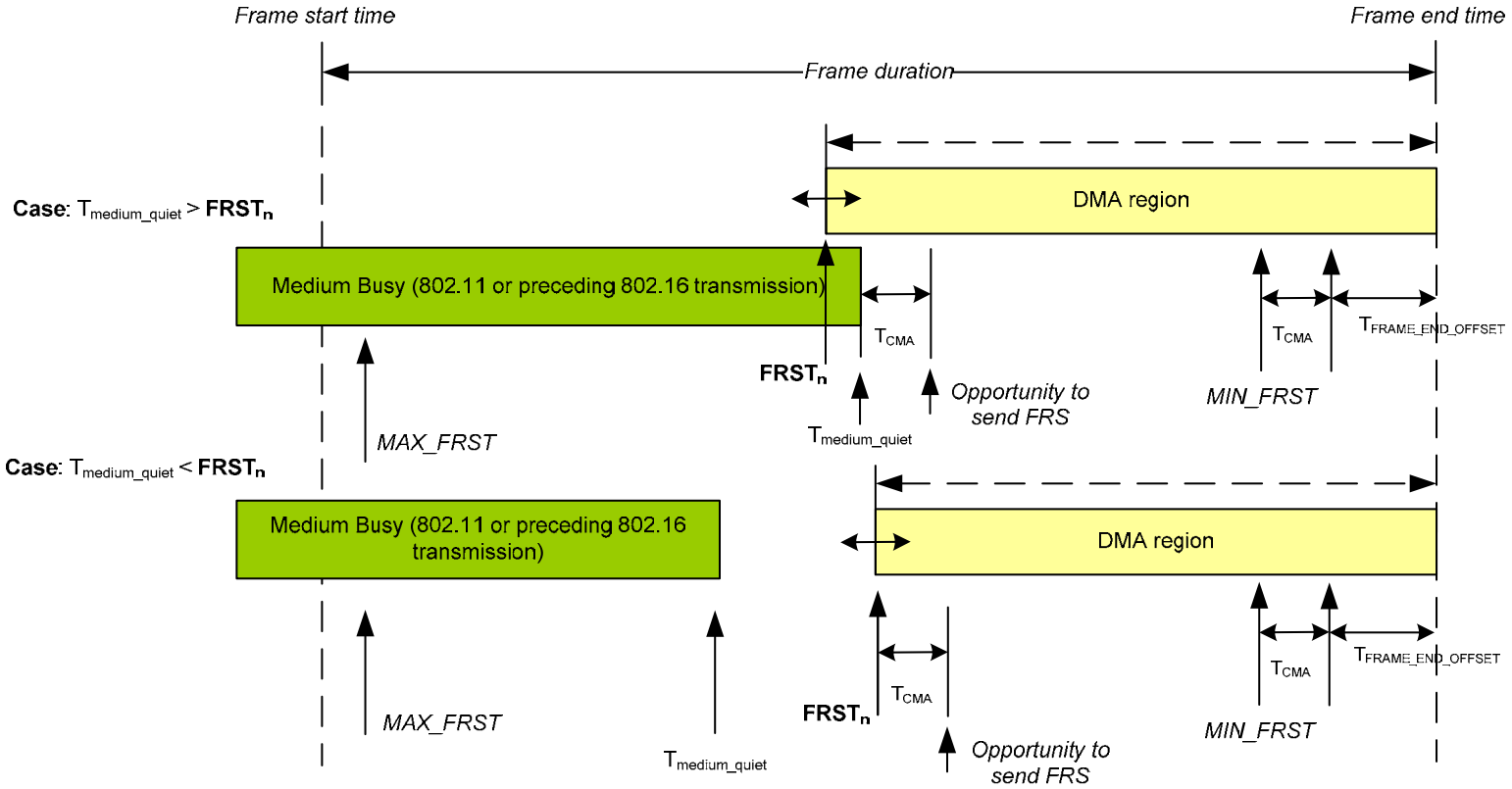
- Bring together asynchronous/synchronous systems at the 802.16 frame boundary
- Provides for controlled reacquisition of the medium from asynchronous systems by synchronous systems
- Subsequent release of the medium to asynchronous systems
- Minimize interference with co-channel asynchronous systems
- Aim to provide fair sharing of the medium

The DMA frame structure



Notes:
This example presents 3 802.16 systems sharing.
Each system updates its own DMA algorithm before monitoring of a frame begins

DMA Algorithm - Reclaiming the medium



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*

The DMA algorithm

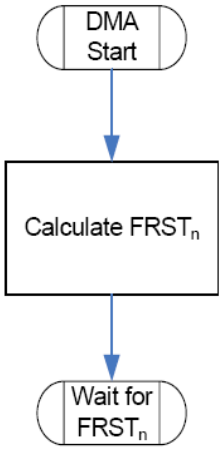
$$UtilizationRatio = \left(\frac{UtilizationGoal}{CurrentUtilization} \right)^{K}$$

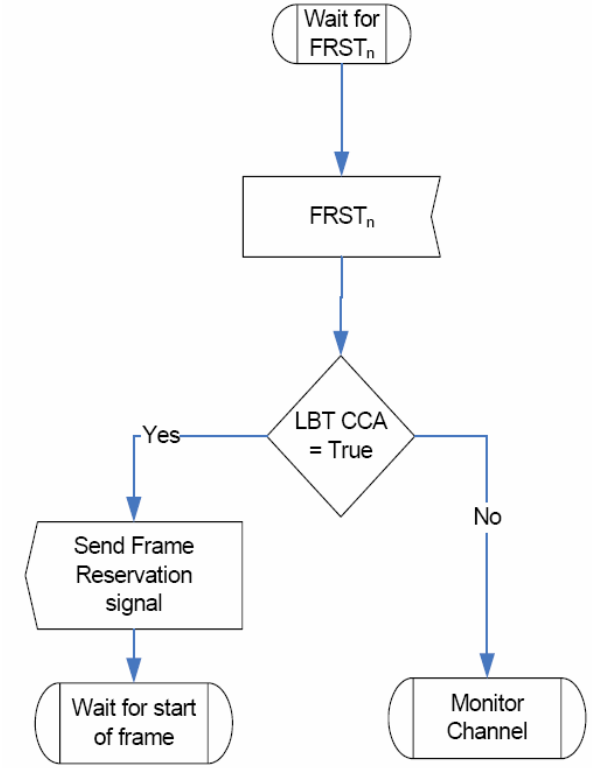
$$FRST_n = MIN(MAXFRST, MAX(UtilizationRatio \times FRST_{n-1}, MINFRST))$$

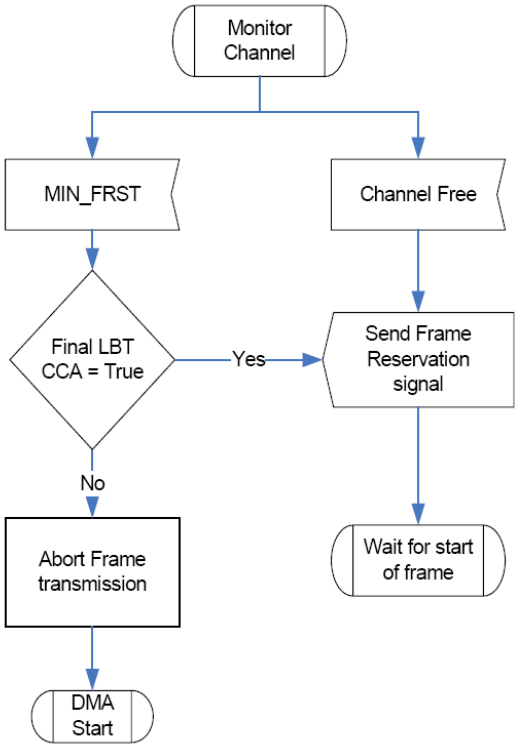
The DMA algorithm

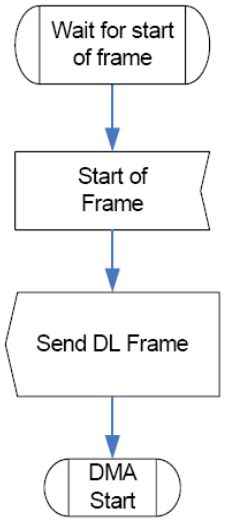
- $FRST_n$ - Frame Reservation Start Time
- *MAXFRST* - The maximum value of *FRST*
- *MINFRST* - the minimum value of *FRST*
- *UtilizationGoal* - the “fair” channel occupancy for this system
- *CurrentUtilization* - the currently achieved channel occupancy for this system
- *UtilizationRatio* - the metric indicating the level to which the *UtilizationGoal* has been achieved

DMA SDL

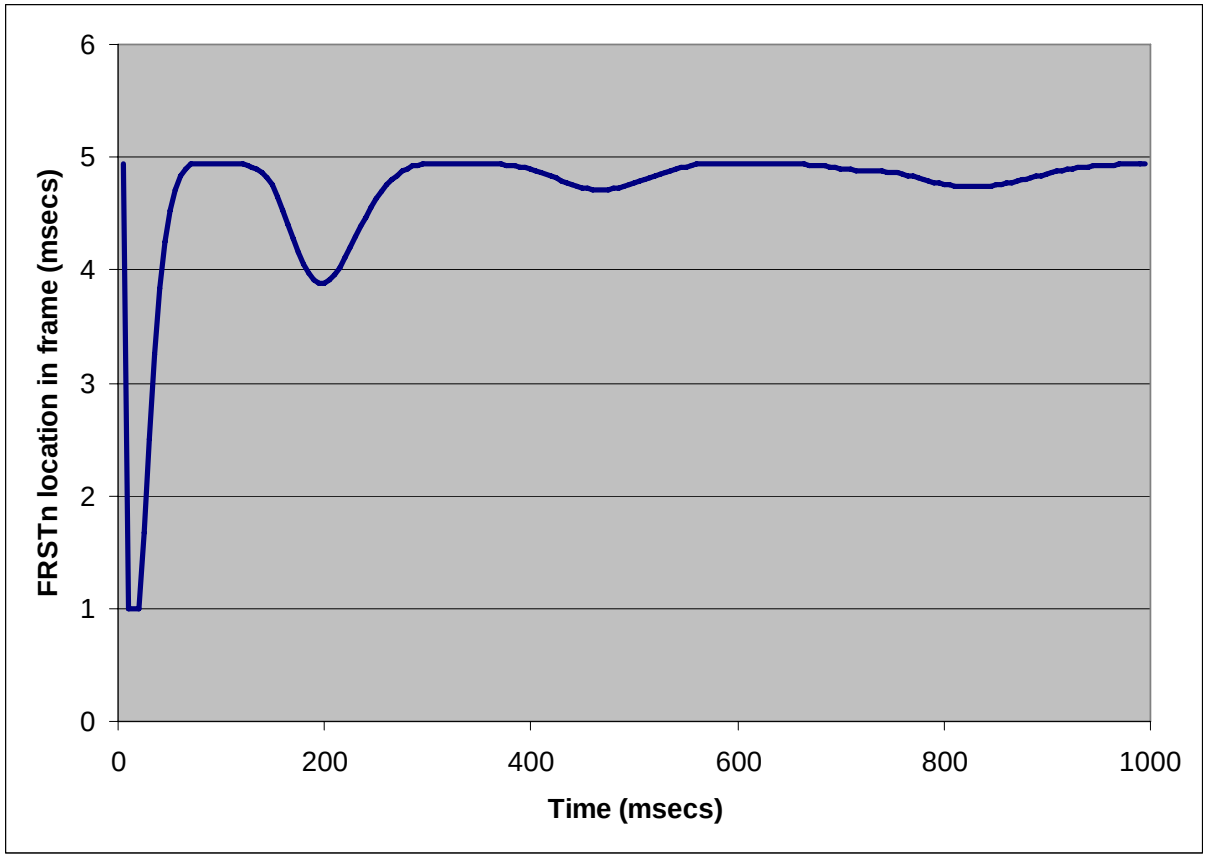

DMA Start
Calculate FRST$_n$
Wait for FRST$_n$

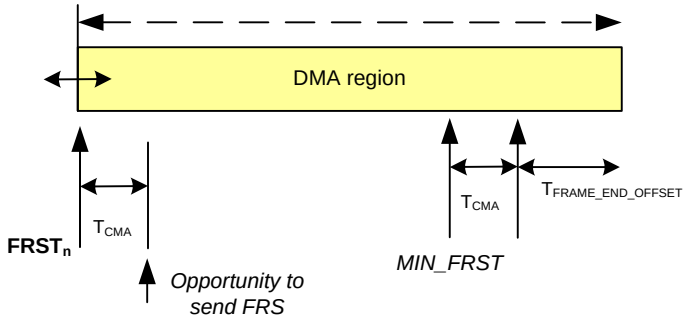

Wait for FRST$_n$
FRST$_n$
LBT CCA = True
Yes
No
Send Frame Reservation signal
Wait for start of frame
Monitor Channel


Monitor Channel
MIN_FRST
Channel Free
Final LBT CCA = True
Yes
No
Send Frame Reservation signal
Abort Frame transmission
Wait for start of frame
DMA Start


Wait for start of frame
Start of Frame
Send DL Frame
DMA Start

The DMA algorithm – variation in $FRST_n$





Simulation Assumptions

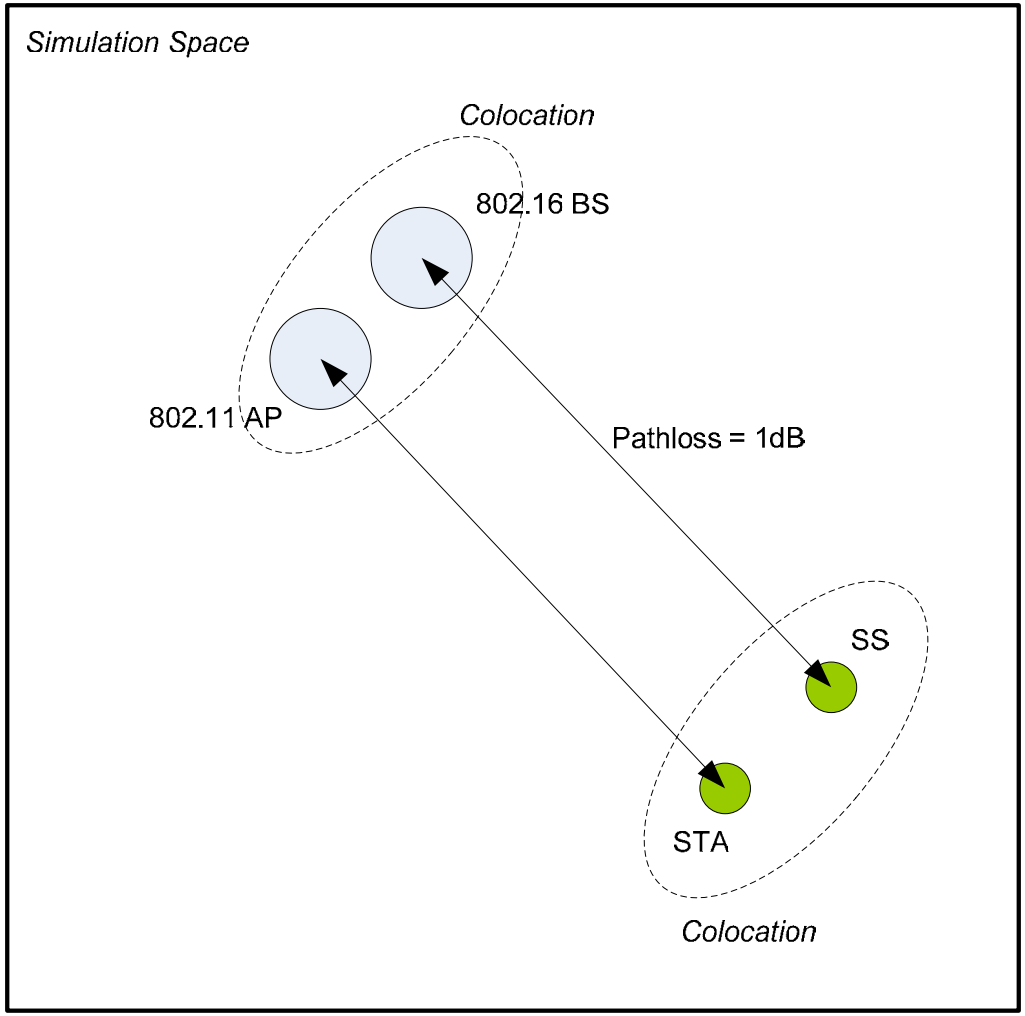
- Results are based on parameters contained within the 802.19 3.65GHz simulation parameters document [Ref 2].
- Each BS (Base Station)/AP (Access Point) has a single associated SS (Subscriber Station)/STA (Station).
- One 802.16 system (10MHz channel) with full access to the channel sees a maximum throughput rate:
  - DL = ~17.8Mbps.
  - UL = ~9.1Mbps
- One 802.11 system (10MHz channel) with full access to the channel sees a maximum throughput rate:
  - DL = ~13.5Mbps.
  - UL = ~13.5Mbps.
- Two 802.16 system (10MHz channel) with full access to the channel sees a maximum throughput rate:
  - DL = ~8.9Mbps.
  - UL = ~4.5Mbps
- Two 802.11 system (10MHz channel) with full access to the channel sees a maximum throughput rate:
  - DL = ~6.6Mbps.
  - UL = ~6.6Mbps.

