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Abstract	
Purpose	[Description of what *specific* action is requested of the 802.16 Working Group or subgroup.]
Notice	
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Some simulation results on the 802.16h coexistence with 802.11y

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Introduction

In this contribution we show some simulation results in order to identify the areas in which the 802.16h protocols might be improved.

Abbreviations

The following abbreviations are used in this document:

- **NI**: No Interference
- **NCX**: No Coexistence
- **UCX**: Uncoordinated Coexistence
- **CCX**: Coordinated Coexistence
- **MCS**: Modulation Coding Scheme
- **ED**: Energy Detect

Simulation Fundamentals

Cell Radius

As defined in the parameter document [1], the path loss in scenario A (outdoor-to-outdoor deployment) uses the following formula:

$$\boldsymbol{PL}[\boldsymbol{dB}] = 20\log_{10}(\left(\frac{4\pi \boldsymbol{d}_0}{\lambda}\right) + 10\gamma\log_{10}\left(\frac{\boldsymbol{d}}{\boldsymbol{d}_0}\right) + \boldsymbol{s} + 6\log_{10}\left(\frac{\boldsymbol{f}_c}{2000}\right) - 10.8\log_{10}\left(\frac{\boldsymbol{h}_R}{2}\right)\boldsymbol{L}$$

$$\boldsymbol{d}_0 = 100\boldsymbol{m}$$

$$\lambda = \boldsymbol{c} / \boldsymbol{f}_c$$

$$\boldsymbol{f}_c = 3675\boldsymbol{MHz}$$

$$\gamma = 4 - 0.0065\boldsymbol{h}_b + \frac{0.005}{\boldsymbol{h}_b}$$

$\boldsymbol{h}_b$ is the base antenna height (= 25 m), $\boldsymbol{h}_R$ the CPE antenna height (= 10 m), and **s** is a shadow fading margin (= 6 dB). The Cell radius is determined by the minimal received power required to reach the minimal sensitivity level of the relevant system:

$$d = 100 \cdot 10^{\frac{P_{sens} + P_{Tx} + G_{Tx} + G_{Rx} + G_{OFDMA} - FM - L_{Tx} - L_{Rx} - 20\log_{10}\left(\left(\frac{4\pi d_0}{\lambda}\right) - s - 6\log_{10}\left(\frac{f_c}{2000}\right) + 10.8\log_{10}\left(\frac{h_R}{2}\right)\right.}{10\gamma}}$$

where:

$\boldsymbol{P_{sens}}$ is the required sensitivity level: $\boldsymbol{P}_{\boldsymbol{sens},802.16} = -91.1\,\boldsymbol{dBm}$, $\boldsymbol{P}_{\boldsymbol{sens},802.11} = -88\,\boldsymbol{dBm}$.
$\boldsymbol{P_{Tx}}$ is the transmitted power: $\boldsymbol{P_{Tx,DL}} = 27\,\boldsymbol{dBm}$, $\boldsymbol{P_{Tx,UL}} = 17\,\boldsymbol{dBm}$.
$\boldsymbol{G_{Tx}}$ and $\boldsymbol{G_{Rx}}$ are the transmitter and receiver antenna gains, respectively: $\boldsymbol{G_{Tx}} + \boldsymbol{G_{Rx}} = 28\,\boldsymbol{dB}$.
$\boldsymbol{L_{Tx}}$ and $\boldsymbol{L_{Rx}}$ are the transmitter and receiver cable losses, respectively: $\boldsymbol{L_{Tx}} + \boldsymbol{L_{Rx}} = 1.5\,\boldsymbol{dB}$.
$\boldsymbol{G_{OFDMA}}$ is the system's OFDMA gain: $\boldsymbol{G}_{\boldsymbol{OFDMA},\boldsymbol{UL},802.16} = 12.3\,\boldsymbol{dB}$, $\boldsymbol{G}_{\boldsymbol{OFDMA},\boldsymbol{DL},802.16} = \boldsymbol{G}_{\boldsymbol{OFDMA},\boldsymbol{DL/UL},802.11} = 0\,\boldsymbol{dB}$.
$\boldsymbol{FM} = 2\,\boldsymbol{dB}$ is the fade margin. The resulting radius appears as in Figure 1, and the cell radius for each system is the minimum of the DL and UL radius of that system.

