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Title	**Enhancements to UCP LBT: Supporting simulation results**	
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Re:	IEEE 802.16h-07/019 Task Group Review of P802.16h/D2c.	
Abstract	This document contains supporting simulation results for the UCP LBT feature enhancements as detailed in IEEE C802.16h-07/078.	
Purpose		
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Enhancements to UCP LBT: Supporting simulation results

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Overview

This contribution contains supporting simulation results for the UCP LBT (Listen Before Talk) feature enhancements as detailed in IEEE C802.16h-07/078 [2]. The results are intended to show:

- Benefits of the enhancements to the LBT feature detailed in [2].
- Equitable fair sharing of the channel between the present in systems.
- Low Frame Error Rates.

Simulation analysis

The simulation scenario

For ease of understanding and to fully quantify the feature's performance within a simulation environment the scenario presented in Figure 1 was adopted in the generation of all results.

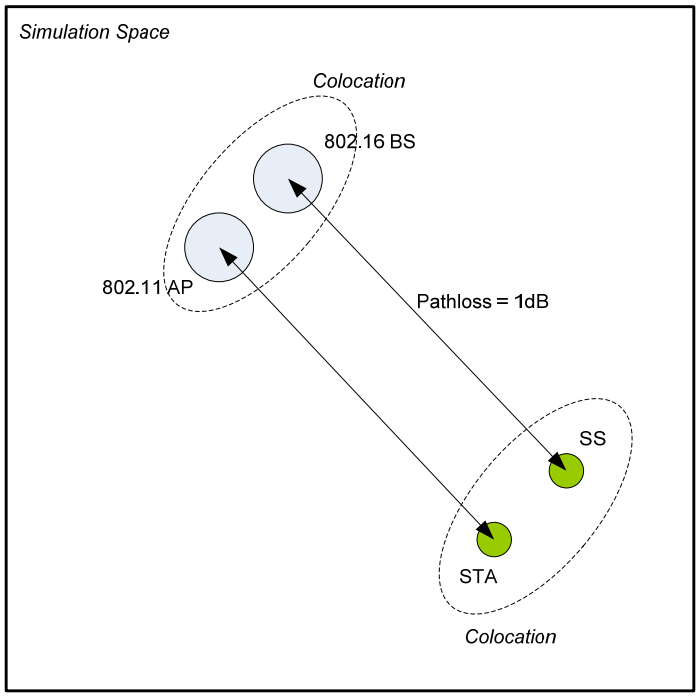


Figure 1 The simulation scenario used to produce all simulation results presented.

Simulation assumptions:

- These results are based on parameters contained within the 802.19 3.65GHz simulation parameters document [3].
- *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 ~102*µs
  - *TTG = 5µs*
  - *1500byte frames sizes*
- 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.

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.

Simulation results I

The following scenarios have been simulated.

NB: The *K* factor is detailed in [2] and is the *Aggressiveness Factor* of an 802.16 system in ensuring it's target utilization factor is maintained.

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.

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].

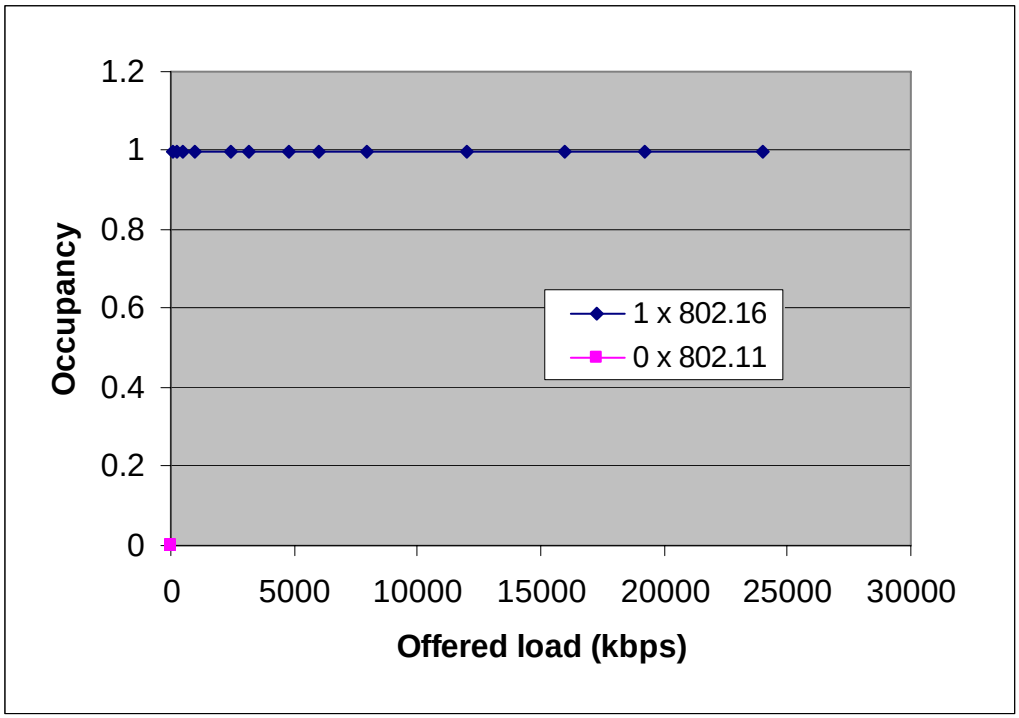
Scenario K: 3 x 802.16 systems + 3 x 802.11 systems [*K* = 1].

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}.



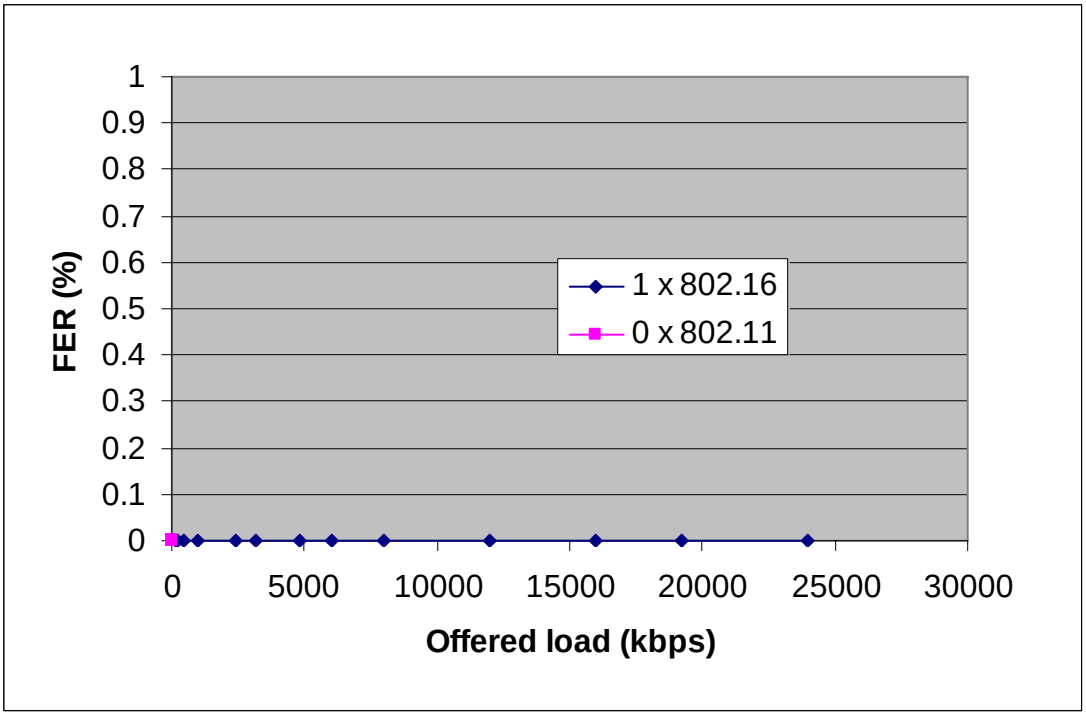
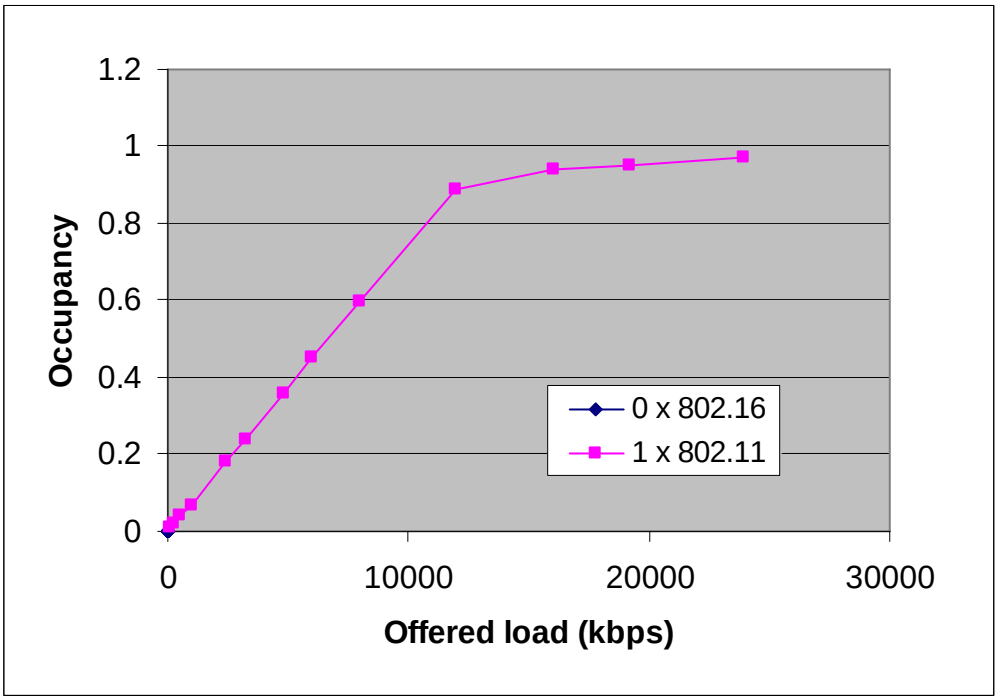


Figure 2 ***Scenario A*** – Occupancy and FER against offered load.



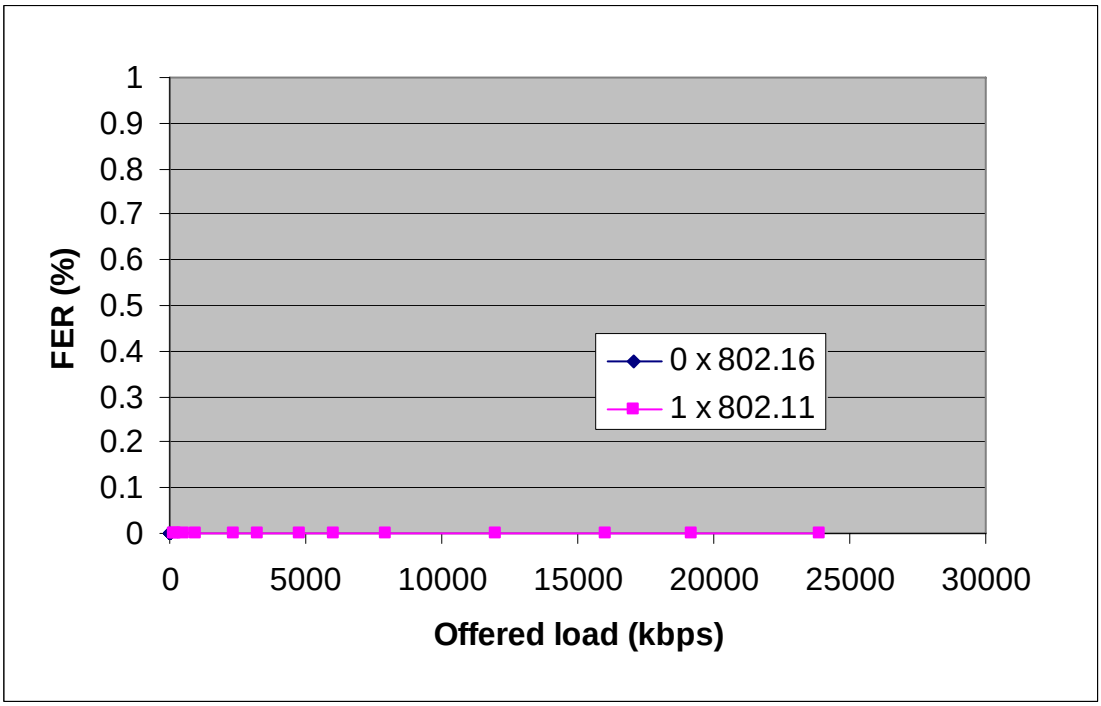
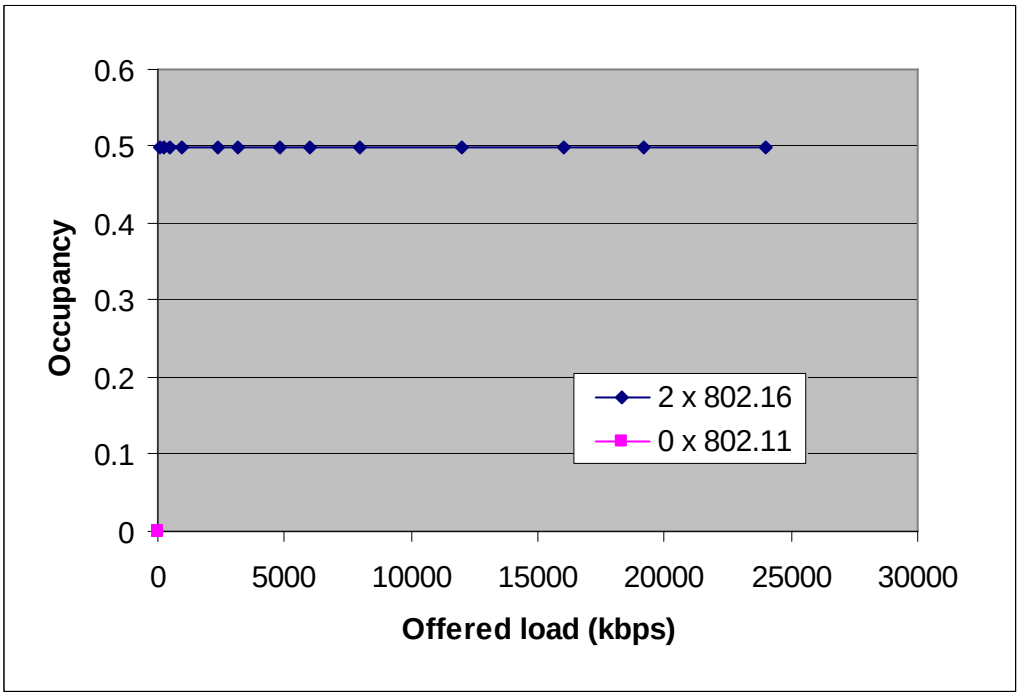


Figure 3 ***Scenario B*** – Occupancy and FER against offered load.