Simulation Configurations

- ***Scenario A***: 1 x 802.16 system alone [*K* =1]
- ***Scenario B***: 1 x 802.11 system alone [*K* = 1]
- ***Scenario C***: 2 x 802.16 systems alone [*K* = 1]
- ***Scenario D***: 2 x 802.11 systems alone [*K* = 1]
- ***Scenario E***: 1 x 802.16 system + 1 x 802.11 system [*K* = 1]
- ***Scenario F***: 2 x 802.16 systems + 1 x 802.11 system [*K* = 1]
- ***Scenario G***: 1 x 802.16 system + 2 x 802.11 systems [*K* = 1]
- ***Scenario H***: 2 x 802.16 systems + 2 x 802.11 systems [*K* = 1]
- ***Scenario I***: 3 x 802.16 systems + 2 x 802.11 systems [*K* = 1]
- ***Scenario J***: 2 x 802.16 systems + 3 x 802.11 systems [*K* = 1]
- ***Scenario K***: 3 x 802.16 systems + 3 x 802.11 systems [*K* = 1]
- ***Scenario L***: 1 x 802.16 system + 1 x 802.11 system [*K* = 2]
- ***Scenario M***: 1 x 802.16 system + 1 x 802.11 system [*K* = 4]
- ***Scenario N***: 1 x 802.16 system + 1 x 802.11 system [*K* = 1] {802.16 load fixed at channel capacity}
- ***Scenario O***: 1 x 802.16 system + 1 x 802.11 system [*K* = 1] {802.16 load fixed at channel capacity}

Scenarios A through M consider an increasing offered load where the increase in load is the same for the case of both 802.16 and 802.11

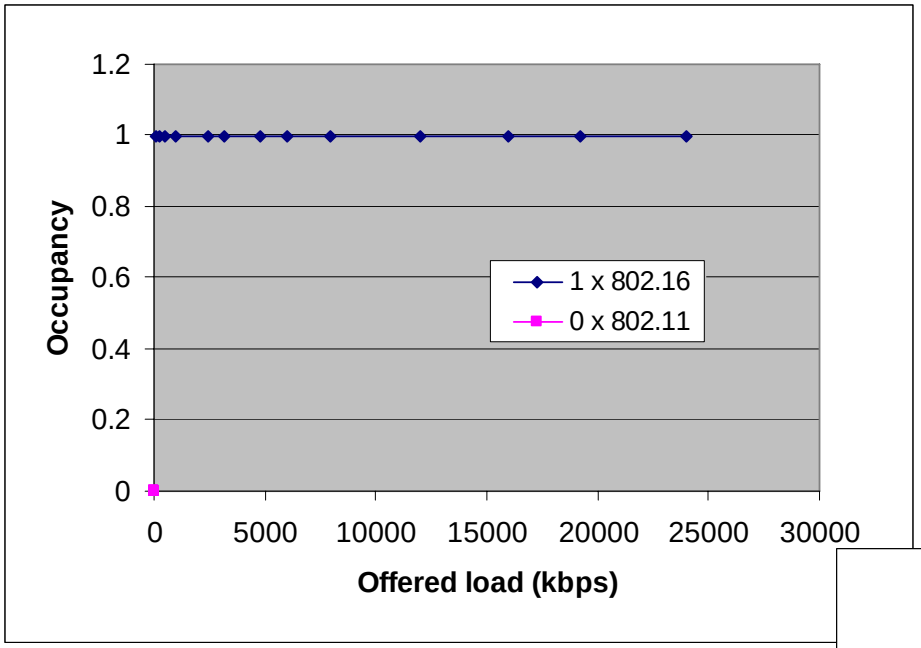
Simulation Scenarios

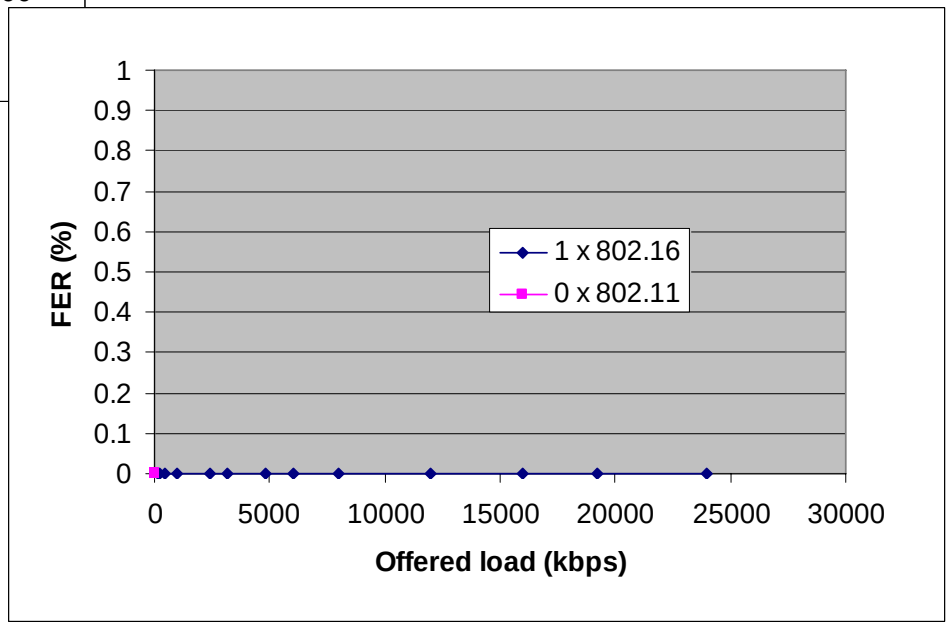


Why is channel occupancy a good metric for analysis?

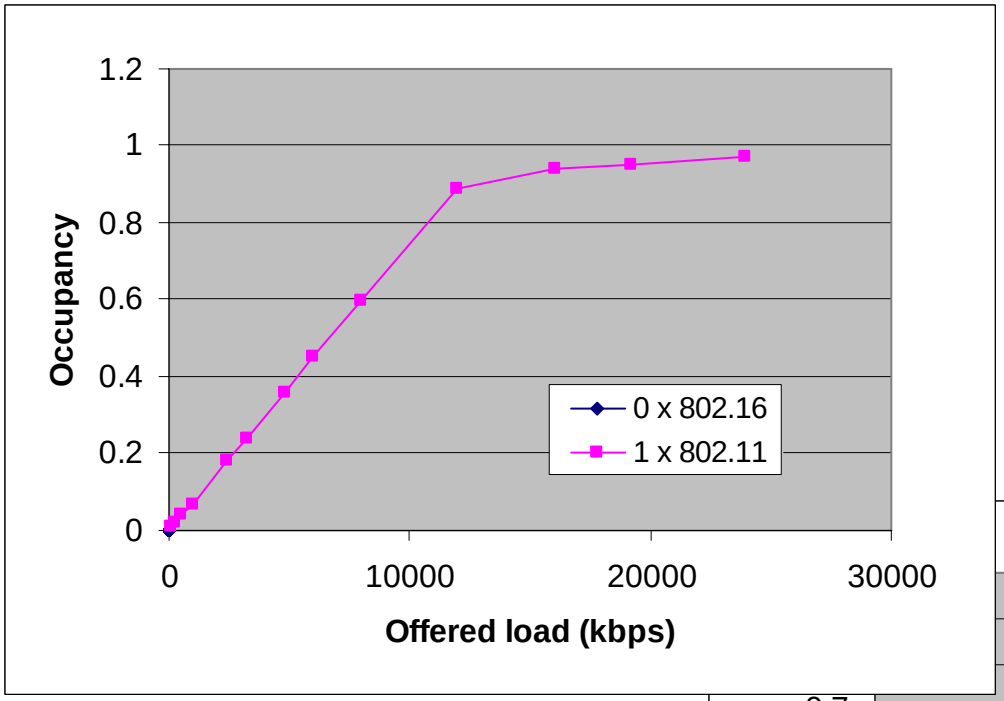
MAC level fairness: At THE MAC level, the amount of time that a system is radiating energy on the channel, including overhead, ACKs, CTS, whatever, is assumed to be “good use of the channel”. Systems shouldn’t be penalized because they are inherently more “good” in their use of the channel. For instance, if the MAC level simulation shows equal opportunity to transmit, yet one system gets higher throughput and better access latency, that’s just because that particular system is inherently more efficient.

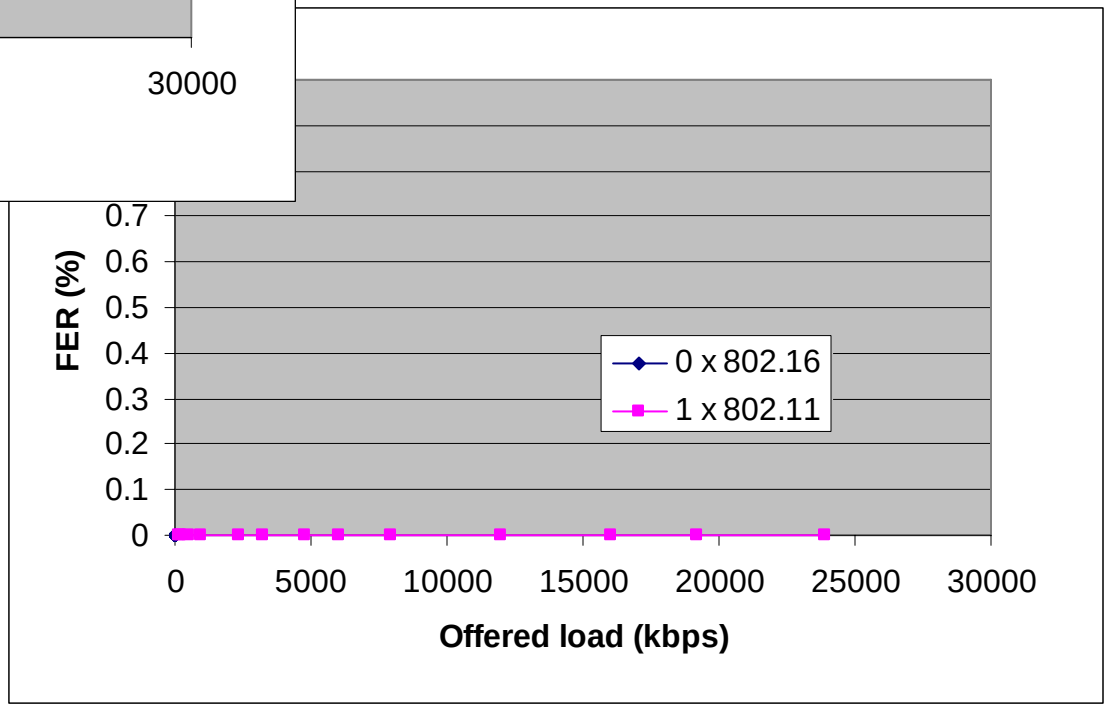
Scenario A


1.2
1
0.8
0.6
0.4
0.2
0
Occupancy
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
1 x 802.16
0 x 802.11

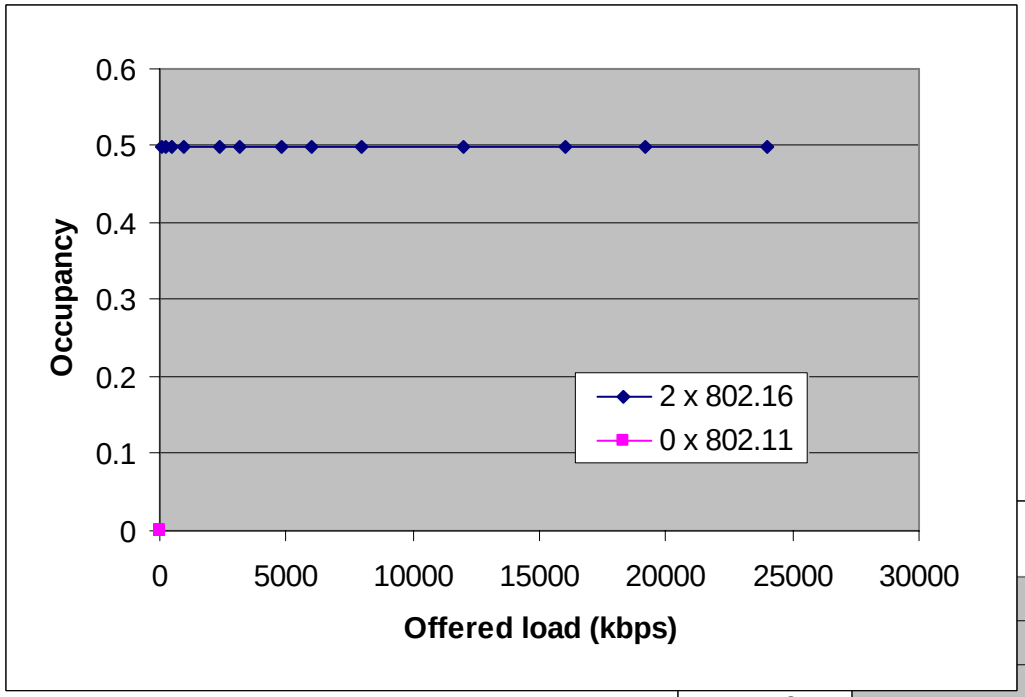

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
FER (%)
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
1 x 802.16
0 x 802.11

