Technical Report

NUFRONT;

Self Evaluation towards IMT-2020 Submission

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# Foreword

This Technical Report has been produced by NUFRONT.

The contents of the present document are subject to continuing work and may change. It will be re-released by NUFRONT with an identifying change of release date and an increase in version number.

# 1 Scope

This document presents the self-evaluation of EUHT according to the IMT-2020 minimum requirements of the eMBB, mMTC and URLLC usage scenarios.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

1. ITU-R M.2412-0: "Guidelines for evaluation of radio interface technologies for IMT-2020".
2. ITU-R M.2410-0: "Minimum requirements related to technical performance for IMT-2020 radio interface(s)".
3. ITU-R M.2411-0: "Requirements, evaluation criteria and submission templates for the development of IMT-2020"
4. RT-180010: "Summary of email discussion [ITU-R AH 01] Calibration for self-evaluation"
5. NUFRONT: "characteristics template for EUHT RIT"

# 3 Abbreviations

CAP Central access point

CDF Cumulative distribution function

eMBB Enhanced Mobile Broadband

EUHT Enhanced Ultra High Throughput

ISD Inter-site distance

LMLC Low mobility large cell

LDPC Low dense parity code

mMTC Massive machine type communications

PDU Protocol data unit

RIT Radio interface technology

SE Spectral efficiency

SRIT Set of radio interface technologies

STA Station

TRxP Transmission reception point

URLLC Ultra-reliable and low latency communications

# 4 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 [1] while the minimum performance requirements are specified in [2].

This document summarizes the self-evaluation results of EUHT RIT for the eMBB, mMTC and URLLC usage scenarios.

The EUHT RIT developed by NUFRONT supports both Sub-6GHz bands (from 450MHz to 6000MHz) and mmWave bands (e.g. above 24GHz).

# 5 Self evaluation of eMBB technical performance

## 5.1 Peak spectral efficiency

As defined in Report ITU-R M.2410, Peak spectral efficiency is the maximum data rate under ideal conditions normalized by channel bandwidth (in bit/s/Hz), where the maximum data rate is the received data bits assuming error-free conditions assignable to a single CAP, when all assignable radio resources for the corresponding link direction are utilized (i.e. excluding radio resources that are used for physical layer synchronization, reference signals or pilots, guard bands and guard times).

This requirement is defined for the purpose of evaluation in the eMBB usage scenario.

The minimum requirements for peak spectral efficiencies are as follows:

- Downlink peak spectral efficiency is 30 bit/s/Hz.

- Uplink peak spectral efficiency is 15 bit/s/Hz.

The generic formula for peak spectral efficiency for a specific component carrier (say *i-th CC*) is given by

 (5.1-1)

*wherein*

* *Rmax  is the maximum code rate of LDPC*
* *For the i-th CC,*
  + * is the maximum number of layers*
  + * is the maximum modulation order*
  + *is the Frame length*
  + * is the duration of Downlink/Uplink in a frame (type)*
  + * is the number of subcarriers allocation in bandwidth  with Frame length, where  is the STA supported maximum bandwidth in the given band or band combination*
  + *is the overhead calculated as the average ratio of the number of OFDMs or subcarriers occupied by L1/L2 control, synchronization signal, sounding signal, demodulation reference signal and guard period , etc.*

*For guard period (GP), 50% of GP symbols are considered as downlink overhead, and 50% of GP symbols are considered as uplink overhead.*

### 5.1.1 DL peak spectral efficiency

DL peak spectral efficiency for both Sub-6GHz bands (450 MHz ~ 6000 MHz) and millimetre Wave (mmWave, above 24.25 GHz) are evaluated

A range of configurations are considered in the evaluation of downlink peak spectral efficiency. The evaluated configurations assume 8-layer downlink transmission for Sub-6GHz bands and 6-layer downlink transmission for mmWave bands, with 256QAM/1024QAM modulation, and a maximum coding rate of 0.875. The ratio of DL to whole link () configurations are evaluated. The difference among the evaluated configurations lays in the overhead of control and reference signals, etc. The detailed assumptions are provided in Annex B.1.1.1.

The evaluation results for Sub-6GHz bands and mmWave bands with =0.5 are provided in Table 5.1.1-1, Table 5.1.1-2.

**Table 5.1.1-1 EUHT DL peak spectral efficiency for Sub-6GHz bands (bit/s/Hz), =0.5**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Frame length *ρ* (ms)** | **1** | **2** | **4** | **Req.** |
| 256QAM | 33.5 | 38.4 | 40.9 | 30 |
| 1024QAM | 41.8 | 48.1 | 51.2 | 30 |

**Table 5.1.1-2 EUHT DL peak spectral efficiency for mmWave bands (bit/s/Hz), =0.5**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Frame length ρ (ms)** | **10** | **20** | **30** | **Req.** |
| 256QAM | 31.71 | 33.53 | 34.13 | 30 |
| 1024QAM | 39.64 | 41.91 | 42.67 | 30 |

The evaluation results for Sub-6GHz bands and mmWave bands with =0.8 are provided in Table 5.1.1-3, Table 5.1.1-4.

**Table 5.1.1-3 EUHT DL peak spectral efficiency for Sub-6GHz bands (bit/s/Hz), =0.8**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Frame length ρ (ms)** | **1** | **2** | **4** | **Req.** |
| 256QAM | 37.3 | 40.4 | 41.9 | 30 |
| 1024QAM | 46.6 | 50.5 | 52.4 | 30 |

**Table 5.1.1-4 EUHT DL peak spectral efficiency for mmWave bands (bit/s/Hz), =0.8**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Frame length ρ (ms)** | **10** | **20** | **30** | **Req.** |
| 256QAM | 33.08 | 34.22 | 34.60 | 30 |
| 1024QAM | 41.35 | 42.77 | 43.25 | 30 |

Based on the above analysis, EUHT fulfills DL peak spectral efficiency requirement with a range of configurations.

### 5.1.2 UL peak spectral efficiency

UL peak spectral efficiency for both Sub-6GHz bands and mmWave bands are evaluated.

A range of configurations are considered in the evaluation of uplink peak spectral efficiency. The evaluated configurations assume 8-layer uplink transmission for Sub-6GHz bands and 4-layer uplink transmission for mmWave bands, with 256QAM/1024QAM modulation, and a maximum coding rate of 0.875. The ratio of UL to whole link () configurations are evaluated. The detailed assumptions are provided in Annex B.1.1.2.

The evaluation results for Sub-6GHz bands and mmWave bands with =0.2 are provided in Table 5.1.2-1 and Table 5.1.2-2.

**Table 5.1.2-1 EUHT UL peak spectral efficiency for Sub-6GHz bands (bit/s/Hz),** **=0.2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Frame length ρ (ms)** | **1** | **2** | **4** | **Req.** |
| 256QAM | 30.5 | 36.5 | 39.8 | 15 |
| 1024QAM | 38.1 | 45.6 | 49.7 | 15 |

**Table 5.1.2-2 EUHT UL peak spectral efficiency for mmWave bands (bit/s/Hz),** **=0.2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Frame length ρ (ms)** | **10** | **20** | **30** | **Req.** |
| 256QAM | 17.49 | 20.50 | 21.50 | 15 |
| 1024QAM | 21.87 | 25.63 | 26.88 | 15 |

The evaluation results for Sub-6GHz bands and mmWave bands with =0.5 are provided in Table 5.1.2-3 and Table 5.1.2-4.

**Table 5.1.2-3 EUHT UL peak spectral efficiency for Sub-6GHz bands (bit/s/Hz),** **=0.5**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Frame length ρ (ms)** | **1** | **2** | **4** | **Req.** |
| 256QAM | 38.3 | 40.8 | 42.1 | 15 |
| 1024QAM | 47.9 | 51.0 | 52.6 | 15 |

**Table 5.1.2-4 EUHT UL peak spectral efficiency for mmWave bands (bit/s/Hz),** **=0.5**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Frame length ρ (ms)** | **10** | **20** | **30** | **Req.** |
| 256QAM | 21.14 | 22.34 | 22.75 | 15 |
| 1024QAM | 26.43 | 27.93 | 28.43 | 15 |

Based on the above analysis, EUHT fulfills UL peak spectral efficiency requirement with a range of configurations.

