Evaluation results on EUHT

# 1 Introduction

This document includes final evaluation results on submissions in Doc.IMT-2020/18 Evaluation results for EUHT.

# 2 EUHT Evaluation results from CIRAT EG

This section includes evaluation results of Peak spectral efficiency, Peak data rate, 5th percentile user spectral efficiency, Average spectral efficiency, Reliability, User experienced data rate, Area traffic capacity, Mobility interruption time and Energy efficiency performance. The simulation assumptions follow those provided by the proponent of EUHT as duplicated in Annex.

## 2.1 Evaluation of eMBB technical performance

### 2.1.1 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 mobile station, 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).

According to the Document IMT-2020/18-(Rev.1), the generic formula for peak spectral efficiency for a specific component carrier (say i-th CC) is given by

 (2.1.1-1)

*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.*

Both downlink (DL) and uplink (UL) peak spectral efficiency are evaluated for various configurations. The detailed evaluation configurations are provided in Annex.

#### 2.1.1.1 DL peak spectral efficiency

The downlink peak spectral efficiency for Sub-6GHz bands and mmWave bands are evaluated. For Sub-6GHz bands, the evaluated configurations for TDD assume 8-layer downlink transmission, with 256QAM/1024QAM modulation, and a maximum coding rate of 0.875. The frame length configurations of 1 ms, 2 ms, and 4 ms are considered. For mmWave bands, the evaluated configurations for TDD assume 8-layer downlink transmission, with 256QAM/1024QAM modulation, and a maximum coding rate of 0.875. The frame length configurations for with 10 ms, 20 ms and 30 ms are evaluated. The downlink time ratio is defined as .

The evaluation results for Sub-6GHz bands and mmWave bands with =0.5 are provided in Table 2.1.1.1-1, Table 2.1.1.1-2.

**Table 2.1.1.1-1 DL peak spectral efficiency for Sub-6GHz bands (bit/s/Hz), =0.5**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Layer number and Modulation** | **1** | **2** | **4** | **Req.** |
| codeword I: 4 layers, 256QAM per layer  codeword II: 4 layers, 256QAM per layer | 32.02 | 37.51 | 40.50 | 30 |
| codeword I: 4 layers, 1024QAM per layer  codeword II: 4 layers, 256QAM per layer | 36.03 | 42.19 | 45.56 | 30 |

**Table 2.1.1.1-2 DL peak spectral efficiency for mmWave bands (bit/s/Hz), =0.5**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Layer number and Modulation** | **10** | **20** | **30** | **Req.** |
| codeword I: 4 layers, 256QAM per layer  codeword II: 4 layers, 256QAM per layer | 41.22 | 41.37 | 41.43 | 30 |
| codeword I: 4 layers, 1024QAM per layer  codeword II: 4 layers, 256QAM per layer | 46.37 | 46.54 | 46.61 | 30 |

The evaluation results for Sub-6GHz bands and mmWave bands with =0.8 are provided in Table 2.1.1.1-3, Table 2.1.1.1-4.

**Table 2.1.1.1-3 DL peak spectral efficiency for Sub-6GHz bands (bit/s/Hz), =0.8**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Layer number and Modulation** | **1** | **2** | **4** | **Req.** |
| codeword I: 4 layers, 256QAM per layer  codeword II: 4 layers, 256QAM per layer | 36.24 | 39.69 | 41.59 | 30 |
| codeword I: 4 layers, 1024QAM per layer  codeword II: 4 layers, 256QAM per layer | 40.77 | 44.65 | 46.79 | 30 |

**Table 2.1.1.1-4 DL peak spectral efficiency for mmWave bands (bit/s/Hz), =0.8**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Layer number and Modulation** | **10** | **20** | **30** | **Req.** |
| codeword I: 4 layers, 256QAM per layer  codeword II: 4 layers, 256QAM per layer | 42.09 | 42.19 | 42.23 | 30 |
| codeword I: 4 layers, 1024QAM per layer  codeword II: 4 layers, 256QAM per layer | 47.36 | 47.46 | 47.50 | 30 |

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

#### 2.1.1.2 UL peak spectral efficiency

Sub-6GHz bands and mmWave bands are evaluated. For Sub-6GHz bands, the evaluated configurations for TDD assume 8-layer uplink transmission, with 256QAM/1024QAM modulation, and a maximum coding rate of 0.875. The frame length of 1 ms, 2 ms, and 4 ms is evaluated. For mmWave bands, the evaluated configurations for TDD assume 8-layer downlink transmission, with 256QAM/1024QAM modulation, and a maximum coding rate of 0.875. The frame length with 10 ms, 20 ms and 30 ms is evaluated. The uplink time ratio is defined as .