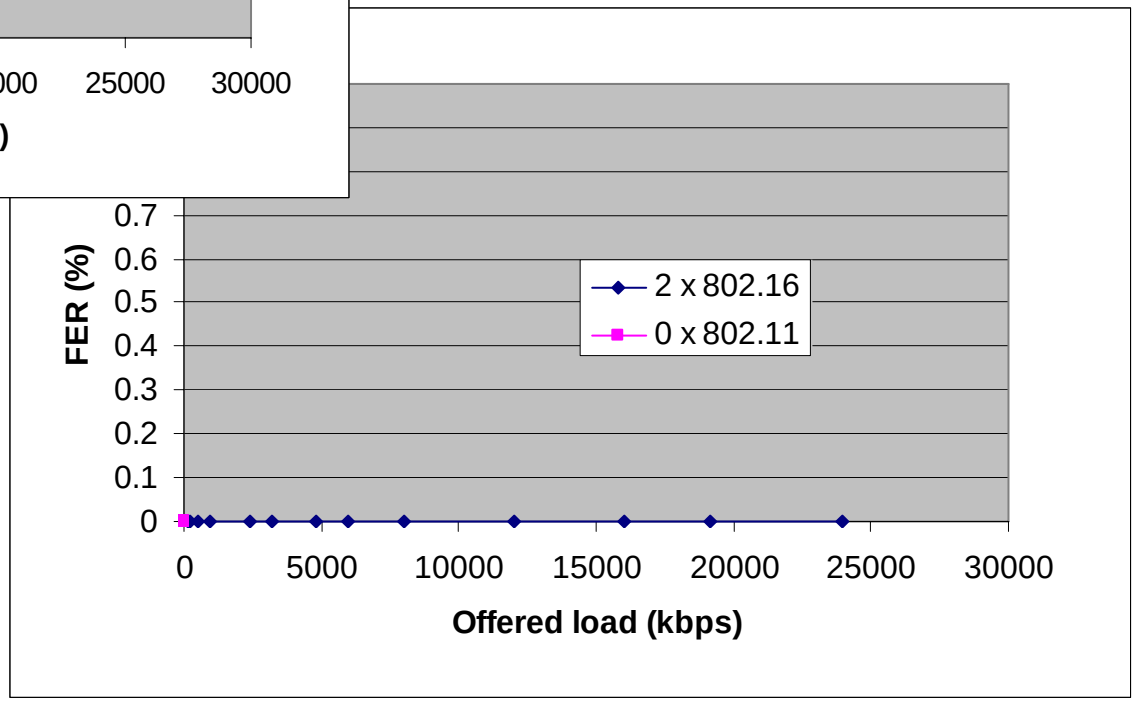
Scenario B


1.2
1
0.8
0.6
0.4
0.2
0
Occupancy
0
10000
20000
30000
Offered load (kbps)
0 x 802.16
1 x 802.11

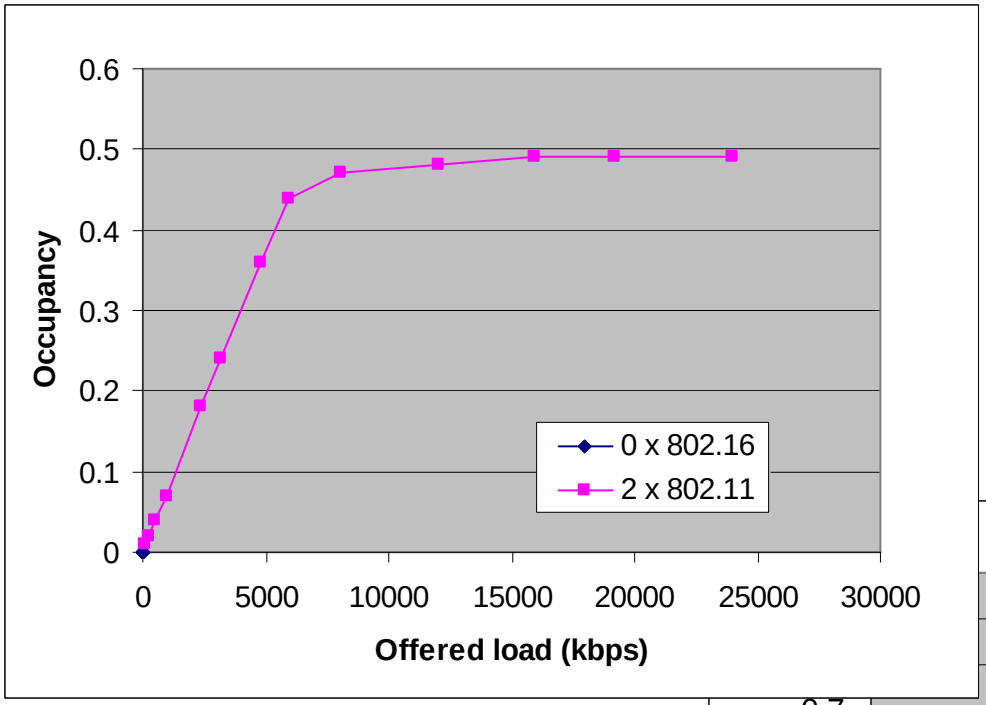

0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
FER (%)
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
0 x 802.16
1 x 802.11

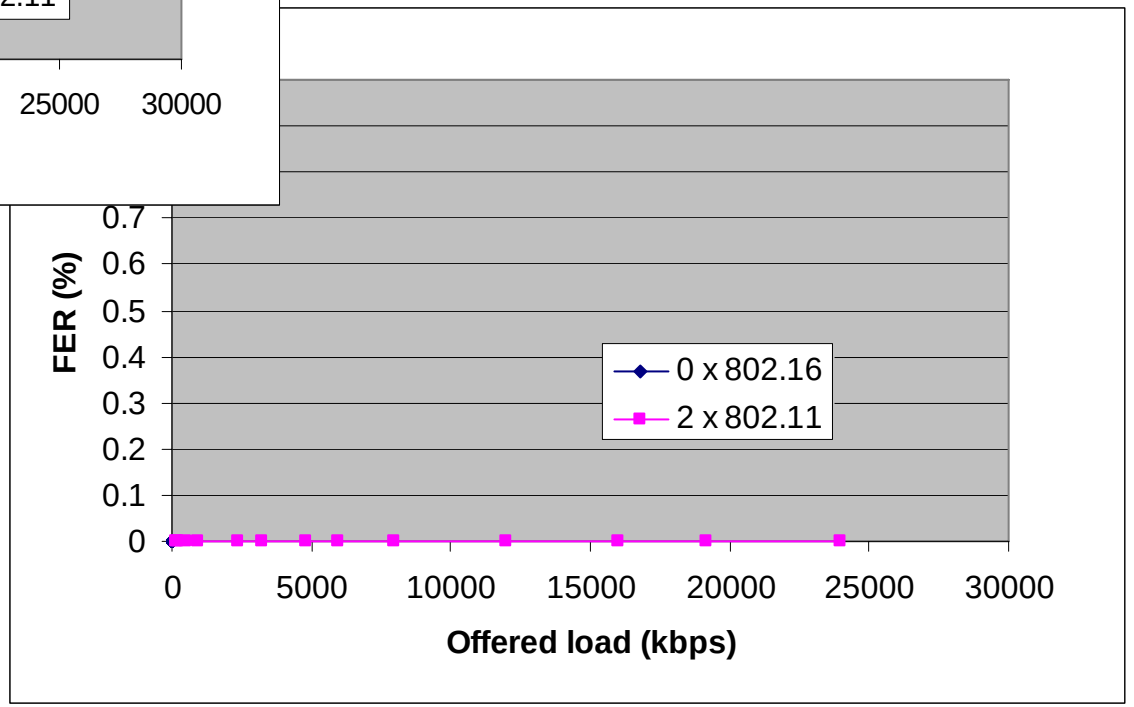
Scenario C


0.6
0.5
0.4
0.3
0.2
0.1
0
Occupancy
2 x 802.16
0 x 802.11
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)

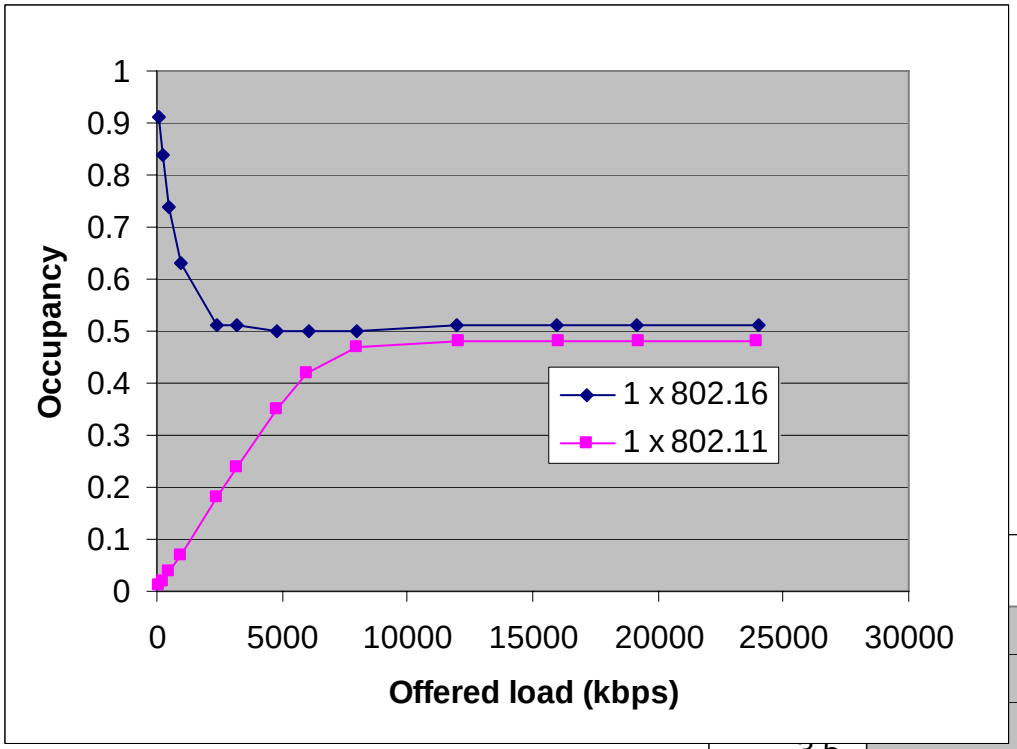

0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
FER (%)
2 x 802.16
0 x 802.11
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)

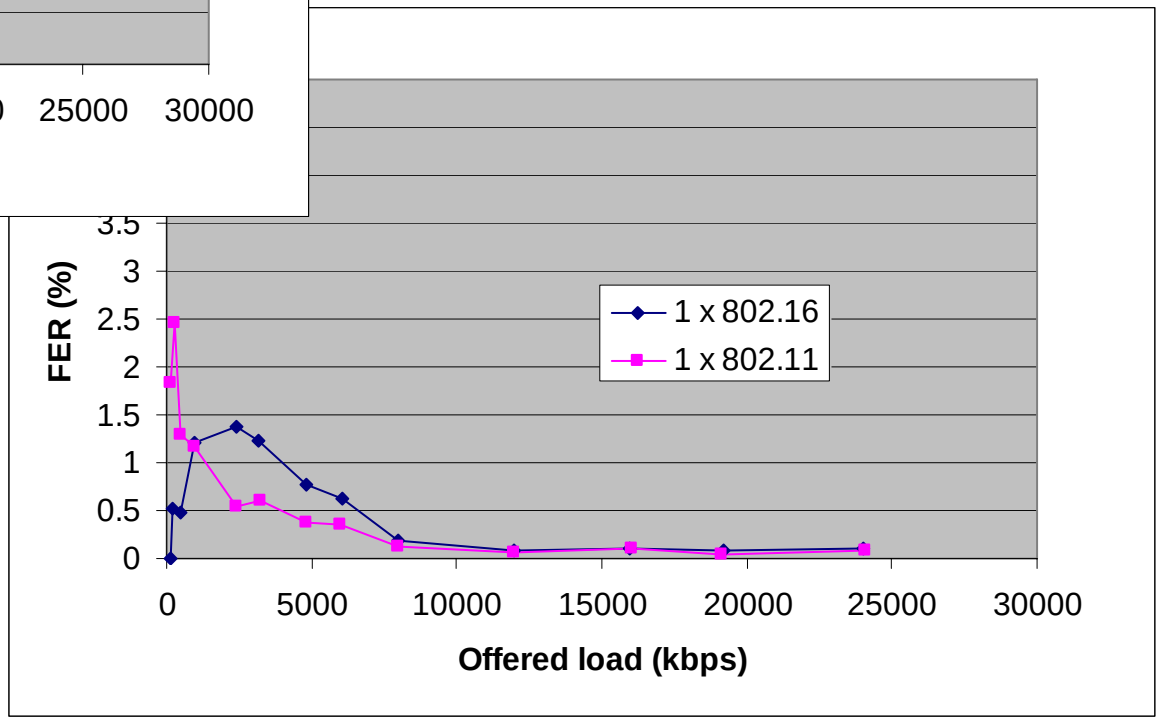
Scenario D


0.6
0.5
0.4
0.3
0.2
0.1
0
Occupancy
0 x 802.16
2 x 802.11
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)

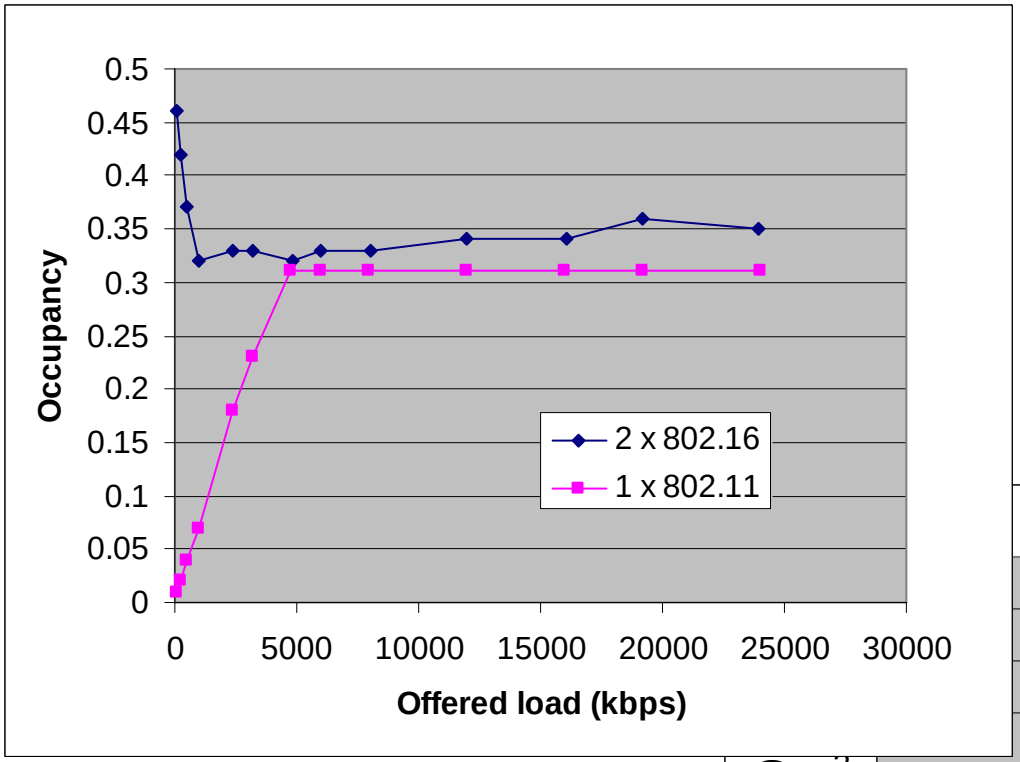

0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
FER (%)
0 x 802.16
2 x 802.11
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)

