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Wireless LANs

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| Summary of 802.11ax Self Evaluation for IMT-2020 EMBB Indoor Hotspot and Dense Urban Test Environments |
| Date: 2018-09-10 |
| Author(s): |
| Name | Affiliation | Address | Phone | email |
| Sindhu Verma | Broadcom |  |  | sindhu.verma@broadcom.com |
| Shubhodeep Adhikari | Broadcom |  |  | shubhodeep.adhikari@broadcom.com |

Abstract

This document presents the self-evaluation of 802.11ax vis-à-vis the IMT-2020 minimum requirements for the Indoor Hotspot and Dense Urban test environments of the eMBB usage scenario [1]. The self-evaluation follows the methodology specified in [2]. This document is a summary of the results presented to IEEE 802.11 in [3], [4] and [5].

# Introduction

ITU-R has set the requirements for the technical performance of IMT-2020 radio interface(s). To qualify to be designated as an IMT-2020 technology, a candidate RAT must meet a set of minimum performance requirements over a set of usage scenarios and test environments. The usage scenarios and test environments are specified in [2] while the minimum performance requirements are specified in [1]. eMBB (Enhanced Mobile Broadband) is one of these usage scenario. Indoor Hotspot and Dense Urban are two test environments of eMBB. These test environments have the following characteristics:

* Indoor Hotspot emulates a deployment typical of indoor offices and/or shopping malls with high density of stationary or pedestrian users. Legacy 802.11 (i.e. 802.11ac and earlier) is almost always deployed in this environment.
* Dense Urban emulates an urban environment with high density of users that are either pedestrian or vehicular at slow speeds. This is an environement where 802.11ax has been designed to operate in addition to Indoor Hotspot.

This document summarizes the evaluation of 802.11ax for the above test environments.

# Discussion

The following are the salient performance metrics specified in [1] for evaluating the technology potential of a RAT in the Indoor Hotspot and Dense Urban test environments:

1. Peak Spectral Efficiency
2. Peak Data Rate
3. 5th percentile User Spectral Efficiency
4. 5th percentile User Experienced Data Rate
5. Average Spectral Efficiency
6. Area Traffic Capacity
7. Mobility
8. Bandwidth

The above metrics are to be evaluated as follows:

1. Peak Spectral Efficiency and Peak Data Rate are evaluated analytically.
2. 5th percentile User Spectral Efficiency, Average Spectral Efficiency and Mobility are evaluated based on the simulation methodology specified by ITU-R.
3. 5th percentile User Experienced Data Rate is derived from 5th percentile User Spectral Efficiency, while the Area Traffic Capacity is derived from the Average Spectral Efficiency.
4. Bandwidth is verified by inspection.

Documents presented to IEEE 802.11 in [3], [4], [5] evaluate the performance of 802.11ax for each of the above metrics for the eMBB Indoor Hotspot environment. These documents also evaluate 802.11ax performance for the eMBB Dense Urban environment. The Dense Urban estimates for the metrics specified in point 2) above have been obtained via analytic estimates and not via the simulation methodology specified in [2]. Efforts are underway to simulate these metrics; the simulations are expected to provide results similar to the analytic estimates.

The following should also be noted in this regard:

1. The evaluations consider only the capabilities that are supported by 802.11ax in its currently standardized form. Specifically, the evaluations consider transmit and receive antenna configuration, number of spatial layers, MIMO configuration, modulation-coding schemes and sensitivity that are already supported by 802.11ax. They do not consider enhancements that may be included in later revisions of 802.11ax or that can be implemented in a non-standardized manner. Better performance could be achieved if for example, a higher number of antennas or spatial layers, as allowed by the ITU-R configuration, were used in the evaluations. From this perspective the estimates are conservative.
* The only exception is the assumption of a 128Tx/Rx antenna configuration at the AP for analytically estimating the 5th percentile and average spectral efficiency in the Dense Urban test environment.
1. The simulator used in the evaluations has been calibrated against the IMT-2020 simulation data presented by multiple companies in 3GPP [6]. This calibration step ensures the relative accuracy and compatibility of the simulation results presented in this document with respect to the results presented in 3GPP for self evaluation of LTE and NR.
2. The evaluations consider a carrier frequency of 4GHz i.e. Configuration A in [2].
3. ITU-R [1] specifies certain other performance metrics too that are applicable for eMBB; not all of which are related to the PHY/MAC technology potential of a RAT. These are the User and Control Plane Latency, Energy Efficiency and Mobility Interruption Time.
4. 802.11ax is expected to easily satisfy the User Plane latency requirement of 4ms in the given test configuration of an unloaded network (section 4.7.1 of [1]). It is also expected to satisfy the Control Plane latecy of 20ms.
5. Mobility Interruption Time and Energy Efficiency are under evaluation.

The following sections contain a summary of evaluation results.

# Evaluation Summary for eMBB Indoor Hotspot

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|  | Metric | ITU-R Evaluation Method | Minimum Requirement | 802.11ax Performance |
| 1 | Peak data rate | Analytical | DL/UL: 20/10 Gbps | DL/UL: 20.78 Gbps [Note 1] |
| 2 | Peak spectral efficiency | Analytical | DL/UL: 30/15 bits/s/Hz | DL/UL: 58.01 bits/s/Hz [Note 2] |
| 3 | User experienced data rate | Analytical for single band and single layer;Simulation for multi-layer | Not applicable for Indoor Hotspot | Not applicable |
| 4 | 5th percentile user spectral efficiency | Simulation | DL/UL: 0.3/0.21 bits/s/Hz | DL/UL: 0.45/0.52 bits/s/Hz [Note 3] |
| 5 | Average spectral efficiency | Simulation | DL/UL = 9/6.75 bits/s/Hz/TRxP | DL/UL: 9.82/13.7 bits/s/Hz/TRxP [Note 3] |
| 6 | Area traffic capacity | Analytical | DL: 10 Mbit/s/m2 | Required DL bandwidth = 170 MHz with 3 TRxP/site. [Note 4] |
| 7 | Mobility | Simulation | UL: 1.5 bits/s/Hz | UL: 9.4 bits/s/Hz |
| 8 | Bandwidth | Inspection | 100 MHz, scalable | 20/40/80/80+80/160 MHz |