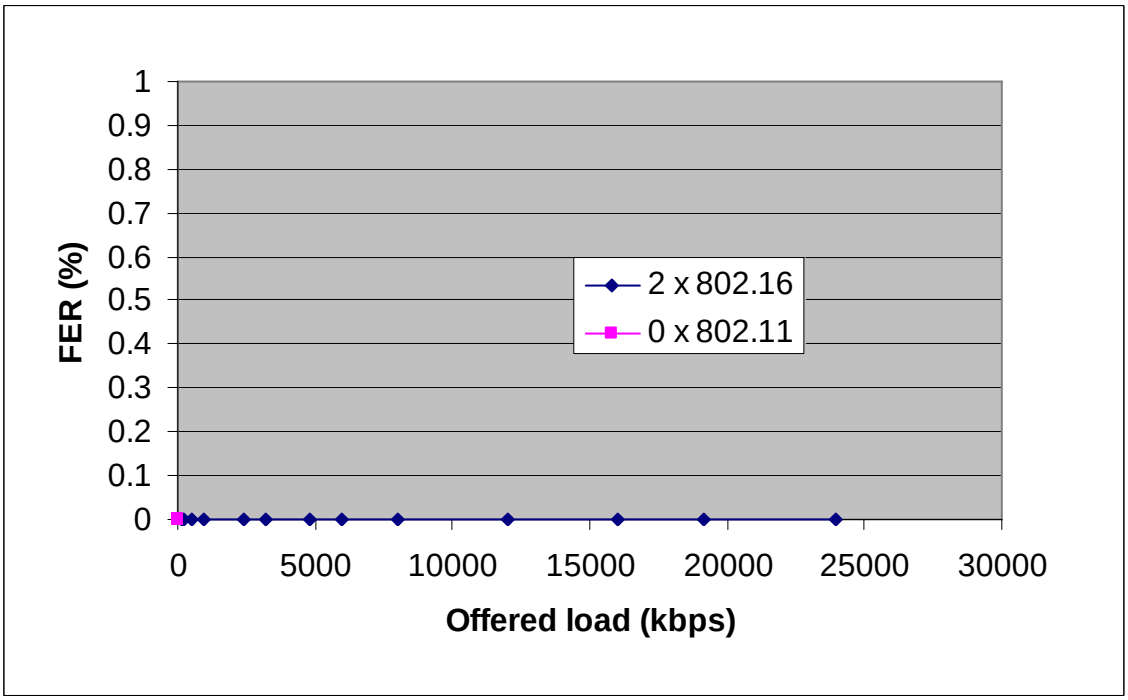
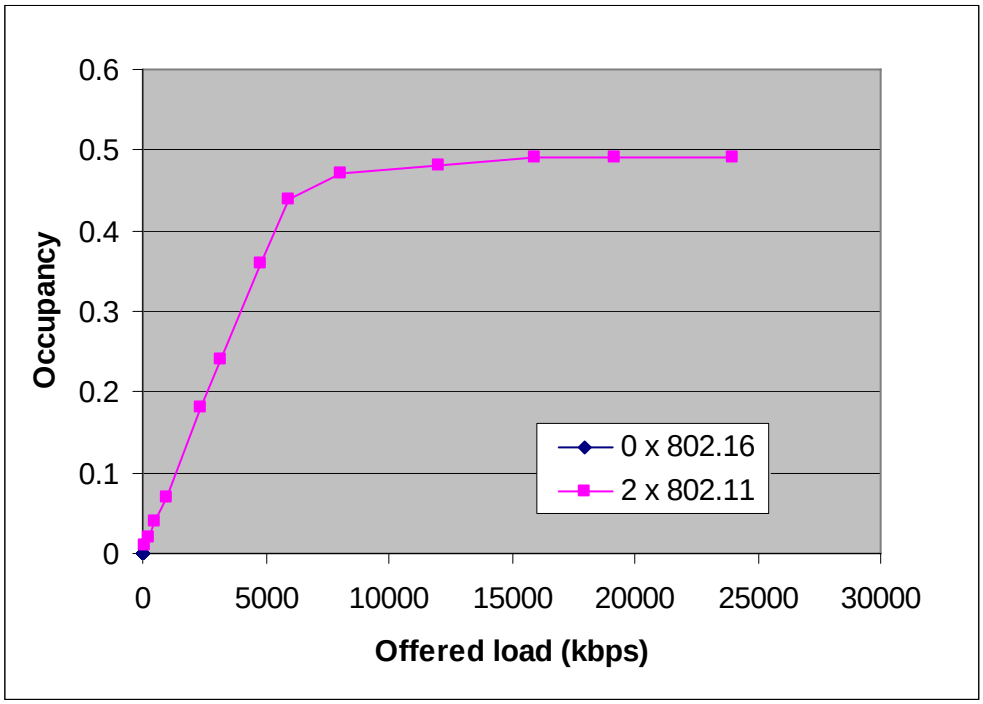


Figure 4 ***Scenario C*** – Occupancy and FER against offered load.



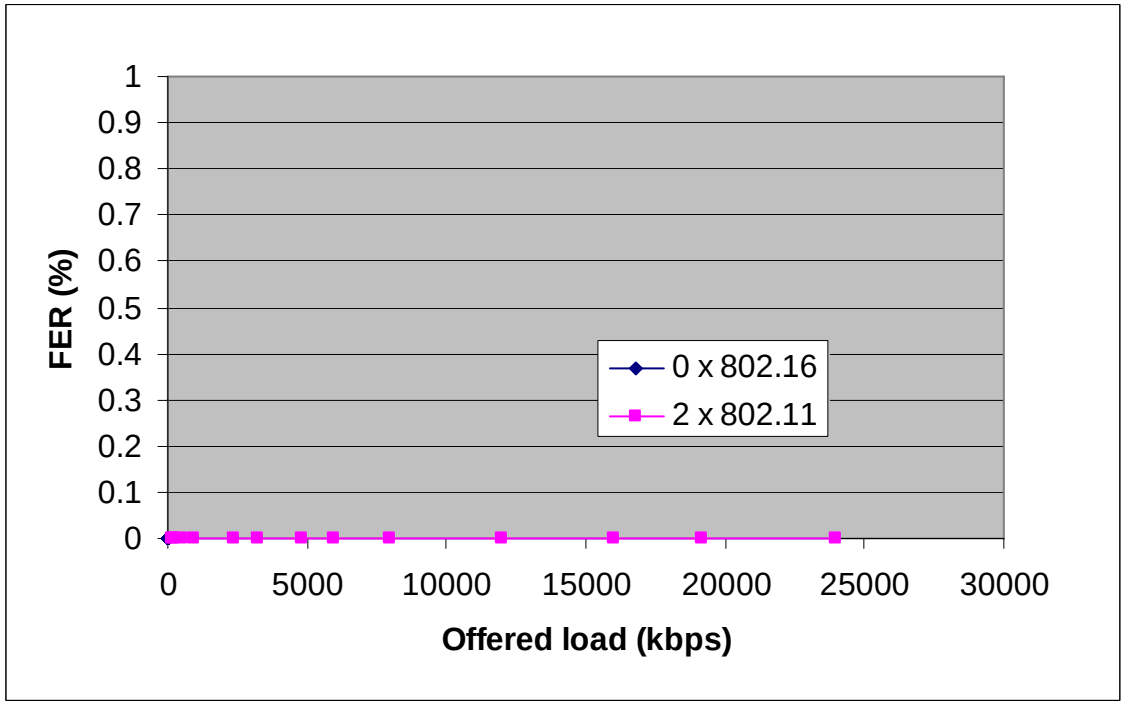
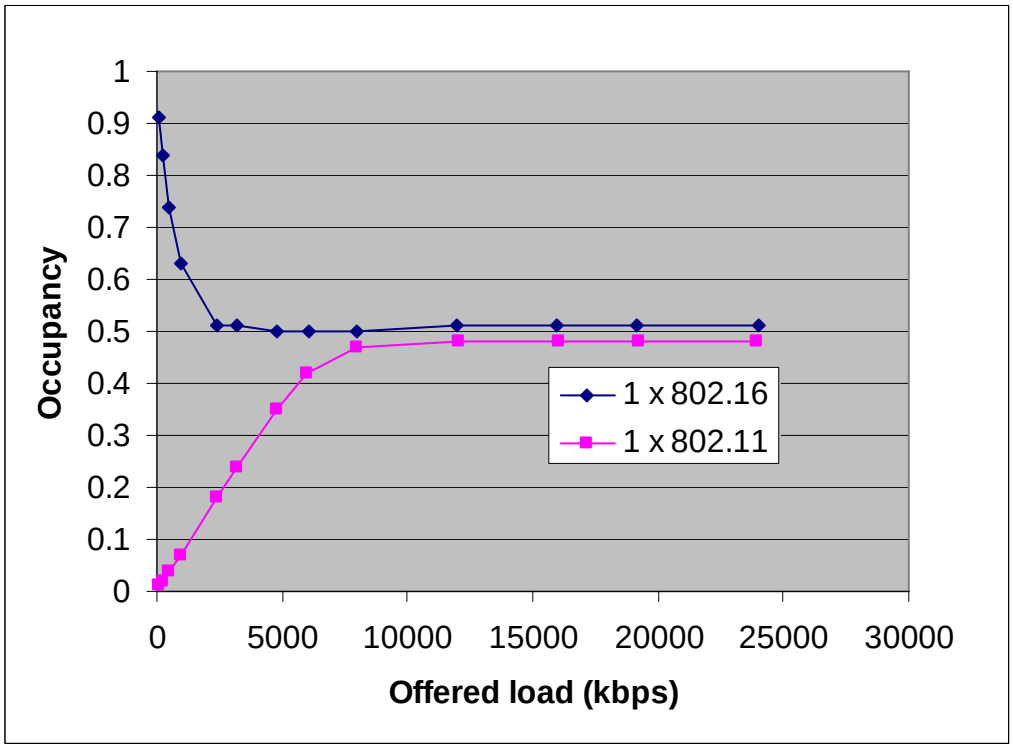


Figure 5 ***Scenario D*** – Occupancy and FER against offered load.