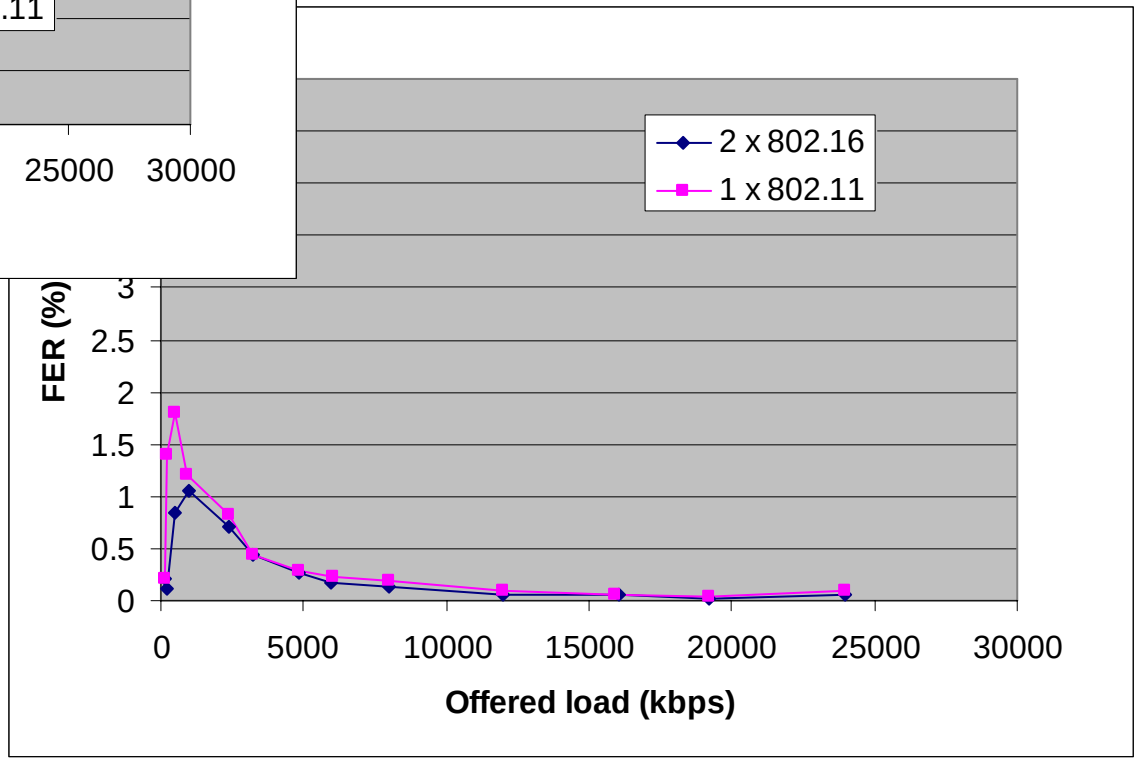
Scenario E


Occupancy
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
1 x 802.16
1 x 802.11

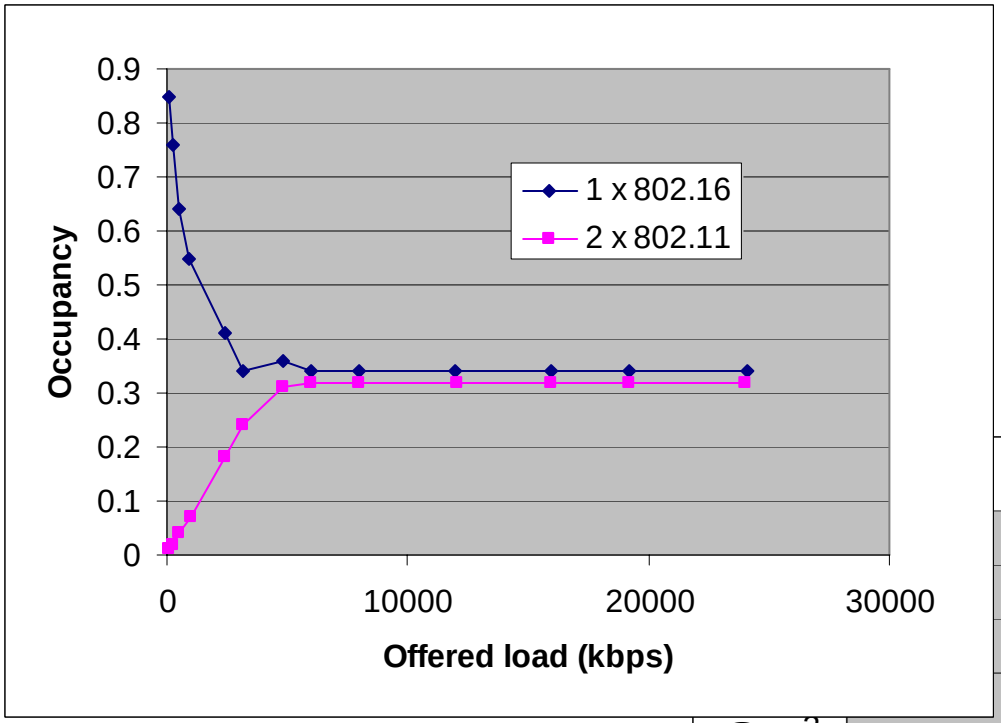

FER (%)
3.5
3
2.5
2
1.5
1
0.5
0
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
1 x 802.16
1 x 802.11

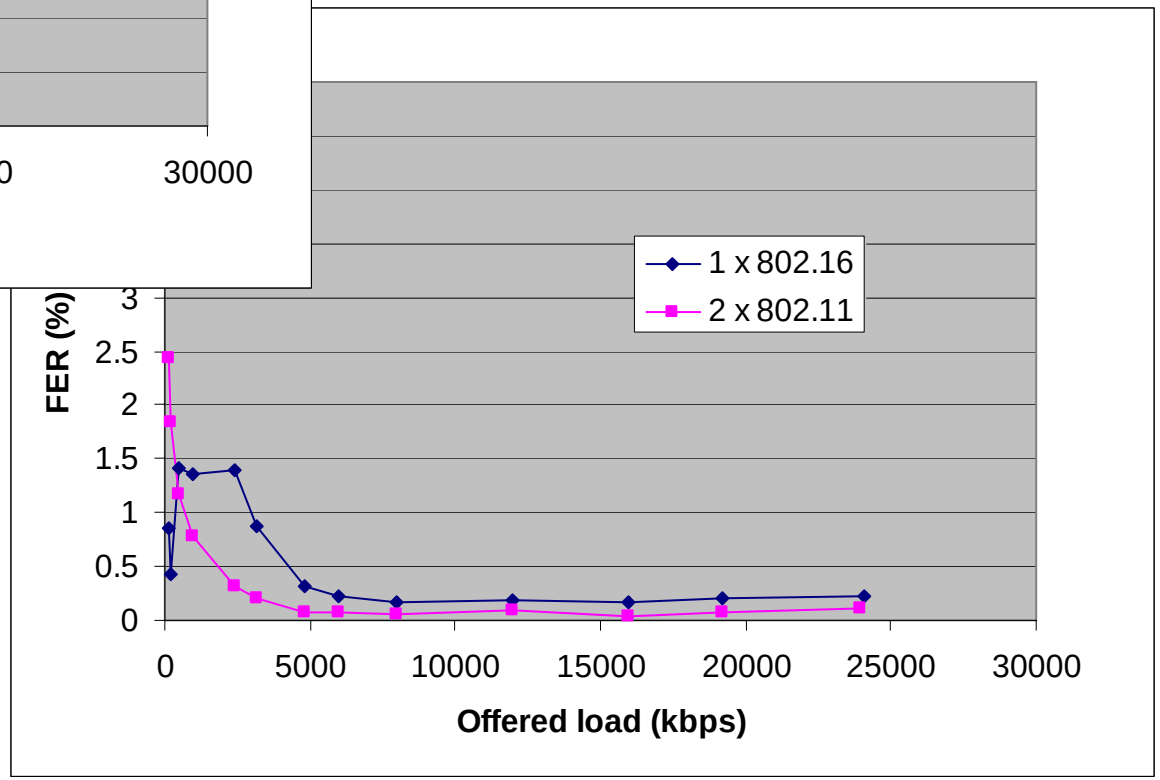
Scenario F


Occupancy
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
2 x 802.16
1 x 802.11

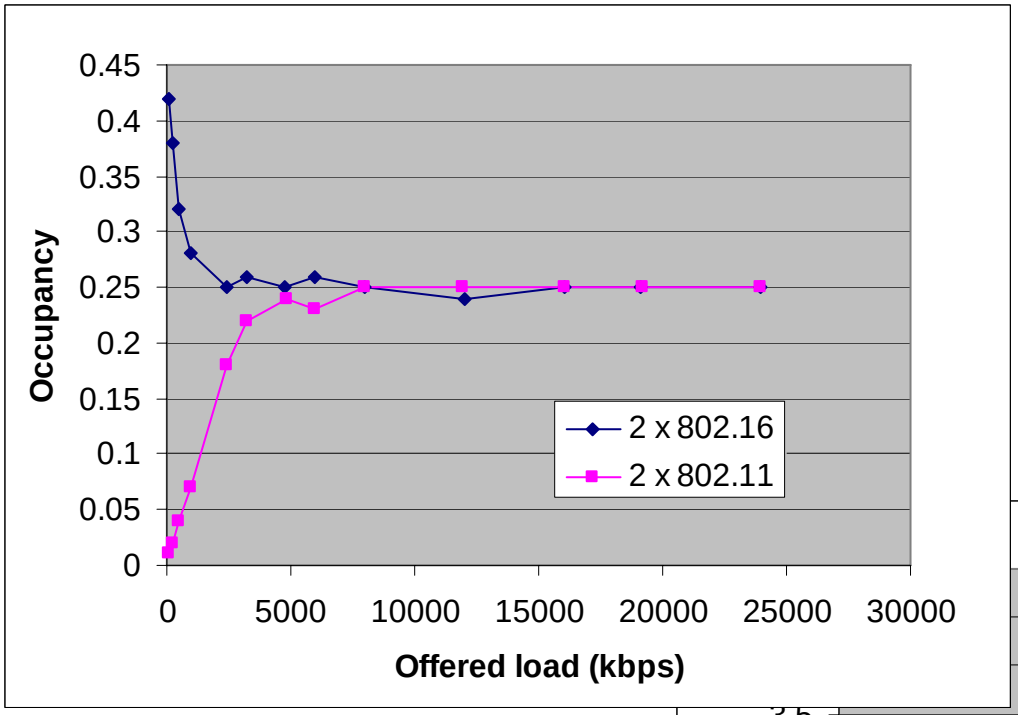

FER (%)
3
2.5
2
1.5
1
0.5
0
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
2 x 802.16
1 x 802.11

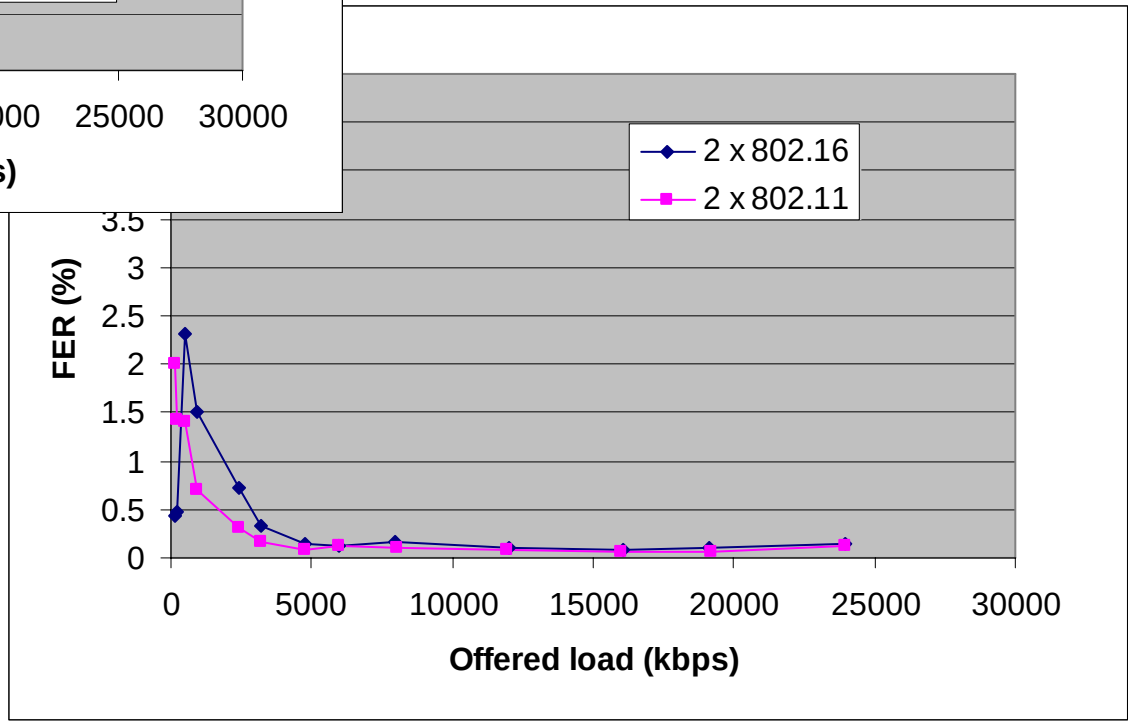
Scenario G


Occupancy
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10000
20000
30000
Offered load (kbps)
1 x 802.16
2 x 802.11

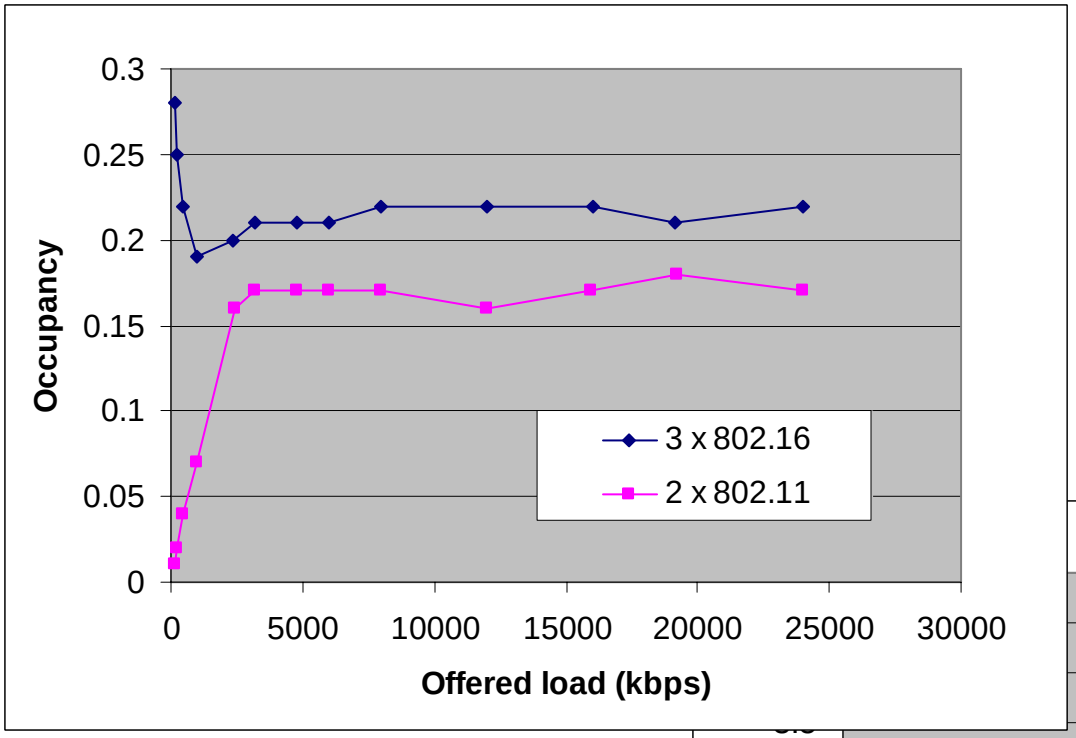

FER (%)
3
2.5
2
1.5
1
0.5
0
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
1 x 802.16
2 x 802.11

