Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Simulation of IEEE 802.16h and IEEE 802.11y Coexistence (Preliminary Report)**
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Re:	Coexistence between IEEE 802.11y and 802.16h systems
Abstract	Simulation results on average throughput and packet delay of IEEE 802.11y and 802.16h systems under various coexistence mechanisms
Purpose	To help resolve the coexistence issues between IEEE 802.11y and 802.16h systems
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Release	
Patent Policy and Procedures	

Simulation of IEEE 802.16h and IEEE 802.11y Coexistence

(Preliminary Report)

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Introduction

The coexistence of IEEE 802.11y and IEEE 802.16h systems is of considerable interest to a number of organizations. There is a large likelihood for example, that such systems will have to work on a co-channel basis in the lightly licensed 3.650-3.700 GHz band in the US.

Objective

The purpose of this simulation is to examine possible coexistence approaches between co-channel and co-located generic IEEE 802.16h and 802.11y systems; the former system incorporates a TDD/TDMA multiple access control while the latter uses a CSMA/CA approach. The interference scenario will be simplified to lower the complexity of the simulations. We will consider a scenario in which the 802.16h base station and 802.11Y access point are in close proximity to each other and can thus interfere with each other. This includes these station's subscriber terminals.

In essence, if either the 802.16h Base Station and its associated subscriber stations and the 802.11y Access point and its associated subscriber stations transmit at the same time, interference is deemed to occur. All overlaps of simultaneous transmission times are construed as lost transmissions.

Coexistence is attempted only by modification of the 802.16h system and different scenarios are investigated, which are detailed in Annex B. The simulation will embody the following general attributes:

1. Both systems will be compared for the same amount of Total Offered Traffic. Uplink traffic will be a fraction (N) of the downlink (specified in Table 3 of Annex A), and this fraction will be fixed for any series of offered traffic. Total Offered Traffic will be the sum of the uplink and downlink offered traffic.
2. Offered traffic will have arrival statistics typical of IP.
3. Of interest to the simulation is the average throughput and delay exhibited by each system as a function of the offered traffic.

All systems will be assumed to operate at the same channel bandwidth and modulation as specified in Annex A.

IEEE 802.11y Model

The simulation will use a generic model of an IEEE 802.11 CSMA/CA (carrier sense multiple access with collision avoidance) basic access system, where an access point (AP) wishing to transmit data on an idle channel transmits a data burst and then waits for a positive acknowledgement (ACK) burst from the destination. Before an 802.11y station is to transmit it shall sense the medium to determine if another station is transmitting. The access point shall have a monitoring (clear channel assessment) period to determine channel occupancy. If the medium is determined to be idle, the transmission may proceed.

The CSMA/CA basic access scheme mandates that a gap of a minimum specified duration exist between contiguous burst sequences. At the end of a transmission the access point waits a fixed period of time called a Distributed Interframe Space (DIFS) and appends an additional backoff (BO) period. The 802.11y protocol adopts an exponential backoff scheme (called the Distributed Coordination Function-DCF). At the end of each burst transmission (and DIFS), and prior to the next, the backoff time is uniformly chosen in the range (0, cw-1). The value cw is called contention window, and depends on the number of transmissions failed for the burst. At the first transmission attempt, cw is set equal to a value Cwmin called the minimum contention window. After each unsuccessful transmission, cw is doubled, up to a maximum value CWmax. If a retransmission succeeds, cw is reset to CWmin .

All the relevant 802.11y parameters along with their default values used in the simulation may be found in Table 1 of Annex A.

IEEE 802.16h Model

IEEE 802.16h system employs OFDM PHY whose parameters are listed in Table 2 of Annex A. The initial simulation uses 5ms frames with a 3ms/2ms split for DL and UL sub-frames, respectively. To achieve coexistence between IEEE 802.16h and 802.11y operating in a co-channel manner, the 802.16h system may implement different coexistence mechanisms. These mechanisms are categorized into different coexistence scenarios as described in Annex B and will be compared through simulations.

Traffic Model

The two systems are assumed to have the same offered traffic statistics. Moreover, the uplink traffic will be simulated having the same statistics as the downlink traffic, except mean offered traffic on the uplink will be some fraction, N, of the downlink.

Packet sizes are assumed to be uniformly distributed in the range [0.1xMaxPacketSize, 0.9xMaxPacketSize] with MaxPacketSize defined in Table 3 of Annex A. The packet inter-arrival time follows exponential distribution with its mean determined by the mean packet size and the average bit-rate of the traffic source.

Simulation Setup

A packet-level simulation of different scenarios described in Annex B has been implemented. Average throughput and delay for each scenario are obtained through multiple independent iterations of the simulation under that particular scenario. Each iteration of the simulation runs for 100s with a 20s warm-up period to allow systems reach steady state (i.e. data collected during the first 20s is discarded).

For each scenario, the offered load is varied in 100kbps increments and each network's throughput and packet delay are recorded. Finally, these values are averaged over multiple independent iterations and the result is plotted versus the offered load.