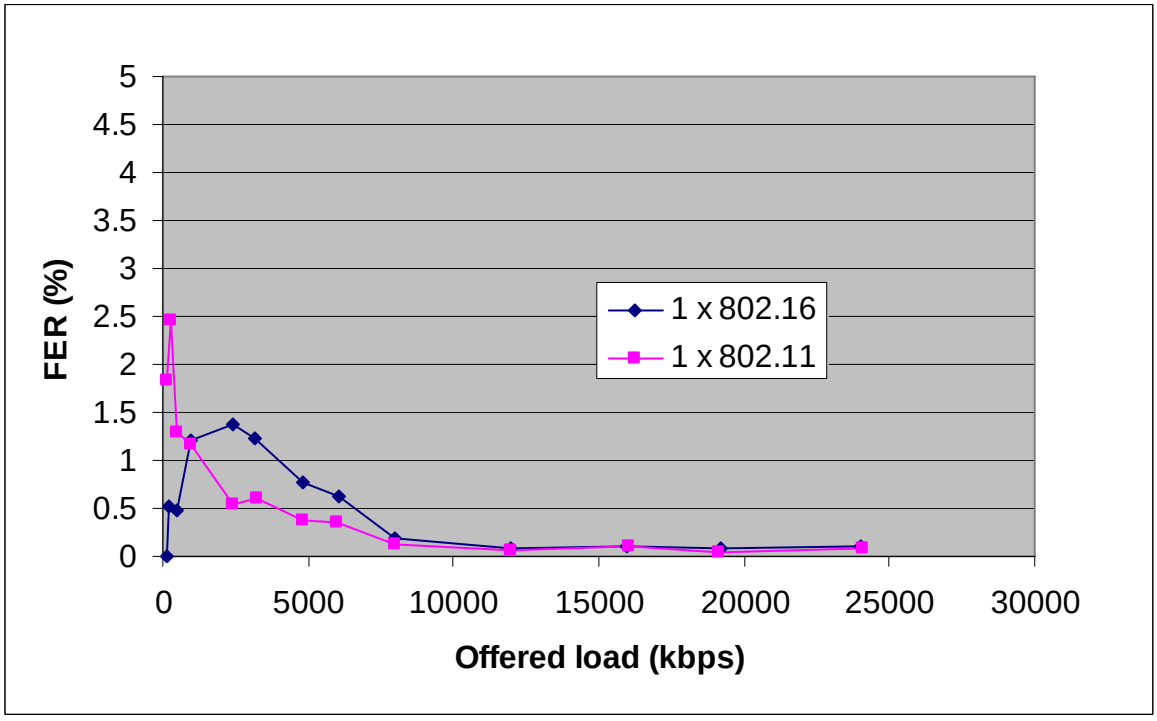
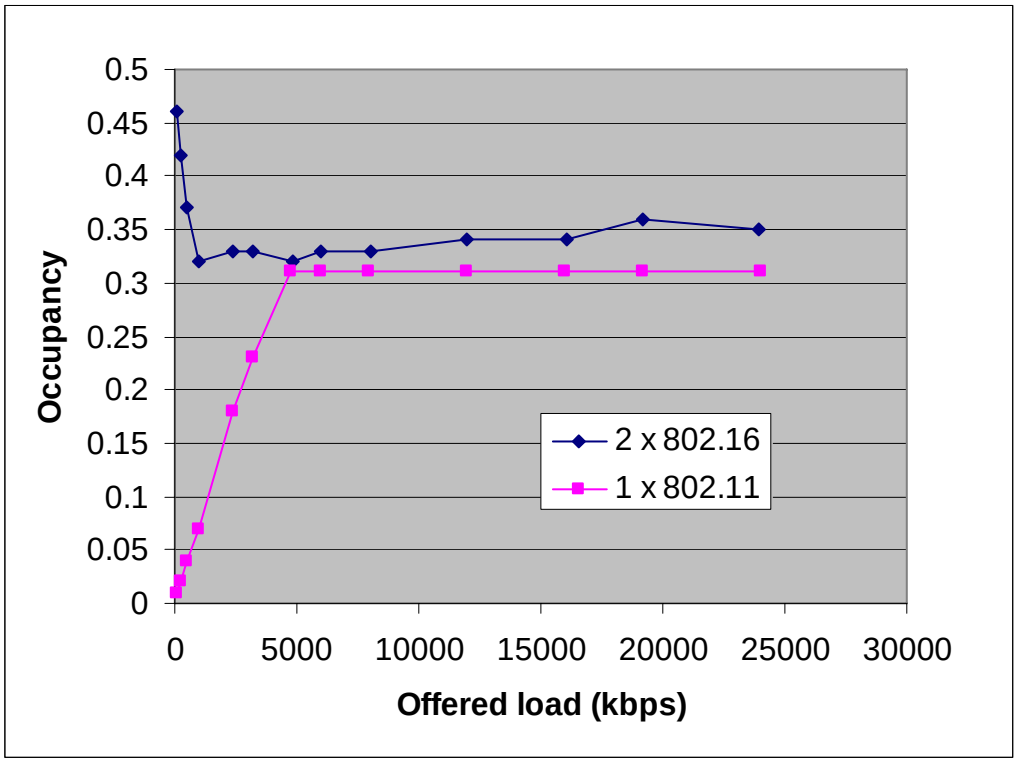


Figure 6 ***Scenario E*** – Occupancy and FER against offered load.



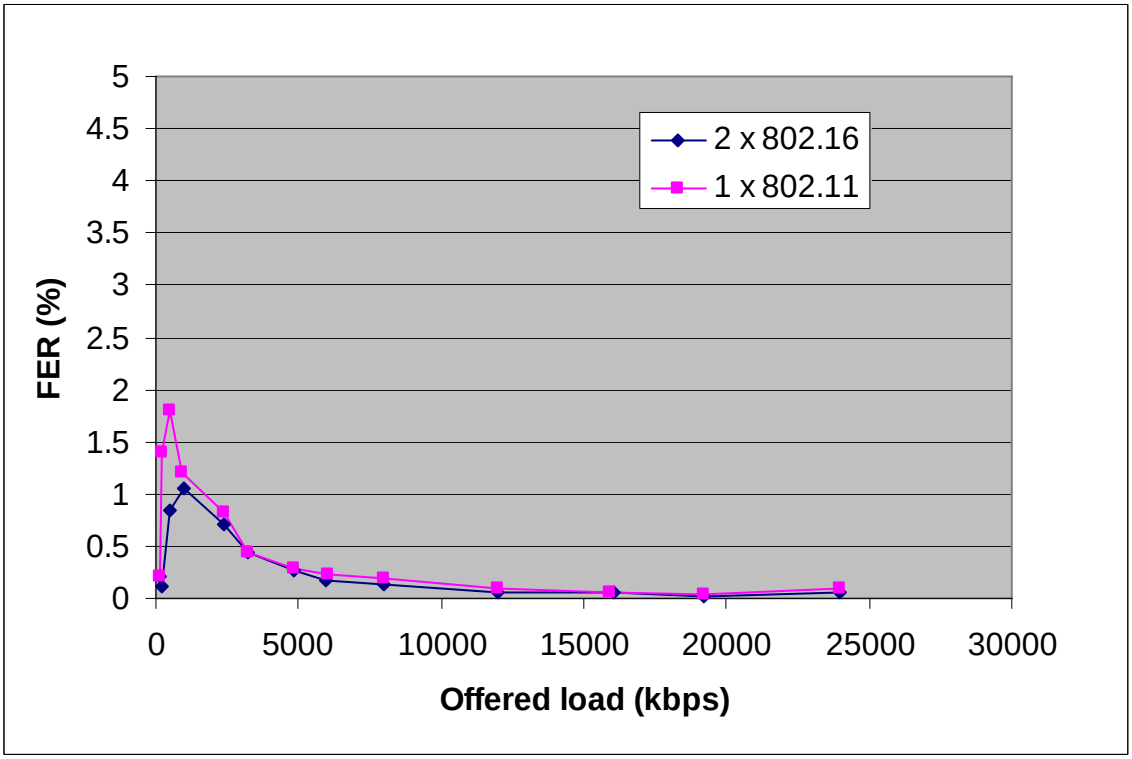
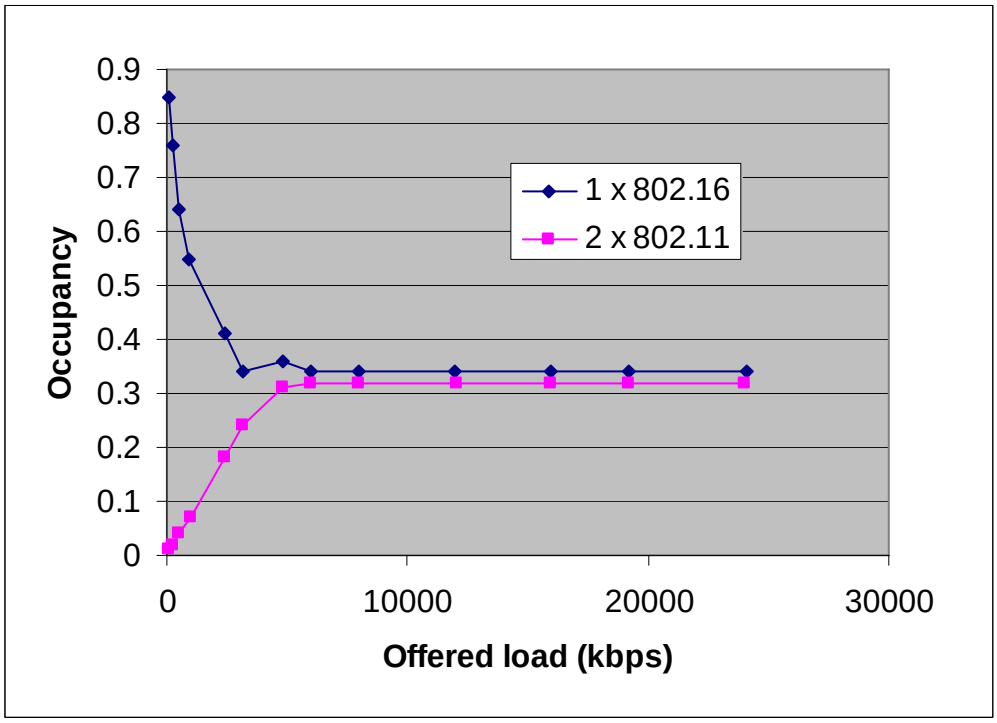


Figure 7 ***Scenario F*** – Occupancy and FER against offered load.



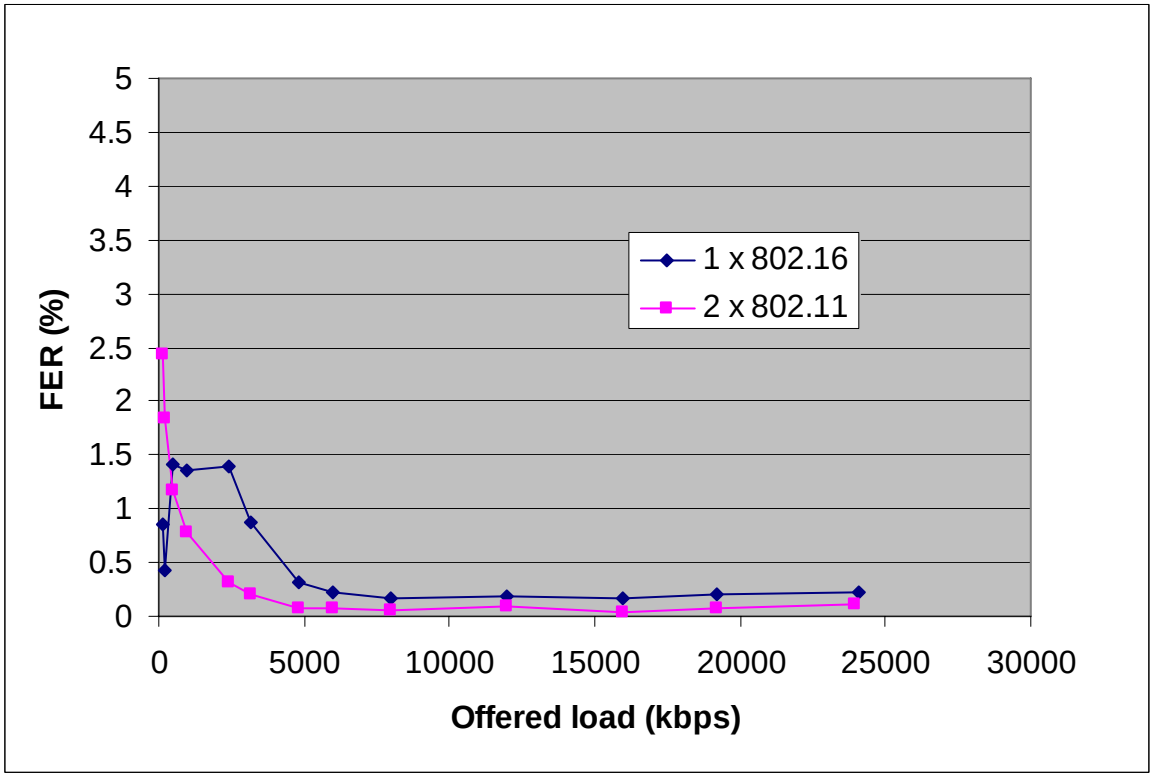
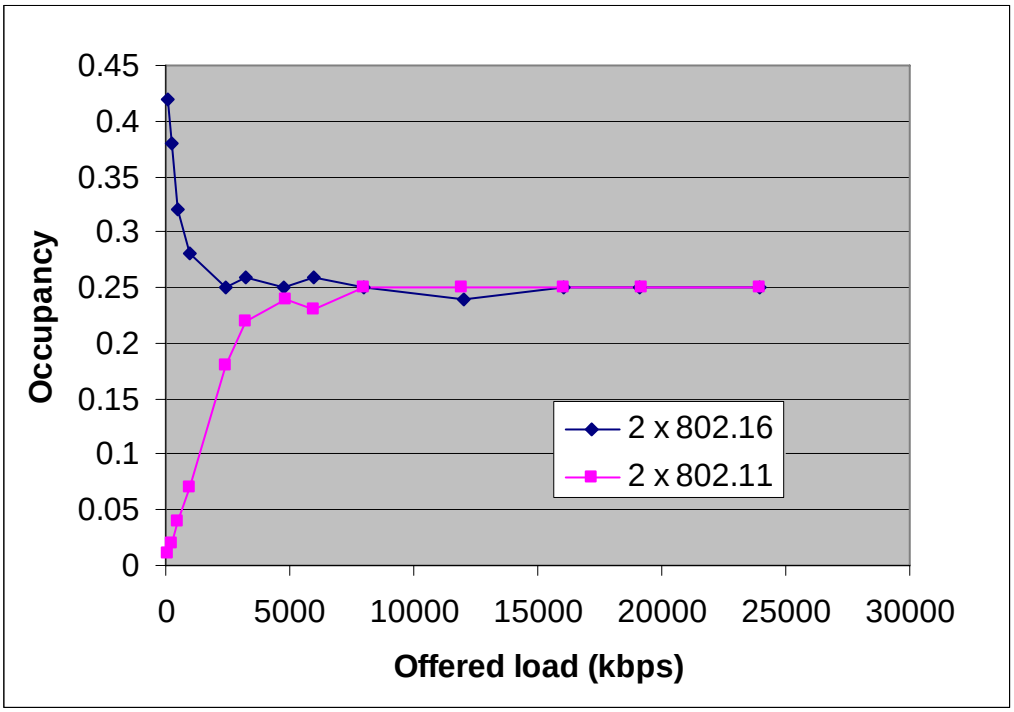


Figure 8 ***Scenario G*** – Occupancy and FER against offered load.