## 5.2 Peak data rate

As defined in Report ITU-R M.2410, peak data rate is the maximum achievable data rate under ideal conditions (in bit/s), which is the received data bits assuming error-free conditions assignable to a single CAP, when all assignable radio resources for the corresponding link direction are utilized (i.e. excluding radio resources that are used for physical layer synchronization, reference signals or pilots, guard bands and guard times).

For a single CAP, let W denote the channel bandwidth and SEp denote the peak spectral efficiency in that band. Then the user peak data rate Rp is given by:



In case bandwidth is aggregated across multiple bands, the peak data rate will be summed over the bands. Therefore the total peak data rate is:

 (5.2-1)

where and  (*i* = 1,…, *Q*) are the effective bandwidth and spectral efficiencies on component carrier *i*, respectively,is the normalized scalar on component carrier *i* considering the downlink/uplink ratio on that component carrier, is the carrier bandwidth of component *i*.

This requirement is defined for the purpose of evaluation in the eMBB usage scenario.

The minimum requirements for peak data rate are as follows:

- Downlink peak data rate is 20 Gbit/s.

- Uplink peak data rate is 10 Gbit/s.

### 5.2.1 DL peak data rate

A range of configurations are considered in the evaluation of downlink peak data rate.

DL peak data rate for EUHT is evaluated based on the evaluation results of EUHT peak spectral efficiency provided in Section 5.1.1. Table 5.2.1-1 and Table 5.2.1-2 provides the evaluation results for the specific component carrier (CC) bandwidth. It is observed that EUHT fulfills the DL peak data rate requirement.

Table 5.2.1-1 EUHT DL peak data ratefor Sub-6GHz bands

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Per CC BW (MHz)1 | Peak data rate per CC (Gbit/s) | Aggregated peak data rate over 16 CCs (Gbit/s) | Required DL bandwidth to meet the requirement (MHz)2 | Req.  (Gbit/s) |
| 0.5 | 80 | 2.05 | 32.77 | 781 | 20 |
| 100 | 2.56 | 40.96 | 781 |
| 0.8 | 80 | 3.35 | 52.66 | 477 |
| 100 | 4.19 | 67.07 | 477 |
| NOTE 1: sub-carrier spacing is 78.125kHz  NOTE 2: The value only indicates the required bandwidth to meet the DL peak data rate. It is not necessarily supported as EUHT Transmission bandwidth. | | | | | |

Table 5.2.1-2 EUHT DL peak data rate for mmWave bands

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Per CC BW (MHz) | Peak data rate per CC (Gbit/s)1 | Aggregated peak data rate over 16 CCs (Gbit/s)1 | Required DL bandwidth to meet the requirement (GHz)2 | Req.  (Gbit/s) |
| 0.5 | 400 | 6.82 | 109.24 | 1.173 | 20 |
| 0.8 | 400 | 11.07 | 177.15 | 0.722 |
| NOTE 1: 256QAM is assumed.  NOTE 2: The value only indicates the required bandwidth to meet the DL peak data rate. It is not necessarily supported as EUHT Transmission bandwidth. | | | | | |

### 5.2.2 UL peak data rate

A range of configurations are considered in the evaluation of uplink peak data rate.

UL peak data rate for EUHT is evaluated based on the evaluation results of EUHT peak spectral efficiency provided in Section 5.1.2.Table 5.2.2-1 and Table 5.2.2-2 provides the evaluation results for the specific component carrier (CC) bandwidth. It is observed that EUHT fulfills the UL peak data rate requirement.

Table 5.2.2-1 EUHT UL peak data rate for Sub-6GHz bands

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Per CC BW (MHz) | Peak data rate per CC (Gbit/s) | Aggregated peak data rate over 16 CCs (Gbit/s) | Required UL bandwidth to meet the requirement (MHz)1 | Req.  (Gbit/s) |
| 0.2 | 80 | 0.80 | 12.72 | 1006 | 10 |
| 100 | 0.99 | 15.91 | 1006 |
| 0.5 | 80 | 2.10 | 33.66 | 380 |
| 100 | 2.63 | 42.08 | 380 |
| NOTE 1: The value only indicates the required bandwidth to meet the UL peak data rate. It is not necessarily supported as EUHT Transmission bandwidth. | | | | | |

Table 5.2.2-2 EUHT UL peak data rate for mmWave bands

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Per CC BW (MHz) | Peak data rate per CC (Gbit/s)1 | Aggregated peak data rate over 16 CCs (Gbit/s)1 | Required UL bandwidth to meet the requirement (GHz)2 | Req.  (Gbit/s) |
| 0.2 | 400 | 1.72 | 27.53 | 2.325 | 10 |
| 0.5 | 400 | 4.55 | 72.80 | 0.879 |
| NOTE 1: 256QAM is assumed.  NOTE 2: The value only indicates the required bandwidth to meet the UL peak data rate. It is not necessarily supported as EUHT Transmission bandwidth. | | | | | |

## 5.3 5th percentile user spectral efficiency

As defined in Report ITU-R M.2410, the 5th percentile user spectral efficiency is the 5% point of the CDF of the normalized user throughput. The normalized user throughput is defined as the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time, divided by the channel bandwidth and is measured in bit/s/Hz.

As required by Report ITU-R M.2412, 5thpercentile user spectral efficiency shall be assessed jointly with average spectral efficiency using the same simulation. Therefore, the evaluation results of the 5th percentile user spectral efficiency are provided together with average spectral efficiency in Section 5.4.

## 5.4 Average spectral efficiency

As defined in Report ITU-R M.2410, average spectral efficiency is the aggregate throughput of all users (the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time) divided by the channel bandwidth of a specific band divided by the number of TRxPs and is measured in bit/s/Hz/TRxP.

As required by Report ITU-R M.2412, average spectral efficiency and 5th percentile user spectral efficiency are assessed jointly using the same simulation.

Average spectral efficiency and 5th percentile user spectral efficiency are evaluated for EUHT. A wide range of antenna configurations and transmission schemes are considered. Detailed evaluation assumptions and results can be found in Annex B.2.1.

The antenna configuration is indicated as (*M*,*N*,*P*,*M*g,*N*g; *M*p,*N*p), where *M* and *N* are the number of vertical, horizontal antenna elements within a panel, *P* is number of polarizations,*M*g is the number of panels in a column, *N*g is the number of panels in row; and *M*p and *N*p are the number of vertical, horizontal TXRUs within a panel and polarization.

### 5.4.1 Indoor Hotspot – eMBB

Evaluation configuration A (carrier frequency = 4 GHz) is applied for the evaluations of Indoor Hotspot – eMBB test environment for EUHT.

#### 5.4.1.1 Evaluation configuration A

The evaluation results of DL spectral efficiency for EUHT for evaluation configuration A are provided in Table 5.4.1.1-1. It is observed that EUHT fulfills the DL spectral efficiency requirement for these configurations in evaluation configuration A.

Table 5.4.1.1-1 DL spectral efficiency for EUHT in Indoor Hotspot – eMBB  
(Evaluation configuration A, CF=4 GHz)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A |
| BW=20MHz |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | Average [bit/s/Hz/TRxP] | 9 | 10.12 |
| 5th-tile [bit/s/Hz] | 0.3 | 0.40 |

The evaluation results of UL spectral efficiency for EUHT for evaluation configuration A are provided in Table 5.4.1.1-2. It is observed that EUHT fulfills the UL spectral efficiency requirement for these configurations in evaluation configuration A.

Table 5.4.1.1-2 UL spectral efficiency for EUHT in Indoor Hotspot – eMBB  
(Evaluation configuration A, CF=4 GHz)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A |
| BW=20MHz |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | Average [bit/s/Hz/TRxP] | 6.75 | 8.81 |
| 5th-tile [bit/s/Hz] | 0.21 | 0.37 |

### 5.4.2 Dense Urban – eMBB

Evaluation configuration A (carrier frequency = 4 GHz) is applied for the evaluations of Dense Urban – eMBB test environment for EUHT.