Simulation Results

Scenario 1: Baseline

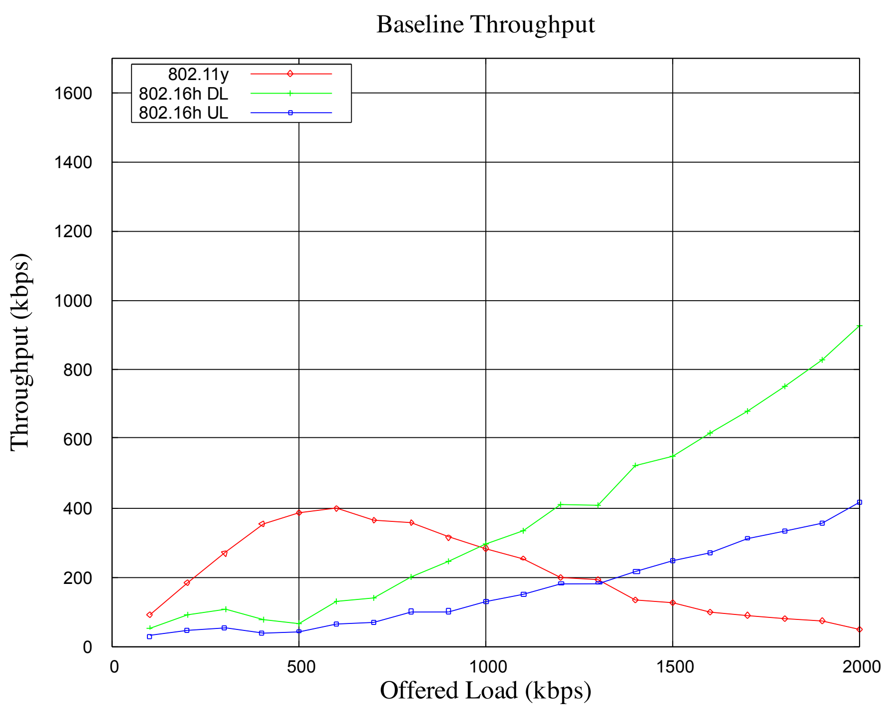

Figure 1. Baseline throughput vs. offered load

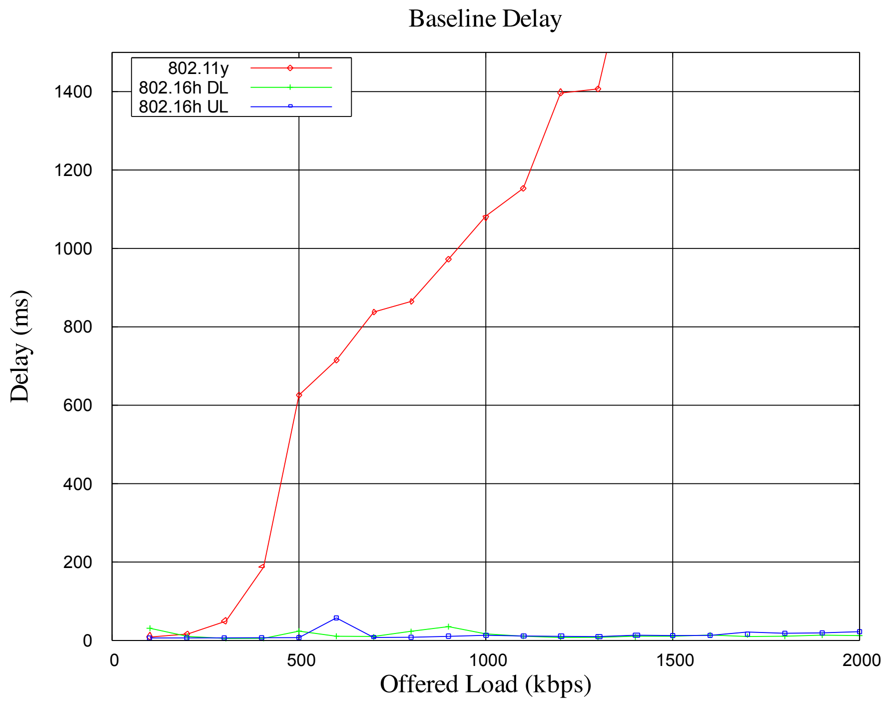

Figure 2. Baseline delay vs. offered load

Scenario 2: LBT

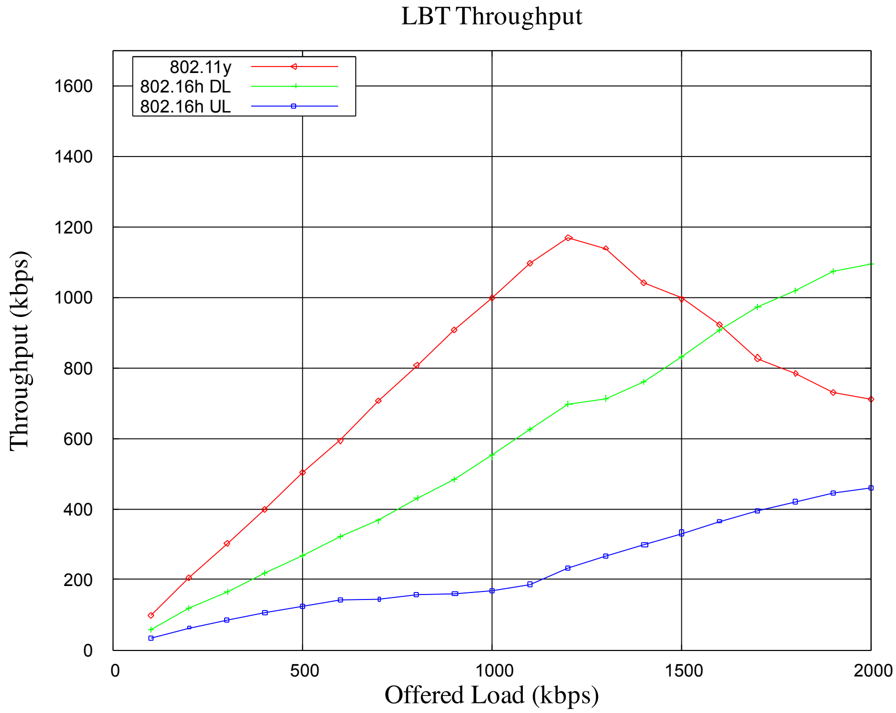

Figure 3. LBT throughput vs. offered load

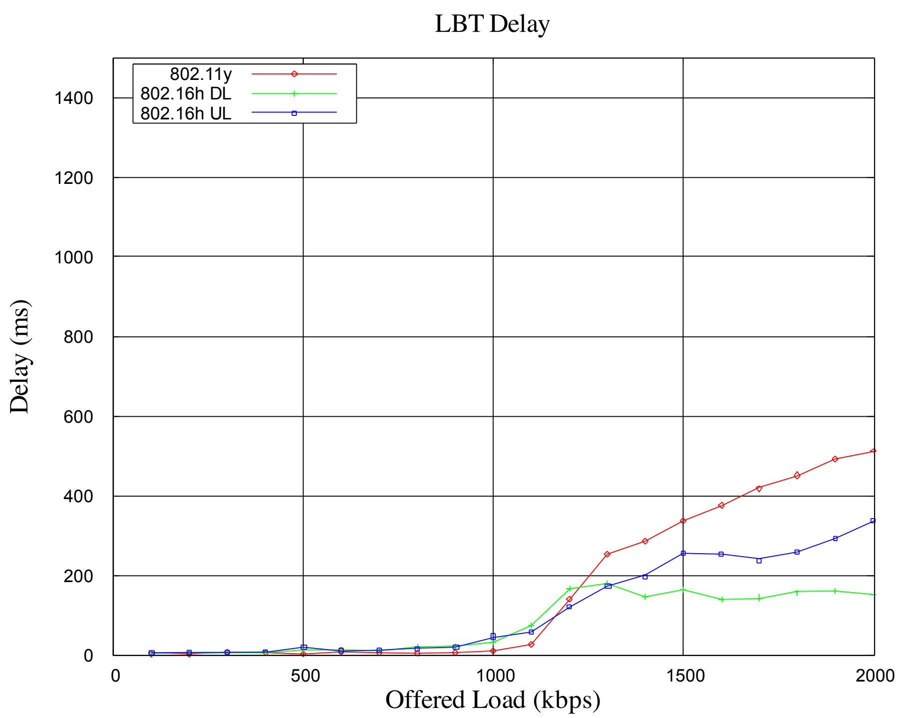

Figure 4. LBT delay vs. offered load

Scenario 3: EQP

In order to study the performance of EQP mechanism, simulations were performed under different EQP periods (1/3/6/10/20 frames) while the EQP duration was fixed at 3 frames (15ms). Note that the EQP duration was chosen according to the minimum EQP duration requirement for a 5MHz channel as specified in Table h1 of [2].

Throughput analysis for different EQP periods:

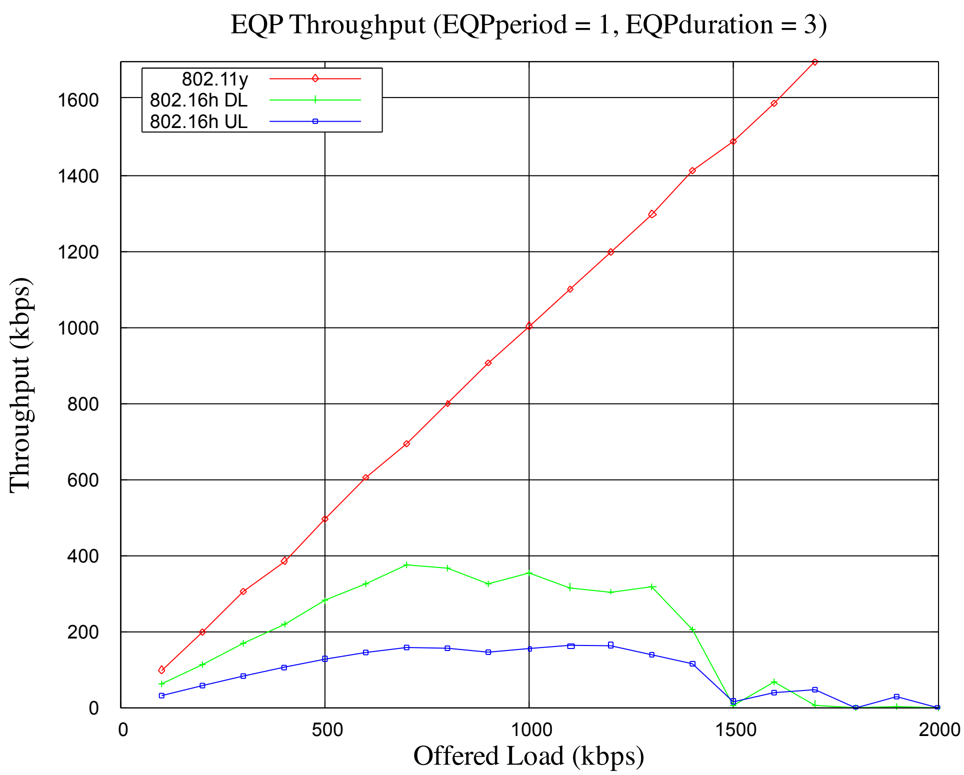

Figure 5. EQP throughput vs. offered load (EQPperiod = 1, EQPduration = 3)