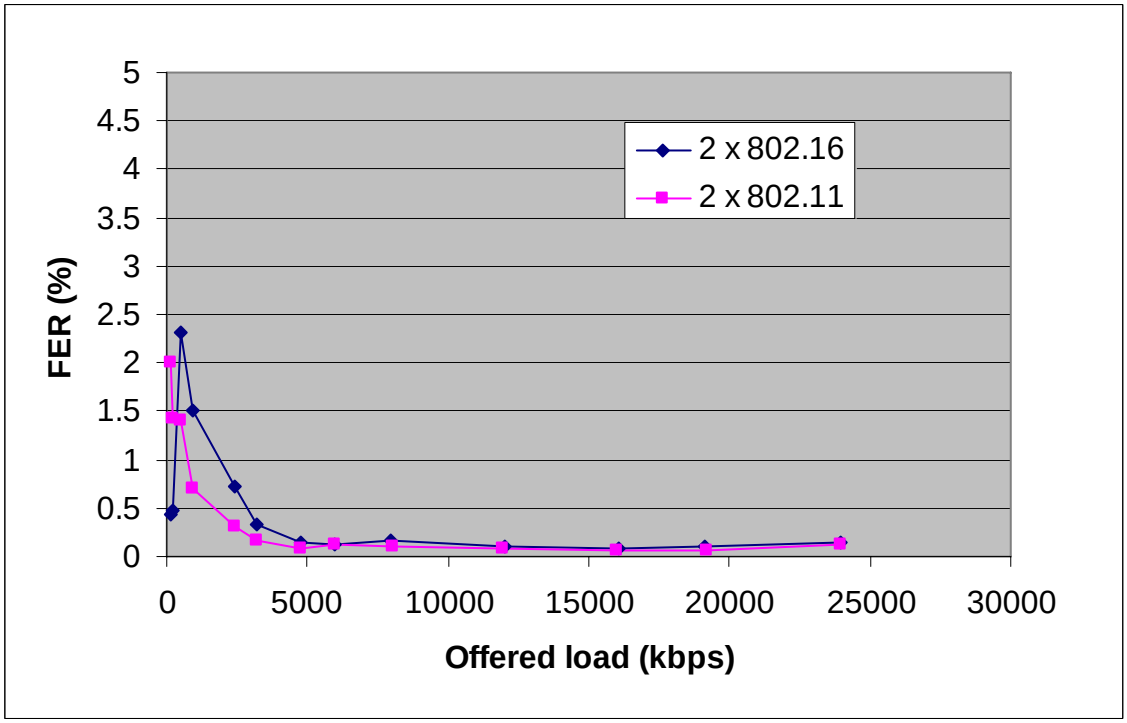
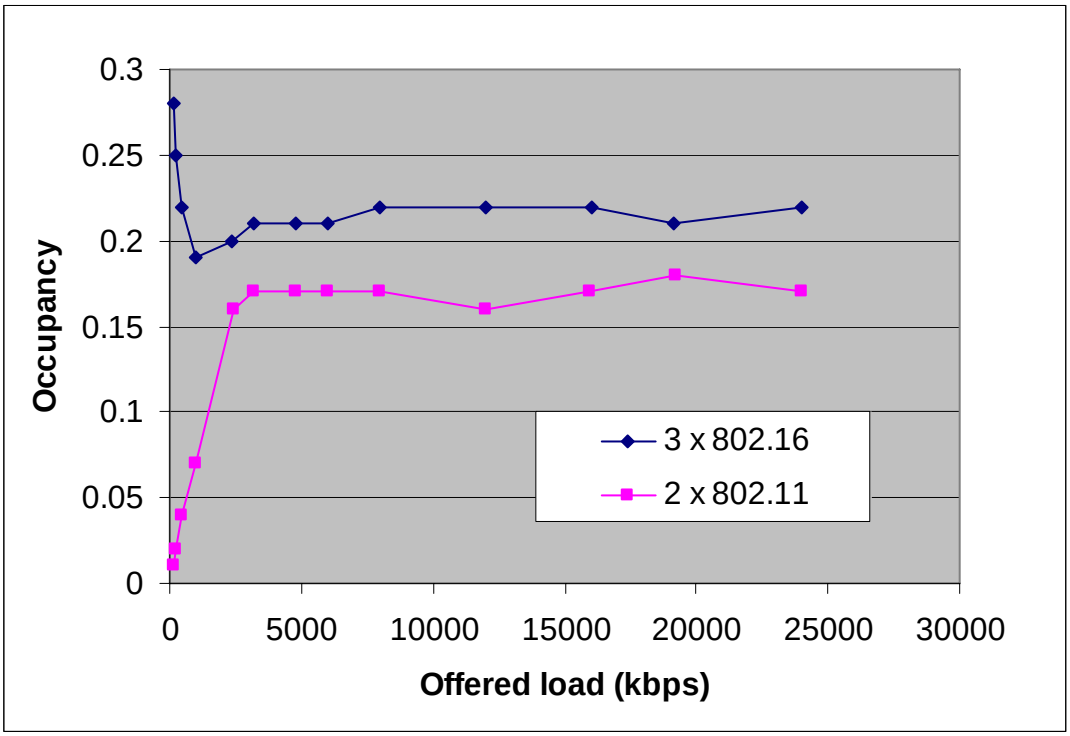


Figure 9 ***Scenario H*** – Occupancy and FER against offered load.



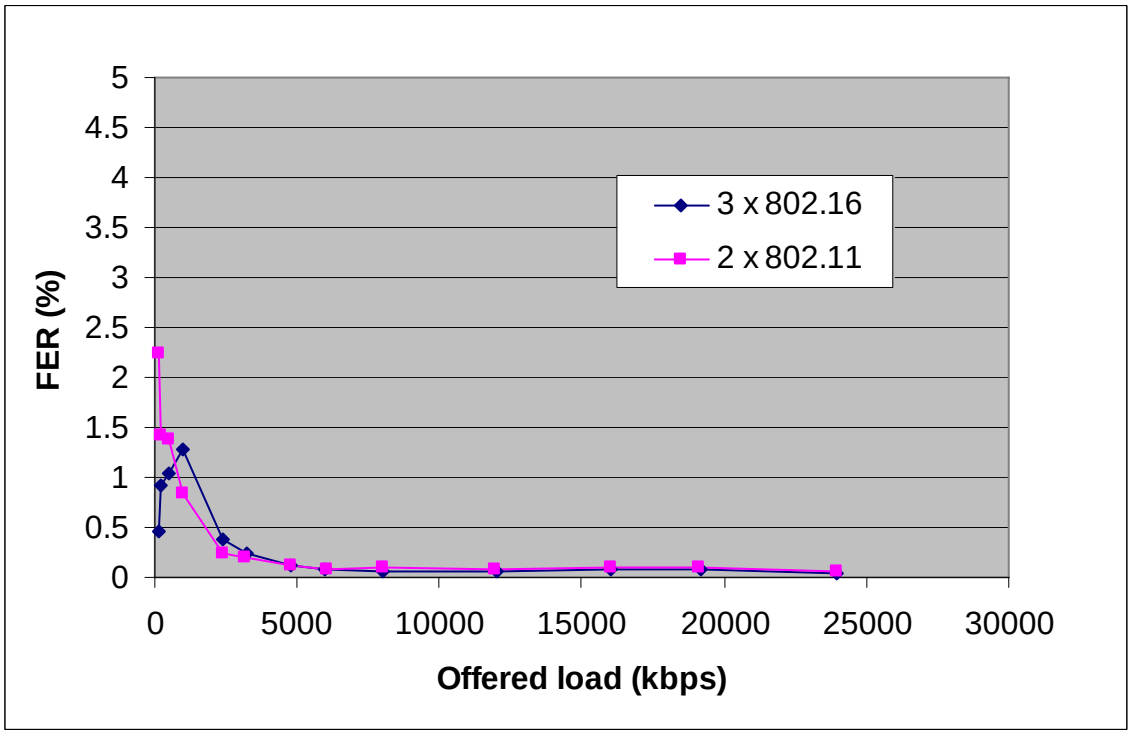
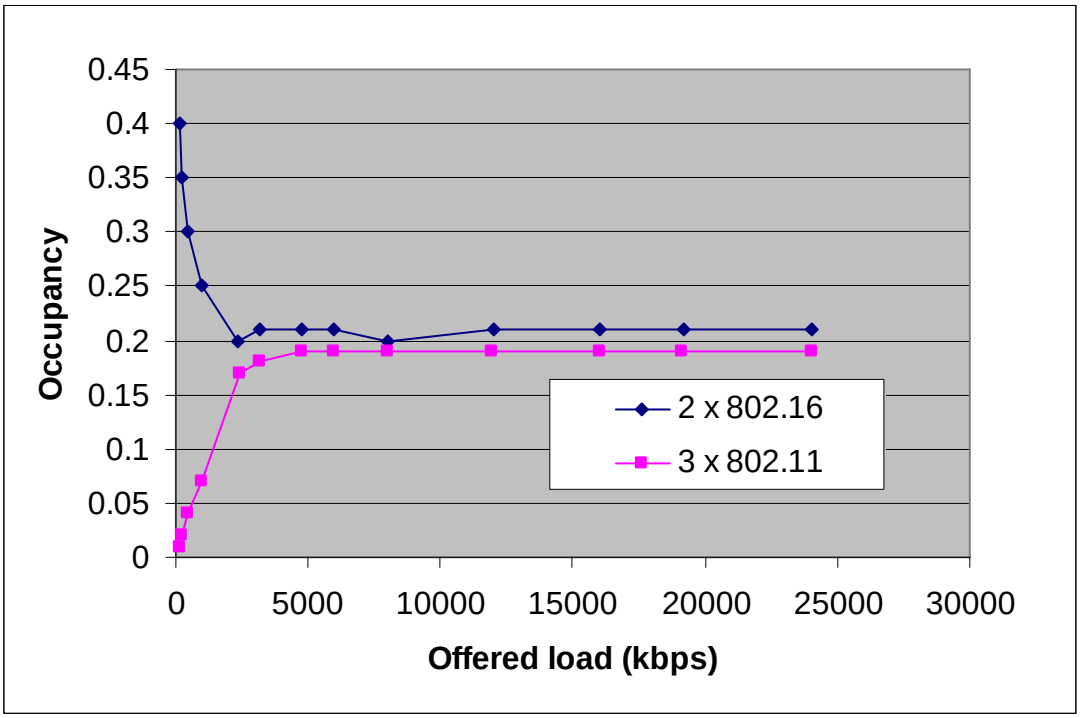


Figure 10 ***Scenario I*** – Occupancy and FER against offered load.



