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| Summary of 802.11ax Self Evaluation for IMT-2020 EMBB Indoor Hotspot and Dense Urban Environments |
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Abstract

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

# Introduction

ITU-R has set the requirements for the technical performance of IMT-2020 radio interface(s). 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 [3] while the minimum performance requirements are specified in [2]. eMBB (Enhanced Mobile Broadband) is one of these usage scenarios. Indoor Hotspot and Dense Urban are test environments of eMBB. Indoor Hostpot models a deployment typical of “*an indoor isolated environment at offices and/or in shopping malls based on stationary and pedestrian users with very high user density*”[3], while Dense Urban models an “*an urban environment with high user density and traffic loads focusing on pedestrian and vehicular users*’[3].

This document summarizes the evaluation of 802.11ax for the Indoor Hotspot and Dense Urban test environments presented to IEEE 802.11 in [4] and [5].

# Discussion

The following are the salient performance metrics specified in [2] 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 [4] and [5] evaluate the performance of 802.11ax for each of the above metrics for the eMBB Indoor Hotspot and Dense Urban environments.

The following should also be noted in this regard:

1. The evaluations consider only the capabilities that are supported by 802.11ax [1]. 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 as allowed by the ITU-R configuration. Better performance could be achieved if for example, a higher number of antennas or spatial layers, were used in the evaluations. From this perspective the estimates are conservative.
2. The simulator used in the evaluations has been calibrated against the IMT-2020 simulation data presented by multiple companies in 3GPP in [6] and [7]. 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.
3. The evaluations consider a carrier frequency of 4GHz i.e. Configuration A in [3].
4. ITU-R [2] specifies certain other objective 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 Control Plane Latency and Mobility Interruption Time. Control plane latency of 20 ms and Mobility Interruption Time of 0 ms as described in [2] are expected to be met by systems that use 802.11ax.

The following section contains 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 |
| 9 | User plane latency | Analytical | DL/UL : 4 ms | DL/UL : 80 us [Note 5] |

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.
5. Assumes the smallest IP packet size without payload as required by 4.7.1 [2] and SIFS delay.

# 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: 113.6/81.6 Mbps [Note 3] |
| 4 | 5th percentile user spectral efficiency | Simulation | DL/UL: 0.225/0.15 bits/s/Hz | DL/UL: 0.71/0.51 bits/s/Hz [Note 3] |
| 5 | Average spectral efficiency | Simulation | DL/UL = 7.8/5.4 bits/s/Hz/TRxP | DL/UL: 10.84/8.75 bits/s/Hz/TRxP [Note 3] |
| 6 | Area traffic capacity | Analytical | Not applicable for Dense Urban | Not applicable |
| 7 | Mobility | Simulation | UL: 1.12 bits/s/Hz | UL : 1.75 bits/s/Hz [Note 4] |
| 8 | Bandwidth | Inspection | 100 MHz, scalable | 20/40/80/80+80/160 MHz |
| 9 | User plane latency | Analytical | DL/UL : 4 ms | DL/UL : 80 us [Note 5] |

1. Assumes a three carrier configuration: 8x8 HE160 + 8x8 HE160 + 8x8 HE40.
2. Assumes an 8x8 configuration.
3. Assumes 4-Factor MU-MIMO without any multi-user scheduling gain.
4. Assumes an 8x8 configuration with a single UL stream.
5. Assumes the smallest IP packet size without payload as required by 4.7.1 [2] and SIFS delay.

# Conclusion and Notes

**Conclusion 1**: 802.11ax [1] satisfies the primary PHY/MAC requirements for the IMT-2020 eMBB Indoor Hotspot and Dense Urban test environments.

**Note 1**:

1. The simulations assume no multi-use scheduling gain. Further, for eMBB Indoor Hotspot they assume only up to 2-factor MU-MIMO, while for eMBB Dense Urban they assume up to 4-factor MU-MIMO. So, the results presented for User experience data rate, 5th percentile user spectral efficiency, Average spectral efficiency and Area traffic capacity 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.

# References

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4. IEEE 802.11-18/1240r4, Benchmarking of 802.11ax against eMBB Indoor Hotspot requirements using IMT-2020 simulation methodology, November, 2018
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7. 3GPP TR 37.910 , Study on self evaluation towards IMT-2020 submission