Annex 2-2. Final evaluation results on 3GPP LTE

# 1 Introduction

This document includes evaluation results on submissions in Doc.IMT-2020/13, 15 (i.e. “3GPP technology”) from ChEG. Evaluation results for LTE are included.

# 2 LTE Evaluation results from ChEG

This section includes evaluation results of 5th percentile user spectral efficiency, Average spectral efficiency, User experienced data rate, Area traffic capacity, Mobility and Connection density performance. All performances are evaluated through simulations conducted by several members of ChEG. The detailed results can be founding in chapter 3. The simulation assumption follows assumptions provided by proponent; and can be found in chapter 3.

## 2.1 Evaluation of eMBB technical performance

### 2.1.1 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 2.2.

### 2.1.2 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 LTE. Both LTE FDD and TDD are evaluated. Detailed evaluation assumptions and results can be found in chapter 3.

#### 2.1.2.1. Indoor Hotspot – eMBB

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

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

The evaluation results of DL spectral efficiency for LTE FDD and LTE TDD for evaluation configuration A with 12TRxP are provided in Table 2.1.2.1.1-1.

It is observed that both LTE FDD and TDD fulfill the DL spectral efficiency requirement for these configurations in evaluation configuration A.

Table 2.1.2.1.1-1 DL spectral efficiency for LTE in Indoor Hotspot – eMBB
(Evaluation configuration A, CF=4 GHz)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=10MHz | Number of samples | BW=10MHz |
| 32x4 MU-MIMO Advanced CSI Codebook; gNB Config = (4,4,2,1,1;4,4) | 15 | Average [bit/s/Hz/TRxP] | 9 | 1 | 9.81 | 1 | 9.86 |
| 5th-tile [bit/s/Hz] | 0.3 | 0.35 | 0.40 |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=20MHz | Number of samples | BW=20MHz |
| 64x2 MU-MIMO, Reciprocity based; 2T SRS; gNB Config = (8,16,2,1,1;4,8) | 15 | DSUDD | Average [bit/s/Hz/TRxP] | 9 | 1 | 9.25 | 1 | 9.61 |
| 5th-tile [bit/s/Hz] | 0.3 | 0.33 | 0.34 |
| 32x4 MU-MIMO, Advanced CSI Codebook; gNB Config = (4,4,2,1,1;1,4) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 9 | 1 | 11.81 | 1 | 11.88 |
| 5th-tile [bit/s/Hz] | 0.3 | 0.42 | 0.35 |
| 32x4 MU-MIMO, Reciprocity based; 4T SRS; gNB Config = (4,4,2,1,1;4,4) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 9 | 1 | 11.76 | 1 | 11.78 |
| 5th-tile [bit/s/Hz] | 0.3 | 0.40 | 0.39 |
| 32x2 MU-MIMO, Reciprocity based; 2T SRS; gNB Config = (4,4,2,1,1;4,4) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 9 | 1 | 9.37 | 1 | 9.46 |
| 5th-tile [bit/s/Hz] | 0.3 | 0.39 | 0.38 |

The evaluation results of UL spectral efficiency for LTE FDD and TDD for evaluation configuration A are provided in Table 2.1.2.1.1-2.

It is observed that both LTE FDD and TDD fulfill the UL spectral efficiency requirement for these configurations in evaluation configuration A.

Table 2.1.2.1.1-2 UL spectral efficiency for LTE in Indoor Hotspot – eMBB
(Evaluation configuration A, CF=4 GHz)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=10MHz | Number of samples | BW=10MHz |
| 4x32 SU-MIMO, Codebook based, DFT-S-OFDM; gNB Config = (4,4,2,1,1;4,4) | 15 | Average [bit/s/Hz/TRxP] | 6.75 | 1 | 8.47 | 1 | 7.96 |
| 5th-tile [bit/s/Hz] | 0.21 | 0.51 | 0.49 |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=20MHz | Number of samples | BW=20MHz |
| 2x64 SU-MIMO, Codebook based, DFT-S-OFDM; gNB Config = (8,16,2,1,1;4,8) | 15 | DSUDD | Average [bit/s/Hz/TRxP] | 6.75 | 1 | 7.37 | 1 | 7.43 |
| 5th-tile [bit/s/Hz] | 0.21 | 0.38 | 0.40 |
| 4x32 SU-MIMO, Codebook based, DFT-S-OFDM; gNB Config = (4,4,2,1,1;4,4) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 6.75 | 1 | 8.05 | 1 | 7.74 |
| 5th-tile [bit/s/Hz] | 0.21 | 0.54 | 0.49 |
| 2x32 SU-MIMO, Codebook based, DFT-S-OFDM; gNB Config = (16,8,2,1,1;4,4) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 6.75 | 1 | 8.84 | 1 | 8.81 |
| 5th-tile [bit/s/Hz] | 0.21 | 0.34 | 0.32 |

#### 2.1.2.2 Dense Urban – eMBB

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

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

The evaluation results of DL spectral efficiency for LTE FDD and LTE TDD for evaluation configuration A are provided in Table 2.1.2.2.1-1.