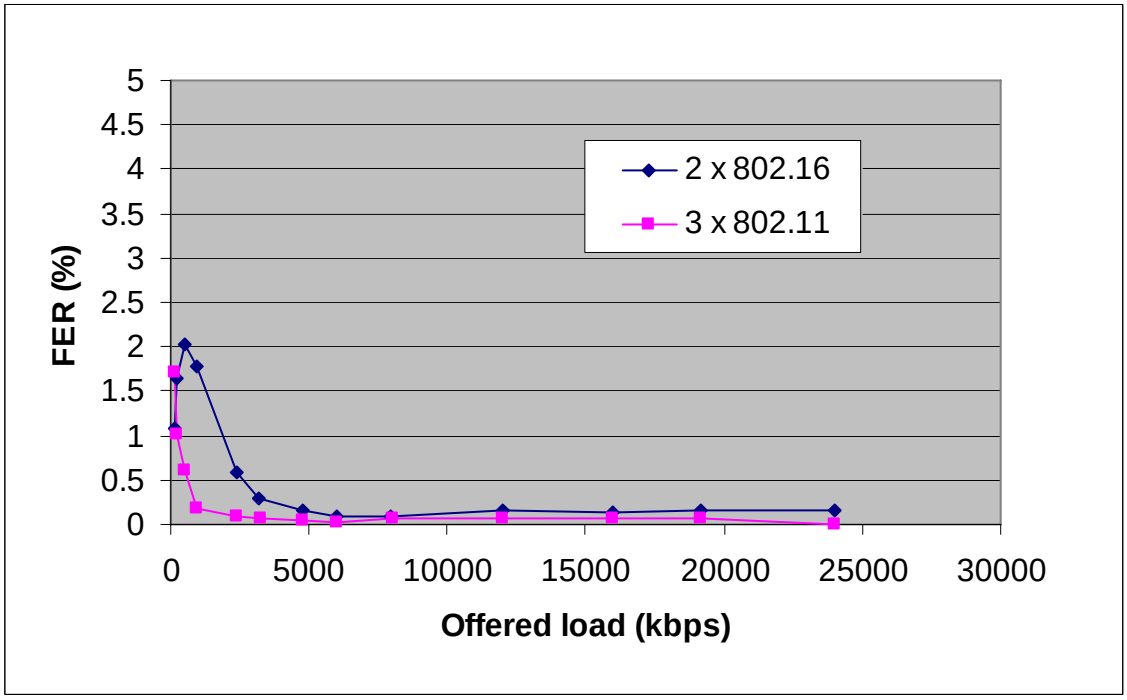
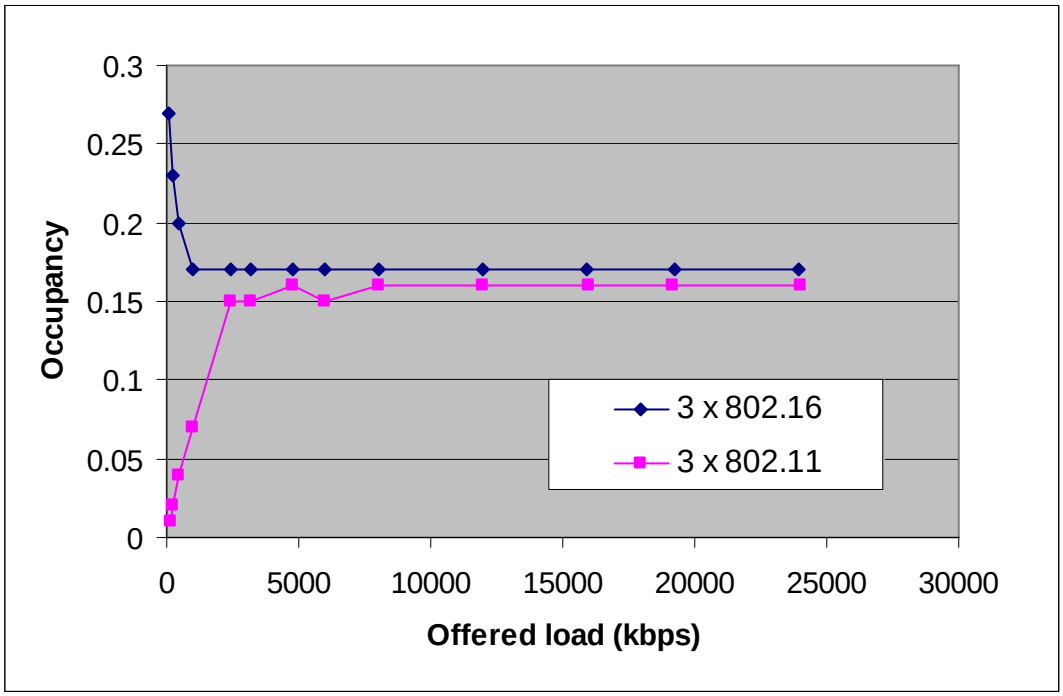


Figure 11 ***Scenario J*** – Occupancy and FER against offered load.



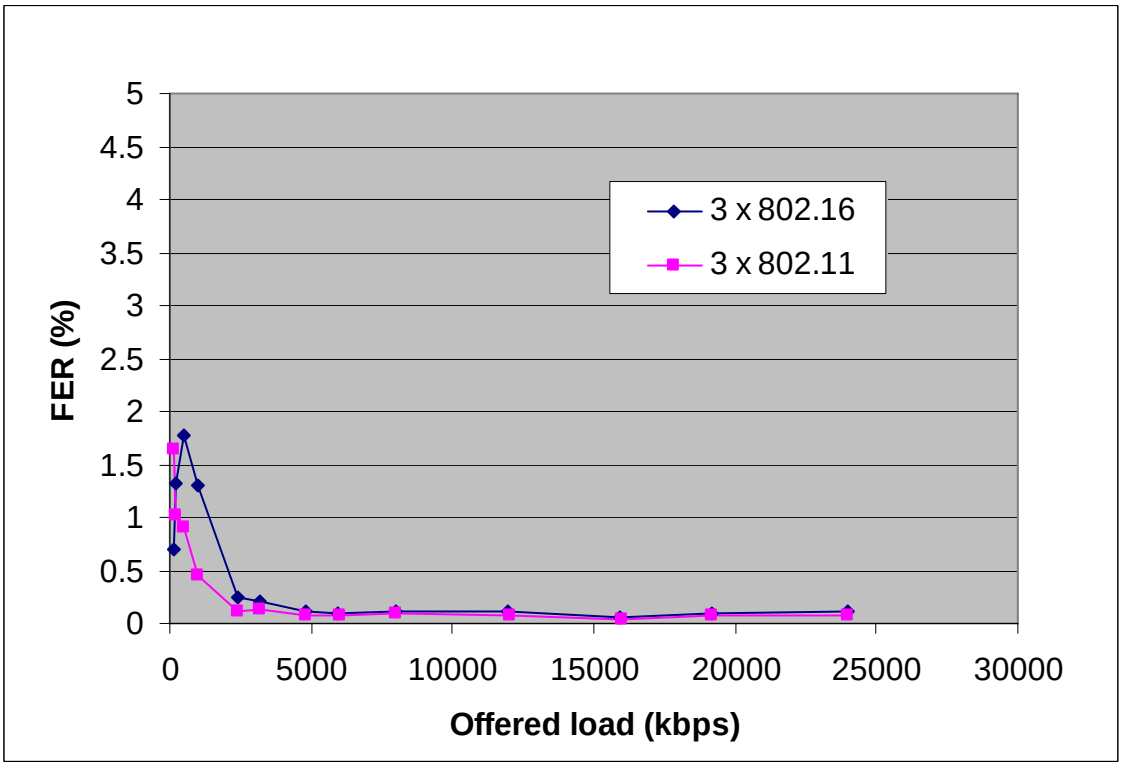
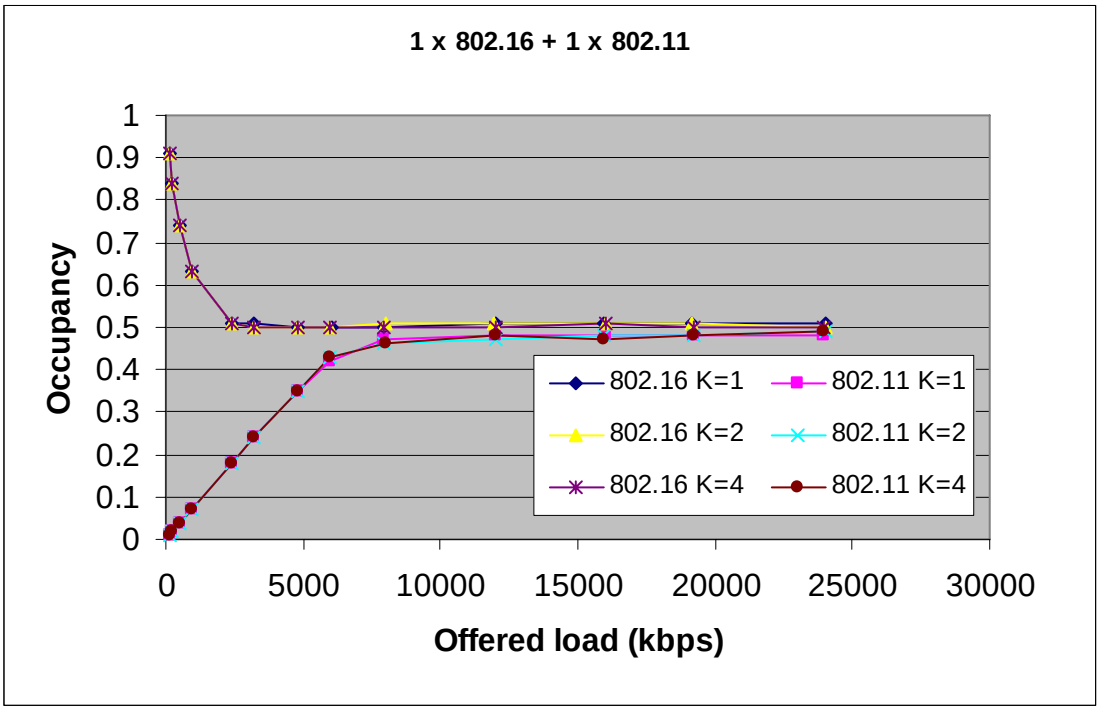


Figure 12 ***Scenario K*** – Occupancy and FER against offered load.



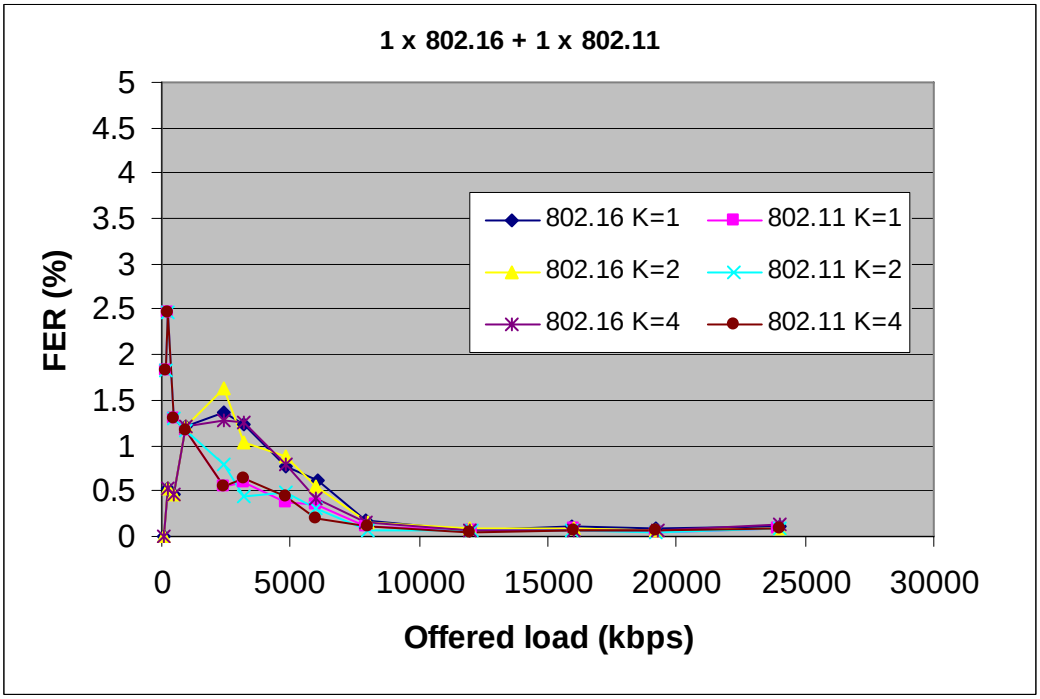
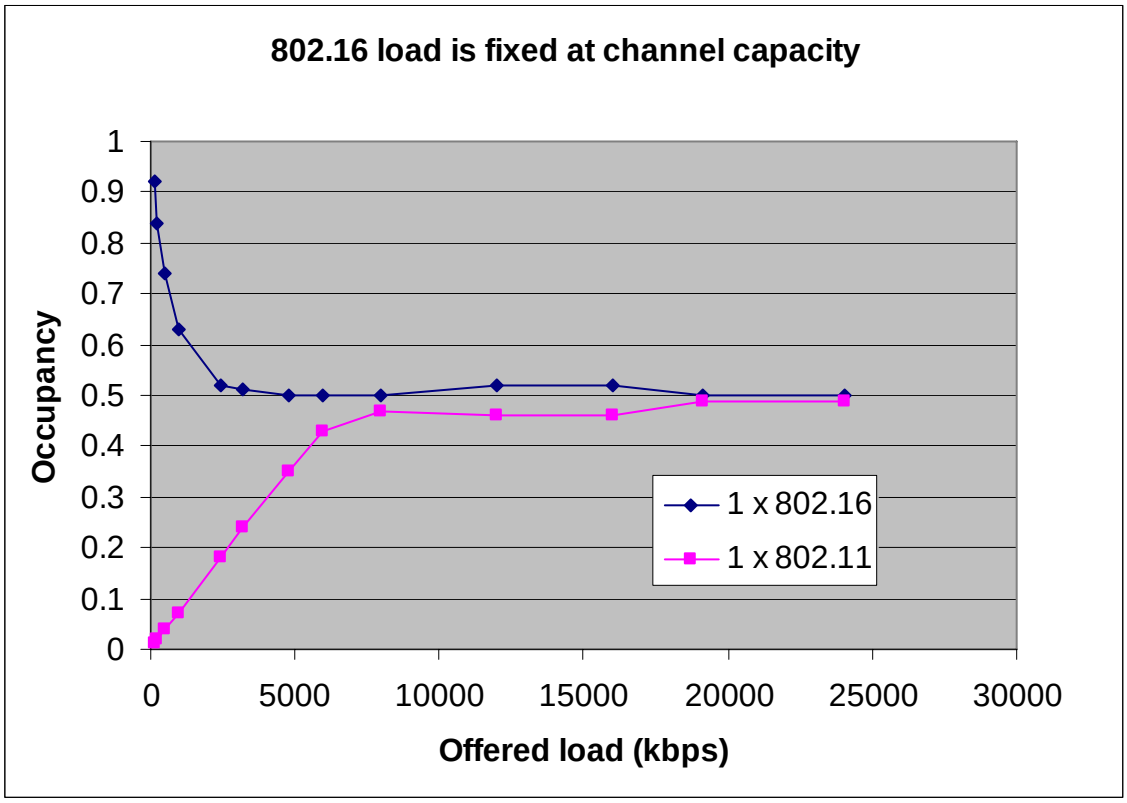


Figure 13 ***Scenario A, L, M*** – Occupancy and FER against offered load, *K*=1, 2, 4.