The evaluation results for Sub-6GHz bands and mmWave bands with =0.5 are provided in Table 2.1.1.2-1 and Table 2.1.1.2-2.

**Table 2.1.1.2-1 UL peak spectral efficiency for Sub-6GHz bands (bit/s/Hz),** **=0.5**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Layer number and Modulation** | **1** | **2** | **4** | **Req.** |
| codeword I: 4 layers, 256QAM per layer  codeword II: 4 layers, 256QAM per layer | 39.20 | 41.14 | 42.24 | 15 |
| codeword I: 4 layers, 1024QAM per layer  codeword II: 4 layers, 256QAM per layer | 44.10 | 46.29 | 47.52 | 15 |

**Table 2.1.1.2-2 UL peak spectral efficiency for mmWave bands (bit/s/Hz),** **=0.5**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Layer number and Modulation** | **10** | **20** | **30** | **Req.** |
| codeword I: 4 layers, 256QAM per layer  codeword II: 4 layers, 256QAM per layer | 41.29 | 41.40 | 41.45 | 15 |
| codeword I: 4 layers, 1024QAM per layer  codeword II: 4 layers, 256QAM per layer | 46.46 | 46.57 | 46.63 | 15 |

The evaluation results for Sub-6GHz bands and mmWave bands with =0.2 are provided in Table 2.1.1.2-3 and Table 2.1.1.2-4.

**Table 2.1.1.2-3 UL peak spectral efficiency for Sub-6GHz bands (bit/s/Hz),** **=0.2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Layer number and Modulation** | **1** | **2** | **4** | **Req.** |
| codeword I: 4 layers, 256QAM per layer  codeword II: 4 layers, 256QAM per layer | 32.62 | 37.83 | 40.43 | 15 |
| codeword I: 4 layers, 1024QAM per layer  codeword II: 4 layers, 256QAM per layer | 36.70 | 42.56 | 45.49 | 15 |

**Table 2.1.1.2-4 UL peak spectral efficiency for mmWave bands (bit/s/Hz),** **=0.2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Layer number and Modulation** | **10** | **20** | **30** | **Req.** |
| codeword I: 4 layers, 256QAM per layer  codeword II: 4 layers, 256QAM per layer | 37.90 | 38.16 | 38.28 | 15 |
| codeword I: 4 layers, 1024QAM per layer  codeword II: 4 layers, 256QAM per layer | 42.64 | 42.93 | 43.07 | 15 |

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

### 2.1.2 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 mobile station, 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).

Peak data rate is defined for a single mobile station. In a single band, it is related to the peak spectral efficiency in that band. 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:

Rp = W × SEp (2.1.2)

#### 2.1.2.1 Carrier aggregation (CA) mode is invalid based on EUHT specification

Section 8.11 Spectrum aggregation mode of the EUHT specification describes the operation of carrier aggregation. However, only one paragraph and one brief illustrative figure are provided in Section 8.11.

* EUHT specification lacks of the essential detailed function of data aggregation and data dividing from/to multiple component carriers in the MAC and higher layer. Without the details of data aggregation and data dividing, the STA (for DL reception) and the CAP (for UL reception) will not be able to correctly aggregate the physical layer data on multiple component carriers.
* EUHT specification lacks of the essential function of component carrier management. There is no specification on how to add or remove a component carrier for a STA.
* EUHT specification lacks of the power allocation between multiple carriers.

**Based on the above consideration, it is concluded that the EUHT technology does not support carrier (spectrum) aggregation. Hence, the evaluations in this report do not consider carrier aggregation.**

#### 2.1.2.2 DL peak data rate

DL peak data rates for Sub-6GHz bands and mmWave bands are provided in Table 2.1.2.2-1 and Table 2.1.2.2-2, respectively. For Sub-6GHz bands, the peak spectral efficiency for 256QAM/1024QAM and 4 ms frame length is applied in the evaluation. The bandwidth (BW) for a single component carrier (CC) is set to 80 MHz and 100 MHz. For mmWave bands, the peak spectral efficiency for 256QAM/1024QAM and 30 ms frame length is applied in the evaluation. The bandwidth (BW) for a single carrier is set to 400 MHz. It is observed that EUHT cannot fulfill the DL peak data rate requirement.