#### 5.4.2.1 Evaluation configuration A

The evaluation results of DL spectral efficiency for EUHT for evaluation configuration A are provided in Table 5.4.2.1-1. It is observed that EUHT fulfills the DL spectral efficiency requirement for these configurations in evaluation configuration A.

Table 5.4.2.1-1 DL spectral efficiency for EUHT in Dense Urban – eMBB  
(Evaluation configuration A, CF=4 GHz)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A |
| BW=20MHz |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | Average [bit/s/Hz/TRxP] | 7.8 | 9.45 |
| 5th-tile [bit/s/Hz] | 0.225 | 0.55 |

The evaluation results of UL spectral efficiency for EUHT for evaluation configuration A are provided in Table 5.4.2.1-2. It is observed that EUHT fulfills the UL spectral efficiency requirement for these configurations in evaluation configuration A.

Table 5.4.2.1-2 UL spectral efficiency for EUHT in Dense Urban – eMBB  
(Evaluation configuration A, CF=4 GHz)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A |
| BW=20MHz |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | Average [bit/s/Hz/TRxP] | 5.4 | 7.80 |
| 5th-tile [bit/s/Hz] | 0.15 | 0.34 |

### 5.4.3 Rural – eMBB

Evaluation configuration B (carrier frequency = 4 GHz), and evaluation configuration C (LMLC) are applied for the evaluations of Rural – eMBB test environment for EUHT.

#### 5.4.3.1 Evaluation configuration B

The evaluation results of DL spectral efficiency for EUHT for evaluation configuration B are provided in Table 5.4.3.1-1. It is observed that EUHT fulfills the DL spectral efficiency requirement for these configurations in evaluation configuration B.

Table 5.4.3.1-1 DL spectral efficiency for EUHT in Rural – eMBB  
(Evaluation configuration B, CF=4 GHz)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A |
| BW=20MHz |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | Average [bit/s/Hz/TRxP] | 3.3 | 8.28 |
| 5th-tile [bit/s/Hz] | 0.12 | 0.37 |

The evaluation results of UL spectral efficiency for EUHT for evaluation configuration B are provided in Table 5.4.3.1-2. It is observed that EUHT fulfills the UL spectral efficiency requirement for these configurations in evaluation configuration B.

Table 5.4.3.1-2 UL spectral efficiency for EUHT in Rural – eMBB  
(Evaluation configuration B, CF=4 GHz)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A |
| BW=20MHz |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | Average [bit/s/Hz/TRxP] | 1.6 | 4.22 |
| 5th-tile [bit/s/Hz] | 0.045 | 0.13 |

#### 5.4.3.2 Evaluation configuration C (LMLC)

LMLC (Low mobility large cell) is characterized by the large inter-site distance (ISD=6000m) and the low mobility users in Rural – eMBB test environment.

The evaluation results of DL spectral efficiency for EUHT for evaluation configuration C are provided in Table 5.4.3.2-1. It is observed that EUHT fulfills the DL spectral efficiency requirement for these configurations in evaluation configuration C.

Table 5.4.3.2-1 DL spectral efficiency for EUHT in Rural – eMBB  
(Evaluation configuration C, LMLC)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A |
| BW=20MHz |
| 8x4 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | Average [bit/s/Hz/TRxP] | 3.3 | 4.48 |
| 5th-tile [bit/s/Hz] | 0.12 | 0.19 |

The evaluation results of UL spectral efficiency for EUHT for evaluation configuration A are provided in Table 5.4.3.2-2. It is observed that EUHT fulfills the UL spectral efficiency requirement for these configurations in evaluation configuration C.

Table 5.4.3.2-2 UL spectral efficiency for EUHT in Rural – eMBB  
(Evaluation configuration C, LMLC)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A |
| BW=20MHz |
| 4x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | Average [bit/s/Hz/TRxP] | 1.6 | 4.38 |
| 5th-tile [bit/s/Hz] | 0.045 | 0.08 |

## 5.5 User experienced data rate

As defined in Report ITU-R M.2410, user experienced data rate is the 5% point of the cumulative distribution function (CDF) of the user throughput. User throughput (during active time) is defined as the number of correctly received bits, i.e. the number of bits contained in the service data units (SDUs) delivered to Layer 3, over a certain period of time.

The target values for the user experienced data rate are as follows in the Dense Urban – eMBB test environment:

- Downlink user experienced data rate is 100 Mbit/s

- Uplink user experienced data rate is 50 Mbit/s

### 5.5.1 Evaluation configuration A

For evaluation configuration A (single-band case), user experienced data rate for EUHT is evaluated based on 5th percentile user spectral efficiency, using the analytical way as provided in Report ITU-R M.2412.

The evaluation results of DL and UL user experienced data rate for EUHT for evaluation configuration A are provided in Table 5.5.1-1 and Table 5.5.1-2 respectively.

Table 5.5.1-1 DL user experienced data rate for EUHT in Dense Urban – eMBB  
(Evaluation configuration A, CF=4 GHz)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement  [Mbps] | Channel model A | |
| Assumed system bandwidth [MHz] | User exp. data rate [Mbps] |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | 100 | 300 | 110.0 |

Table 5.5.1-2 UL user experienced data rate for EUHT in Dense Urban – eMBB  
(Evaluation configuration A, CF=4 GHz)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement  [Mbps] | Channel model A | |
| Assumed system bandwidth [MHz] | User exp. data rate [Mbps] |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | 50 | 600 | 68.0 |

It is observed that both DL and UL fulfills the user experienced data rate requirements in evaluation configuration A.

## 5.6 Area traffic capacity

As defined in Report ITU-R M.2410, area traffic capacity is the total traffic throughput served per geographic area (in Mbit/s/m2).The throughput is the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time.

This requirement is defined for the purpose of evaluation in the related eMBB test environment.

The target value for area traffic capacity in downlink is 10 Mbit/s/m2 in the Indoor Hotspot - eMBB test environment.

### 5.6.1 Evaluation configuration A

The evaluation results of area traffic capacity for EUHT for evaluation configuration A with 3TRxP/site are provided in Table 5.6.1-1.

Table 5.6.1-1 Area traffic capacity for EUHT in Indoor Hotspot – eMBB  
(Evaluation configuration A, CF=4 GHz)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Req.  [Mbps/m2] | Channel model A | |
| Assumed system bandwidth [MHz] | Area traffic capacity [Mbps/m2] |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | 10 | 300 | 12.14 |

It is observed that area traffic capacity fulfills the requirement in evaluation configuration A.

## 5.7 Latency

### 5.7.1 User plane latency

As defined in Report ITU-R M.2410, user plane latency is the contribution of the radio network to the time from when the source sends a packet to when the destination receives it (in ms).

The evaluation of EUHT user plane latency is based on the procedure illustrated in Figure 5.7.1-1.

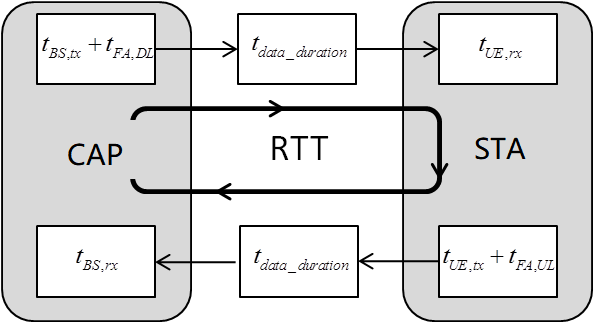


Figure 5.7.1-1 User plane procedure for evaluation

The detailed assumptions of each step are provided in Table 5.7.1.1-1 and Table 5.7.1.2-1 for downlink and uplink, respectively.

The additional assumptions to derive the evaluation results of EUHT user plane latency are list as below.

* It is assumed that the packet arrives at any time of any OFDM symbol. In this case, the 0.5 symbol length is added as the “average symbol alignment time” at the beginning of the procedure.
* The transmission of CCH, DL-TCH, UL-TCH cannot be across the frame. Otherwise the transmission will wait for the next frame.
* The frame length of 1/2/4 ms are evaluated. A schedule unit of 4/7/14 OFDM symbol and frame based scheduling is used.
* Resource allocation is flexible according to requirements.