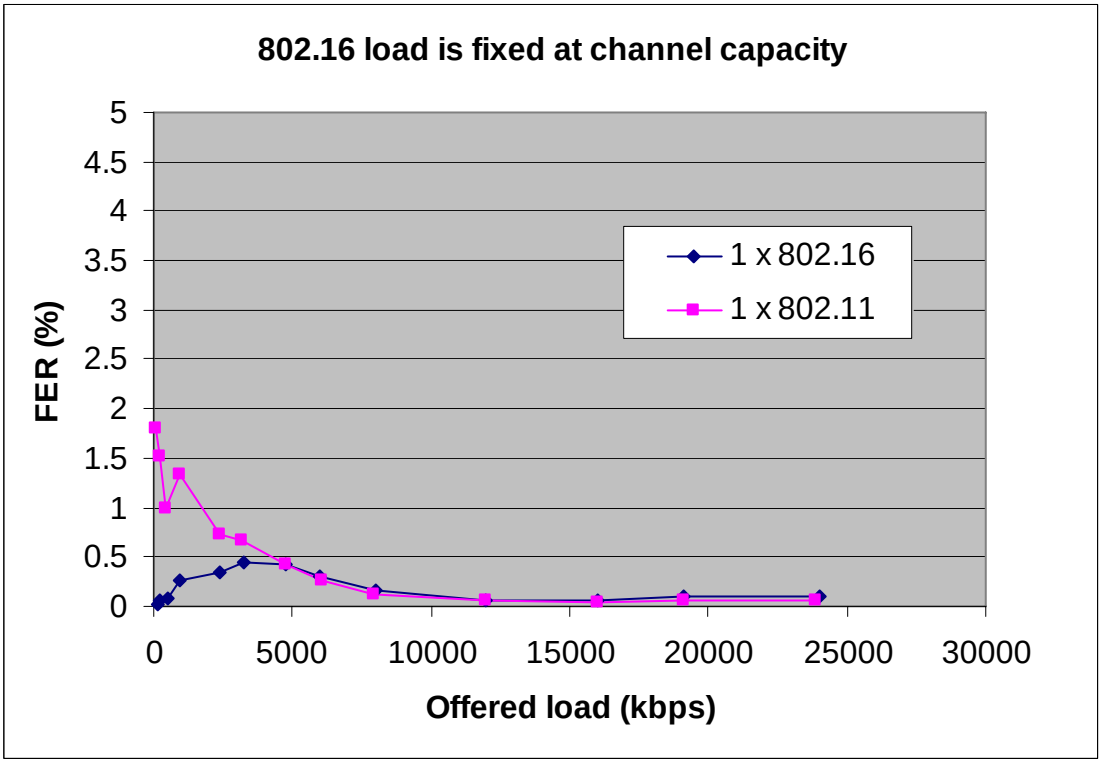
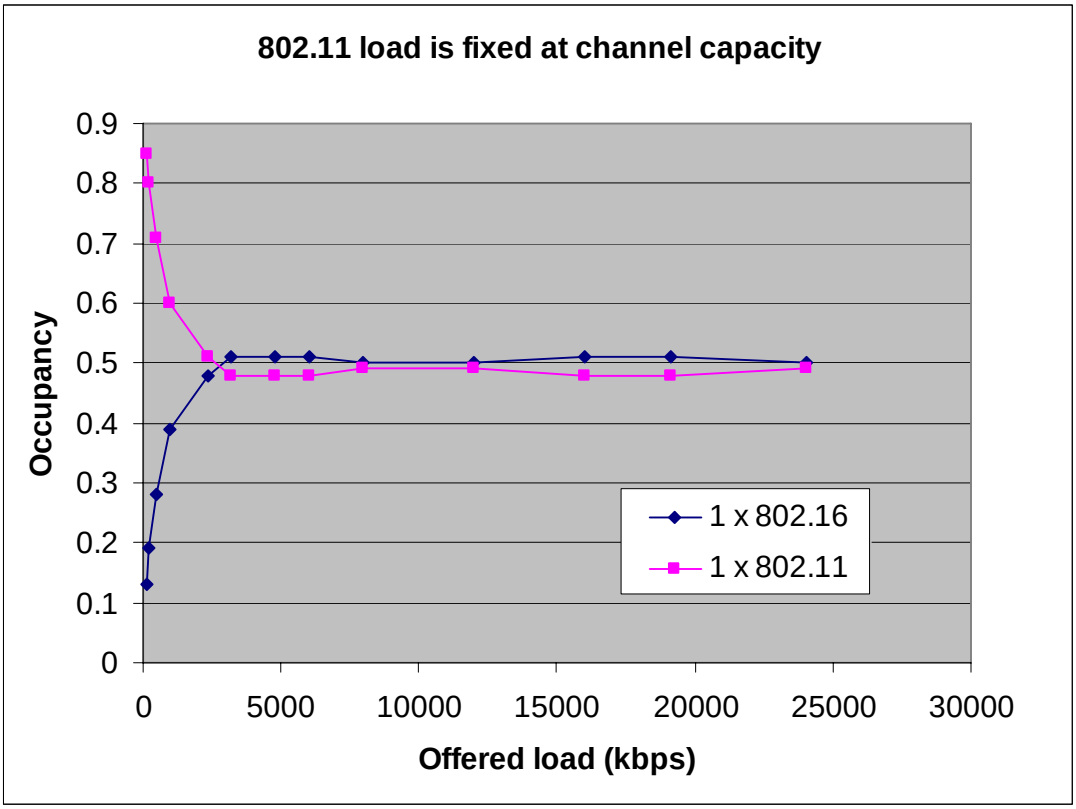


Figure 14 ***Scenario N*** – Occupancy and FER against offered load. 802.16 load fixed at channel capacity.



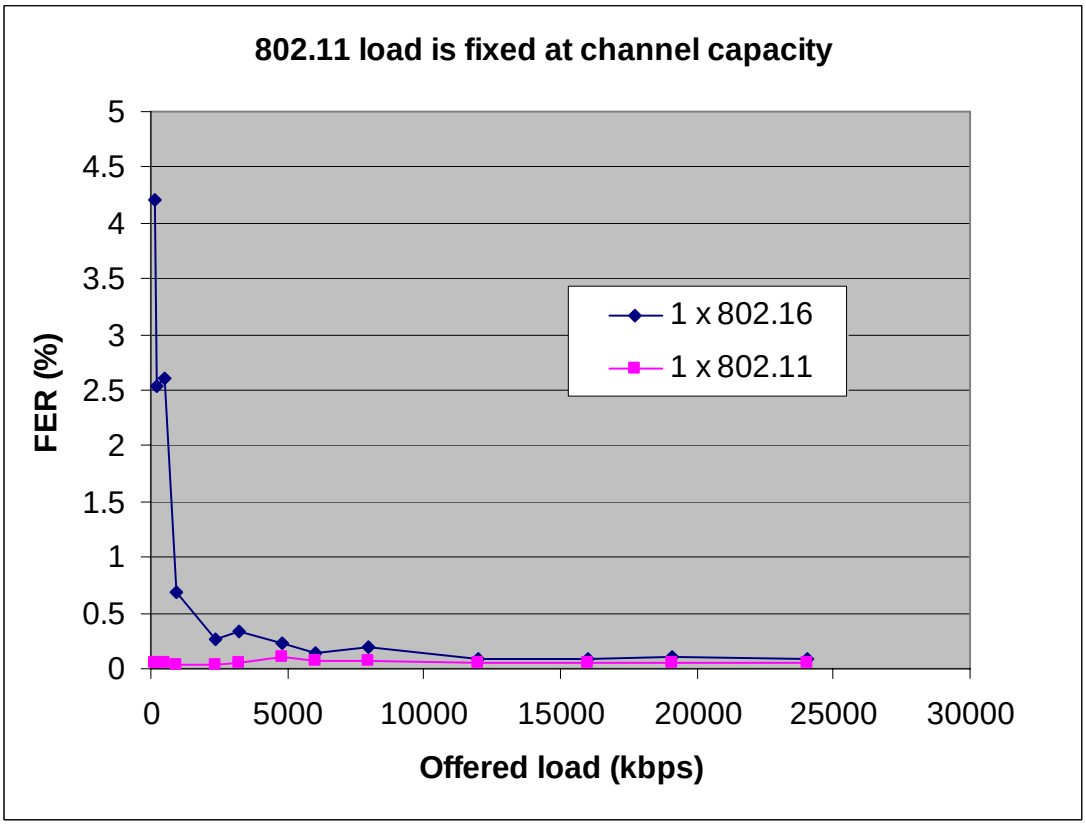


Figure 15 ***Scenario O*** – Occupancy and FER against offered load. 802.11 load fixed at channel capacity

Interim conclusions I

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* 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

The analysis is extended to cover spatially distributed scenarios. Extending the scenario presented in Figure 1 then the following scenarios in Figure 16 logically follow.

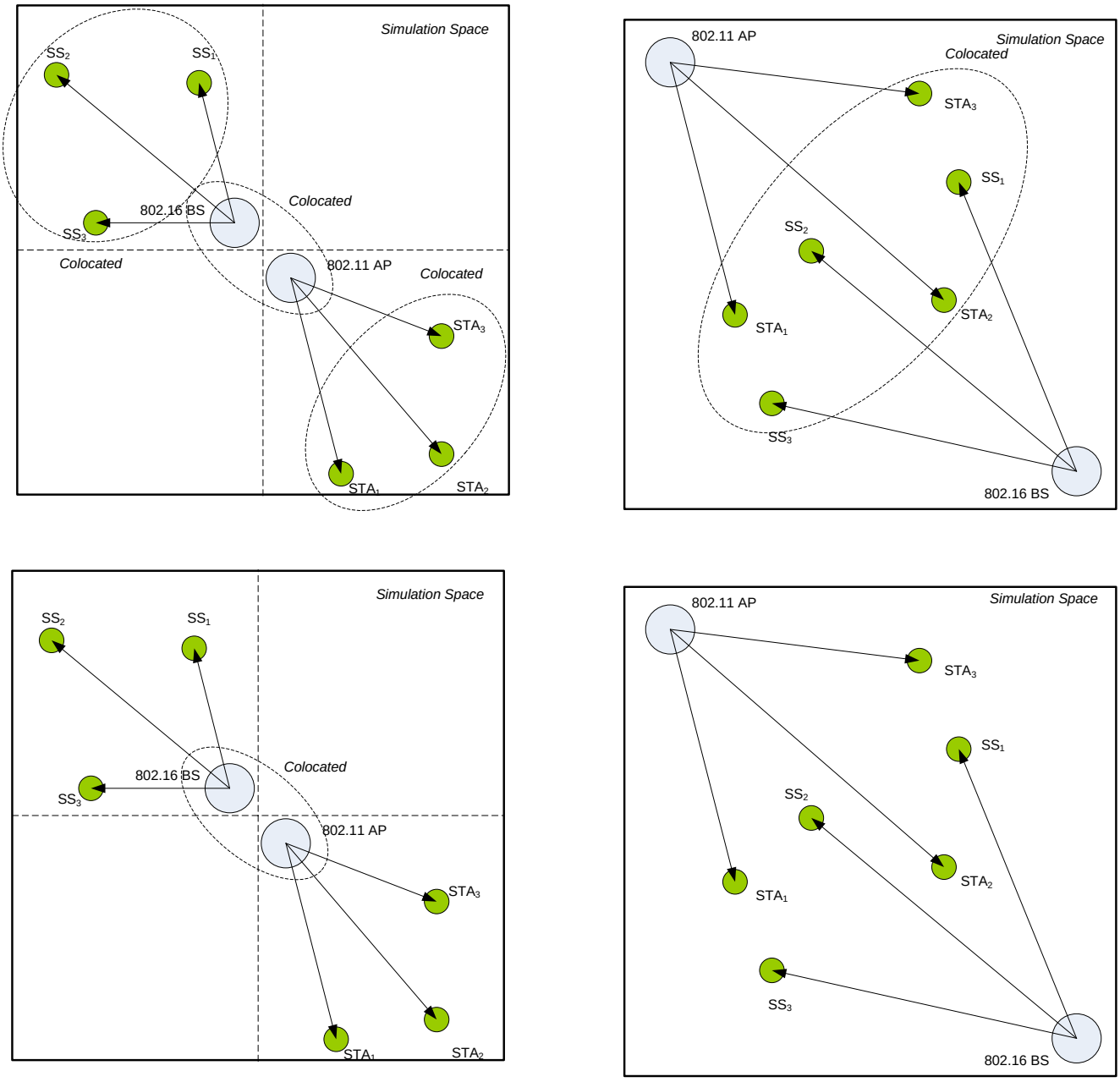


Figure 16 Examples of spatially distributed scenarios.