Table 2.1.1.2-1 DL peak data ratefor Sub-6GHz bands

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| DL time ratio  () | Per CC BW (MHz)1 | Peak data rate per CC (Gbit/s) | Required DL bandwidth to meet the requirement (MHz)2 | Req.  (Gbit/s) |
| 0.5 | 80 | 1.83 | 875 | 20 |
| 100 | 2.29 | 875 |
| 0.8 | 80 | 3.00 | 534 |
| 100 | 3.75 | 534 |

Table 2.1.2.2-2 DL peak data rate for mmWave bands

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| DL time ratio  () | Per CC BW (MHz) | Peak data rate per CC (Gbit/s)1 | Required DL bandwidth to meet the requirement (MHz)2 | Req.  (Gbit/s) |
| 0.5 | 400 | 9.32 | 859 | 20 |
| 0.8 | 400 | 15.20 | 527 |

#### 2.1.2.3 UL peak data rate

UL peak data rate for Sub-6GHz bands and mmWave bands is provided in Table 2.1.2.3-1 and Table 2.1.2.3-2, respectively. For Sub-6GHz bands, the peak spectral efficiency for 256QAM/1024QAM and 4 ms frame length is applied in the evaluation. The bandwidth (BW) for a single component carrier (CC) is set to 80 MHz and 100 MHz. For mmWave bands, the peak spectral efficiency for 256QAM/1024QAM and 30 ms frame length is applied in the evaluation. The bandwidth (BW) for a single component carrier is set to 400 MHz. It is observed that EUHT cannot fulfill the UL peak data rate requirement.

Table 2.1.2.3-1 UL peak data rate for Sub-6GHz bands

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| UL time ratio  () | Per CC BW (MHz) | Peak data rate per CC (Gbit/s) | Required UL bandwidth to meet the requirement (MHz)1 | Req.  (Gbit/s) |
| 0.2 | 80 | 0.72 | 1108 | 10 |
| 100 | 0.90 | 1108 |
| 0.5 | 80 | 1.89 | 423 |
| 100 | 2.37 | 423 |

Table 2.1.2.3-2 UL peak data rate for mmWave bands

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Per CC BW (MHz) | Peak data rate per CC (Gbit/s)1 | Required UL bandwidth to meet the requirement (MHz)2 | Req.  (Gbit/s) |
| 0.2 | 400 | 3.45 | 1162 | 10 |
| 0.5 | 400 | 9.33 | 429 |

### 2.1.3 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, 5th percentile 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 2.1.4.

### 2.1.4 Average spectral efficiency

As defined in Report ITU-R M.2410, average spectral efficiencyis 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.

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.

#### 2.1.4.1 Indoor Hotspot – eMBB

Evaluation configuration A (carrier frequency = 4 GHz) and configuration B (carrier frequency = 30 GHz) with either 12TRxP or 36TRxP cases are applied for the evaluations of Indoor Hotspot– eMBB test environment for EUHT.

##### 2.1.4.1.1 Evaluation configuration A (CF = 4 GHz)

The evaluation results of spectral efficiency for evaluation configuration A with 12TRxP and 36TRxP are provided in Table 2.1.4.1.1-1.

It is observed that EUHT cannot fulfill the spectral efficiency requirement for these configurations in evaluation configuration A.

Table 2.1.4.1.1-1 Spectral efficiency for EUHT in Indoor Hotspot – eMBB   
(Evaluation configuration A, CF=4 GHz, for 12TRxP)

| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A | | | Channel model B | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Average | Sample 1 | Sample 2 | Average | Sample 1 |
| 8T, (8,4,2,1,1; 1,4)  8R, (1,4,2,1,1; 1,4) MU-MIMO | 78.125 | DL:UL = 2:1 | Average [bit/s/Hz/TRxP] | 9 | 7.340 | 7.339 | 7.34 | 7.35 | 7.35 |
| 5th-tile [bit/s/Hz] | 0.3 | 0.236 | 0.232 | 0.240 | 0.23 | 0.23 |

1. Downlink

| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A | | | Channel model B | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Average | Sample 1 | Sample 2 | Average | Sample 1 |
| 8T, (8,4,2,1,1; 1,4)  8R, (1,4,2,1,1; 1,4) MU-MIMO | 78.125 | DL:UL = 2:1 | Average [bit/s/Hz/TRxP] | 6.75 | 4.02 | 4.11 | 3.93 | 3.98 | 3.98 |
| 5th-tile [bit/s/Hz] | 0.21 | 0.165 | 0.17 | 0.16 | 0.18 | 0.18 |