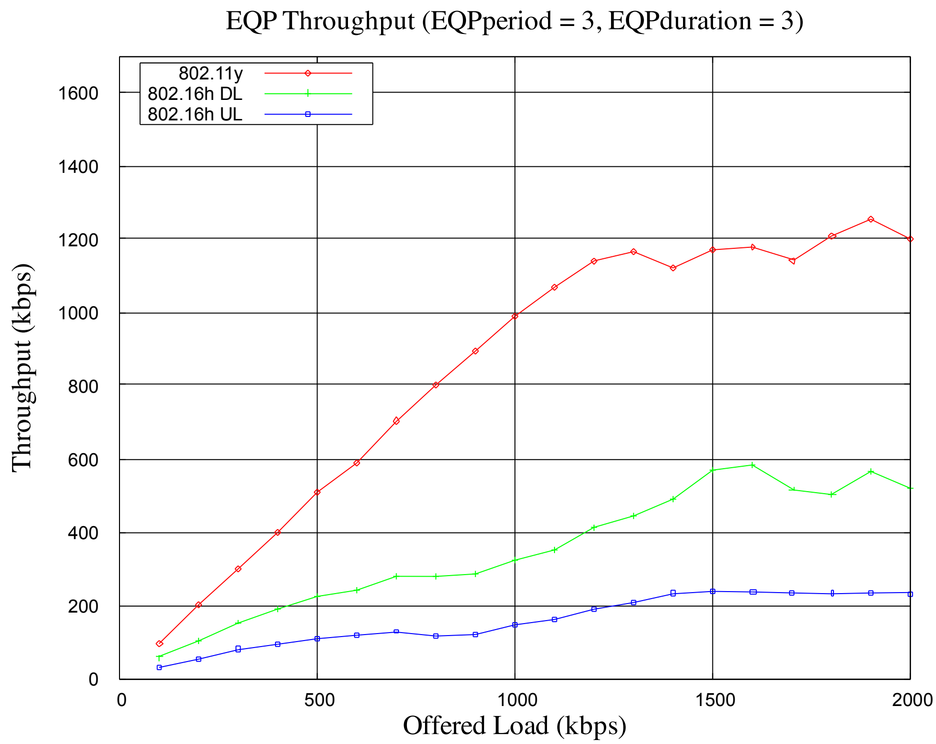

Figure 6. EQP throughput vs. offered load (EQPperiod = 3, EQPduration = 3)

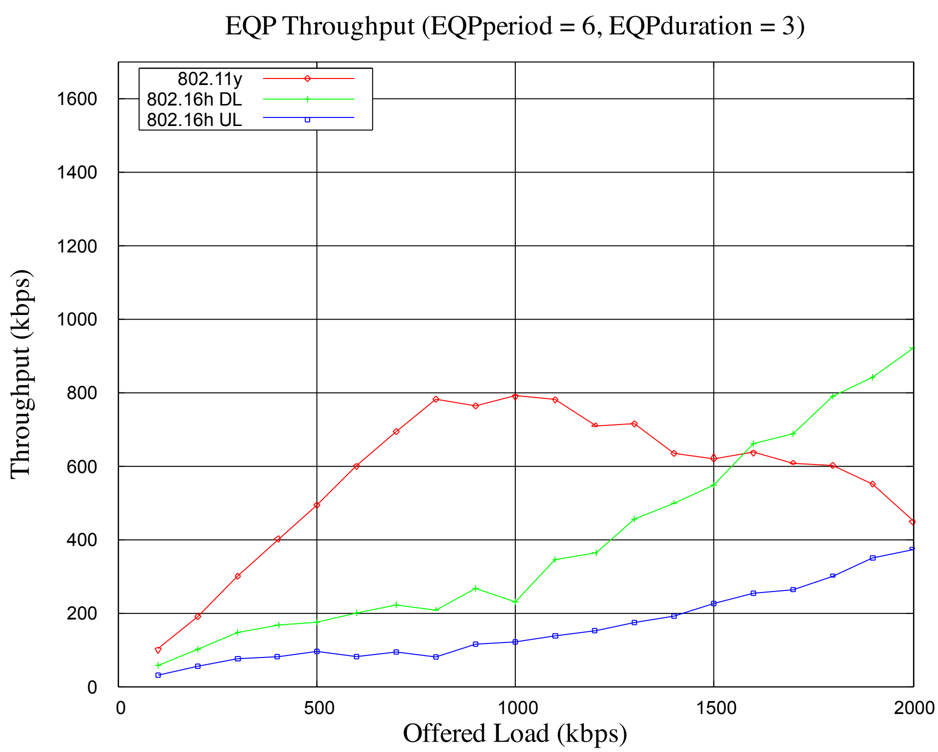

Figure 7. EQP throughput vs. offered load (EQPperiod = 6, EQPduration = 3)

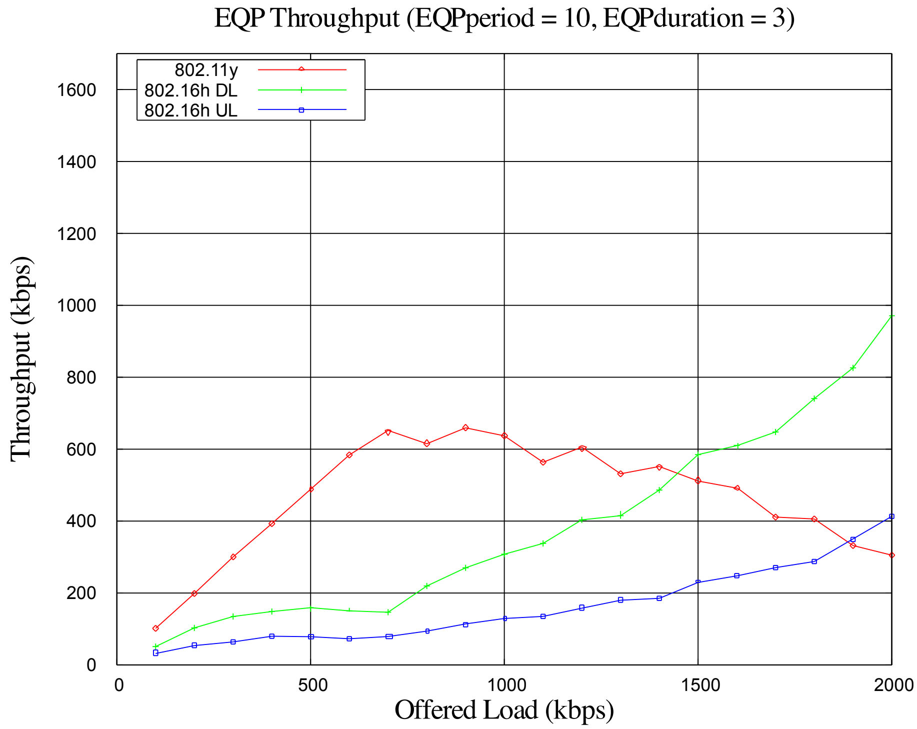

Figure 8. EQP throughput vs. offered load (EQPperiod = 10, EQPduration = 3)