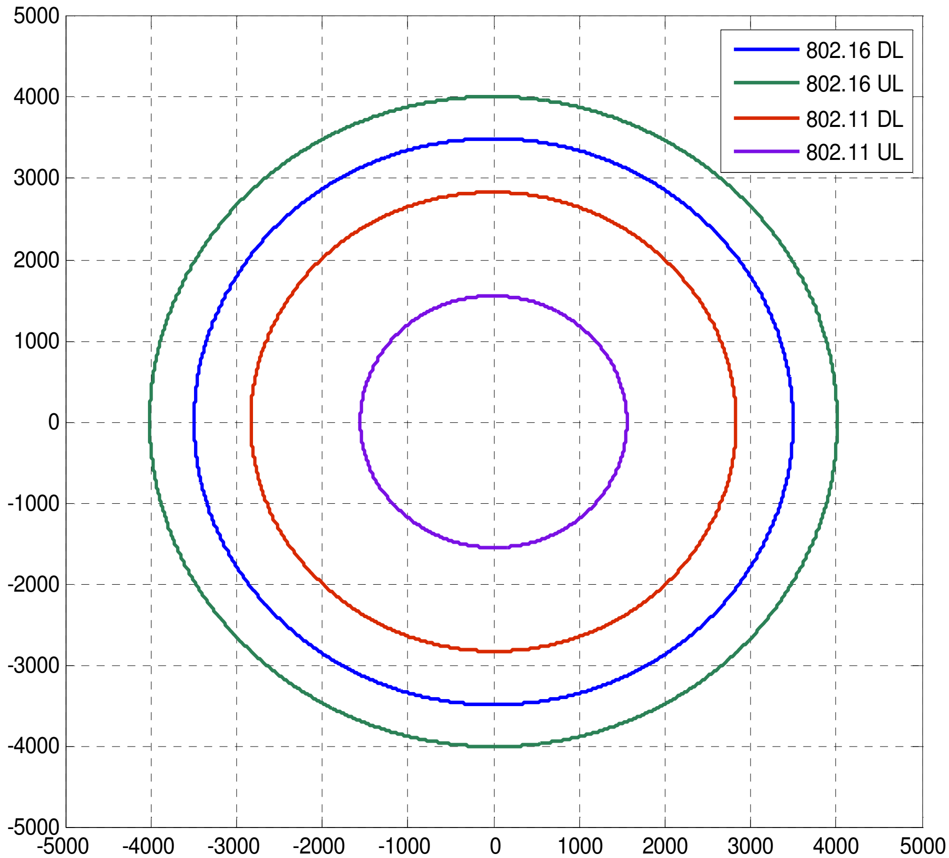

Figure 1: Maximal distance for sensitivity

The 802.16 cell radius is determined by its DL radius (= 3.5 km), and the 802.11 cell radius is determined the UL radius (= 1.5 km).

Parameters

- Scenario A
- 802.16 cell radius 3.5 km
- 802.11 cell radius 1.5 km
- Variable MCS
  - 802.11 MCS determined by Rx power for each CPE
  - 802.16 DL MCS determined by Rx power in CPE
  - 802.16 UL MCS is optimized by usage of subchannelization.
- ED threshold is -78 dBm for all systems
  - For 802.11 in no-CX, uncoordinated CX and coordinated CX modes
  - For 802.16 in uncoordinated and coordinated CX modes
- Unimodal Data traffic model for 50% load

Coexistence Methods

There are two coexistence methods proposed in [2], both modifying the scheduling of the 802.16 in the 3.65 GHz band. The two methods are the uncoordinated and coordinated coexistence.