1. Uplink

Table 2.1.4.1.1-2 Spectral efficiency for EUHT in Indoor Hotspot – eMBB   
(Evaluation configuration A, CF=4 GHz, for 36TRxP)

| **/** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A | | Channel model B | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Average | Sample 1 | Average | Sample 1 |
| 8T, (8,4,2,1,1; 1,4)  8R, (1,4,2,1,1; 1,4) MU-MIMO | 78.125 | DL:UL = 2:1 | Average [bit/s/Hz/TRxP] | 9 | 4.99 | 4.99 | 4.93 | 4.93 |
| 5th-tile [bit/s/Hz] | 0.3 | 0.03 | 0.03 | 0.07 | 0.07 |

1. Downlink

| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A | | Channel model B | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Average | Sample 1 | Average | Sample 1 |
| 8T, (8,4,2,1,1; 1,4)  8R, (1,4,2,1,1; 1,4) MU-MIMO | 78.125 | DL:UL = 2:1 | Average [bit/s/Hz/TRxP] | 6.75 | 2.71 | 2.71 | 2.76 | 2.76 |
| 5th-tile [bit/s/Hz] | 0.21 | 0.08 | 0.08 | 0.08 | 0.08 |

1. Uplink

##### 2.1.4.1.2 Evaluation configuration B (CF = 30 GHz)

The evaluation results of spectral efficiency for evaluation configuration B with 12TRxP and 36 TRxP are provided in Table 2.1.4.1.2-1.

It is observed that EUHT cannot fulfill the spectral efficiency requirement for these configurations in evaluation configuration B.

Table 2.1.4.1.2-1 Spectral efficiency for EUHT in Indoor Hotspot – eMBB   
(Evaluation configuration B, CF=30 GHz, for 12TRxP)

| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A/B | |
| --- | --- | --- | --- | --- | --- | --- |
| Average | Sample 1 |
| 8T, (8,4,2,1,1; 1,4)  8R, (1,4,2,1,1; 1,4) MU-MIMO | 78.125 | DL:UL = 2:1 | Average [bit/s/Hz/TRxP] | 9 | 5.42 | 5.42 |
| 5th-tile [bit/s/Hz] | 0.3 | 0.06 | 0.06 |

1. Downlink

| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A/B | |
| --- | --- | --- | --- | --- | --- | --- |
| Average | Sample 1 |
| 8T, (8,4,2,1,1; 1,4)  8R, (1,4,2,1,1; 1,4) MU-MIMO | 78.125 | DL:UL = 2:1 | Average [bit/s/Hz/TRxP] | 6.75 | 2.48 | 2.48 |
| 5th-tile [bit/s/Hz] | 0.21 | 0.05 | 0.05 |

1. Uplink

Table 2.1.4.1.2-2 Spectral efficiency for EUHT in Indoor Hotspot – eMBB   
(Evaluation configuration B, CF=30 GHz, for 36TRxP)

| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A/B | |
| --- | --- | --- | --- | --- | --- | --- |
| Average | Sample 1 |
| 8T, (8,4,2,1,1; 1,4)  8R, (1,4,2,1,1; 1,4) MU-MIMO | 78.125 | DL:UL = 2:1 | Average [bit/s/Hz/TRxP] | 9 | 4.77 | 4.77 |
| 5th-tile [bit/s/Hz] | 0.3 | 0.01 | 0.01 |

1. Downlink

| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A/B | |
| --- | --- | --- | --- | --- | --- | --- |
| Average | Sample 1 |
| 8T, (8,4,2,1,1; 1,4)  8R, (1,4,2,1,1; 1,4) MU-MIMO | 78.125 | DL:UL = 2:1 | Average [bit/s/Hz/TRxP] | 6.75 | 3.61 | 3.61 |
| 5th-tile [bit/s/Hz] | 0.21 | 0.1 | 0.1 |

1. Uplink

#### 2.1.4.2 Dense Urban – eMBB

Evaluation configuration A (carrier frequency = 4 GHz) and configuration B (carrier frequency = 30 GHz) are applied for the evaluations of Dense Urban – eMBB test environment for EUHT.

##### 2.1.4.2.1 Evaluation configuration A (CF = 4 GHz)

The evaluation results of spectral efficiency for EUHT for evaluation configuration A are provided in Table 2.4.1.2.1-1.

It is observed that EUHT cannot fulfill the spectral efficiency requirement for these configurations in evaluation configuration A.