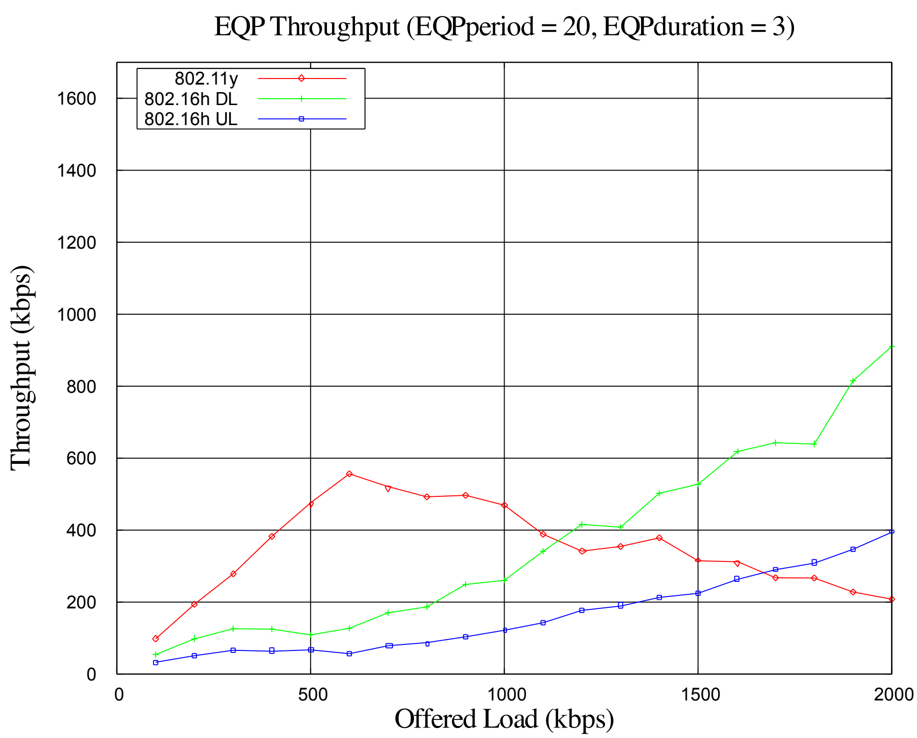

Figure 9. EQP throughput vs. offered load (EQPperiod = 20, EQPduration = 3)

Delay analysis for different EQP periods:

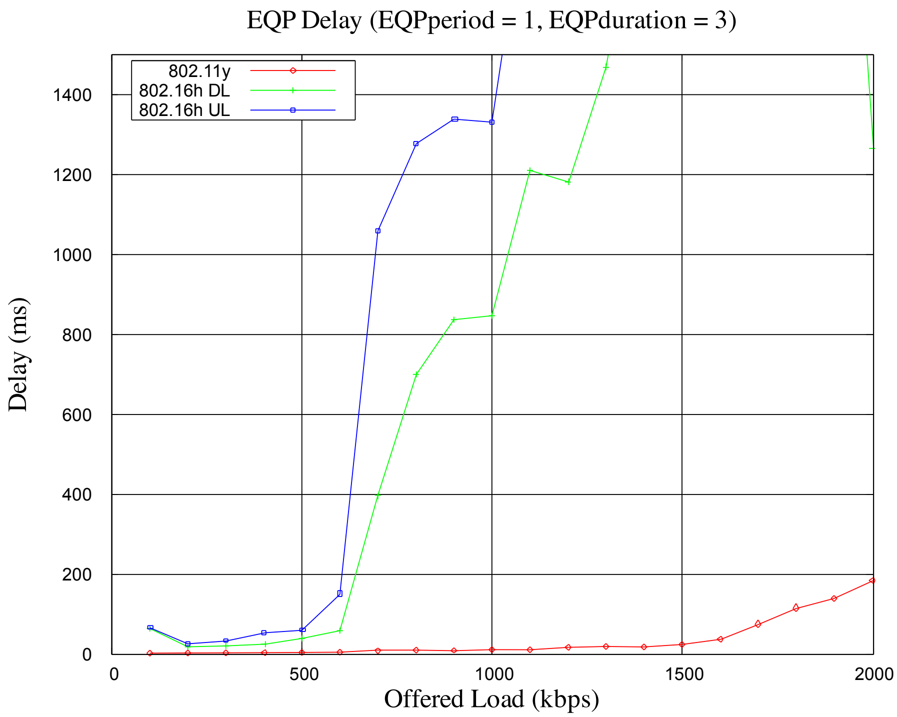

Figure 10. EQP delay vs. offered load (EQPperiod = 1, EQPduration = 3)

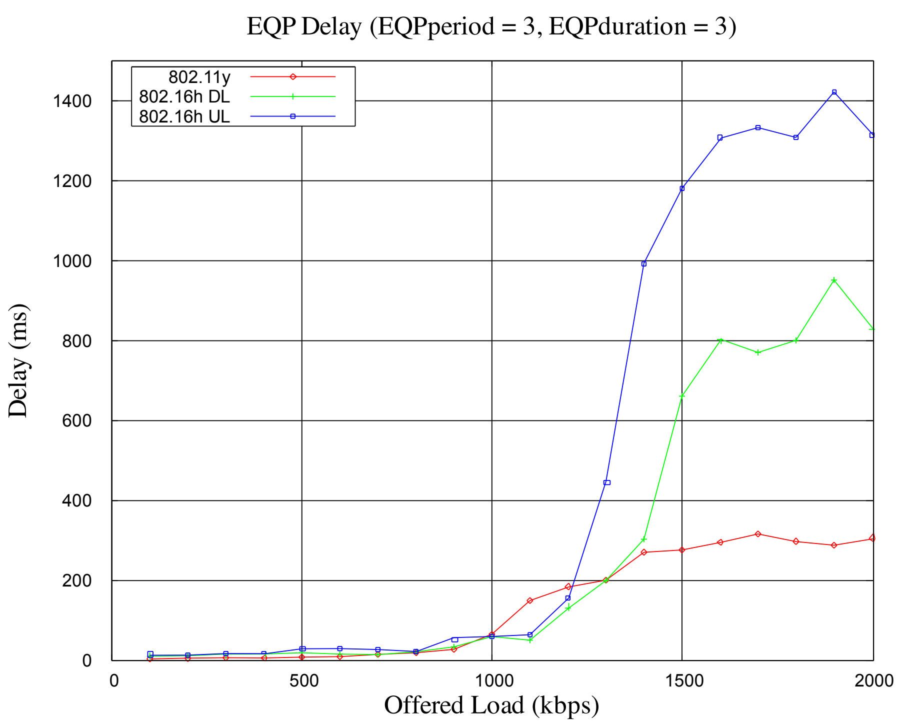

Figure 11. EQP delay vs. offered load (EQPperiod = 3, EQPduration = 3)

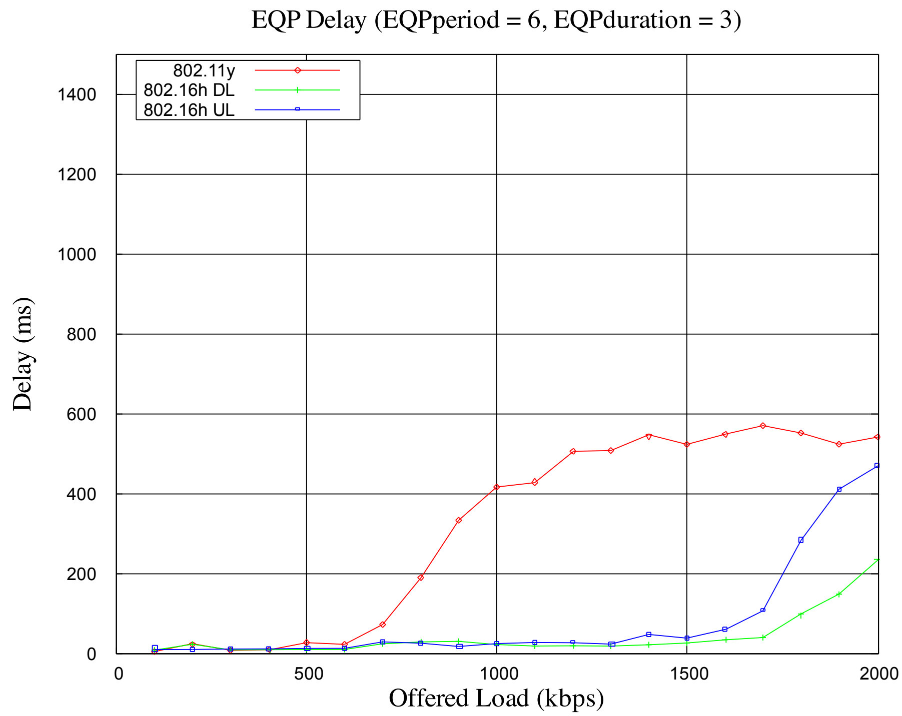

Figure 12. EQP delay vs. offered load (EQPperiod = 6, EQPduration = 3)