#### 5.7.1.1 Downlink

The downlink procedure is abstracted in Table 5.7.1.1-1, where the assumptions of each step for evaluation are given.

Table 5.7.1.1-1 DL user plane procedure for EUHT

|  |  |  |  |
| --- | --- | --- | --- |
| ID | Component | Notations | Value |
| 1 | DL data transfer | *T*1 = (*t*CAP,tx + *t*FA,DL) + *t*DL\_duration + *t*STA,rx |  |
| 1.1 | CAP processing delay | *t*CAP,tx  The time interval between the data is arrived, and packet is generated. | Tproc,2 =1.5 os( Note 1) |
| 1.2 | DL Frame alignment (transmission alignment) | *t*FA,DL  It includes frame alignment time, and the waiting time for next available DL Frame | *T*FAis the frame alignment time within the current DL Frame and waiting time for next available DL Frame ; |
| 1.3 | Time for DL data packet transmission | *t*DL\_duratio  It includes the time between the DL period start and the DL data packet transmission complete. | Variable length of (1~xxx  OFDM symbol length) depend on DL period configuration. |
| 1.4 | STA processing delay | *t*STA,rx  The time interval between the DL PDTCH is received and the data is decoded; | Tproc,1=1.5 os |
| 2 | I-ACK (Note 2) retransmission | *T*I-ACK = *T*1 + *T*2  *T*2 = (*t*STA,tx + *t*FA,UL)+ *t*UL\_duration+ *t*CAP,rx (For Steps 2.1 to 2.4) |  |
| 2.1 | STA processing delay | *t*STA,tx  The time interval between the data is decoded, and I-ACK packet is generated. | Tproc,1=1.5 os |
| 2.2 | UL frame alignment (transmission alignment) | *t*FA,UL  It includes frame alignment time, and the waiting time for the next available UL period | *T*FA + *T*wait,  *T*FA is the frame alignment time within the current DL framet;  *T*wait is the waiting time for next available UL period |
| 2.3 | Time for I-ACK transmission | *t*UL\_duration | 2 OFDM symbol |
| 2.4 | CAP processing delay | *t*CAP,rx  The time interval between the ACK is received and the I-ACK is decoded. | Tproc, 2=1.5 os (Note 1) |
| 2.5 | Repeat DL data transfer from 1.1 to 1.4 | *T*1 |  |
| - | Total one way user plane latency for DL | *T*UP= *T*1 + *n*×*T*I-ACK  where *n* is the number of re-transmissions (*n*≥0) | |
| Note:  1. The value is used for evaluation only; CAP processing delay may vary depending on implementation.  2. I-ACK: Instantaneous ACK. | | | |

Based on the DL user plane procedure and assumptions given in Table 5.7.1.1-1, a variety of configurations and STA capabilities are evaluated for EUHT.

For EUHT, the 1:1 DL/UL configurations are evaluated. The evaluation results of 1/2/4 ms are provided in Table5.7.1.1-2.

Table 5.7.1.1-2 DL user plane latency for EUHT (ms)

(Frame structure DL:UL=1:1, Frame length: 1/2/4 ms)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| DL user plane latency – EUHT | | | STA | | |
| Frame Length | | |
| 1 ms | 2 ms | 4 ms |
| **Resource scheduling unit** | M=4 (4OS) | p=0 | 0.6552 | 1.1521 | 2.1528 |
| p=0.1 | 0.7661 | 1.3486 | 2.5589 |
| M=7 (7OS) | p=0 | 0.6984 | 1.1953 | 2.1960 |
| p=0.1 | 0.8093 | 1.4105 | 2.5963 |
| M=14 (14OS) | p=0 | 0.7992 | 1.2961 | 2.2968 |
| p=0.1 | 0.9101 | 1.5171 | 2.7216 |

#### 5.7.1.2 Uplink

The uplink procedure using a grant free transmission is abstracted in Table 5.7.1.2-1, where the assumptions of each step for evaluation are given.

Table 5.7.1.2-1 UL user plane procedure for EUHT

|  |  |  |  |
| --- | --- | --- | --- |
| Step | Component | Notations | Value |
| 1 | UL data transfer | *T*1 = (*t*STA,tx + *t*FA,UL)+ *t*UL\_duration+ *t*CAP,rx |  |
| 1.1 | STA processing delay | *t*STA,tx  The time interval between the data is arrived, and packet is generated; | Tproc,2=1.5os |
| 1.2 | UL Frame alignment (transmission alignment) | *t*FA,UL  It includes frame alignment time, and the waiting time for next available UL period. | *T*FA  *T*FA is the frame alignment time within the current UL period, |
| 1.3 | Time for UL data packet transmission | *t*UL\_duration | Variable length of (1~140) OFDM symbol length) |
| 1.4 | CAP processing delay | *t*CAP,rx  The time interval between the UL\_TCH is received and the data is decoded; | Tproc,1 =1.5os |
| 2 | I-ACK retransmission | *T*I-ACK = *T*2 + *T*1  *T*2 = (*t*CAP,tx + *t*FA,DL) + *t*DL\_duration + *t*STA,rx (For Steps 2.1 to 2.4) |  |
| 2.1 | CAP processing delay | *t*CAP,tx  The time interval between the data is decoded, and CCH preparation | Tproc,1 = 1.5os |
| 2.2 | DL Frame alignment (transmission alignment) | *t*FA,DL  It includes frame alignment time, and the waiting time for next available DL period. | *T*FA,DL  *T*FA,DL is the frame alignment time and the waiting time for next available DL period. |
| 2.3 | DL period for DL I-ACK transmission | *t*DL\_duration | Including the DL period of DL I-ACK scheduling transmission. |
| 2.4 | STA processing delay | *t*STA,rx  The time interval between the I-ACK is received and decoded. | Tproc,2=1.5os |
| 2.5 | Repeat UL data transfer from 1.1 to 1.4 | *T*1 |  |
|  | Total one way user plane latency for UL | *T*UP= *T*1 + *n*×*T*I-ACK  where *n* is the number of re-transmissions (*n*≥0) | |
| Note:  1. The value is used for evaluation only; CAP processing delay may vary depending on implementation.  2.The grant free transmission is assumed to use the following start symbols: | | | |

Based on the UL user plane procedure and assumptions given in Table 5.7.1.2-1, a variety of configurations are evaluated for EUHT.

For EUHT, the 1:1 DL/UL configurations are evaluated. The evaluation results of 1/2/4 ms are provided in Table 5.7.1.2-2.

Table 5.7.1.2-2 UL user plane latency for EUHT with grant free transmission (ms)  
(Frame structure DL:UL=1:1 , Frame length: 1/2/4 ms)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| UL user plane latency – EUHT | | | STA | | |
| Frame Length | | |
| 1 ms | 2 ms | 4 ms |
| **Resource scheduling unit** | M=4 (4OS) | p=0 | 0.5904 | 1.0872 | 2.0880 |
| p=0.1 | 0.7042 | 1.2996 | 2.5013 |
| M=7 (7OS) | p=0 | 0.6336 | 1.1304 | 2.1312 |
| p=0.1 | 0.7474 | 1.3428 | 2.5445 |
| M=14 (14OS) | p=0 | 0.7344 | 1.2312 | 2.2320 |
| p=0.1 | 0.8482 | 1.4436 | 2.6453 |

It is observed that EUHT fulfills UL user plane latency requirement in a wide range of configurations.

### 5.7.2 Control plane latency

As defined in Report ITU-R M.2410, control plane latency refers to the transition time from Idle state to the start of continuous data transfer.

There are two modes for this procedure in EUHT, basic recovery mode and fast recovery mode. The former will guarantee the rate of uplink data transmission, and the later could reduce the latency of uplink date transmission.

#### 5.7.2.1 Basic recovery Mode

For EUHT, control plane latency is evaluated from MAC\_INACTIVE state to MAC\_CONNECTED state. It is noted that, for EUHT, when Connection is suspended, date transmission will resume is permitted by CAP. Figure 5.7.2.1-1 provides an example control plane flow for the above-mentioned MAC\_INACTIVE to MAC\_CONNECTED state transition for EUHT.