Simulation Results

We present here the simulation results for a range-limited scenario. However, due to the relatively low throughput per cell we consider that it is needed also the simulation of a capacity-limited scenario.

Throughputs

The throughputs below are per user.

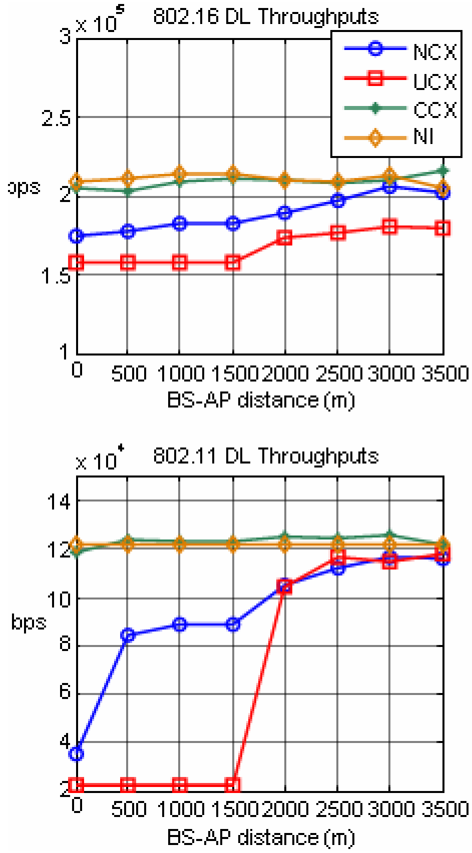

Fig. 2 Throughputs per system/direction

- CCX 802.11 Throughput
  - The 802.11 throughput is limited by the return link throughput, because of the requirement that each sent packet be acknowledged. When the 802.11 can operate slave mode, it performs CSMA on the medium also during the CXSBI. This means that for distances of 1.5 km and below between BS and AP, its DL throughput will be limited. The DL throughput limitation is also a limitation on the UL throughput, and therefore the 802.11 system's total throughput is degraded for distances of 1.5 km between the BS and AP. However, when the 802.11 can't operate during the CXSBI, it won't perform CSMA there, thereby not performing additional back-off. This means that the AP can access the medium just as much as the 802.11 CPEs, even for distances of 1.5 km or less between the BS and AP. This equal time share between the DL and UL medium access ensures that none of the links will limit the other one, and the throughput is significantly increased.
  - The 802.11 throughputs remain constant regardless of the distance between BS and AP, because it can only transmit during the CXCBI portion of the CX_MAC frame.

- CCX 802.16 Throughput
  - Because of the increased traffic of the 802.11 system, the 802.16 system will have less transmit opportunities during the CXCBI portion of the CX_MAC frame. However, its CCX throughput is still more than half of the throughput in the No Interference case.

Hidden Nodes Probability

- 802.11: As the 802.11 system only transmits during the CXCBI portion of the CX_MAC frame, it always uses its full power capabilities, and therefore the interference caused by the 802.16 system has less impact on the received SINR.
- 802.16: As the 802.11 DL access to the medium during the CXCBI is increased, the sLBT process is more likely to detect it, and therefore the 802.16 is less probable to schedule frames during the CSCBI period and less likely that those frames will be corrupted due to interference from 802.11.