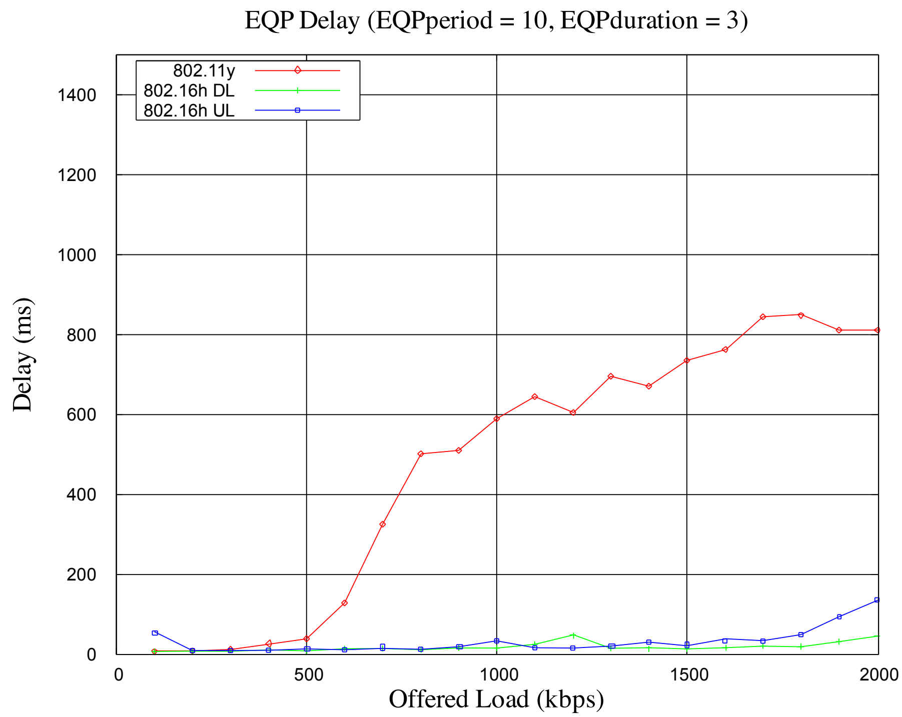

Figure 13. EQP delay vs. offered load (EQPperiod = 10, EQPduration = 3)

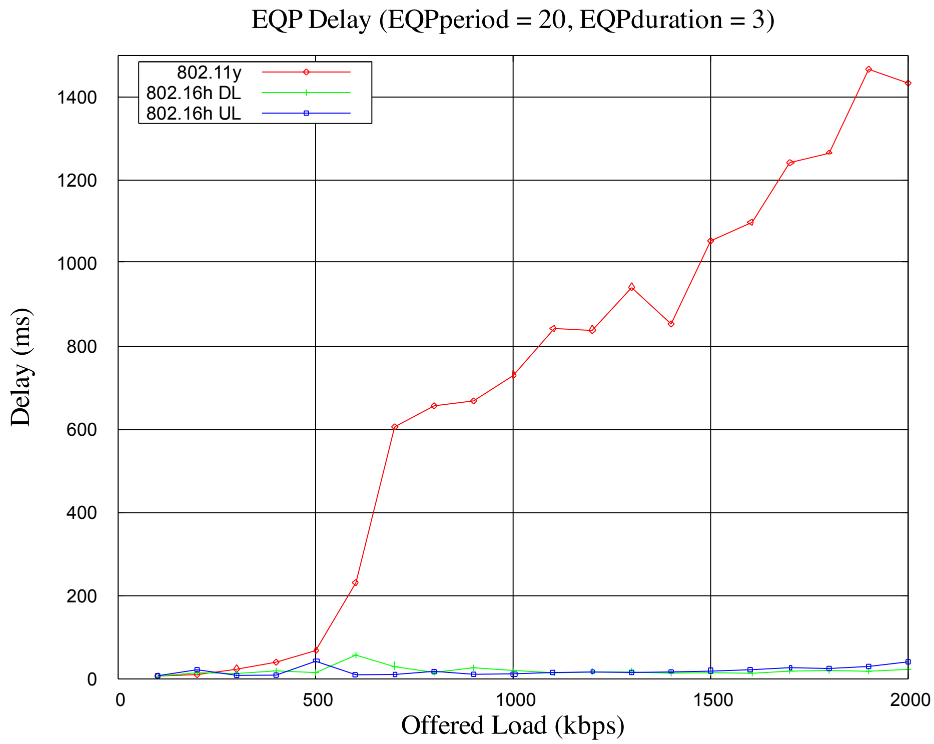

Figure 14. EQP delay vs. offered load (EQPperiod = 20, EQPduration = 3)

Scenario 4: LBT + EQP

As in the case of EQP, simulations of this scenario were performed under different EQP periods (1/3/6/10/20 frames) while EQP duration was fixed at 3 frames (15ms).

Throughput analysis for different EQP periods:

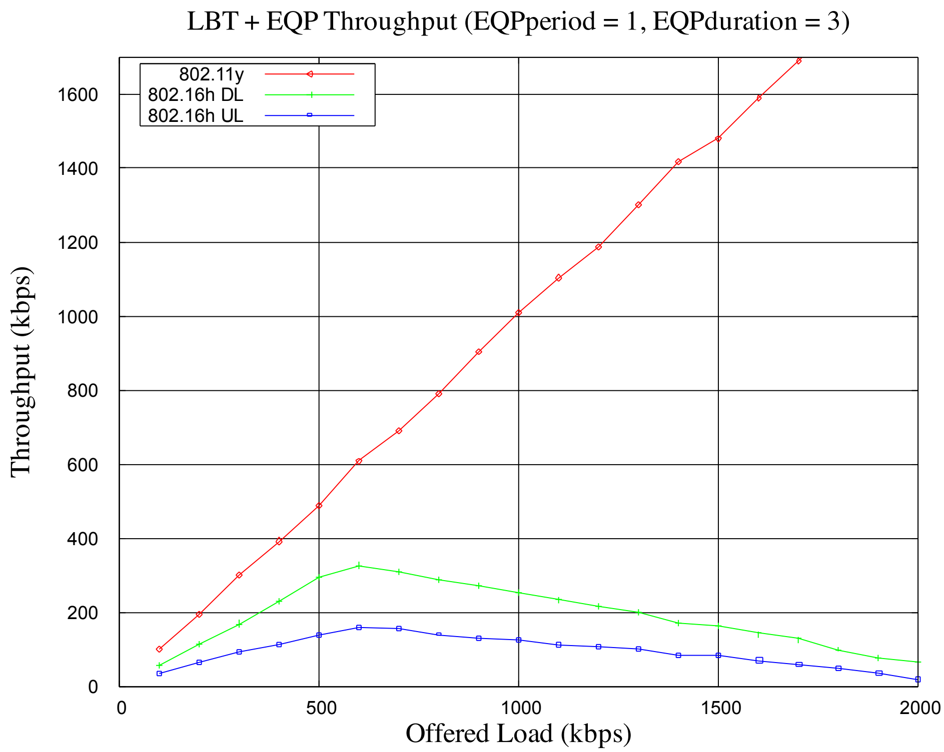

Figure 15. LBT + EQP throughput vs. offered load (EQPperiod = 1, EQPduration = 3)

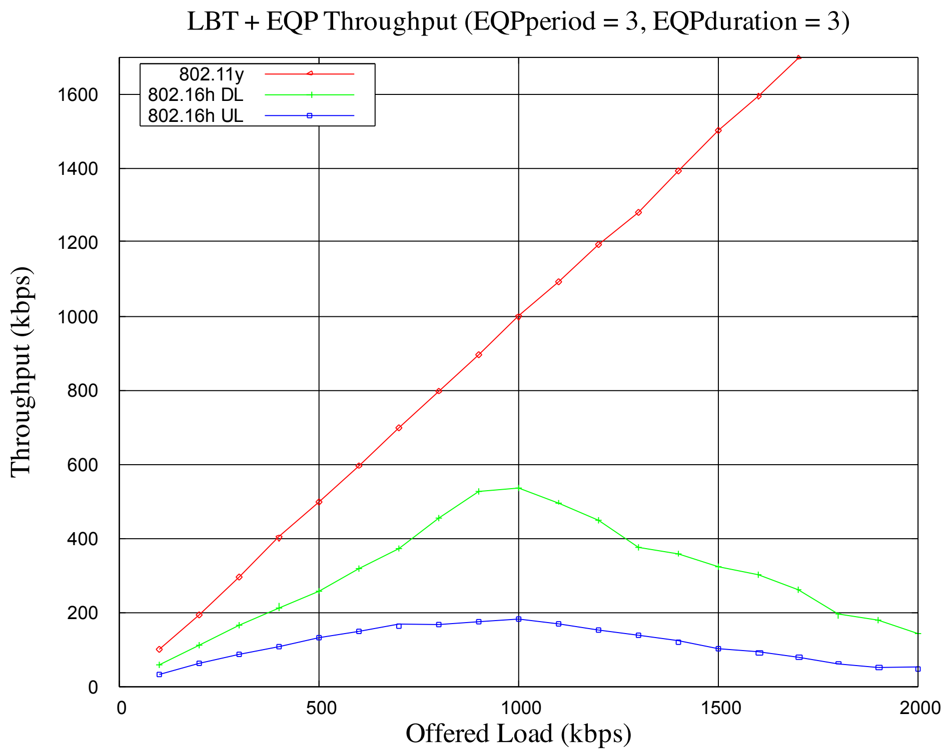

Figure 16. LBT + EQP throughput vs. offered load (EQPperiod = 3, EQPduration = 3)