Table 2.1.4.2.1-1 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 | | | Channel model B | |
| Average | Sample 1 | Sample 2 | Average | Sample 1 |
| 8T, (8,4,2,1,1; 1,4)  8R, (1,4,2,1,1; 1,4) MU-MIMO | 78.125 | DL:UL = 2:1 | Average [bit/s/Hz/TRxP] | 7.8 | 7.505 | 7.33 | 7.68 | 7.74 | 7.74 |
| 5th-tile [bit/s/Hz] | 0.225 | 0.269 | 0.287 | 0.25 | 0.22 | 0.22 |

1. Downlink

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A | | | Channel model B | |
| Average | Sample 1 | Sample 2 | Average | Sample 1 |
| 8T, (8,4,2,1,1; 1,4)  8R, (1,4,2,1,1; 1,4) MU-MIMO | 78.125 | DL:UL = 2:1 | Average [bit/s/Hz/TRxP] | 5.4 | 3.607 | 3.633 | 3.58 | 3.71 | 3.71 |
| 5th-tile [bit/s/Hz] | 0.15 | 0.093 | 0.085 | 0.1 | 0.08 | 0.08 |

1. Uplink

##### 2.1.4.2.2 Evaluation configuration B (CF = 30 GHz)

The evaluation results of spectral efficiency for EUHT for evaluation configuration B are provided in Table 2.1.4.2.2-1.

It is observed that EUHT cannot fulfill the spectral efficiency requirement for these configurations in evaluation configuration B.

Table 2.1.4.2.2-1 Spectral efficiency for EUHT in Dense Urban – eMBB   
(Evaluation configuration B, CF=30 GHz)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A/B | |
| Average | Sample 1 |
| 8T, (8,4,2,1,1; 1,4)  8R, (1,4,2,1,1; 1,4) MU-MIMO | 78.125 | DL:UL = 2:1 | Average [bit/s/Hz/TRxP] | 7.8 | 5.53 | 5.53 |
| 5th-tile [bit/s/Hz] | 0.225 | 0.001 | 0.001 |

1. Downlink

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Requirement | | Channel model A/B | |
| Average | Sample 1 |
| 8T, (8,4,2,1,1; 1,4)  8R, (1,4,2,1,1; 1,4) MU-MIMO | 78.125 | DL:UL = 2:1 | Average [bit/s/Hz/TRxP] | 5.4 | 1.70 | 1.70 |
| 5th-tile [bit/s/Hz] | 0.15 | 0 | 0 |

1. Uplink

### 2.1.5 User experienced data rate

It is noted that in the evaluation of this section, carrier aggregation (CA) is not assumed per reasons provided in Section 2.1.2.1.

#### 2.1.5.1 Evaluation configuration A

It is assumed that for TDD with 78.125 kHz SCS, a component carrier with 100 MHz bandwidth is used in downlink and uplink evaluation. Based on the 5% user spectral efficiency in Section 2.1.4.2.1, the user experienced data rates are given in Table 2.1.5.2-1 and Table 2.1.5.2-2, respectively.

It is observed that EUHT cannot fulfill the user experienced data rate requirement in evaluation configuration A.

Table 2.1.5.1-1 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 | | Channel model B | |
| Assumed system bandwidth [MHz] | User exp. data rate [Mbps] | Assumed system bandwidth [MHz] | User exp. data rate [Mbps] |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | 100 | 100 | 17.9 | 100.00 | 14.67 |

Table 2.1.5.1-2 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 | | Channel model B | |
| Assumed system bandwidth [MHz] | Assumed system bandwidth [MHz] | Assumed system bandwidth [MHz] | Assumed system bandwidth [MHz] |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | 50 | 100 | 3.08 | 100.00 | 2.67 |

#### 2.1.5.2 Evaluation configuration B

Based on the 5% user spectral efficiency in Section 2.1.4.2.2, the user experienced data rate is equal to 0.

It is observed that EUHT cannot fulfill the user experienced data rate requirement in evaluation configuration B.

### 2.1.6 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.

It is noted that in the evaluation of this section, carrier aggregation (CA) is not assumed per reasons provided in Section 2.1.2.1.

#### 2.1.6.1 Evaluation configuration A

It is assumed that for TDD with 78.125 kHz SCS, a component carrier with 100 MHz bandwidth is used in downlink and uplink evaluation.

The evaluation results of area traffic capacity for EUHT for evaluation configuration A with 12 TRxP and 36 TRxP cases are provided in Table 2.1.6.2.1-1 and Table 2.1.6.2.1-2, respectively.