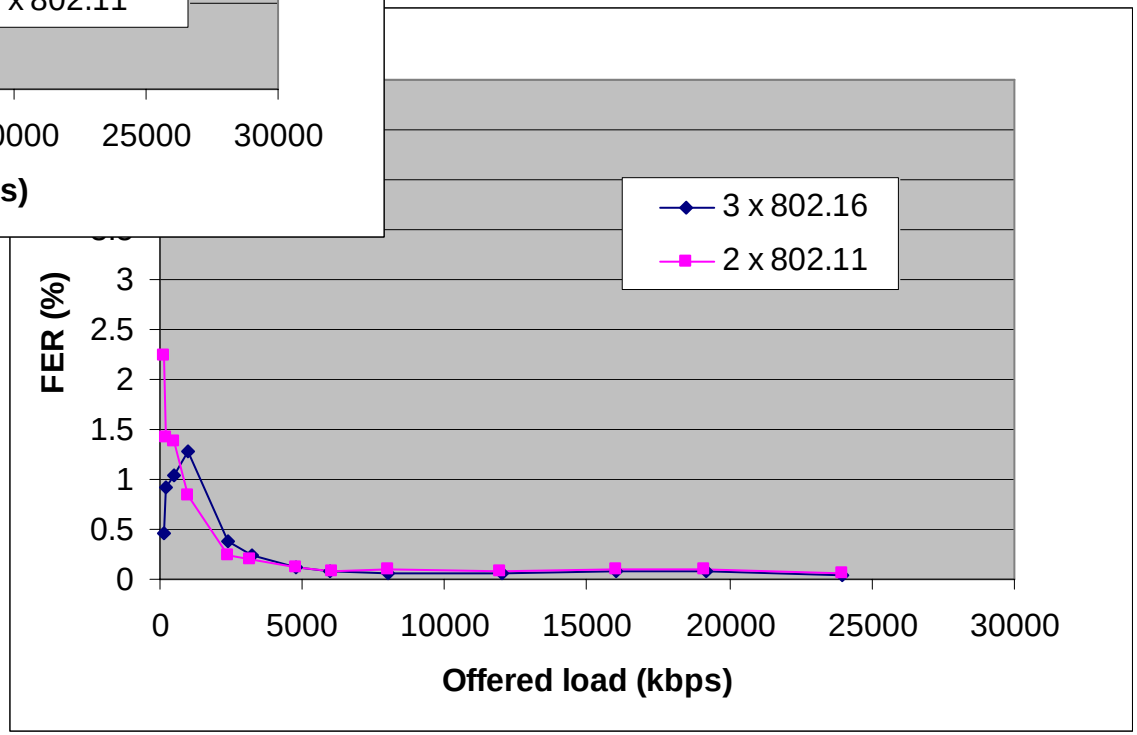
Scenario H


0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Occupancy
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
2 x 802.16
2 x 802.11

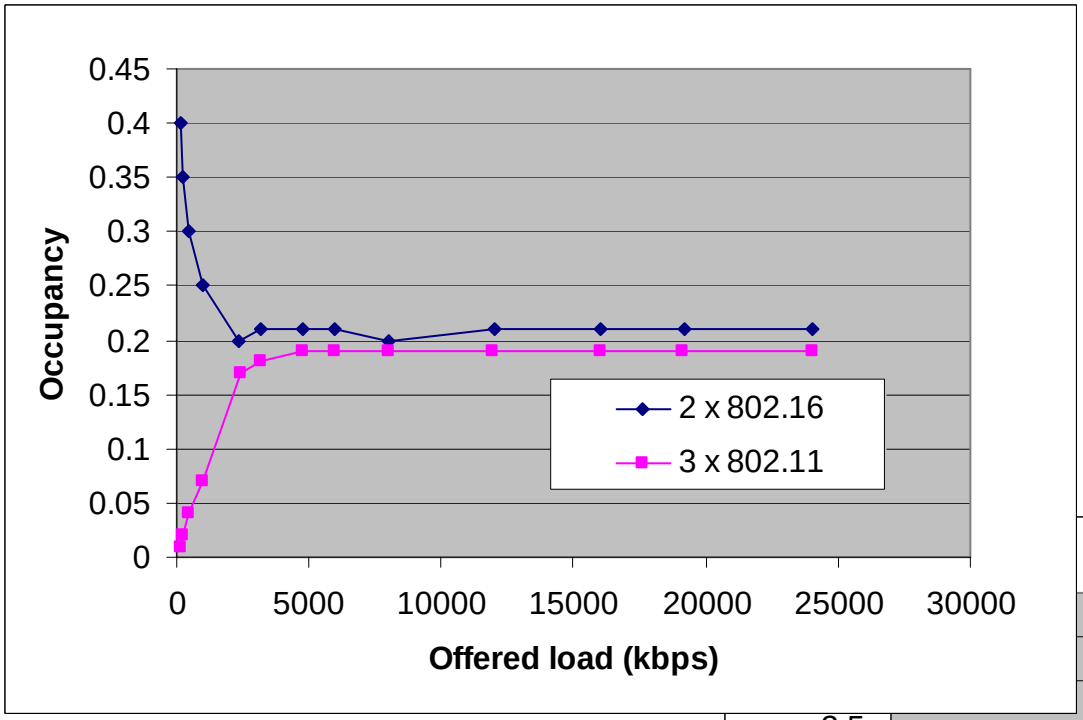

3.5
3
2.5
2
1.5
1
0.5
0
FER (%)
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
2 x 802.16
2 x 802.11

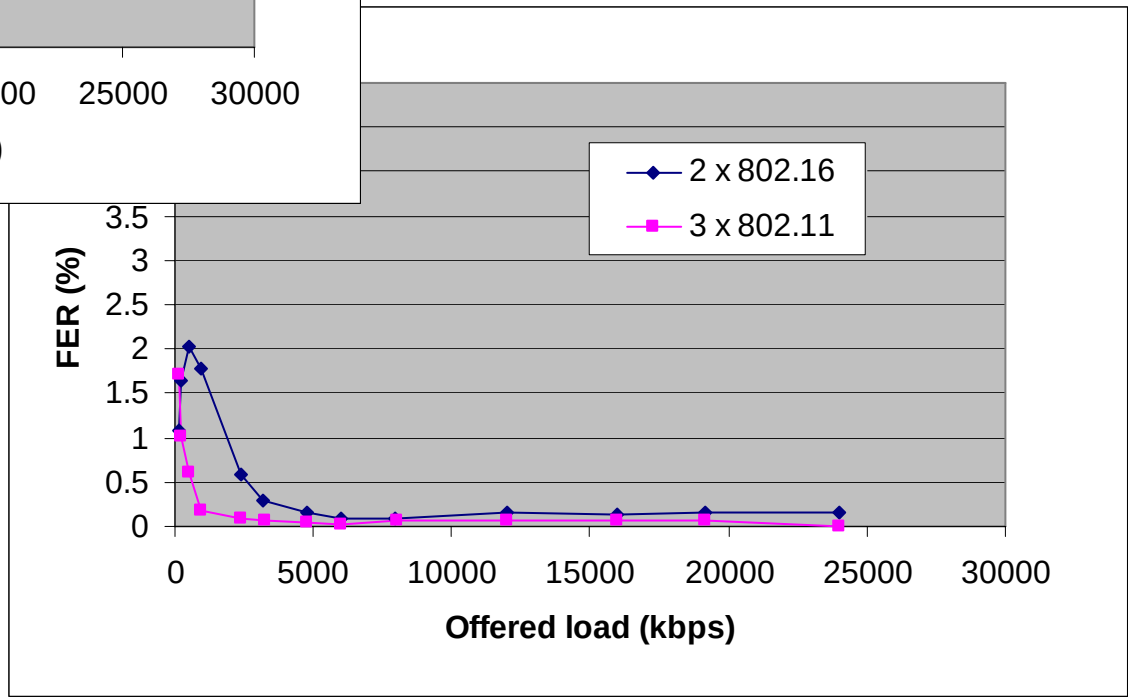
Scenario I


Occupancy
0.3
0.25
0.2
0.15
0.1
0.05
0
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
3 x 802.16
2 x 802.11

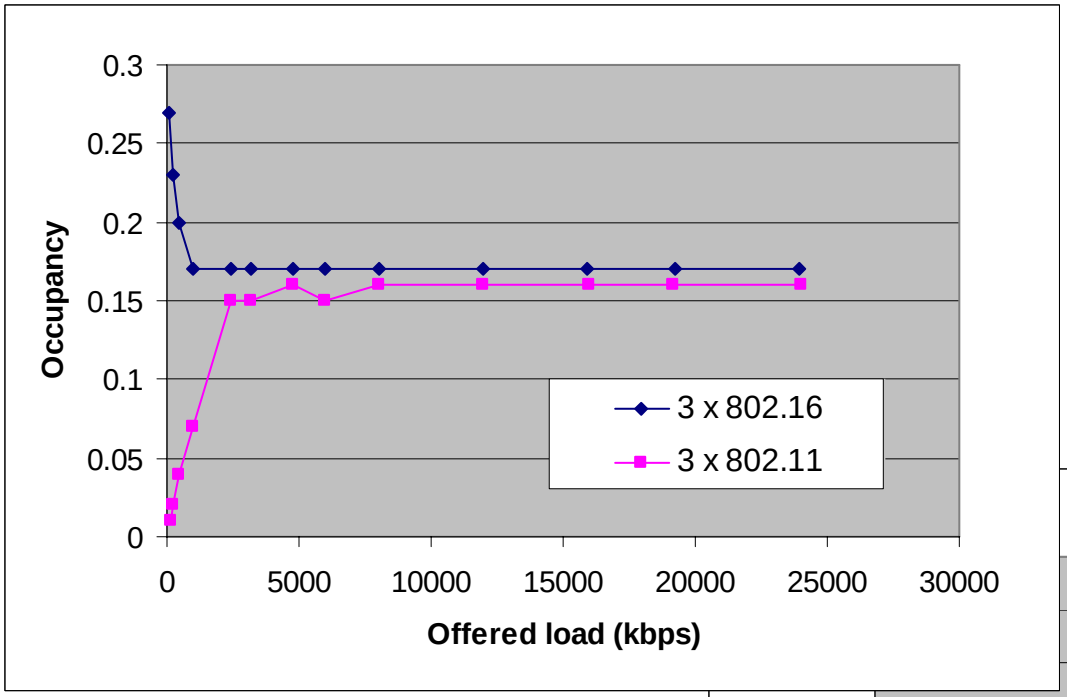

FER (%)
3
2.5
2
1.5
1
0.5
0
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
3 x 802.16
2 x 802.11

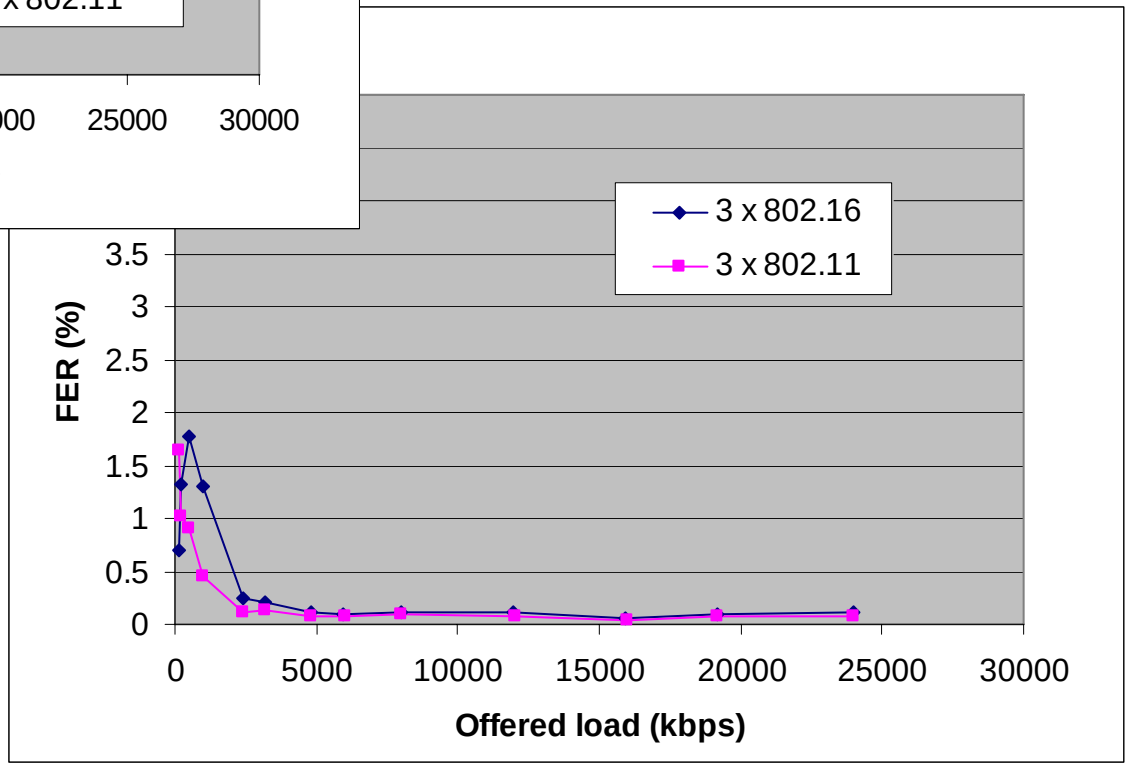
Scenario J


0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Occupancy
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
2 x 802.16
3 x 802.11