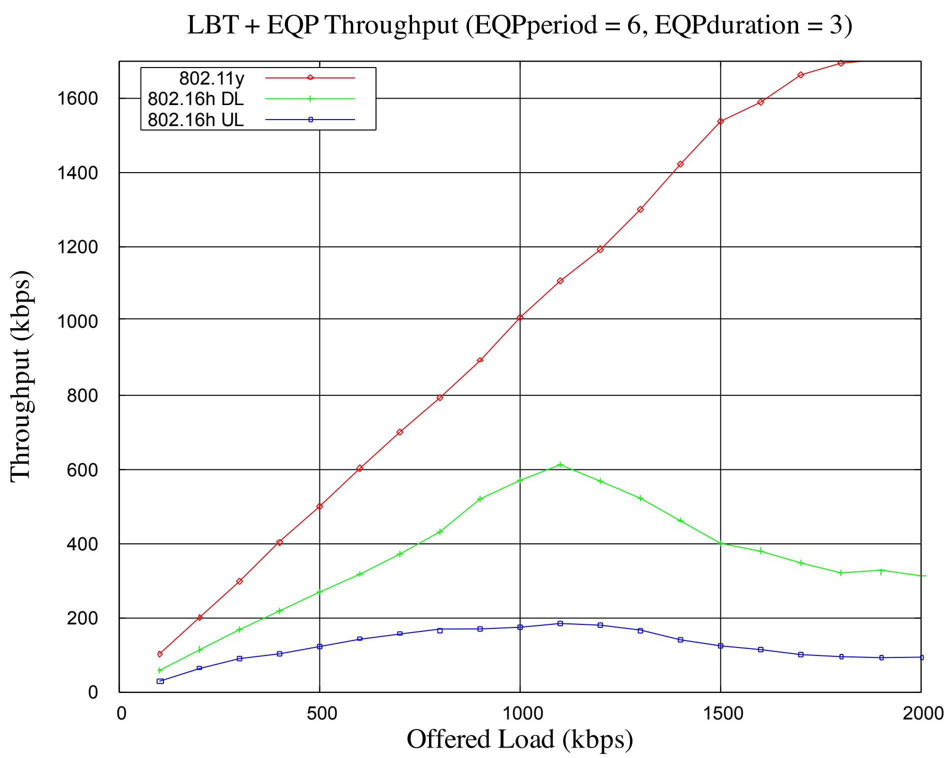

Figure 17. LBT + EQP throughput vs. offered load (EQPperiod = 6, EQPduration = 3)

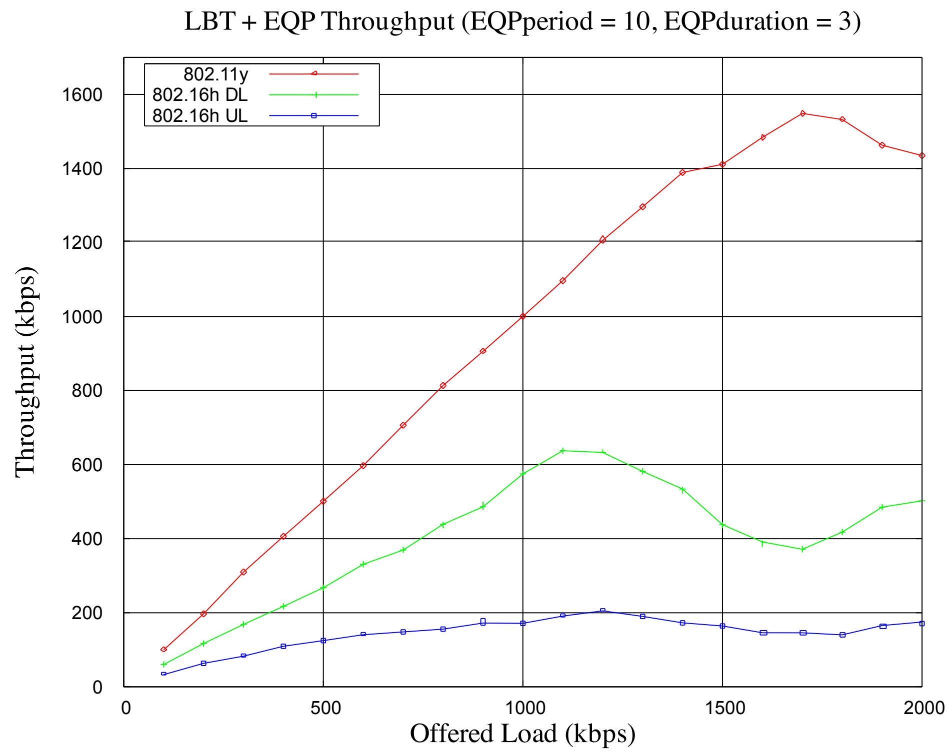

Figure 18. LBT + EQP throughput vs. offered load (EQPperiod = 10, EQPduration = 3)

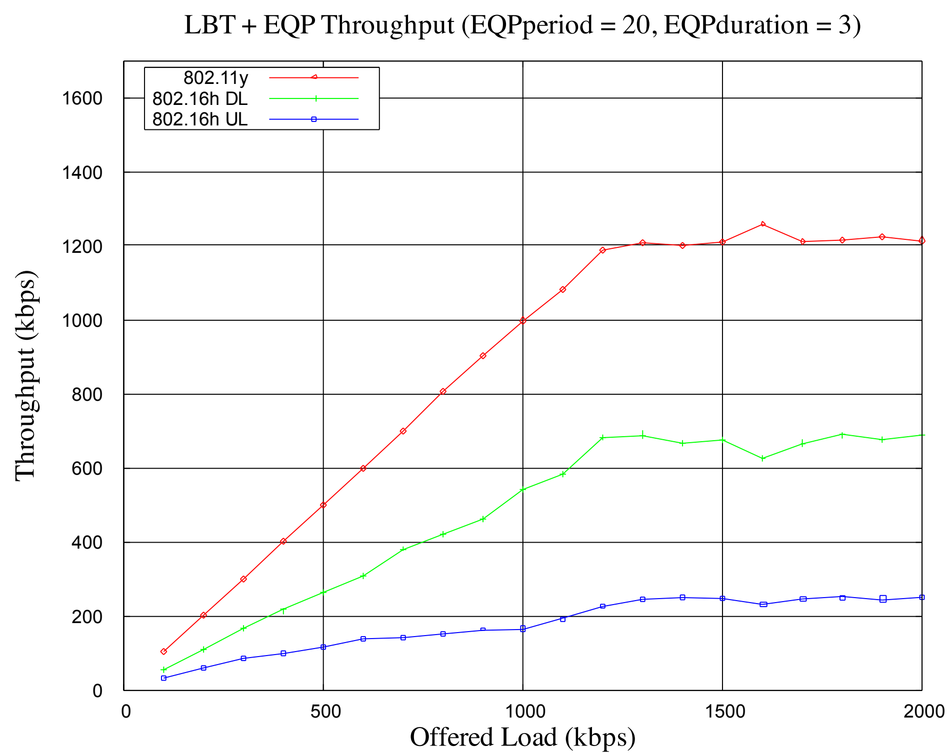

Figure 19. LBT + EQP throughput vs. offered load (EQPperiod = 20, EQPduration = 3)