Table 2.1.6.2.1-1 Area traffic capacity for EUHT in Indoor Hotspot – eMBB  
(Evaluation configuration A, CF=4 GHz, 36 TRxP case)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Req.  [Mbps/m2] | Channel model A | | Channel model B | |
| Assumed system bandwidth [MHz] | Area traffic capacity [Mbps/m2] | Assumed system bandwidth [MHz] | Area traffic capacity [Mbps/m2] |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | 10 | 100 | 2.0 | 100 | 1.97 |

Table 2.1.6.2.1-2 Area traffic capacity for EUHT in Indoor Hotspot – eMBB  
(Evaluation configuration A, CF=4 GHz, 12 TRxP case)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITU  Req.  [Mbps/m2] | Channel model A | | Channel model B | |
| Assumed system bandwidth [MHz] | Area traffic capacity [Mbps/m2] | Assumed system bandwidth [MHz] | Area traffic capacity [Mbps/m2] |
| 8x8 adaptive SU/MU -MIMO | 78.125 | DL:UL=2:1 | 10 | 100 | 0.98 | 100 | 0.98 |

It is observed that area traffic capacity cannot fulfill the requirement in evaluation configuration A.

#### 2.1.6.2 Evaluation configuration B

The evaluation results of area traffic capacity for EUHT for evaluation configuration B with 12 TRxP and 36 TRxP cases are provided in Table 2.1.6.2.2-1 and Table 2.1.6.2.2-2, respectively.

Table 2.1.6.2.2-1 Area traffic capacity for EUHT in Indoor Hotspot – eMBB  
(Evaluation configuration B, CF=30 GHz, 36 TRxP case)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **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 | 390.625 | DL:UL=2:1 | 10 | 400 | 7.63 |

Table 2.1.6.2.3-2 Area traffic capacity for EUHT in Indoor Hotspot – eMBB  
(Evaluation configuration B, CF=30 GHz, 12 TRxP case)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **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 | 390.625 | DL:UL=2:1 | 10 | 400 | 2.89 |

It is observed that area traffic capacity cannot fulfill the requirement in evaluation configuration B.

### 2.1.7 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 user terminal cannot exchange user plane packets with any base station during 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 mobile station and the radio access network, as applicable to the candidate RIT/SRIT.

The following text exists in the EUHT specification:

“*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.”*

It is noted that 0ms interruption time requires the STA to establish and maintain two connections to two CAPs. Further, higher layer data needs to be available at both CAPs. However, this is no such specification in the EUHT technology.

It is further noted that RACH-less handover only saves the RACH overhead during the handover and thus cannot be used to support 0ms interruption time. Carrier aggregation is not supported by EUHT as well, per reasons provided in Section 2.1.2.1.

Hence, it observes EUHT cannot fulfil the 0ms interruption time.

### 2.1.8 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.

Energy efficiency of the network and the device can relate to the support for the following two aspects:

a) Efficient data transmission in a loaded case;

b) Low energy consumption when there is no data.

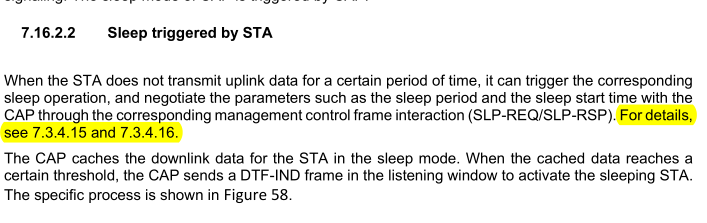
The sleep ratio is the fraction of unoccupied time resources (for the network) or sleeping time (for the device) in a period of time corresponding to the cycle of the control signaling (for the network) or the cycle of discontinuous reception (for the device) when no user data transfer takes place. The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

**For a),** efficient data transmission in a loaded case is demonstrated by the average spectral efficiency (see § 2.1.4). Hence, the efficient data transmission cannot fulfil the requirement in energy efficiency.

**For b),** The EUHT RIT provided a framework to allow STA and CAP to go to sleep. However, details of sleep procedure and wake-up procedures are not complete in the EUHT specification, as analyzed below.