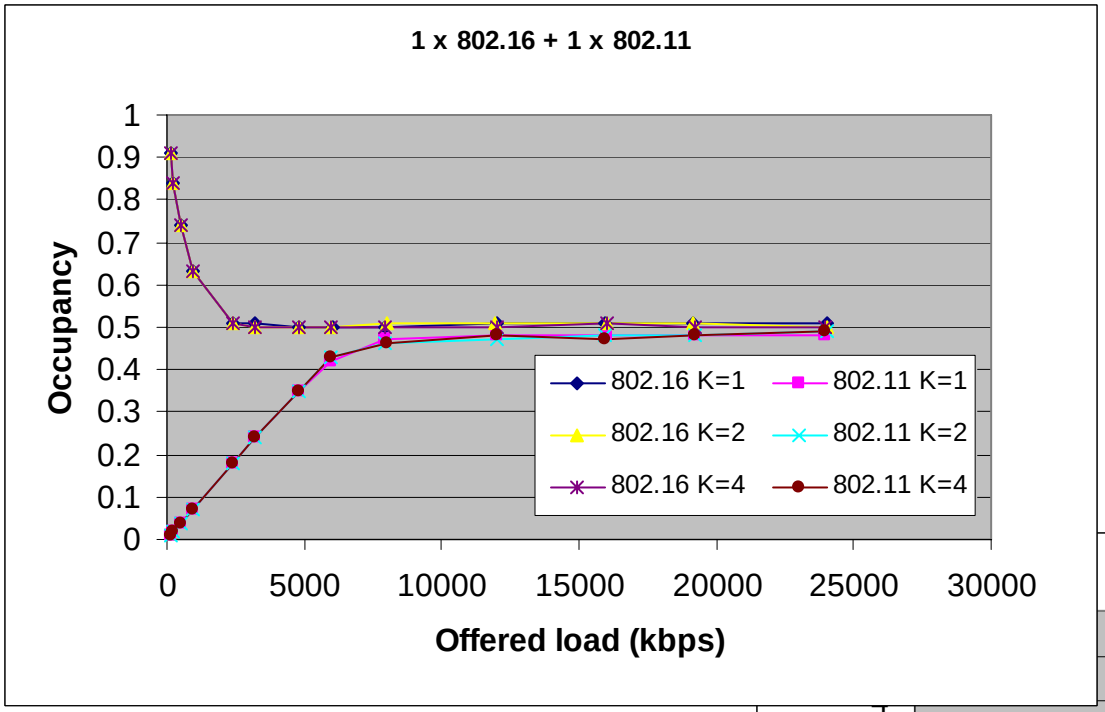

3.5
3
2.5
2
1.5
1
0.5
0
FER (%)
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
2 x 802.16
3 x 802.11

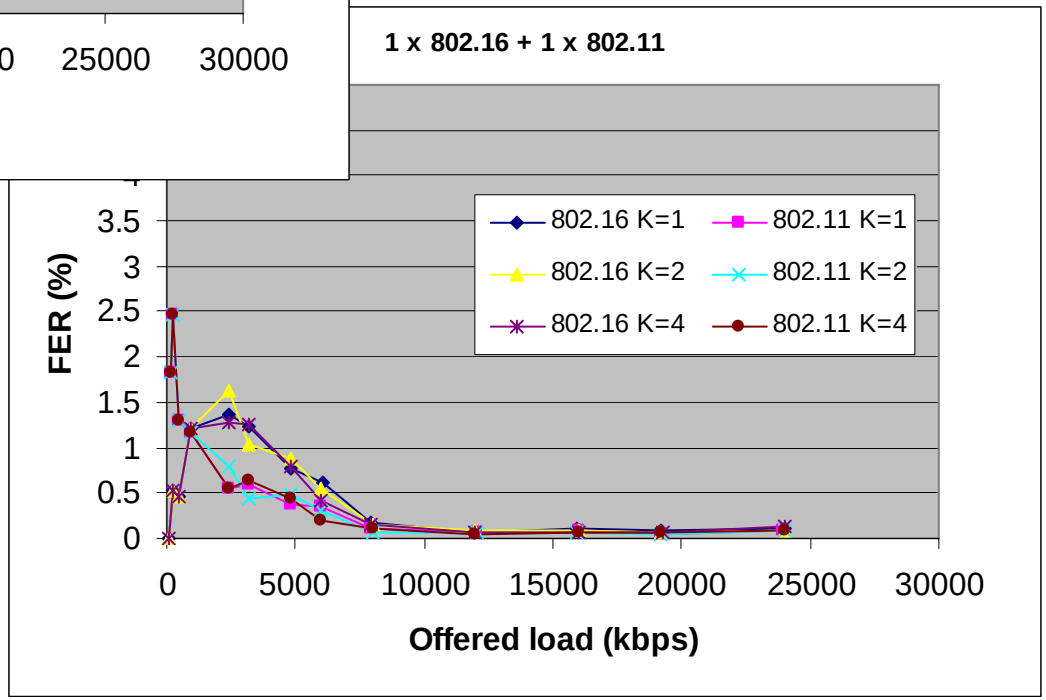
Scenario K


0.3
0.25
0.2
0.15
0.1
0.05
0
Occupancy
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
3 x 802.16
3 x 802.11

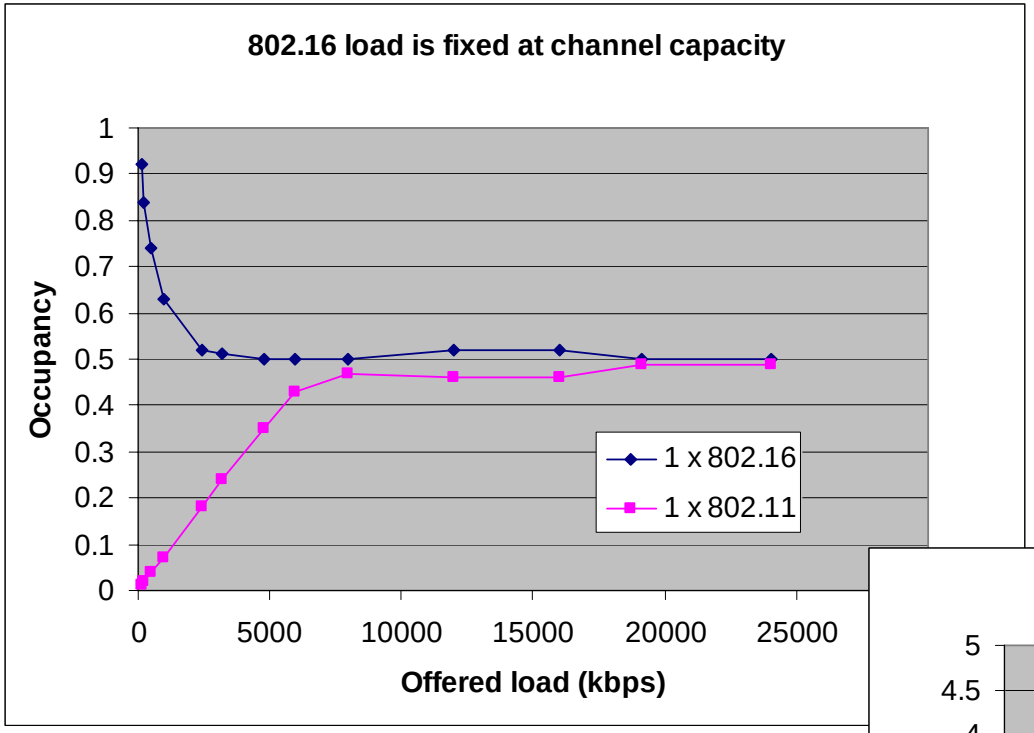

3.5
3
2.5
2
1.5
1
0.5
0
FER (%)
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
3 x 802.16
3 x 802.11

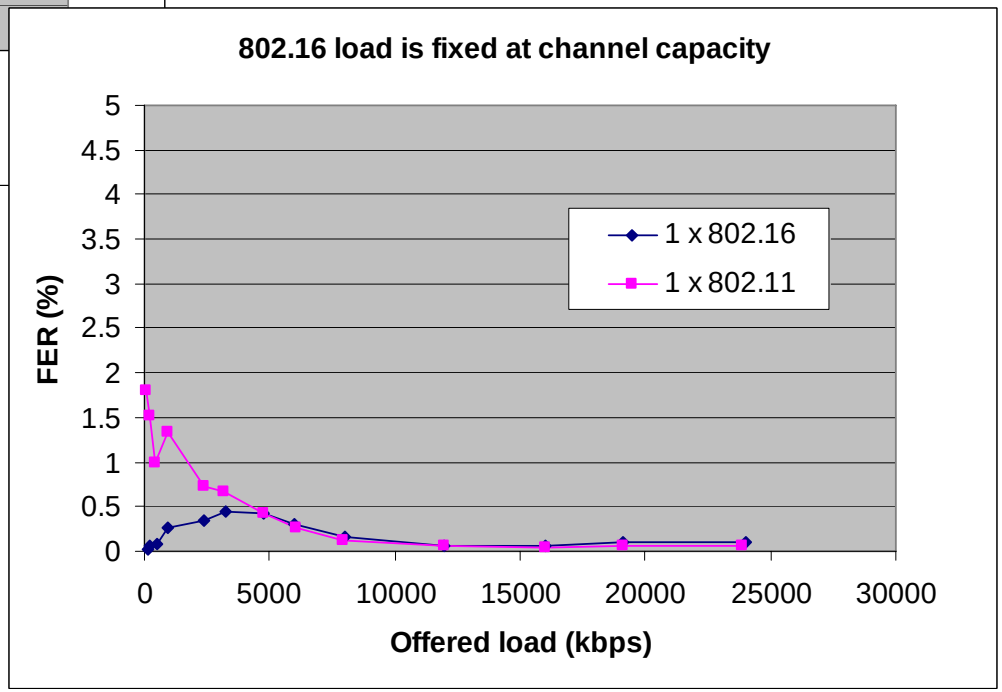
Scenario A, L, M *Sensitivity to K factor*



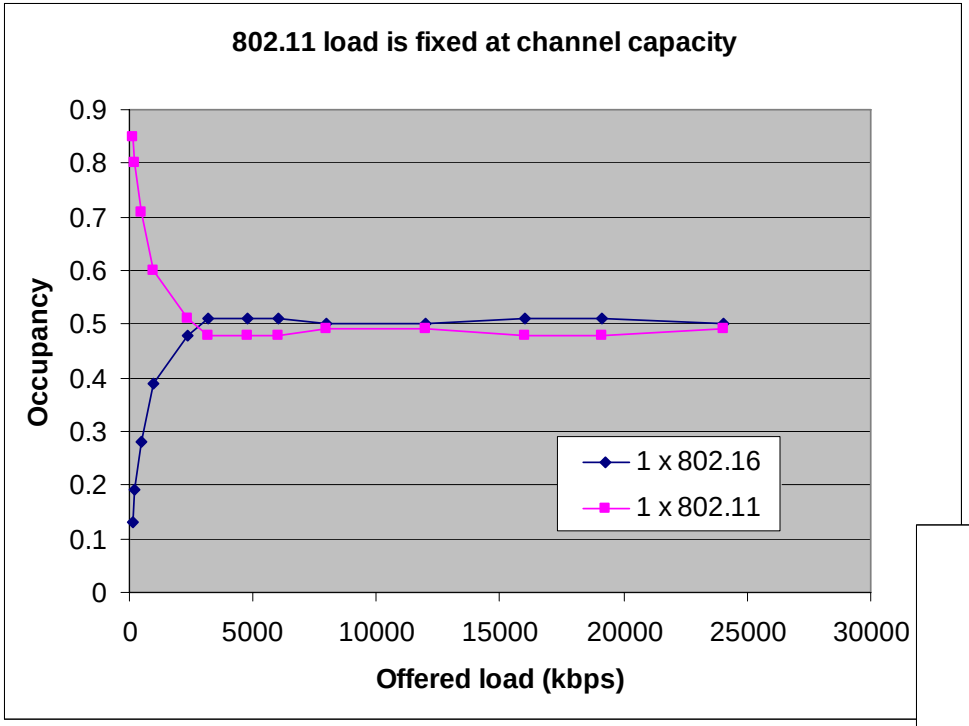


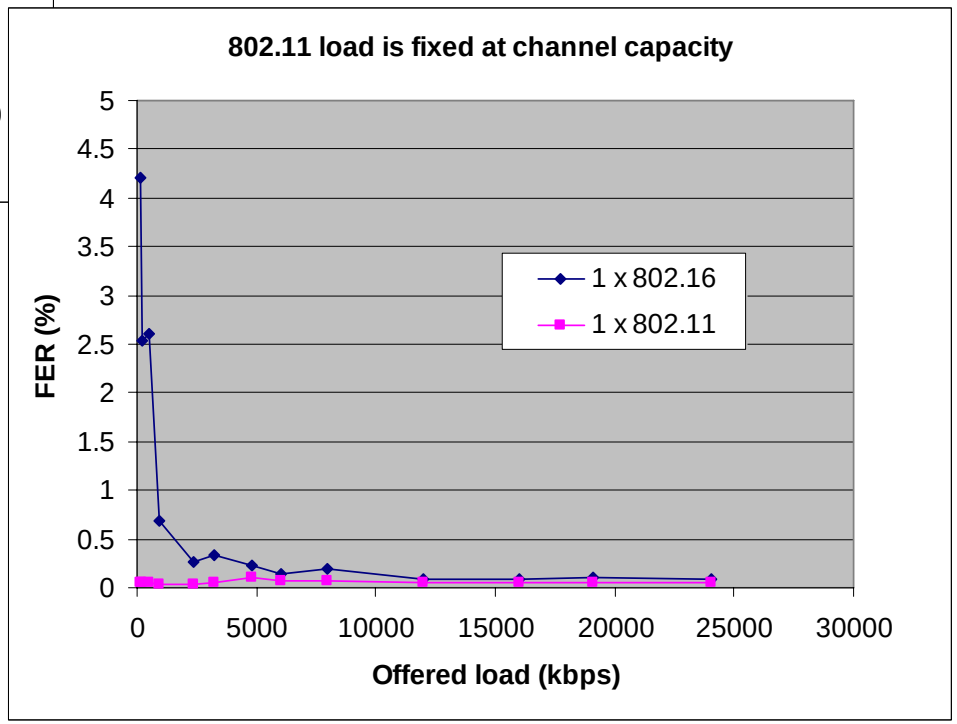
Scenario N


802.16 load is fixed at channel capacity
Occupancy
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5000
10000
15000
20000
25000
Offered load (kbps)
1 x 802.16
1 x 802.11


802.16 load is fixed at channel capacity
FER (%)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
1 x 802.16
1 x 802.11

Scenario O


802.11 load is fixed at channel capacity
Occupancy
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
1 x 802.16
1 x 802.11

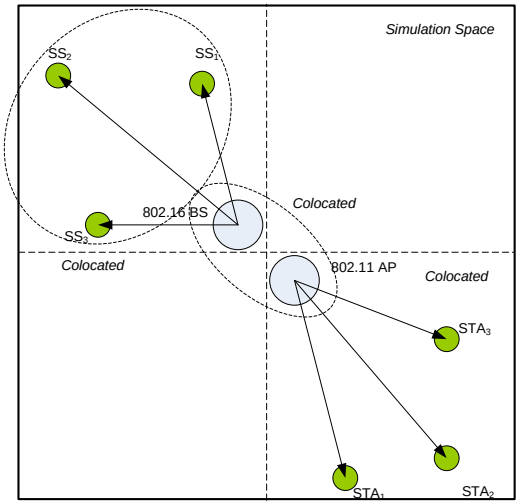

802.11 load is fixed at channel capacity
FER (%)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
5000
10000
15000
20000
25000
30000
Offered load (kbps)
1 x 802.16
1 x 802.11