Figure 5.7.2.1-1 C-plane activation procedure (example for Uplink Secure Mode)

Table 5.7.2.1-1 Control plane latency of Basic Mode

|  |  |  |  |
| --- | --- | --- | --- |
| **Step** | **Description** | **CP Latency for UL data transfer [ms]** | |
| **frame length is 1ms** | **frame length is 2ms** |
| 1 | Delay due to RaPn scheduling period | 0 | 0 |
| 2 | Transmission of RaPn | 0.25 | 1 |
| 3 | Processing delay in CAP including RaPn detection and Timing Advance Calculation | 1 | 2 |
| 4 | Assign UL Source for Ra Request | 0.25 | 0.5 |
| 5 | STA Processing Delay of Constructing RaReq message | 0.5 | 0.5 |
| 6 | Transmission of Ra Request | 0.25 | 0.5 |
| 7 | Processing delay in CAP including analysis of Ra Request and Constructing Ra Response | 1 | 1 |
| 8 | Transmission of Ra Response | 0.25 | 0.5 |
| 9 | Processing delay in STA of Ra Response | 0.5 | 2 |
| 10 | Delay due to SrPn scheduling period and Transmission of SrPn | 0 | 0 |
| 11 | Processing delay in CAP including Srpn detection | 1 | 2 |
| 12 | Assign UL Source for Sr Request | 0.25 | 0.5 |
| 13 | STA Processing Delay of Constructing SrReq message | 0.5 | 1 |
| 14 | Transmission of Sr Request | 0.25 | 0.5 |
| 15 | Processing delay in CAP including analysis of Sr Request and start schedule UL resource in the next frame | 0.5 | 1 |
|  | Total delay [ms] | 6.5 | 13 |
| Note:   1. For step 2, when the STA received Bcf in the DL area of Nth frame, it will send RaPn at the end of this frame. The latency is 1/2 frame length. 2. For step 3 and step 4, the delay is 2.5ms. it is not really processing delay, but because of the Rach Channel is at the end of frame. When the CAP detects RaPn at the end of Nth frame, it will allocate the resource of Ra Request at the N+2 frame. 3. For step 6, in the UL area of N+2 frame, CAP will receive the Ra Request. 4. For step 7, after the CAP receive Ra Request, it can compose Ra Response immediately, that benefit of pre-schedule resource. CAP will send this message in the DL area of N+3 frame. 5. For step 8，STA will start receive downlink scheduling from CAP in the N+4 frame after receipt of Ra Response. 6. For step 10, if uplink data will be transmitted, STA send SrPn at SRCH in UL area of N+4 frame. 7. For step 11, step 12, step 13，step14, Similar RaPn, after reception of SrPn, CAP will allocate resource of SrReq in the CCH, that locates in the DL area of N+6 frame. 8. For step 15，CAP receives RaReq in the UL area of N+6 frame, then allocate the UL resource according to the bytes and actual ability. | | | |

#### 5.7.2.2 Fast recovery Mode

In this Mode, STA will report the ID of STA, bytes of data to CAP by the message of Ra Request. So the ending point of resume is step 9 in the figure 5.7.2.1-1, as follows:



Figure 5.7.2.2-1 C-plane activation procedure (example for Fast recovery Mode)

Table 5.7.2.2-1 Control plane latency of Fast recovery Mode

|  |  |  |  |
| --- | --- | --- | --- |
| **Step** | **Description** | **CP Latency for UL data transfer[ms]** | |
| **frame length is 1ms** | **frame length is 2ms** |
| 1 | Delay due to RaPn scheduling period | 0 | 0 |
| 2 | Transmission of RaPn | 0.25 | 0.5 |
| 3 | Processing delay in CAP including Preamble detection and Calculation Timing Advance; | 1 | 2 |
| 4 | Assign UL Source for Ra Request | 0.25 | 0.5 |
| 5 | STA Processing Delay of Constructing RaReq message, including ID, bytes will be send | 0.5 | 1 |
| 6 | Transmission of Ra Request | 0.25 | 0.5 |
| 7 | Processing delay in CAP including analysis of Ra Request and Constructing Ra Response | 1 | 2 |
| 8 | Transmission of Ra Response | 0.25 | 0.5 |
| 9 | Processing delay in STA of Ra Response | 0.5 | 1 |
|  | Total delay [ms] | 4 | 8 |

## 5.8 Energy efficiency

As defined in Report ITU-R M.2410, network energy efficiency is the capability of a RIT/SRIT to minimize the radio access network energy consumption in relation to the traffic capacity provided. Device energy efficiency is the capability of the RIT/SRIT to minimize the power consumed by the device modem in relation to the traffic characteristics.

The RIT/SRIT shall have the capability to support a high sleep ratio and long sleep duration.

The sleep ratio is the fraction of unoccupied time resources (for the network) or sleeping time (for the device) in a period of time corresponding to the cycle of the control signaling (for the network) or the cycle of discontinuous reception (for the device) when no user data transfer takes place. The sleep duration is the continuous period of time with no transmission (for network and device) and reception (for the device).

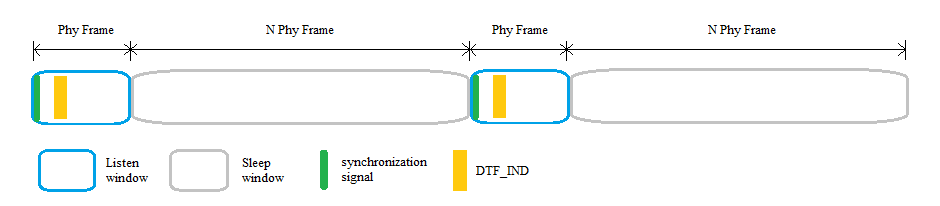
### 5.8.1 Network Side

The sleep ratio and sleep duration for EUHT network under unloaded case are evaluated.

The fundamental always-on transmission that must take place is the periodic BCF frame. The BCF frame is used for the STA to detect the CAP, obtain basic information of it. The BCF interval, PHY frame length depends on the network setup. BCF frame is sent in each single sub-band. PHY frame length is one from set of {0.5, 1, 1.6, 2, 2.5, 4, other} ms.

Remaining minimum system information carried over BCF frame needs to be broadcast at least once in BCF intervals in which the STAs are expected to be able to set up the connection to the network. When one STA acquires the BCF frame and joins the CAP, it does not need to read it again. It is illustrated in Figure 5.8.1-1.

* One DTF\_IND occupies 1 OFDM symbols.
* Listen window and Sleep window should be an integral multiple of PHY frame length.



**Figure 5.8.1-1 Illustration of synchronization signal and DTF\_IND transmission**

The sleep ratio is computed by equation of *BCF interval/duration*, and duration is length of (N+1) PHY Frame, which is up to 100ms.

### 5.8.2 Device Side

The sleep ratio and sleep duration under unloaded case are evaluated.

#### 5.8.2.1 Evaluation of sleep ratio

For Sleep mode, the STA should monitor synchronization signal and DTF\_IND frame per duration of Sleep. STA can get how long sleep window will last after DTF\_IND reception. Sleep window is assumed one PHY frame length,1ms or 2ms for instance. Sleep window should be an integral multiple of PHY frame length.

The duration of Sleep mode consists of a "listen" during which the STA should perform DTF\_IND monitoring, and a "sleep" during which the STA can skip reception of downlink channels to save energy. It's illustrated in Figure 5.8.2.1-1. Different the duration of Sleep is illustrated in Figure 5.8.2.1-2.

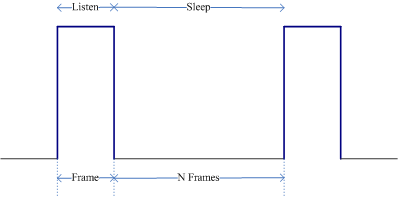


Figure 5.8.2.1-1 Illustration of Listen window and sleep window in Sleep mode

It is assumed that synchronization signal and DTF\_IND frame can be received in the same PHY frame length. After decoding DTF\_IND, the STA will learn if it should keep on sleep mode or not.

The length of duration may be different. It's probably configured by 10ms, 20ms or 40ms. The "sleep" is 9,19,39 according to configuration if PHY frame length is 1ms. The "sleep" is 4,9,19, if PHY frame length is 2ms.the"listen" is one frame no matter how long frame length is.