1. Unclear Sleep procedure

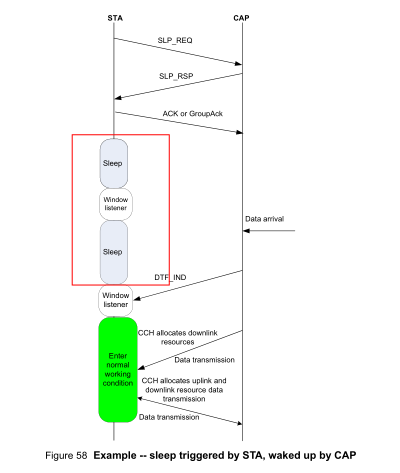
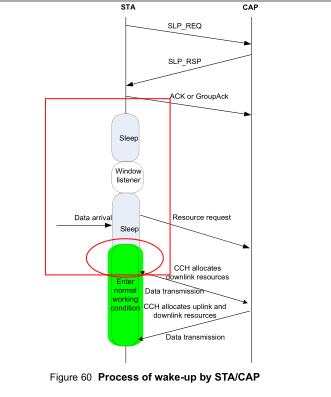
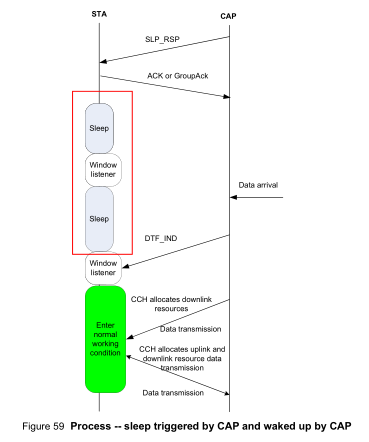
There are no 7.3.4.15/16 sections. It may intend to refer to: 6.3.4.15 Sleep request frame and 6.3.4.16 Sleep response frame. But 6.3.4.15 and 6.3.4.16 only include the frame format and the definition of parameters in the format. The detailed procedure is not defined.



1. Unclear start sleep time in next sleep period

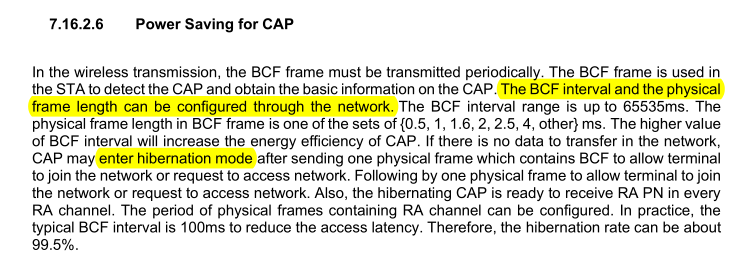
This specification uses Figure 58 to describe the sleep procedure. However, the figure is ambiguous. From this figure, it is not clear on the exact timing that STA starts its sleep period. Although a parameter named “sleep start time” is included in SLP\_RSP frame, there is no detailed description or procedure to elaborate how this parameter is used for period. If the starting point of the next period is ambiguous, there could be a mismatch between STA and CAP on the listening window and therefore the transmission during the listening window would be failed.

Figure 59 and Figure 60 in EUHT specifications have the same problem as in Figure 58. It is not clear on the exact timing STA that starts its sleep period is. In addition, from the Figure 60 it is also unclear on the exact timing to enter normal working condition.

1. Unclear terminology and configuration information

In the following paragraph from the EUHT specification, it is stated that the physical frame length is configured by the BCF frame. However, there is no such field/signaling in the BCF frame to configure the physical frame length. Furthermore, it is noted that the definition of physical frame is not clear in the EUHT specification.



Based on these considerations, it observes EUHT cannot fulfil the Energy efficiency.

## 2.2 Evaluation of URLLC technical performance

### 2.2.1 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.

Reliability for the EUHT technology is evaluated under the Urban Macro – URLLC test environment. Both downlink and uplink are evaluated. Detailed assumptions and results are provided in Annex.

#### 2.2.1.1 DL reliability

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

The evaluation results of EUHT for downlink reliability are provided in Table 2.2.1.1-1. All the evaluation results are derived with 20 MHz bandwidth for evaluation configuration A (CF = 4 GHz).

It is observed that EUHT cannot fulfil the reliability requirement for downlink.

Table 2.2.1.1-1 Evaluation results of downlink reliability for EUHT

(Evaluation configuration A, CF = 4 GHz)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Scheme and antenna configuration | Sub-carrier spacing [kHz] | ITU  Requirement | Channel condition | Channel model A | |
| Number of samples | Reliability |
| 8x2 SU-MIMO | 78.125 | 99.999% | NLOS | 1 | 99.54% |

#### 2.2.1.2 UL reliability

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

The evaluation results of EUHT for uplink reliability are provided in Table 2.2.1.2-1. All the evaluation results are derived with 20 MHz bandwidth for evaluation configuration A (CF = 4 GHz).

It is observed that EUHT cannot fulfil the reliability requirement for uplink.

Table 2.2.1.2-1 Evaluation results of uplink reliability for EUHT

(Evaluation configuration A, CF = 4 GHz)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Scheme and antenna configuration | Sub-carrier spacing [kHz] | ITU  Requirement | Channel condition | Channel model A | |
| Number of samples | Reliability |
| 2x8 SU-MIMO | 78.125 | 99.999% | NLOS | 1 | 92.37% |

### 2.2.2 Mobility interruption time

Same conclusion as Section 2.1.7.