1. Assumes a three carrier configuration: 8x8 HE160 + 8x8 HE160 + 8x8 HE40.
2. Assumes an 8x8 configuration.
3. Assumes 2-Factor MU-MIMO without any multi-user scheduling gain.
4. Some of the 802.11ax configurations that satisfy an Area Traffic Capacity of 10 Mbits/m2 are 8x8HE160 + 8x8HE40 or 8x8HE160 + 8x8HE160. There can be other configurations too.

# Evaluation Summary for eMBB Dense Urban

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| --- | --- | --- | --- | --- |
|  | Metric | ITU-R Evaluation Method | Minimum Requirement | 802.11ax Performance |
| 1 | Peak data rate | Analytical | DL/UL: 20/10 Gbps | DL/UL: 20.78 Gbps [Note 1] |
| 2 | Peak spectral efficiency | Analytical | DL/UL: 30/15 bits/s/Hz | DL/UL: 58.01 bits/s/Hz [Note 2] |
| 3 | User experienced data rate | Analytical for single band and single layer;Simulation for multi-layer | DL/UL: 100/50 Mbit/s | DL/UL: 195.2/73.6 Mbps [Note 3] |
| 4 | 5th percentile user spectral efficiency | Simulation | DL/UL: 0.225/0.15 bits/s/Hz | DL/UL: 1.22/0.46 bits/s/Hz [Note 4] |
| 5 | Average spectral efficiency | Simulation | DL/UL = 7.8/5.4 bits/s/Hz/TRxP | DL/UL: 11.34/5.37 bits/s/Hz/TRxP |
| 6 | Area traffic capacity | Analytical | Not applicable for Dense Urban | Not applicable |
| 7 | Mobility | Simulation | UL: 1.5 bits/s/Hz | Not evaluated |
| 8 | Bandwidth | Inspection | 100 MHz, scalable | 20/40/80/80+80/160 MHz |

1. Assumes a three carrier configuration: 8x8 HE160 + 8x8 HE160 + 8x8 HE40.
2. Assumes an 8x8 configuration.
3. Assumes 160MHz transmission bandwidth only. It is possible for 802.11ax to support a higher three carrier transmission bandwidth of (160+160+40) MHz.
4. This is an estimated value. It assumes the following antenna configuration: AP: 128Tx/Rx, Client: 4Tx/Rx.

# Conclusion and Notes

**Conclusion 1**: 802.11ax in its currently standardized form satisfies the primary PHY/MAC requirements for the IMT-2020 eMBB Indoor Hotspot test environment.

**Conclusion 2**: 802.11ax is expected to satisfy the IMT-2020 requirements for the eMBB Dense Urban test environment. Efforts are underway to simulate the 5th percentile user spectral efficiency, Average spectral efficiency and Mobility metrics. The simulations are expected to provide results in line with the analytic estimates.

**Note 1**: Indoor Hotspot:

1. The simulation based evaluations for eMBB Indoor Hotspot assume no multi-user scheduling gain and only 2-factor MU-MIMO. So, the results presented for 5th percentile user spectral efficiency, Average spectral efficiency, Area traffic capacity and Mobility are more conservative than what can be supported by 802.11ax.
2. The derivations do not assume any of the following features and procedures. Some of these are already supported in 802.11ax and some have been proposed for the next generation of 802.11. These additional features and procedures can improve the performance of 802.11ax beyond what has been presented in this document.
	1. Increasing the number of simultaneous operating bands.
	2. Increasing the maximum supported bandwidth.
	3. Antenna configuration higher than 8x8 and correspondingly a higher number of spatial layers.
	4. 4096 QAM
	5. Increasing the maximum code rate for 1024 QAM beyond the currently supported 0.83.
	6. Interference coordination among APs.
	7. Successive Interference Cancellation
	8. Frequency Reuse
	9. Improvements in device sensitivity that are be possible in the next 4-5 years.

**Note 2**: Dense Urban

1. The estimates for 5th percentile user spectral efficiency and Average spectral efficiency do not assume any diversity gain at the transmitter or receiver. So, the estimated values for these metrics are more conservative than what can be supported in the simulation configuration specified by ITU-R [2].
2. The improved performance expected from the additional features and procedures listed in Points 1, 2, and 4 to 9 in Note 1b, are also expected for the Dense Urban evaluations.

# References

1. Report ITU-R M.2410-0 (11/2017), Minimum requirements related to technical performance for IMT-2020 radio interface(s)
2. Report ITU-R M.2412-0 (10/2017), Guidelines for evaluation of radio interface technologies for IMT-2020
3. IEEE 802.11-18/1240r2, Benchmarking of 802.11ax against eMBB Indoor Hotspot requirements using IMT-2020 simulation methodology, July, 2018
4. IEEE 802.11-18/0915r1, Benchmarking of 802.11ax against eMBB Indoor Hotspot requirements using IMT-2020 simulation methodology, May, 2018
5. IEEE 802.11-18/0517r1, 802.11ax for IMT-2020 EMBB Indoor Hotspot and Dense Urban, March, 2018
6. RT-170019, “Summary of email discussion “[ITU-R AH 01] Calibration for self-evaluation”, Huawei, December 2017