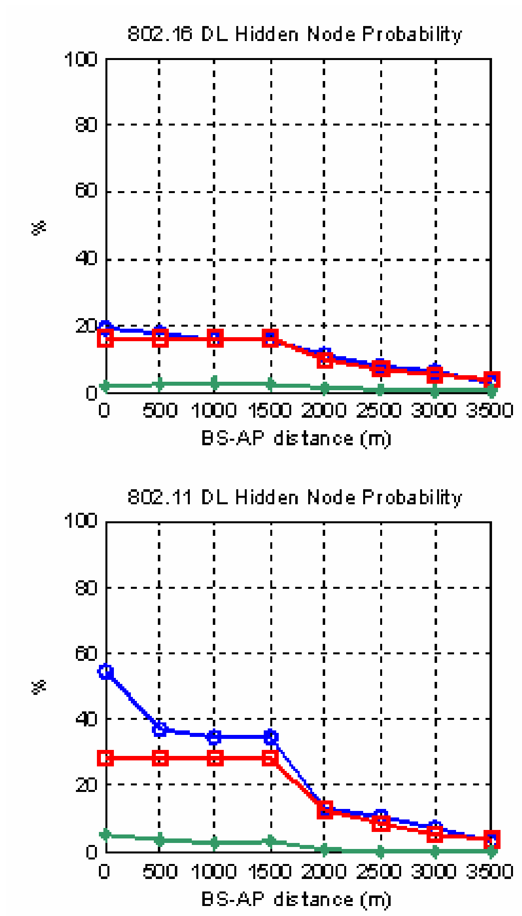

Fig. 3 Hidden nodes probabilities per system /direction

Delay

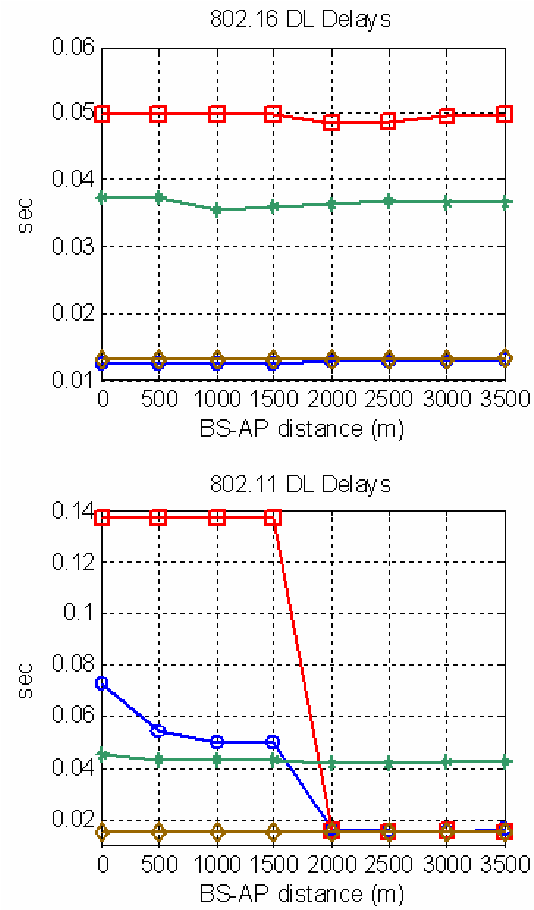

Fig. 4 Delays per system /direction

- 802.16 System
  - NCX Delay: Since packets with higher MCS (and hence with less delay) are more likely to be degraded by noise, then the NCX delay of the 802.16 system is slightly higher than in the no interference case.
  - UCX Delay: The 802.16 doesn't transmit in two cases: (a) if it achieved its utilization ratio (0.5 for this simulation), (b) if it detects energy in the beginning of the frame. Because of these two conditions, the utilization achieved by the 802.16 is slightly less than half, and therefore the delay in this case would be greater then one frame length (5 ms) relative to the no interference case
  - CCX Delay: The average relative delay is 5 ms, as seen in Figure 11 above.

References

[1] Parameters for simulation of Wireless Coexistence in the US 3.65GHz band, IEEE 802.19-07/11r10
[2] Draft Amendment to IEEE Standard for Local and Metropolitan Area Networks, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Improved Coexistence Mechanisms for License-Exempt Operation, IEEE P802.16h/D3, Oct 2007.