# 3 Conclusion

During evaluation phase, all CIRATEG members participated in evaluation and all members provided EUHT results.

EUHT (IMT-2020/18) cannot meet all ITU-R IMT-2020 requirements, including 5th percentile user spectral efficiency, Average spectral efficiency, Reliability. So, the EUHT cannot fulfil the Indoor Hotspot-eMBB, Dense Urban-eMBB, Rural – eMBB and Urban Macro – URLLC test environments.

|  |  |
| --- | --- |
| Test environment | Does the evaluation report indicate that the minimum technical performance requirements are met in the test environment? |
| 🗹 Indoor Hotspot – eMBB | 🞎 Yes 🗹 No |
| 🗹 Dense Urban – eMBB | 🞎 Yes 🗹 No |
| 🗹 Rural – eMBB | 🞎 Yes 🞎 No (CIRAT EG does not evaluate the test environment) |
| 🗹 User experienced data rate– eMBB | 🞎 Yes 🗹 No |
| 🗹 Area traffic capacity– eMBB | 🞎 Yes 🗹 No |
| 🗹 Mobility interruption time– eMBB | 🞎 Yes 🗹 No |
| 🗹 Energy efficiency– eMBB | 🞎 Yes 🗹 No |
| 🞎 Urban Macro – mMTC | 🞎 Yes 🞎 No (CIRAT EG does not evaluate the test environment) |
| 🗹 Urban Macro – URLLC | 🞎 Yes 🗹 No |
| 🗹 Mobility interruption time– URLLC | 🞎 Yes 🗹 No |

# Annex A Calibration results

To facilitate the self evaluation towards IMT-2020 submission, the system level simulators have been calibrated to for 3GPP submission. Detailed calibration parameters and assumptions are found in RP-180524. It should be noted that these parameters are used for calibration purpose only.

The calibration results for five test environments are provided in the following attached files. There is a comparison of the calibration results for CIRAT and 3GPP. The 3GPP results are based on the average of the independent results in RP-180524.

For the calibration results of CIRAT and 3GPP, the difference of 50% percentage Geometry SINR is less than 0.71 dB. The comparison results for five test environments are provided in Table A-1.

Table A-1 Calibration results comparison for ITU-R test environments

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Test environment** | **Evaluation configuration** | **Channel model / Topology** | | **CIRAT** | **3GPP** | **DL wideband SINR difference compared to average SINR (at 50%-tile CDF point)** |
| Indoor Hotspot - eMBB | Config. A (4 GHz) | Channel model A | 12TRxP | 2.42 | 2.24 | 0.18 |
| 36TRxP | -1.46 | -0.76 | 0.71 |
| Channel model B | 12TRxP | 2.52 | 2.31 | 0.21 |
| 36TRxP | -1.41 | -1.19 | 0.22 |
| Config. B (30 GHz) | Channel model A/B | 12TRxP | 21.80 | 21.23 | 0.56 |
| 36TRxP | 16.50 | 16.41 | 0.10 |
| Dense Urban - eMBB | Config. A (4 GHz) | Channel model A | | 14.90 | 15.17 | 0.27 |
| Channel model B | | 14.78 | 15.01 | 0.24 |
| Config. B (30 GHz) | Channel model A/B | | 14.69 | 14.25 | 0.44 |
| Rural - eMBB | Config. A (1732 m, 700 MHz) | Channel model A | | 8.44 | 8.57 | 0.13 |
| Channel model B | | 8.33 | 8.55 | 0.22 |
| Config. B (1732 m, 4 GHz) | Channel model A | | 7.41 | 7.52 | 0.11 |
| Channel model B | | 7.15 | 7.21 | 0.06 |
| Config. C (LMLC, 6000 m, 700 MHz) | Channel model A | | 3.99 | 4.25 | 0.26 |
| Channel model B | | 3.99 | 4.36 | 0.37 |
| Urban Macro - mMTC | Config. A (500 m, 700 MHz) | Channel model A | | 0.42 | 0.36 | 0.06 |
| Channel model B | | 4.98 | 4.98 | 0.01 |
| Urban Macro - URLLC | Config. A (4 GHz) | Channel model A | | 4.95 | 5.16 | 0.21 |
| Channel model B | | 5.13 | 5.44 | 0.31 |

# Annex B Evaluation assumptions for peak spectral efficiency



# Annex C Evaluation assumptions for 5% user and average spectral efficiency

# Annex D Evaluation assumptions for reliability