Further simulation results are presented based on that scenario given in Figure 17.

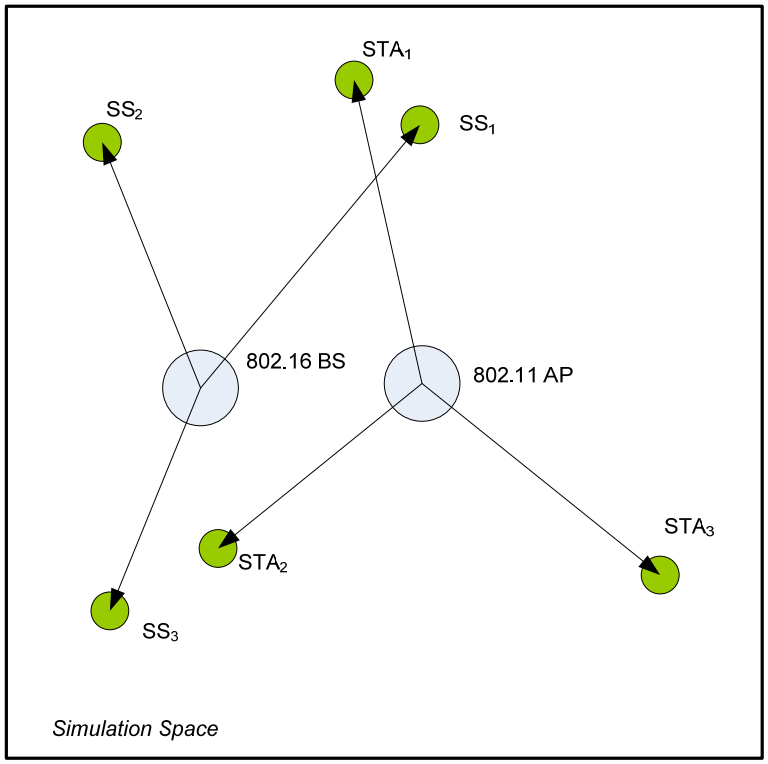


Figure 17 Randomly distributed BS/AP and MS/STAs for further simulation studies.

802.16 FRS transmission strategy

Within a spatially distributed scenario it may necessary to consider the transmission and reception of channel reservation signals similar to those used by 802.11 systems.

- No FRS/CTS capability.
- FRS Transmission capability by 802.16.
- CTS Reception capability by 802.16.
- FRS/CTS capability.

The FRS transmission strategy is given in Figure 18 to Figure 21 with simulation results presented in Figure 22 to Figure 25.

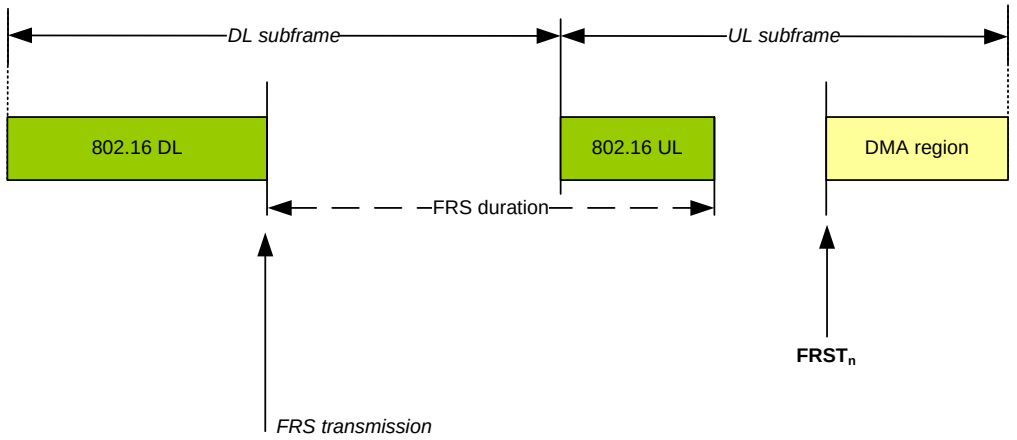


Figure 18 FRS transmission in the DL subframe protecting the UL transmission.

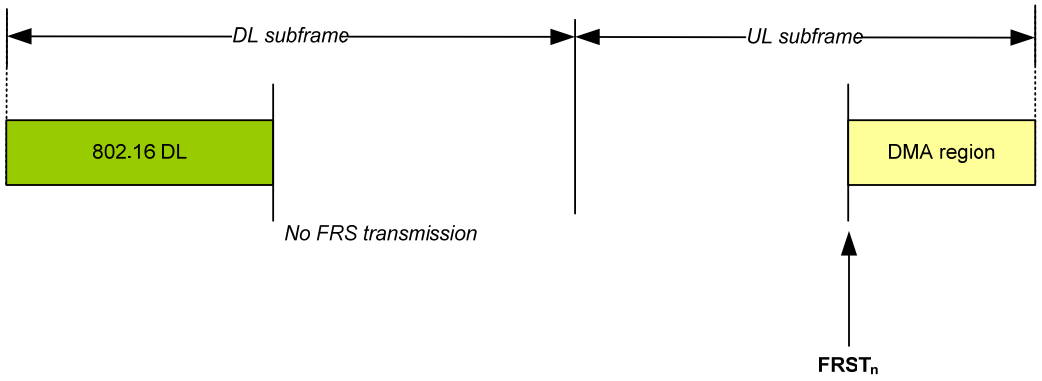


Figure 19 *FRS not transmitted in the DL subframe due to no UL transmission*

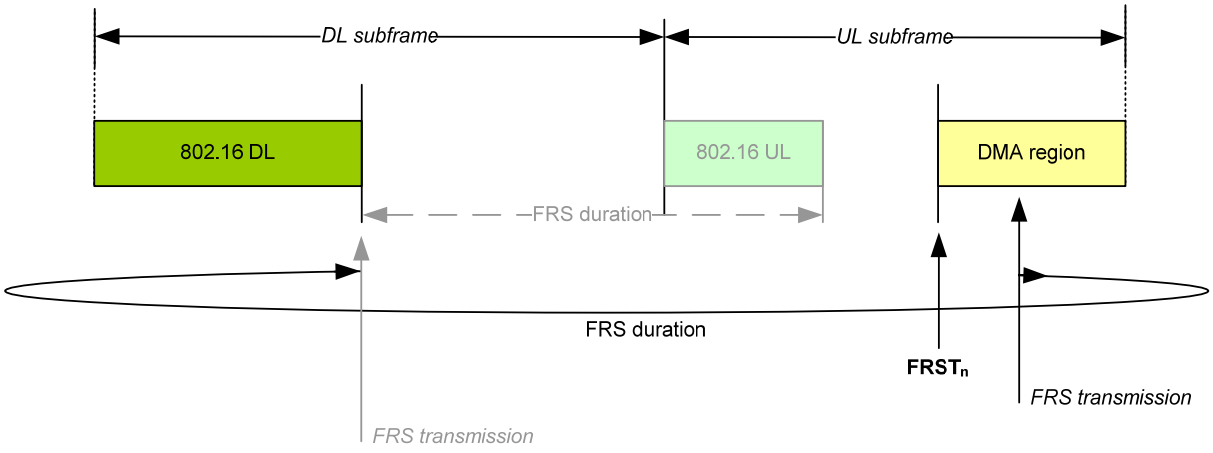


Figure 20 *FRS transmission in the UL subframe protecting the following frame as claimed by DMA algorithm*

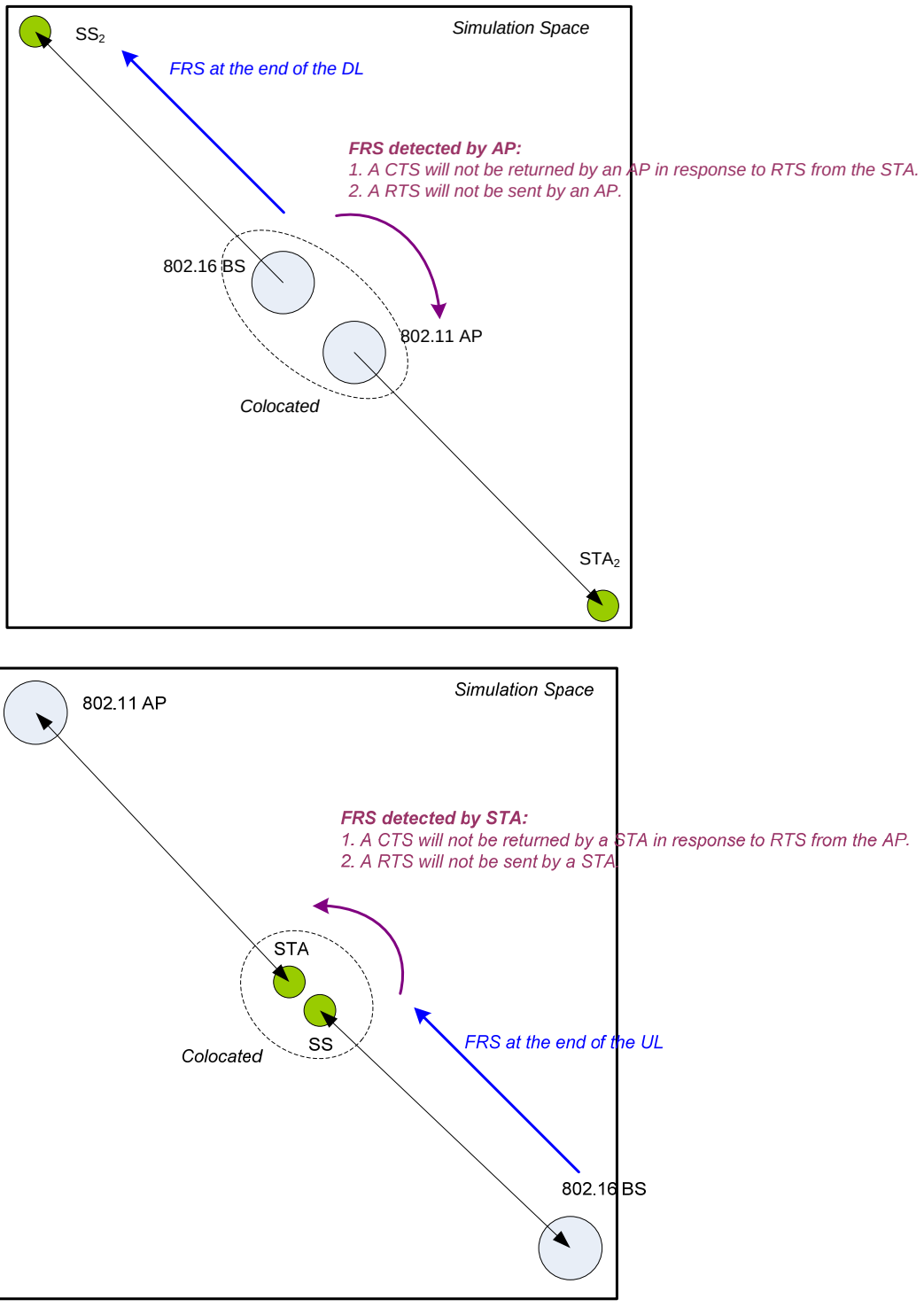


Figure 21 Representation of FRS handling by 802.11 systems.