Therefore the sleep ratio is determined by the length of "listen", the length" sleep" and PHY frame length.

Based on the above configuration and assumption, the sleep ratio is evaluated shown in Table 5.8.2.1-1 for 1ms frame length, and Table 5.8.2.1-2 for 2ms frame length.



Figure 5.8.2.1-2 Different the duration of Sleep

Table 5.8.2.1-1 EUHT STA sleep ratio for 1ms frame length

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Duration of sleep (ms)** | **numbers of duration** | **sleep time (ms)** | **listen time (ms)** | **Frame length (ms)** | **Frame numbers in sleep** | **Frame numbers in listen** | **Sleep ratio** |
| 10 | 40 | 9 | 1 | 1 | 9 | 1 | 90% |
| 20 | 20 | 19 | 1 | 1 | 19 | 1 | 95% |
| 40 | 10 | 39 | 1 | 1 | 39 | 1 | 97.5% |
| … | | | | | | | |
| 1000 | 1 | 999 | 1 | 1 | 999 | 1 | 99.9% |

Table 5.8.2.1-2 EUHTSTA sleep ratio for 2ms frame length

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Duration of sleep (ms)** | **numbers of duration** | **sleep time (ms)** | **listen time (ms)** | **Frame length (ms)** | **Frame numbers in sleep** | **Frame numbers in listen** | **Sleep ratio** |
| 10 | 40 | 8 | 2 | 2 | 4 | 1 | 80% |
| 20 | 20 | 18 | 2 | 2 | 9 | 1 | 90% |
| 40 | 10 | 38 | 2 | 2 | 19 | 1 | 95% |
| … | | | | | | | |
| 1000 | 1 | 998 | 2 | 2 | 499 | 1 | 99.8% |

The sleep ratio is computed by equation of listen time/duration, and duration is up to 1s.

#### 5.8.2.2 Evaluation of sleep duration

As the results shown in tables above, the more sleep duration for EUHT STA in Sleep mode is, the more energy efficiency is. As for different frame length, the short frame length is more effective.

It is therefore concluded that how to choose sleep duration in terms of specific circumstance. Sleep ratio will be a bit more effective if it's given in symbol level, because more than half frame length can be cut down.

## 5.9 Mobility

As defined in Report ITU-R M.2410, Mobility is the maximum CAP speed at which a defined QoS can be achieved (in km/h). The QoS is defined as normalized traffic channel link data rate.

A wide range of antenna configurations and transmission schemes are considered for EUHT.

### 5.9.1 Indoor Hotspot – eMBB

Evaluation configuration A (carrier frequency = 4 GHz) is applied for the evaluations of Indoor Hotspot – eMBB test environment for EUHT. The mobility class of 10km/h are considered.

The evaluation results of mobility for EUHT for evaluation configuration A for mobility class of 10km/h are provided in Table 5.9.1-1. It is observed that EUHT fulfills the mobility requirement under configuration A.

Table 5.9.1-1 EUHT mobility in Indoor Hotspot – eMBB  
(Evaluation configuration A, CF=4 GHz, Mobility class of 10km/h)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement (bit/s/Hz) | Channel model A | |
| Channel condition | Normalized traffic channel link data rate (bit/s/Hz) |
| 8x8 SU-MIMO | 78.125 | Full uplink | 1.5 | NLOS | 7.20 |

### 5.9.2 Dense Urban – eMBB

Evaluation configuration A (carrier frequency = 4 GHz) is applied for the evaluations of Dense Urban – eMBB test environment for EUHT. The mobility class of 30km/h are considered.

The evaluation results of mobility for EUHT for evaluation configuration A for mobility class of 30km/h are provided in Table 5.9.1-1. It is observed that EUHT fulfills the mobility requirement under configuration A.

Table 5.9.2-1 EUHT mobility in Dense Urban – eMBB  
(Evaluation configuration A, CF=4 GHz, Mobility class of 30km/h)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement (bit/s/Hz) | Channel model A | |
| Channel condition | Normalized traffic channel link data rate (bit/s/Hz) |
| 2x8 SU-MIMO | 78.125 | Full uplink | 1.12 | NLOS | 2.48 |

### 5.9.3 Rural – eMBB

Evaluation configuration A (carrier frequency = 700 MHz) and Evaluation configuration B (carrier frequency = 4 GHz) are applied for the evaluations of Rural – eMBB test environment for EUHT. The mobility class of 120km/h and 500km/h are considered.

The evaluation results of mobility for EUHT for evaluation configuration A for mobility class of 120km/h, 500km/h are provided in Table 5.9.3-1, Table 5.9.3-2 respectively.

Table 5.9.3-1 EUHT mobility in Rural – eMBB  
(Evaluation configuration A, CF=700 MHz, Mobility class of 120km/h)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement (bit/s/Hz) | Channel model A | |
| Channel condition | Normalized traffic channel link data rate (bit/s/Hz) |
| 2x8 SU-MIMO | 78.125 | Full uplink | 0.8 | NLOS | 4.23 |

Table 5.9.3-2 EUHT mobility in Rural – eMBB  
(Evaluation configuration A, CF=700 MHz, Mobility class of 500km/h)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement (bit/s/Hz) | Channel model A | |
| Channel condition | Normalized traffic channel link data rate (bit/s/Hz) |
| 2x8 SU-MIMO | 78.125 | Full uplink | 0.45 | NLOS | 3.95 |

The evaluation results of mobility for EUHT for evaluation configuration B for mobility class of 120km/h, 500km/h are provided in Table 5.9.3-3, Table 5.9.3-4 respectively.

Table 5.9.3-3 EUHT mobility in Rural – eMBB  
(Evaluation configuration B, CF=4 GHz, Mobility class of 120km/h)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement (bit/s/Hz) | Channel model A | |
| Channel condition | Normalized traffic channel link data rate (bit/s/Hz) |
| 2x8 SU-MIMO | 78.125 | Full uplink | 0.8 | NLOS | 2.00 |

Table 5.9.3-4 EUHT mobility in Rural – eMBB  
(Evaluation configuration B, CF=4 GHz, Mobility class of 500km/h)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement (bit/s/Hz) | Channel model A | |
| Channel condition | Normalized traffic channel link data rate (bit/s/Hz) |
| 2x8 SU-MIMO | 78.125 | Full uplink | 0.45 | NLOS | 1.44 |

It is observed that EUHT fulfills the mobility requirement under both configuration A and configuration B.

## 5.10 Mobility interruption time

As defined in Report ITU-R M.2410, mobility interruption time is the shortest time duration supported by the system during which a STA cannot exchange user plane packets with any CAP during mobility transitions.

The mobility interruption time includes the time required to execute any radio access network procedure, radio resource control signalling protocol, or other message exchanges between the STA and CAP, as applicable to the candidate RIT/SRIT.

There are some properties support 0ms interrupt time in EUHT, such as:

1. The mode of multiple access is OFDMA in EUHT, thus can realize the carrier aggregation (CA) function, and STA could connect with source CAP and target CAP.
2. RACH – less is used in EUHT, interaction between source CAP and target CAP could save the time when RACH process occurs.

Figure 5.10-1 shows the 0ms interrupt time procedure in EUHT.

**

Figure 5.10-1 the 0ms interrupt time procedure in EUHT

Important notes as follows:

1. the message ‘handover Request & Rach - less Request’ is send from Source CAP to target CAP, which carry the information with sub-band scheduling, time domain scheduling about the resources of the STA;
2. After the source CAP received feedback back news ‘Handover Response’ from Target CAP, the both CAP will schedule the frequency and time domain resource accordance with the contract. At this time, STA will communicate with two CAP at the same time.
3. the Target CAP establish connection with STA and transfer the effective data, then inform the source CAP would release STA. The Target CAP will schedule time and frequency resource to STA by itself.

Based on the previous introduction, the STA can always exchange user plane packets with two CAP during the mobility transitions. Therefore, 0ms mobility interruption time is achieved in EUHT for this scenario.