Delay analysis for different EQP periods:

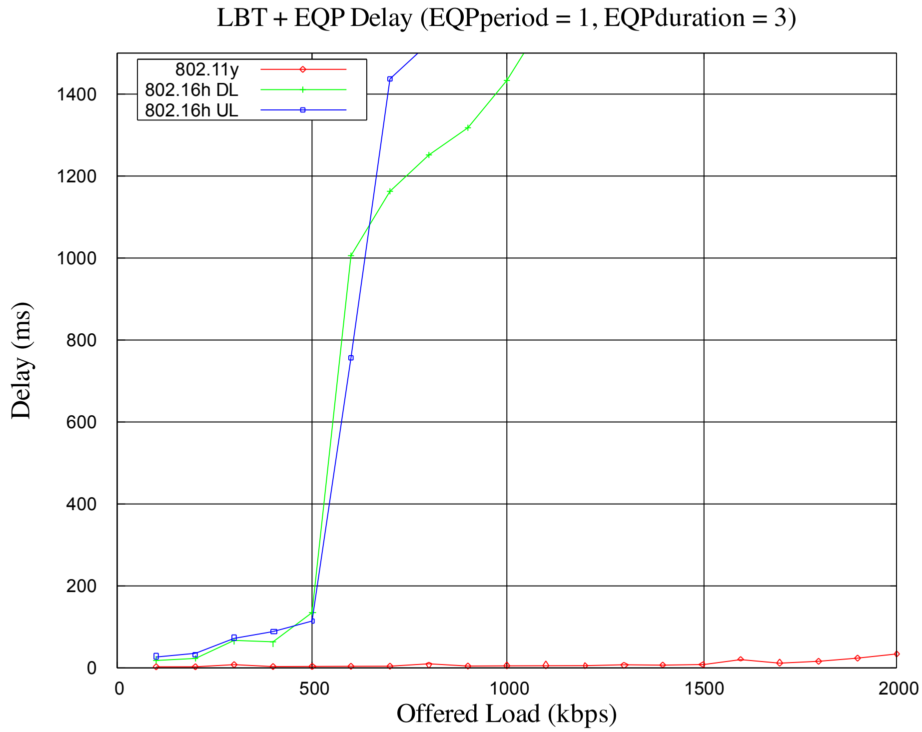

Figure 20. LBT + EQP delay vs. offered load (EQPperiod = 1, EQPduration = 3)

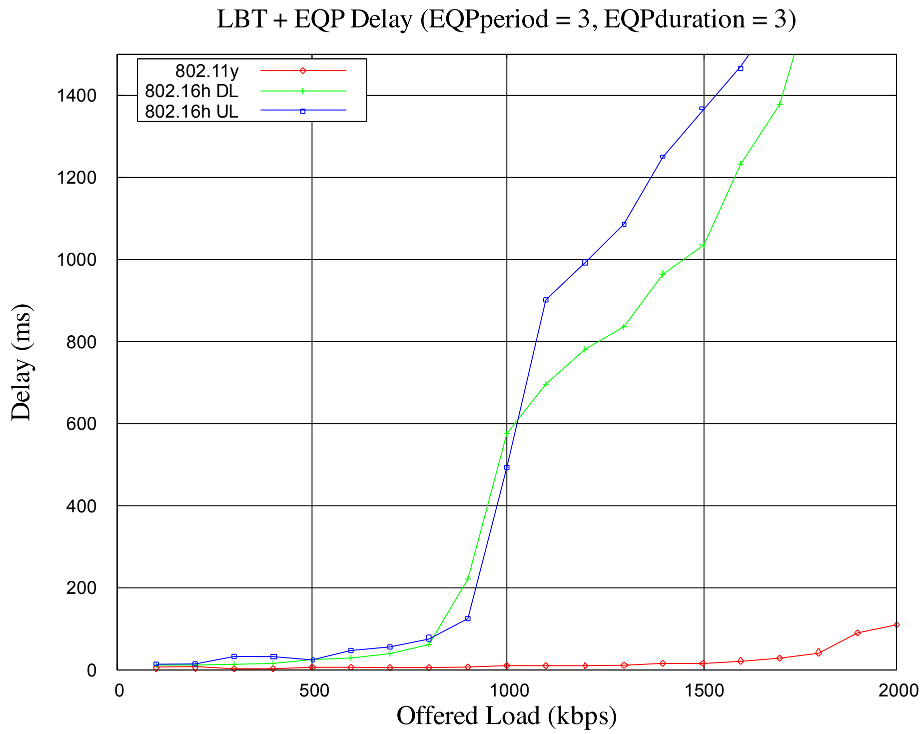

Figure 21. LBT + EQP delay vs. offered load (EQPperiod = 3, EQPduration = 3)

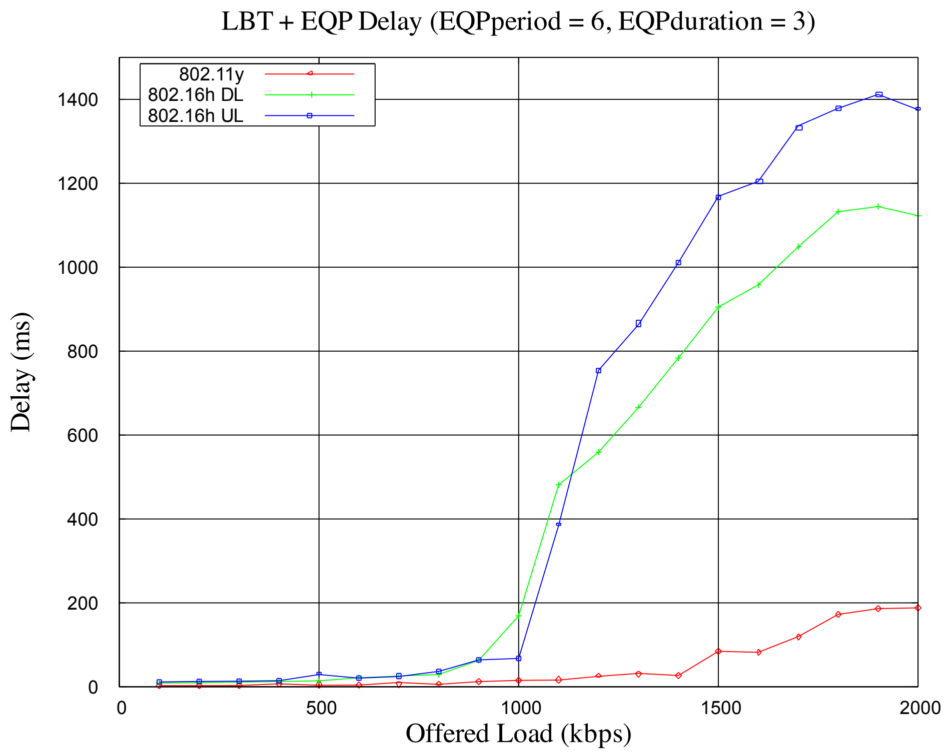

Figure 22. LBT + EQP delay vs. offered load (EQPperiod = 6, EQPduration = 3)