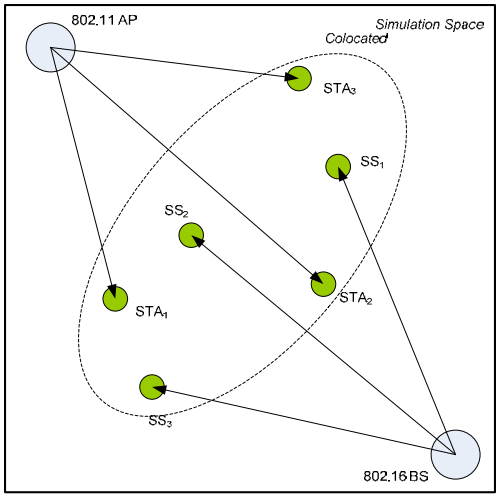
Interim conclusions

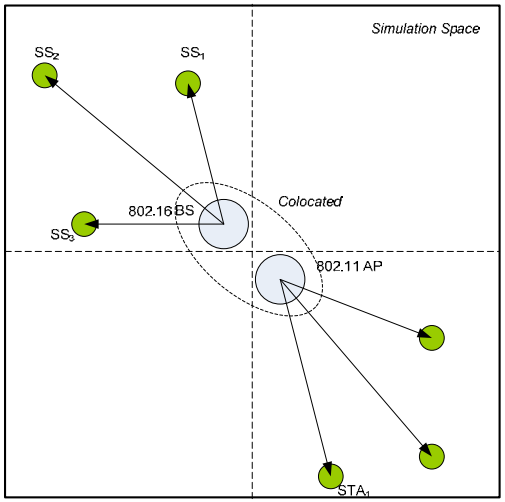
The conclusions to be drawn from the simulation results presented are thus:

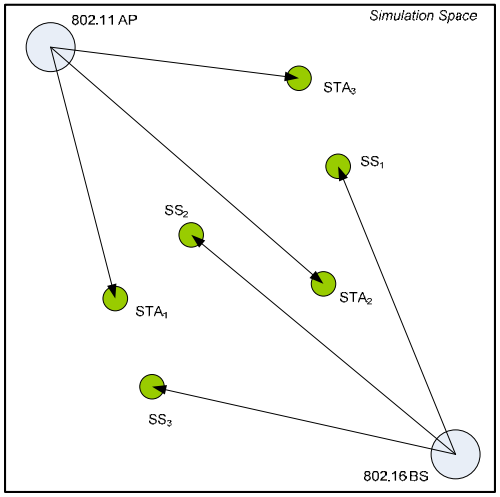
- Equitable system sharing is achieved with the cited enhancements to LBT.
- Sharing is achieved with a demonstrably low FER.
- For this specific simulation configuration the sensitivity of *channel occupancy* to *K* factor is low.
- Concerning scenarios N and O:
  - Scenario N shows that for the case where 802.16 has high loading then 802.16 demonstrates high occupancy for the case where 802.11 loading is low. As the 802.11 load increases then fair sharing is demonstrated.
  - Scenario O shows high occupancy of 802.11 where its loading is high, and where 802.16 loading is low. This is for the case where the loading scenario is reversed to that given in scenario N. Again this shows fair sharing for the case where high loading is apparent for both systems.

Extending analysis to spatially distributed scenarios

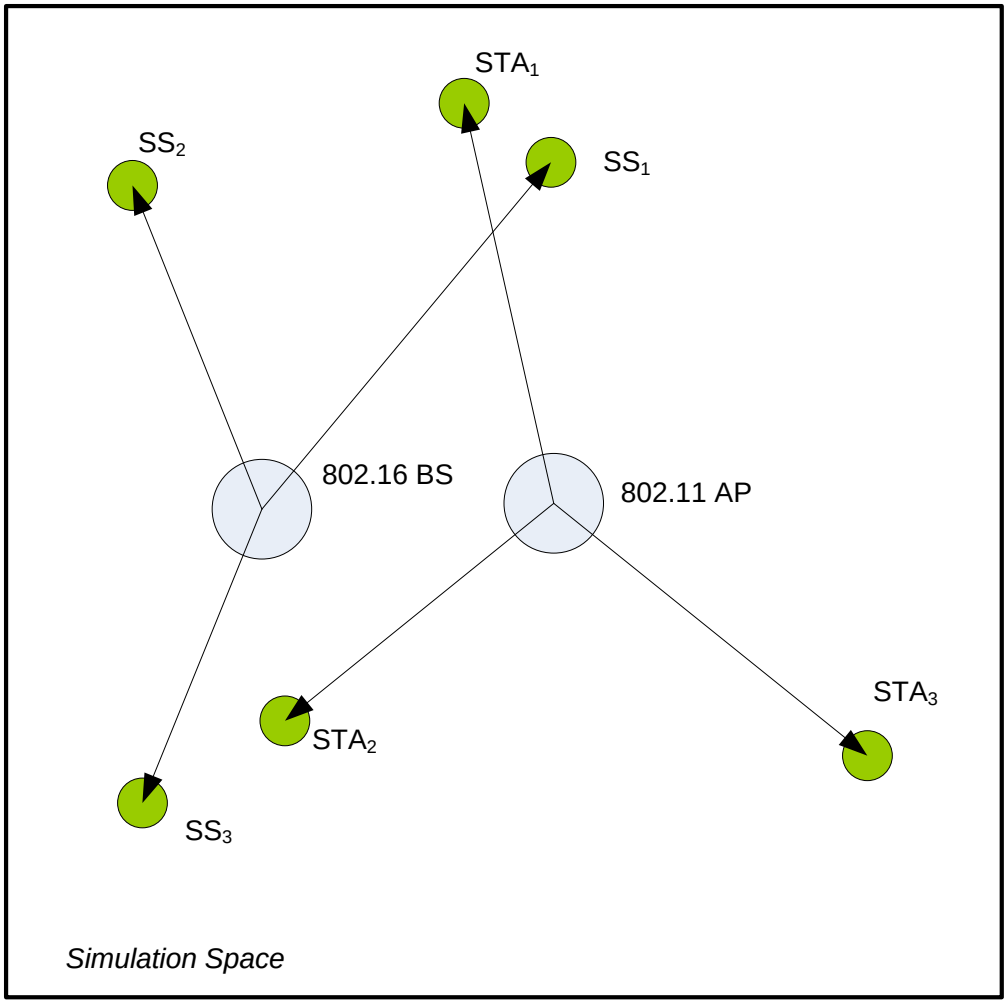




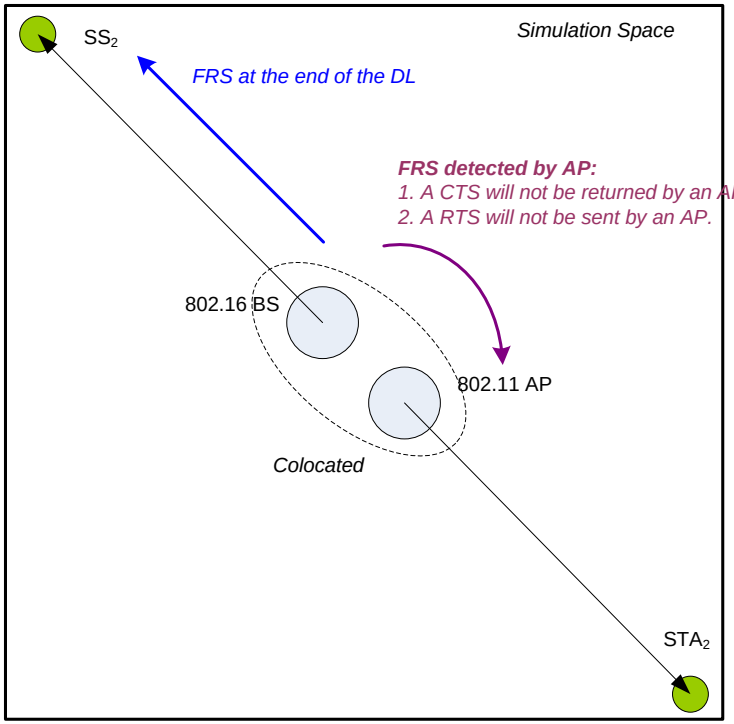


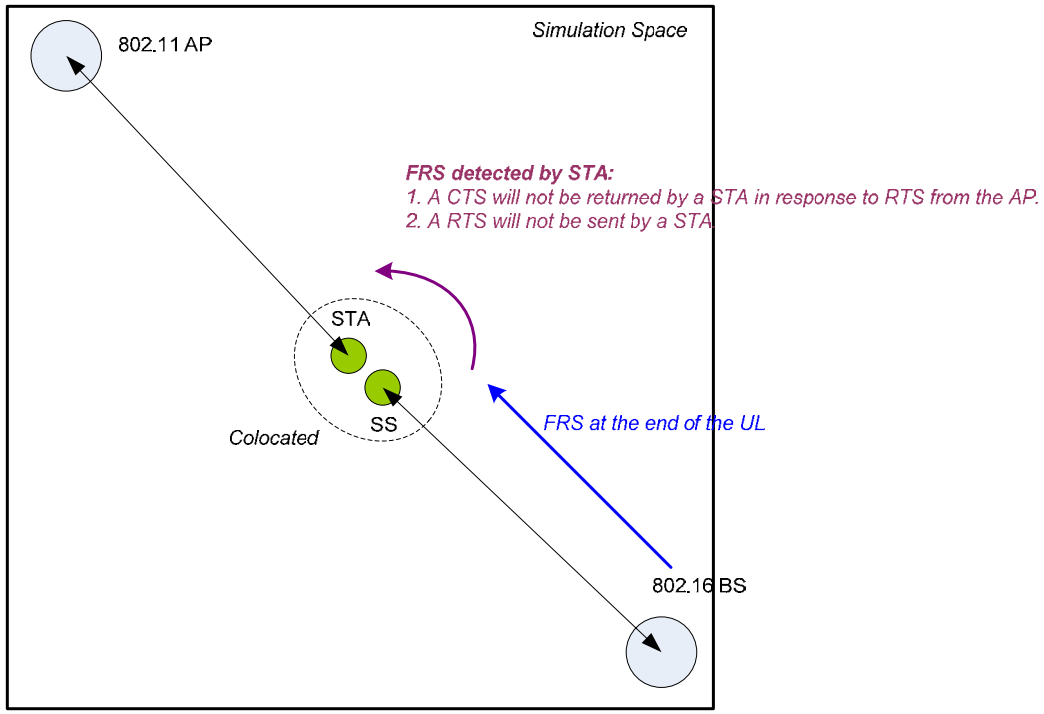


Extending analysis to spatially distributed scenarios



FRS (Frame Reservation Signal)

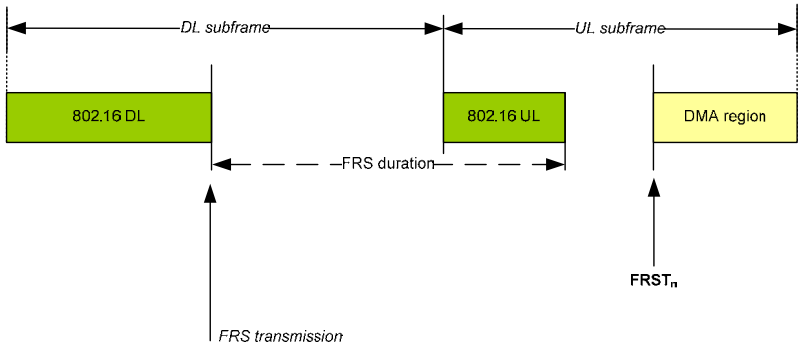




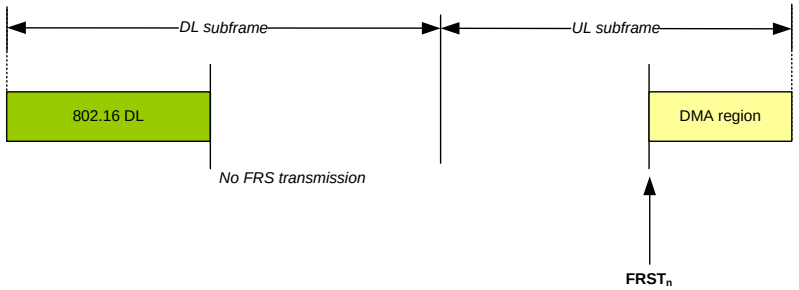
- FRS Transmission capability
- CTS Reception capability
- UL Map relevance – modified due to the usage of an FRS (Frame Reservation Signal)

802.16 FRS transmission strategy

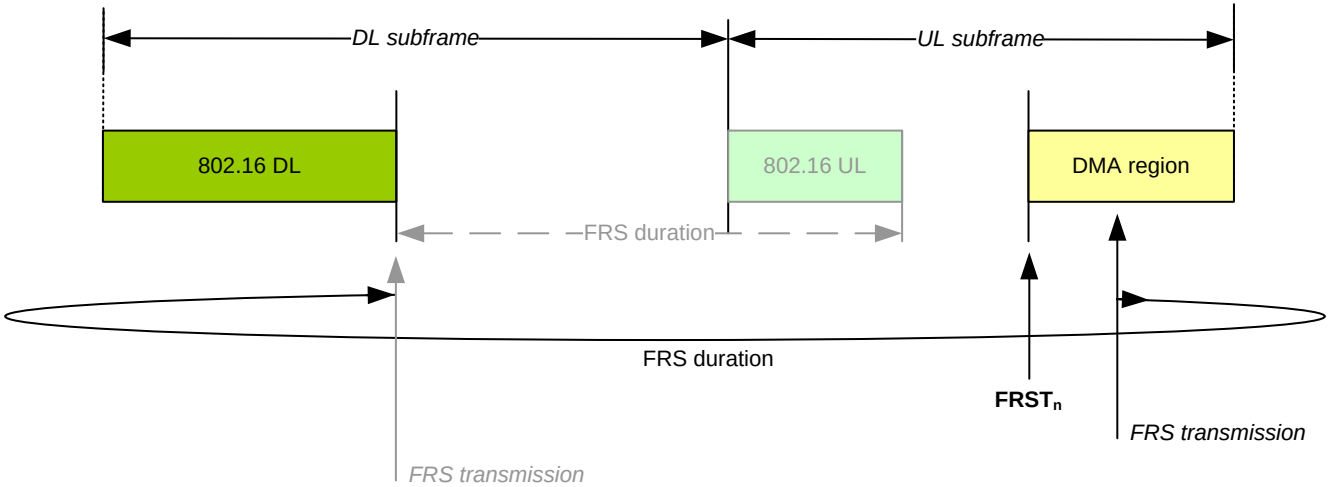
FRS transmission in the DL subframe protecting the UL transmission