# 6 Self evaluation of URLLC technical performance

## 6.1 Reliability

As defined in Report ITU-R M.2412, reliability is the success probability of transmitting a layer 2/3 packet within a required maximum time, which is the time it takes to deliver a small data packet from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface at a certain channel quality.

This requirement is defined for the purpose of evaluation in the URLLC usage scenario.

The minimum requirement for the reliability is 1-10-5 success probability of transmitting a layer 2 PDU(protocol data unit) of 32 bytes within 1 ms in channel quality of coverage edge for the Urban Macro-URLLC test environment.

EUHT Reliability is evaluated under Urban Macro-URLLC test environment. Both downlink and uplink are evaluated. A variety of configurations are considered. Detailed assumptions and results are provided in Annex B.2.4.

### 6.1.1 DL reliability

For downlink reliability, evaluation configuration A (carrier frequency = 4GHz) is evaluated.

The evaluation result of EUHT for downlink reliability is provided in Table 6.1.1-1. The evaluation result is derived with 20MHz bandwidth for evaluation configuration A. And channel model A is considered. It is observed that EUHT fulfills the reliability requirement for downlink.

Table 6.1.1-1 Evaluation results of downlink reliability - Configuration A

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Scheme and Antenna Configuration | Subcarrier Spacing [kHz] | Frame structure | Channel condition | Reliability | ITU Req. |
| 8x2 SU-MIMO | 78.125 | DL:UL=2:1 | NLOS | > 99.99999% | 99.999% |

### 6.1.2 UL reliability

For uplink reliability, evaluation configuration A (carrier frequency = 4GHz) is evaluated.

The evaluation result of EUHT for uplink reliability is provided in Table 6.1.2-1. The evaluation result is derived with 20MHz bandwidth for evaluation configuration A. And channel model A is considered. It is observed that EUHT fulfills the reliability requirement for uplink.

Table 6.1.2-1 Evaluation results of uplink reliability - configuration A

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Scheme and Antenna Configuration | Subcarrier Spacing [kHz] | Frame structure | Channel condition | Reliability | ITU Req. |
| 2x8 SU-MIMO | 78.125 | DL:UL=2:1 | NLOS | > 99.99999% | 99.999% |

## 6.2 Latency

### 6.2.1 User plane latency

EUHT user plane latency for URLLC is evaluated based on the procedures and parameters as described in Section 5.7.1.

The evaluation results are shown in Section 5.7.1. It is observed that under a wide range of configurations EUHT fulfills both downlink and uplink user plane latency requirement of 1ms for URLLC.

### 6.2.2 Control plane latency

Based on the evaluation results shown in Section 5.7.2, the control plane latency requirement is fulfilled by EUHT .

## 6.3 Mobility interruption time

Based on the evaluation results shown in Section 5.10, the mobility interruption time requirement is fulfilled by EUHT.

# 7 Self evaluation of mMTC technical performance

## 7.1 Connection density

As specified in Report ITU-R M.2410, connection density is the total number of devices fulfilling a specific quality of service(QoS) per unit area (per km2).

In Report ITU-R M.2412, the required QoS is that a 32-byte packet is successfully received within 10s.

The connection density can be evaluated using one or both of two alternative methods: The Full-buffer system-level simulation followed by link level simulation, and the Non-full-buffer system level simulation. These are defined in section 7.1.3 of Report ITU-R M.2412.The detailed assumptions for these approaches, including system level configurations and traffic model, are defined in Table 5-d) in Report ITU-R M.2412.

The connection density is defined for the purpose of evaluation in the mMTC usage scenario. The minimum requirement for connection density is 1 000 000 devices per km2.

The connection density of EUHT is evaluated by using the full buffer system level simulation followed by link level simulation.

In a first step this evaluation method employs a full buffer system level simulation to derive the uplink SINR distribution for a candidate technology. In a second step link level simulation are performed to determine the uplink spectral efficiency and data rate as functions of SINR. When combined these three functions supports the calculation of the expected long-term time-frequency resources required for each SINR to support the specified traffic model.

Connection density is in a final step conceptually derived by the system bandwidth, declared for the candidate technology, divided by the average required frequency resource. The requirement is fulfilled if the recorded connection density exceeds the 1.000.000 devices/km2, while the packet delay at the 99th percentile SINR is less than 10s.

This evaluation method is targeted to evaluate the connection density in terms of the capability of uplink data transmission. The capacity calculation is based on an assumption of ideal resource allocation among the multiple packets and users (e.g., there is no collision on resource allocation). The packet delay calculation does not consider the delays introduced by the connection access procedure.

The Urban Macro-mMTC test environment is used for evaluation. Evaluation configuration A (ISD=500m) is considered. And channel model A is considered. Traffic model is 1 message/2 hours/device with layer 2 PDU 32 bytes.

The evaluation results of EUHT are shown in Table 7.1-1. It is observed that EUHT fulfills connection density requirement under full buffer system level simulation followed by link level simulation. Detailed simulation assumptions and results can be found in Annex B.2.5.

Table 7.1-1 Evaluation results of connection density for EUHT - Configuration A

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Antenna Configuration** | Resource Unit bandwidth  [KHz] | Subcarrier Spacing [kHz] | Frame structure | Connection  Density (device/km2) | Req.  (device/km2) |
| 1x2 SIMO | 625 | 39.0625 | Full uplink | 135,900,382 | 1,000,000 |

# 8 Self evaluation of generic requirements

## 8.1 Bandwidth and scalability

As defined in Report ITU-R M.2410, bandwidth is the maximum aggregated system bandwidth. The bandwidth may be supported by single or multiple radio frequency (RF) carriers.

Scalable bandwidth is the ability of the candidate RIT/SRIT to operate with different bandwidths.

The capability of bandwidth and bandwidth scalability for EUHT are evaluated.

According to EUHT, the maximum bandwidth related to specific sub-carrier spacing (SCS) and frequency range for a component carrier is provided in Table 8.1-1.Therefore the bandwidth requirement of at least 100 MHz is met by EUHT under all frequency ranges for all sub-carrier spacing values.

Table 8.1-1EUHT capability on bandwidth

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **SCS [kHz]** | **Maximum bandwidth for one component carrier (MHz)** | **Maximum number of component carriers for carrier aggregation** | **Maximum aggregated bandwidth (MHz)** |
| Sub-6GHz bands  (Below 6 GHz) | 19.53125 | 50 | 16 | 800 |
| 39.0625 | 100 | 16 | 1600 |
| 78.125 | 100 | 16 | 1600 |
| mmWave bands  (Above 24 GHz) | 390.625 | 400 | 16 | 6400 |

According to EUHT, different bandwidths and number of data subcarriers (NSD) are supported for a component carrier at given SCS as listed in Table 8.1-2. Accordingly, the bandwidth scalability capability of EUHT is summarized in Table 8.1-3. It is observed that up to 11 different bandwidths are supported for Sub-6GHz bands, and up to 4 different bandwidths are supported for mmWave bands. Therefore bandwidth scalability capability is fulfilled by EUHT.

Table 8.1-2 Transmission bandwidth configuration NSD in EUHT

1. for Sub-6GHz bands

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SCS (kHz) | 5  MHz | 10  MHz | 15  MHz | 20  MHz | 25  MHz | 30  MHz | 40  MHz | 50  MHz | 60  MHz | 80 MHz | 100 MHz |
| NSD | NSD | NSD | NSD | NSD | NSD | NSD | NSD | NSD | NSD | NSD |
| 19.53125 | 224 | 448 | 672 | 896 | 1120 | 1344 | 1792 | 2240 | N/A | N/A | N/A |
| 39.0625 | 112 | 224 | 336 | 448 | 560 | 672 | 896 | 1120 | 1344 | 1792 | 2240 |
| 78.125 | 56 | 112 | 168 | 224 | 280 | 336 | 448 | 560 | 672 | 896 | 1120 |

(b) for mmWave bands

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SCS [kHz] | 50 MHz | 100 MHz | 200 MHz | 400 MHz |
| NSD | NSD | NSD | NSD |
| 390.625 | 112 | 224 | 448 | 896 |

Table 8.1-3 Bandwidth scalability capability for EUHT

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **SCS [kHz]** | **Minimum component carrier bandwidth (MHz)** | **Maximum component carrier bandwidth (MHz)** | **Maximum Number of supported bandwidth for a component carrier** |
| Sub-6GHz bands | 19.53125 | 5 | 50 | 8 |
| 39.0625 | 5 | 100 | 11 |
| 78.125 | 5 | 100 | 11 |
| mmWave bands | 390.625 | 50 | 400 | 4 |

## 8.2 Spectrum

As defined in Report ITU-R M.2411, spectrum requirement includes

* The capability of being able to utilize at least one frequency band identified for IMT in the ITU Radio Regulations, and
* The capability of being able to utilize the higher frequency range/band(s) above 24.25 GHz (NOTE: In the case of the candidate SRIT, at least one of the component RITs need to fulfil this requirement.)