Simulation results II

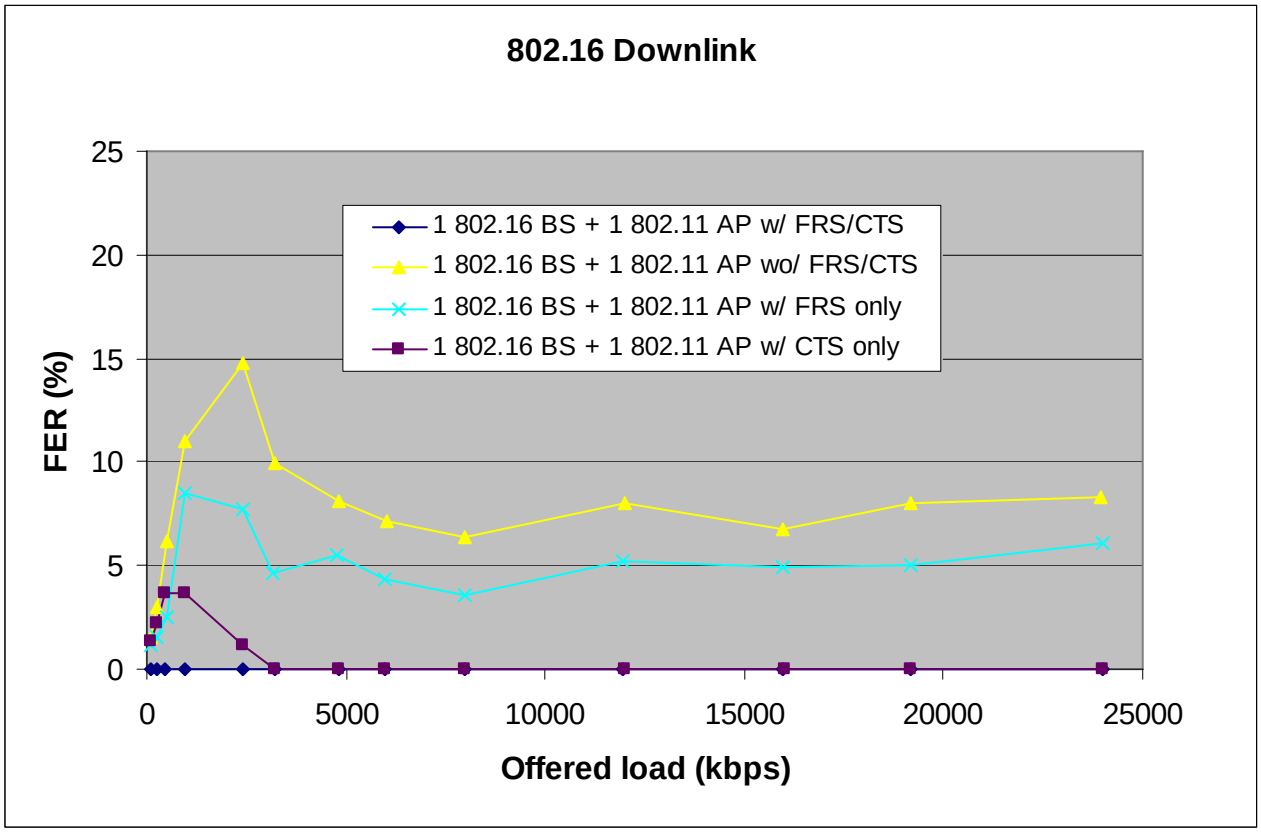


Figure 22 802.16 downlink FER results for a spatially distributed scenario.

NB *'FRS only' – FRS transmission capability by 802.16*

'CTS only' – CTS reception capability by 802.16

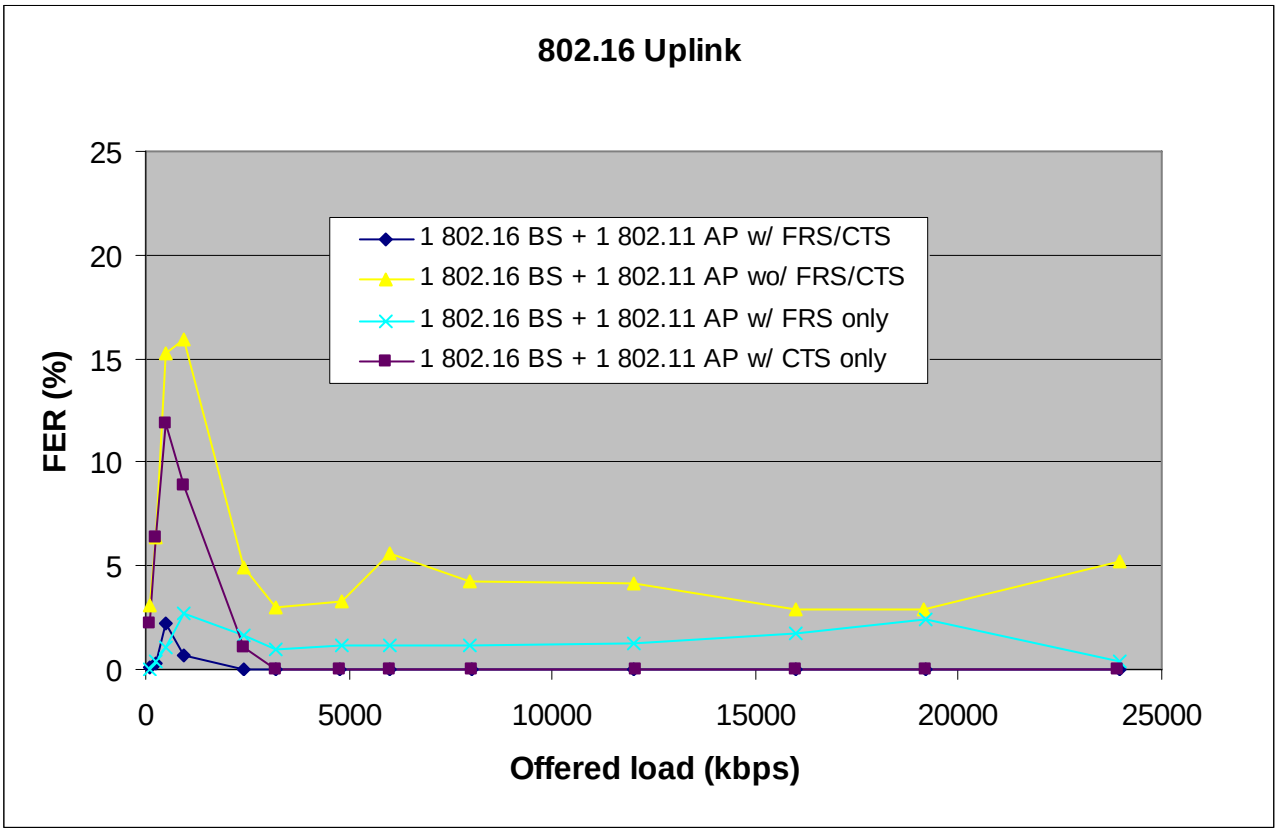


Figure 23 802.16 uplink FER results for a spatially distributed scenario.

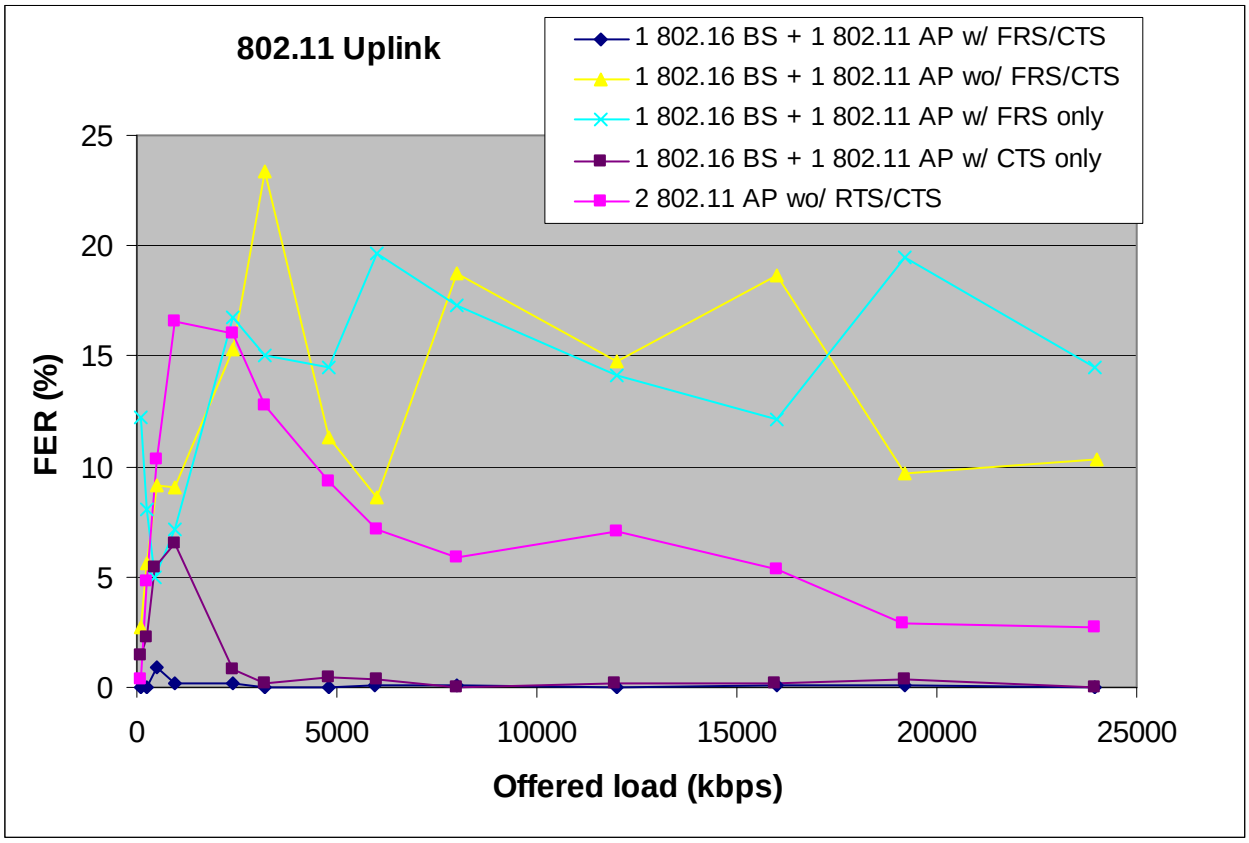


Figure 24 802.11 downlink FER results for a spatially distributed scenario.

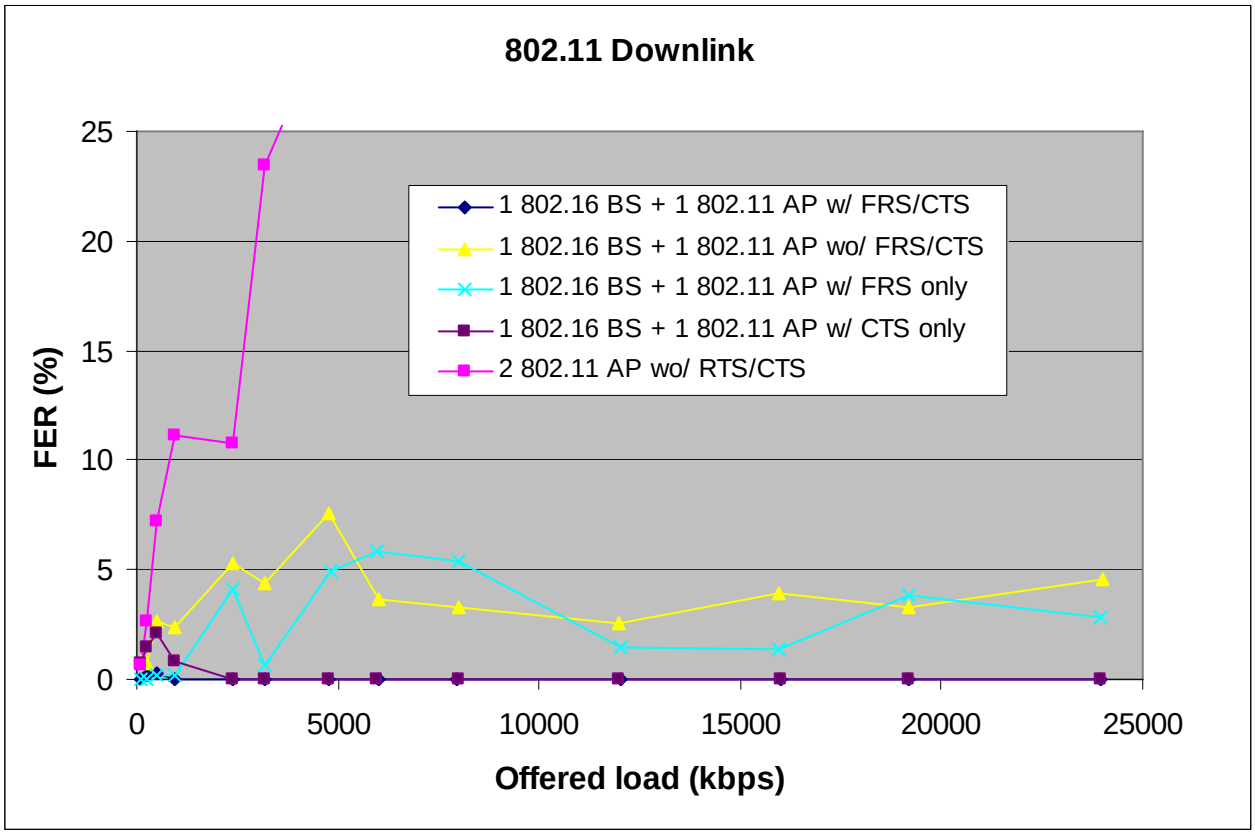


Figure 25 802.11 uplink FER results for a spatially distributed scenario.

Interim conclusions II

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

- 802.16 systems supporting FRS transmission and CTS reception present very low FER results. These results are in line with the collocated case.
- High FERs are observed for the case where FRS transmission and CTS reception is not implemented.
- Considering performance for the case of applying FRS transmission only and CTS reception only then individually CTS reception only provides a significantly lower FER than FRS transmission only.

Specific editing changes

None.

References

[1] IEEE P802.16h/D2c: *Air Interface for Fixed Broadband Wireless Access Systems Improved Coexistence*

Mechanisms for License-Exempt Operation, Draft Standard.

[2] Paul Piggin et al., *Enhancements to UCP LBT*, IEEE 802.16-07/078, September 2007.

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