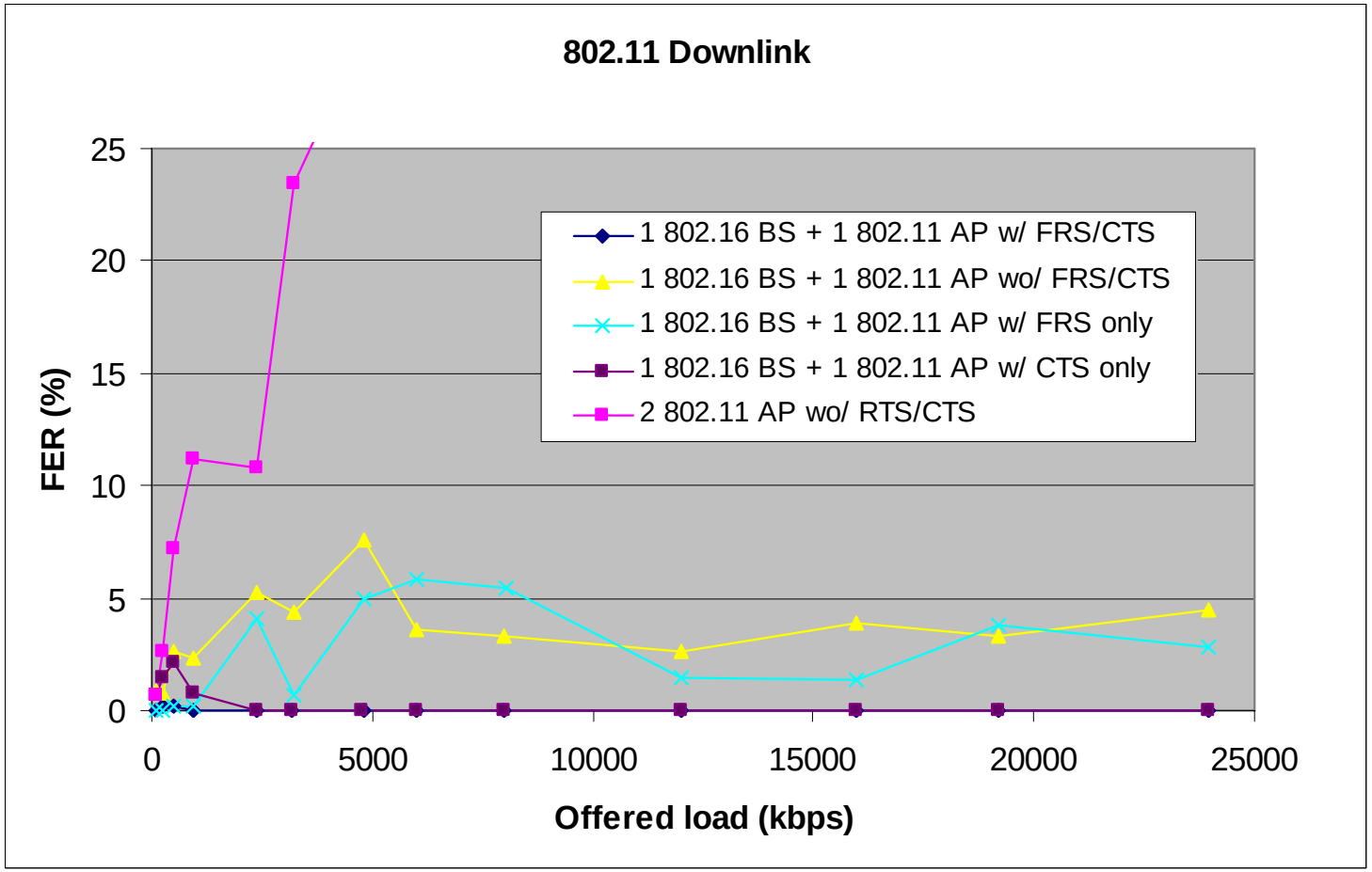
FRS not transmitted in the DL subframe due to no UL transmission



FRS transmission in the UL subframe protecting the following frame as claimed by DMA algorithm

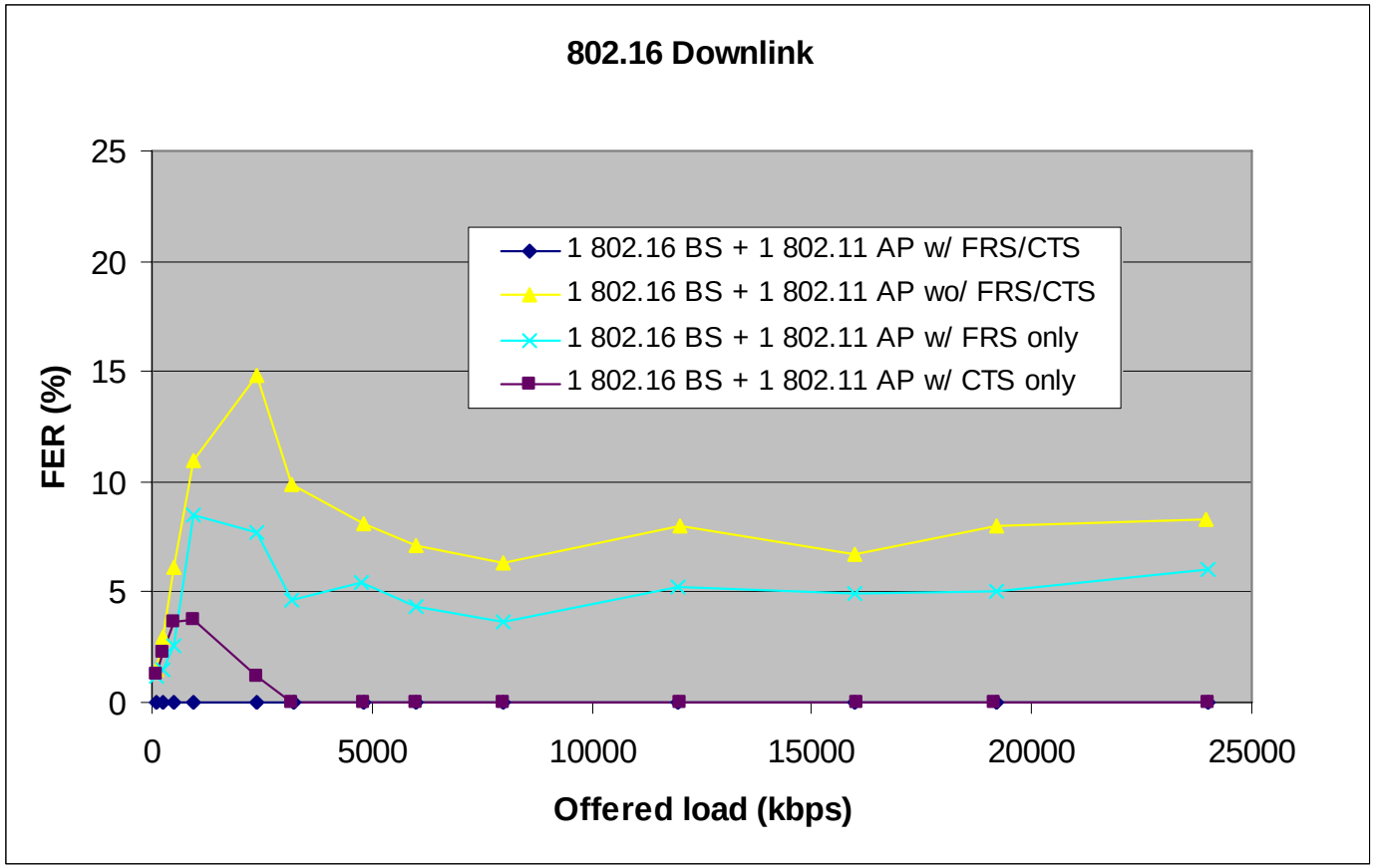


Spatially distributed scenarios

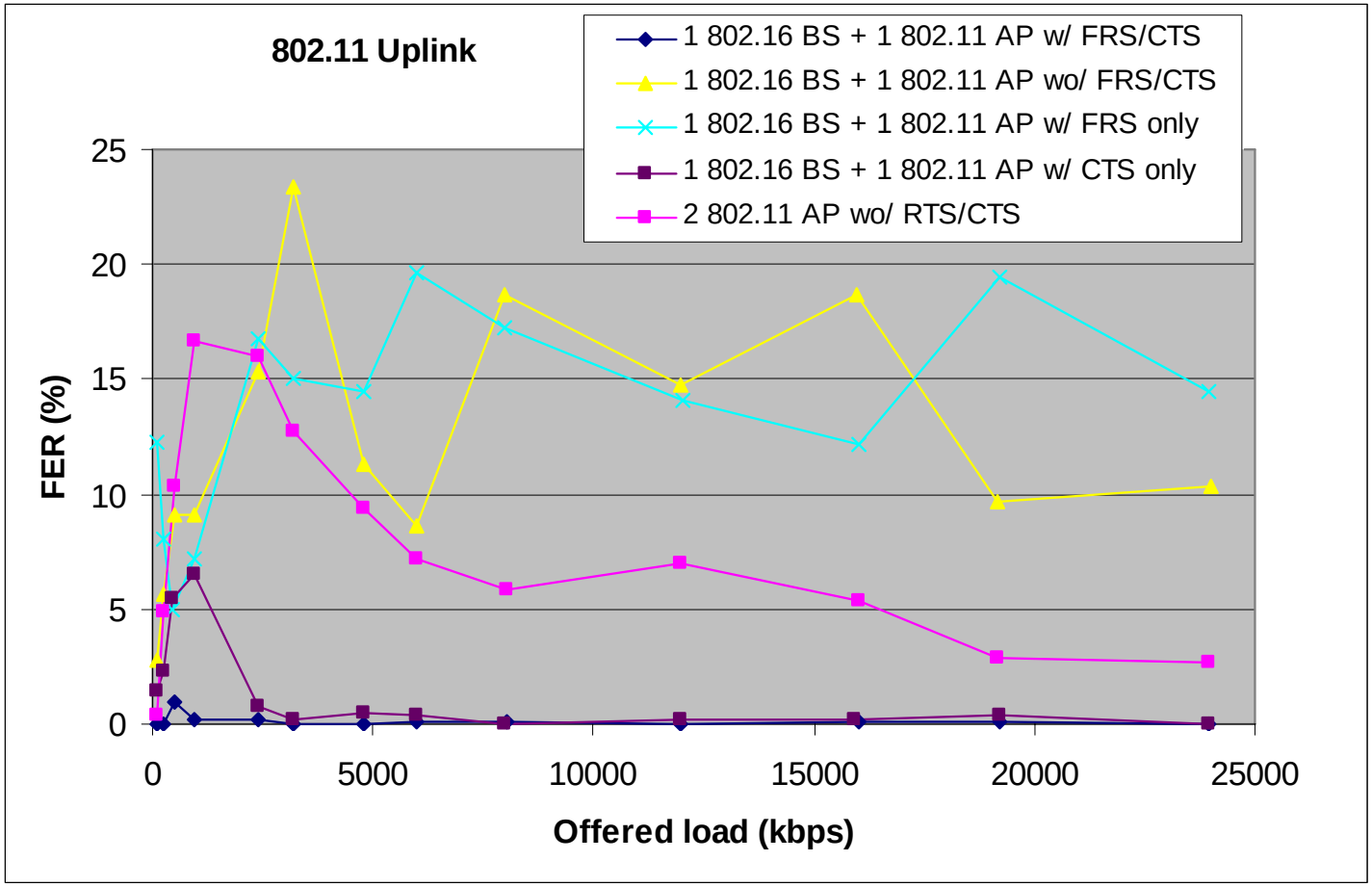


- *'FRS only' – FRS transmission capability by 802.16*
- *'CTS only' – CTS reception capability by 802.16*

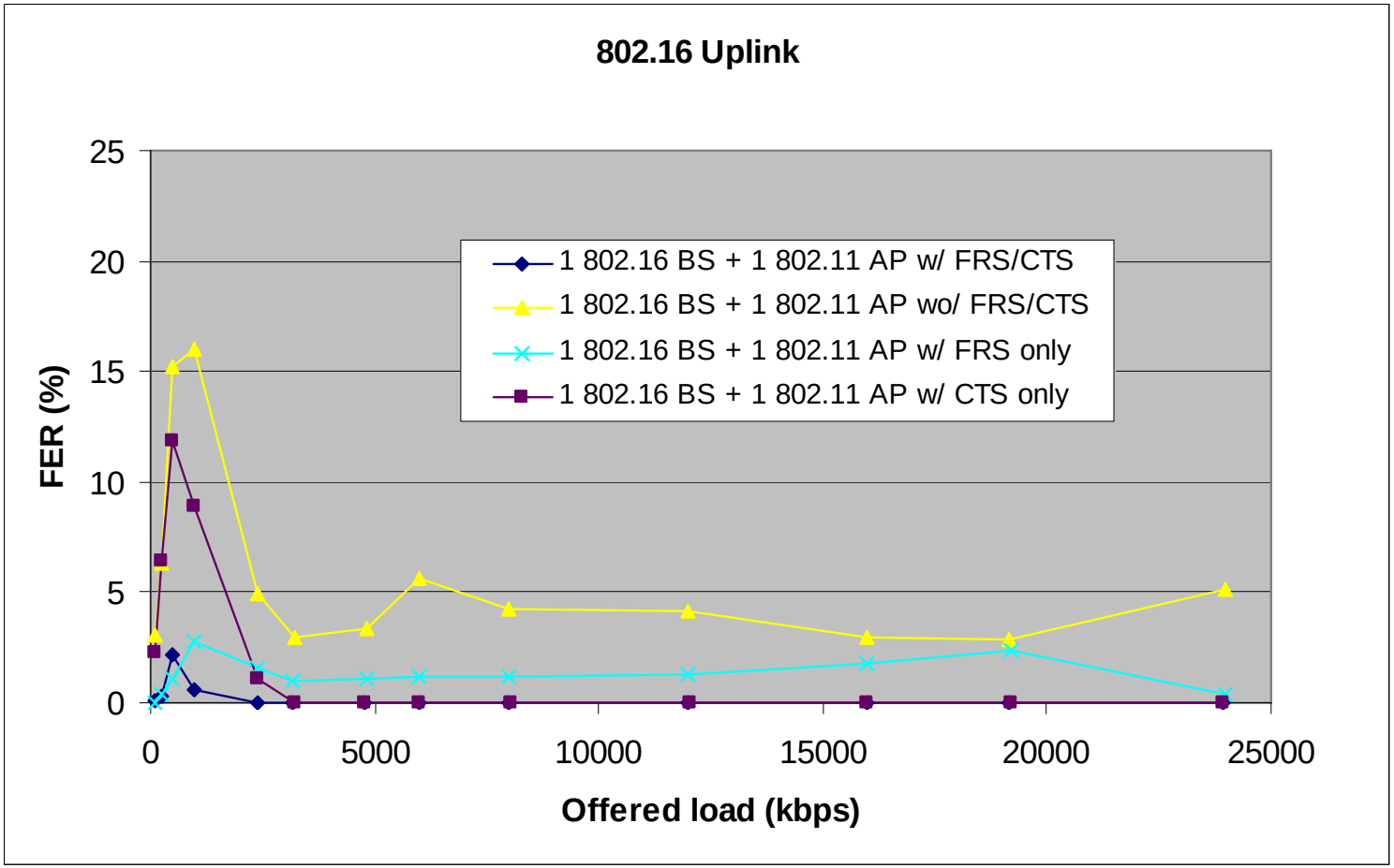
Spatially distributed scenarios (cont.)



Spatially distributed scenarios (cont.)



Spatially distributed scenarios (cont.)



Backup

References

[Ref 1] IEEE P802.16h/D2c: *Air Interface for Fixed Broadband Wireless Access Systems Improved Coexistence Mechanisms for License-Exempt Operation*, Draft Standard.

[Ref 2] Paul Piggin, *Parameters for simulation of Wireless Coexistence in the US 3.65GHz band*, IEEE 802.19-07/11r7, September 2007.