The frequency bands in which EUHT can be deployed are given in Table 8.2-1 and Table 8.2-2. It is observed that EUHT can support at least one frequency band for IMT, as well as to utilize the higher frequency range/bands above 24.25 GHz. Therefore, EUHT fulfills spectrum requirement.

Table 8.2-1: EUHT operating bands in Sub-6GHz bands

|  |  |
| --- | --- |
| **Uplink (UL) and Downlink (DL)operating band** | **Duplex Mode** |
| 450 - 470 MHz | TDD |
| 470 - 698 MHz | TDD |
| 694/698 - 960 MHz | TDD |
| 1427 - 1518 MHz | TDD |
| 1710 - 2025 MHz | TDD |
| 2110 - 2200 MHz | TDD |
| 2300 - 2400 MHz | TDD |
| 2500 - 2690 MHz | TDD |
| 3300 - 3400 MHz | TDD |
| 3400 - 3600 MHz | TDD |
| 3600 - 3700 MHz | TDD |
| 4800 - 4990 MHz | TDD |

Table 8.2-2: EUHT operating bands in mmWave bands

|  |  |
| --- | --- |
| **Uplink (UL) and Downlink (DL) operating band** | **Duplex Mode** |
| 26500 MHz – 29500 MHz | TDD |
| 24250 MHz – 27500 MHz | TDD |
| 37000 MHz – 40000 MHz | TDD |
| 27500 MHz – 28350 MHz | TDD |

# 9 Conclusion

EUHT can meet the requirements of IMT-2020 over a set of usage scenarios and test environments of Indoor Hotspot - eMBB, Dense Urban - eMBB, Rural - eMBB, mMTC and URLLC.

# Annex A: Calibration for self evaluation

To facilitate the self evaluation towards IMT-2020 submission, the system level simulation and link level simulation have been calibrated to ensure the correctness of the simulation environment. The calibration results are compared with the results from 3GPP entities [4].

The following metrics are selected for calibration of self evaluation:

* DL Geometry (wideband SINR)
* Coupling gain

The calibration was conducted to the corresponding evaluation configurations of Indoor Hotspot - eMBB, Dense Urban - eMBB, Rural - eMBB, Urban Macro - mMTC and Urban Macro - URLLC test environment as defined in Report ITU-R M.2412. The channel model A is applied in the calibration.

The Geometry (Wideband SINR) is selected for calibration of self evaluation in system level simulation.

The calibration results for the five test environments are shown through Figure A.1 to Figure A.5, respectively. The results are based on the average of the independent results from the simulators of the contributing entities. The results of DL geometry (wideband SINR) from Nufront are typically within 1~2 dB of the average 3GPP SINR.

****

**Figure A.1 Coupling gain and DL geometry of Indoor Hotspot - eMBB test environment**

****

**Figure A.2 Coupling gain and DL geometry of Dense Urban - eMBB test environment**

****

****

**Figure A.3 Coupling gain and DL geometry of Rural - eMBB test environment**

****

**Figure A.4 Coupling gain and DL geometry of Urban Macro - mMTC test environment**

****

Figure A.5 Coupling gain and DL geometry of Urban Macro - URLLC test environment

A summary of the collected samples for calibration of each test environment and evaluation configuration is shown in Table A.1.

**Table A.1. Sample statistics for ITU-R test environments.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Test environment** | **Evaluation configuration** | **Channel model / Topology** | | **DL wideband SINR difference compared to average SINR of 3GPP results (at 50%-tile CDF point)** |
| Indoor Hotspot - eMBB | Configuration A (4 GHz) | Channel model A | 12TRxP | <0.7 dB |
| Dense Urban - eMBB | Configuration A (4 GHz) | Channel model A | | <1.3 dB |
| Rural - eMBB | Configuration B (1732 m, 4 GHz) | Channel model A | | <0.5 dB |
| Configuration C (LMLC, 6000 m, 700 MHz) | Channel model A | | <0.4 dB |
| Urban Macro - mMTC | Configuration A (500 m, 700 MHz) | Channel model A | | <0.6 dB |
| Urban Macro - URLLC | Configuration A (4 GHz) | Channel model A | | <0.8 dB |

# Annex B: Simulation models and assumptions

# B.1 Evaluation assumption for peak spectral efficiency and peak data rate

## B.1.1 Evaluation assumption for EUHT

Please refer to section 5.2.3.2.4.2 of “characteristics template for EUHT” [5] for EUHT overhead.

### B.1.1.1 EUHT downlink

Evaluation parameters for EUHT DL peak spectral efficiency and peak data rate is shown in Table B.1.1.1-1. The notations can be found in equation (5.1-1) in Section 5.1.

Table B.1.1.1-1 EUHT Parameters for DL peak spectral efficiency and peak data rate evaluation

|  |  |  |
| --- | --- | --- |
| Parameters | Values | Remarks |
| Max. number of layers | For Sub-6GHz bands: 8  For mmWave bands: 6 |  |
| Highest modulation order | 10,8 | 1024QAM, 256QAM |
| Max. coding rate  *Rmax* | 7/8 = 0.875 | LDPC |
|  | For Sub-6GHz bands: 1, 2, 4  For mmWave bands:10, 20, 30 | Frame length (ms) |
|  | See Table 8.1-2 for Sub-6GHz bands and mmWave bands for specific component carrier bandwidth and SCS. | The maximum number of sub-carrier data for the specific component carrier bandwidth and SCS is used. |

### B.1.1.2 EUHT uplink

Evaluation parameters for EUHT UL peak spectral efficiency and peak data rate is shown in Table B.1.1.2-1.

Table B.1.1.2-1 EUHT Parameters for UL peak spectral efficiency and peak data rate evaluation

|  |  |  |
| --- | --- | --- |
| Parameters | Values | Remarks |
| Max. number of layers | For Sub-6GHz bands: 8  For mmWave bands: 4 |  |
| Highest modulation order | 10, 8 | 1024QAM, 256QAM |
| Max. coding rate  *Rmax* | 7/8 = 0.875 | LDPC |
|  | For Sub-6GHz bands: 1, 2, 4  For mmWave bands:10, 20, 30 | Frame length (ms) |
|  | See Table 8.1-2 for Sub-6GHz bands and mmWave bands for specific component carrier bandwidth and SCS. | The maximum number of sub-carrier data for the specific component carrier bandwidth and SCS is used. |

# B.2 Detailed assumptions and evaluation results for simulation related technical performance requirements

## B.2.1 Detailed assumptions and results for average and 5th percentile user spectral efficiency

The detailed assumptions and results for average and 5th percentile user spectral efficiency can be found in the attached document SpectralEfficiency.zip.



## B.2.2 Detailed assumptions and results for mobility

The detailed assumptions and results for mobility can be found in the attached document Mobility.zip.



## B.2.3 Detailed assumptions and results for user experienced data rate

The detailed assumptions and results for user experienced data rate for multi-band/layer can be found in the attached document UserExpDataRate.zip.



## B.2.4 Detailed assumptions and results for reliability

The detailed assumptions and results for reliability can be found in the attached document Reliability.zip.



## B.2.5 Detailed assumptions and results for connection density

The detailed assumptions and results for connection density can be found in the attached document ConnectionDensity.zip.



# Annex C: Change history

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Date** | **TDoc** | **Cat** | **Subject/Comment** | **New version** |
| 2019-06 |  |  | EUHT Self Evaluation towards IMT-2020 Submission | 1.0.0 |
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