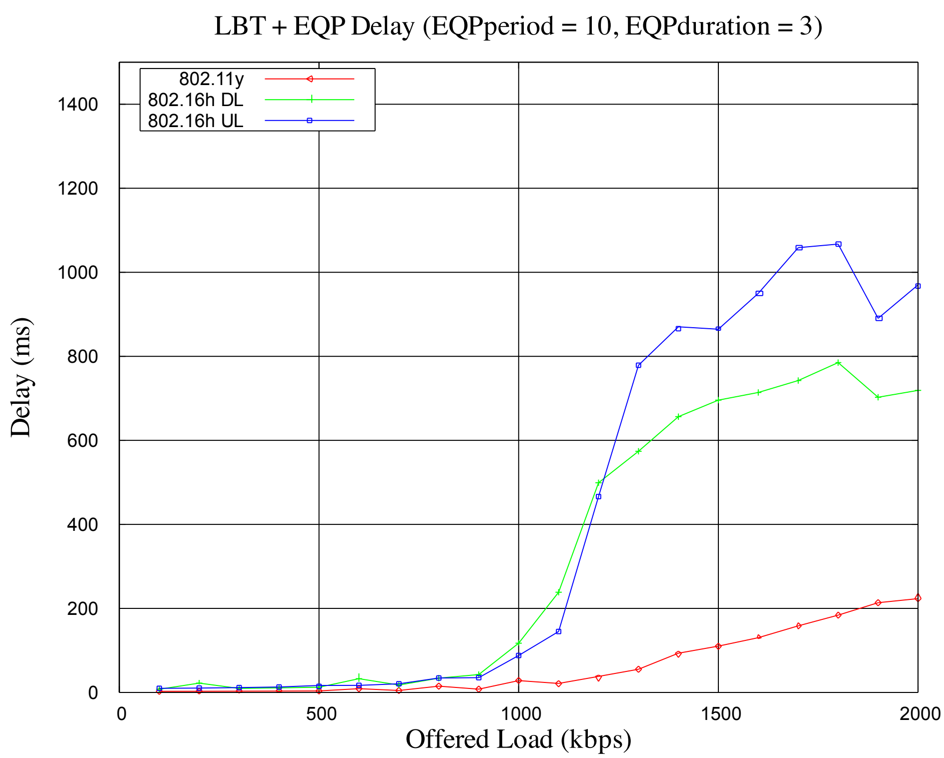

Figure 23. LBT + EQP delay vs. offered load (EQPperiod = 10, EQPduration = 3)

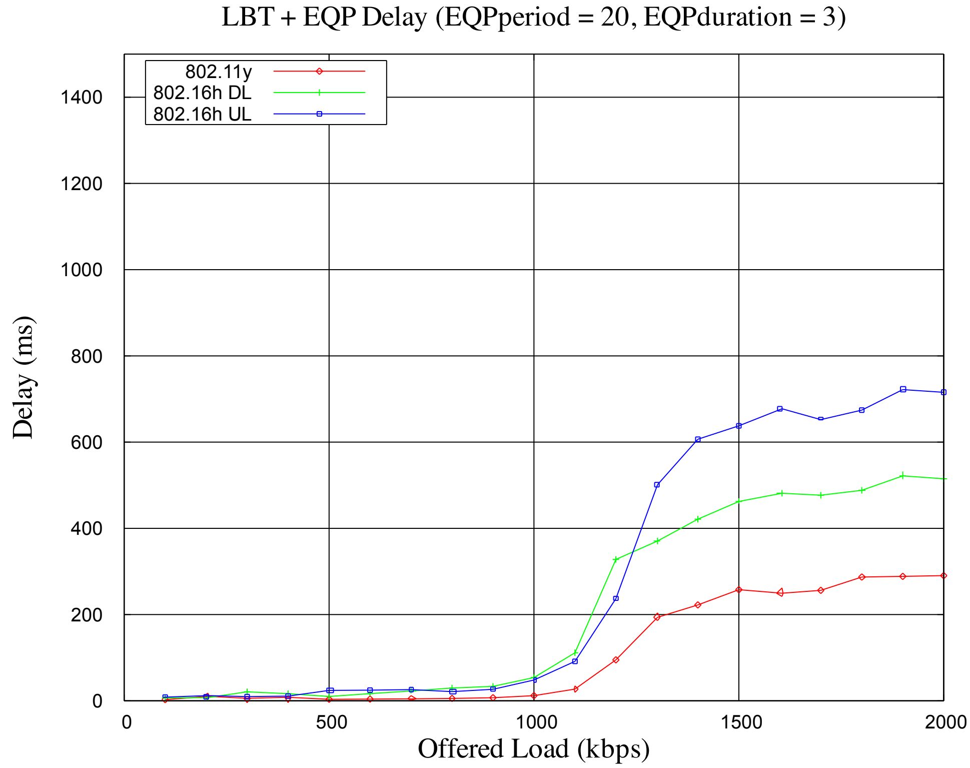

Figure 24. LBT + EQP delay vs. offered load (EQPperiod = 20, EQPduration = 3)

Scenario 5: EQPv2

This scenario is currently being coded and simulation results will be added as soon as they become available.

Annex A: Simulation parameters

The parameters used for configuration of the 802.11y and 802.16h systems have been summarized in Tables 1 and 2, respectively. 802.11y parameters are in line with those specified in [1] for a 5 MHz channel. 802.16h system employs OFDM PHY with 5ms frames (3ms DL, 2ms UL).

MAC Protocol	CSMA/CA
Channel Bandwidth	5 MHz
N_{FFT}	64
OFDM Sub-carriers	52
Data Sub-carriers	48
OFDM Symbol Duration	16 μs (T_{FFT} + T_{GI})
Raw Bit-rate	3.0 Mbps (QPSK 1/2)
Basic Rate	1.5 Mbps (BPSK 1/2)
Slot Time	21 μs
SIFS	64 μs
Preamble Length	64 μs
CWmin	15
CWmax	1023
RTS/CTS	Disabled

Table 1. 802.11y parameters

MAC Protocol	TDMA TDD
Channel Bandwidth	5 MHz
n: Oversampling Factor	144/125
N_{FFT}	256
OFDM Sub-carriers	200
Data Sub-carriers	192
Cyclic Prefix	1/4
OFDM Symbol Duration	55.5 μs (T_{FFT} + T_{CP})
Raw Bit-rate	3.3 Mbps (QPSK 1/2)
Frame Duration	5 ms
DL Sub-frame Duration	3 ms
UL Sub-frame Duration	2 ms
EQP Duration	3 frames (15 ms)
EQP Period	Varied from 1 to 20 frames
TTG	10 PS
RTG	10 PS

Table 2. 802.16h parameters

Transport Protocol	UDP

Offered Load	Varied from 100 kbps (lightly loaded) to 2.0 Mbps (overloaded)
DL/UL Load Ratio	60/40
Packet Inter-arrival Time	Exponentially distributed
MaxPacketSize	1500 Bytes
PktSizeLowerBound	0.1 * MaxPacketSize
PktSizeUpperBound	0.9 * MaxPacketSize
Packet Size	Uniformly distributed between PktSizeLowerBound and PktSizeUpperBound

Table 3. Traffic parameters

Annex B: Simulation scenarios for 802.16h and 802.11y coexistence

This is a summary of various scenarios implemented in the first round of simulations. In all simulations we assume that systems are collocated therefore, any interference results in collision. Each network's parameters, as well as the traffic model are as described in the Annex A.

Scenario 1: Baseline

This scenario assumes generic 802.11 and 802.16 systems without implementing any additional coexistence mechanisms and will serve as a benchmark against which other mechanisms will be evaluated.

Scenario 2: LBT

In this scenario, 802.16h system employs Listen-Before-Talk as detailed in Clause 6.4.3.5 of [2] by undertaking clear channel assessment before embarking on any transmission. Data that is deferred from transmission because of channel activity is buffered for the next transmission. Otherwise the system behaves in the same manner as normal 802.16h system. Note that LBT is applied independently to both DL and UL sub-frames as shown in the “revised” Figure h7 of [2]. The uplink monitoring period takes place in a regular manner at the Transmit/Receive gap of the 802.16h TTD cycle.

Scenario 3: EQP

This is the implementation of Extended-Quiet-Period concept for the 802.16h system, as described in Clause 6.4.3.3 of [2]. The EQPduration (integer number of quiet .16 frames) and the EQPperiod (integer number of active .16 frames before going into quiet period again) will be varied to quantify their effect on the average throughput and delay of each network.

Scenario 4: LBT + EQP

This is a combination of Scenarios 2 and 3 where EQP is performed periodically as in Scenario 3 with LBT being applied to “active” (non-quiet) frames of 802.16h system.

Scenario 5: EQPv2

This is a variation on the EQP concept of Scenario 3 where there is 16ms of continuous activity (3x5ms .16 frames + 1ms) from 802.16h side followed by a quiet 4ms period for the 802.11y system. The first 16ms are fully populated using filling bytes to prevent 802.11y’s transmission.

References

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

[2] P. Piggin, C802.16h-06/125r1, “Consolidation of UCP – Uncoordinated Coexistence Protocol”.