It is observed that both LTE FDD and TDD fulfill the DL spectral efficiency requirement for these configurations in evaluation configuration A.

Table 2.1.2.2.1-1 DL spectral efficiency for LTE in Dense Urban – eMBB
(Evaluation configuration A, CF=4 GHz)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=10MHz | Number of samples | BW=10MHz |
| 32x4 MU-MIMO Advanced CSI Codebook; gNB Config = (8,8,2,1,1;2,8) | 15 | Average [bit/s/Hz/TRxP] | 7.8 | 1 | 8.96 | 1 | 9.03 |
| 5th-tile [bit/s/Hz] | 0.225 | 0.28 | 0.28 |
| 32x4 MU-MIMO Advanced CSI Codebook; gNB Config = (16,8,2,1,1;2,8) | 15 | Average [bit/s/Hz/TRxP] | 7.8 | 1 | 9.31 | 1 | 9.18 |
| 5th-tile [bit/s/Hz] | 0.225 | 0.29 | 0.29 |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=20MHz | Number of samples | BW=20MHz |
| 64x2 MU-MIMO, Reciprocity based; 2T SRS; gNB Config = (12,8,2,1,1;4,8) | 15 | DSUDD | Average [bit/s/Hz/TRxP] | 7.8 | 1 | 8.78 | 1 | 9.05 |
| 5th-tile [bit/s/Hz] | 0.225 | 0.25 | 0.26 |
| 32x4 MU-MIMO, Reciprocity based; 4T SRS; gNB Config = (16,8,2,1,1;2,8) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 7.8 | 1 | 12.25 | 1 | 12.15 |
| 5th-tile [bit/s/Hz] | 0.225 | 0.39 | 0.38 |
| 64x4 MU-MIMO, Reciprocity based; 4T SRS; gNB Config = (12,8,2,1,1;4,8) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 7.8 | 1 | 14.53 | 1 | 14.59 |
| 5th-tile [bit/s/Hz] | 0.225 | 0.52 | 0.50 |
| 64x4 MU-MIMO, Reciprocity based; 4T SRS; gNB Config = (16,8,2,1,1;4,8) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 7.8 | 1 | 14.91 | 1 | 14.89 |
| 5th-tile [bit/s/Hz] | 0.225 | 0.52 | 0.52 |
| 32x2 MU-MIMO, Reciprocity based; 2T SRS; gNB Config = (12,8,2,1,1;4,4) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 7.8 | 1 | 10.06 | 1 | 10.03 |
| 5th-tile [bit/s/Hz] | 0.225 | 0.33 | 0.34 |

The evaluation results of UL spectral efficiency for LTE FDD and TDD for evaluation configuration A are provided in Table 2.1.2.2.1-2.

It is observed that both LTE FDD and TDD fulfill the UL spectral efficiency requirement for these configurations in evaluation configuration A.

Table 2.1.2.2.1-2 UL spectral efficiency for LTE in Dense Urban – eMBB
(Evaluation configuration A, CF=4 GHz)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=10MHz | Number of samples | BW=10MHz |
| 4x32 SU-MIMO, Codebook based, DFT-S-OFDM; gNB Config = (16,8,2,1,1;2,8) | 15 | Average [bit/s/Hz/TRxP] | 5.4 | 1 | 6.95 | 1 | 7.21 |
| 5th-tile [bit/s/Hz] | 0.15 | 0.39 | 0.41 |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=20MHz | Number of samples | BW=20MHz |
| 2x64 SU-MIMO, Codebook based, DFT-S-OFDM; gNB Config = (12,8,2,1,1;4,8) | 15 | DSUDD | Average [bit/s/Hz/TRxP] | 5.4 | 1 | 6.65 | 1 | 6.59 |
| 5th-tile [bit/s/Hz] | 0.15 | 0.33 | 0.30 |
| 4x32 SU-MIMO, Codebook based, DFT-S-OFDM; gNB Config = (16,8,2,1,1;2,8) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 5.4 | 1 | 6.60 | 1 | 6.77 |
| 5th-tile [bit/s/Hz] | 0.15 | 0.30 | 0.32 |
| 2x32 SU-MIMO, Codebook based, DFT-S-OFDM; gNB Config = (16,8,2,1,1;4,4) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 5.4 | 1 | 7.68 | 1 | 7.66 |
| 5th-tile [bit/s/Hz] | 0.15 | 0.38 | 0.37 |

#### 2.1.2.3 Rural – eMBB

Evaluation configuration A (carrier frequency = 700 MHz), evaluation configuration B (carrier frequency = 4 GHz), and evaluation configuration C (LMLC) are applied for the evaluations of Rural – eMBB test environment for LTE.

##### 2.1.2.3.1 Evaluation configuration A (CF = 700 MHz)

The evaluation results of DL spectral efficiency for LTE FDD and TDD for evaluation configuration A are provided in Table 2.1.2.3.1-1.

It is observed that both LTE FDD and TDD fulfill the DL spectral efficiency requirement for these configurations in evaluation configuration A.

Table 2.1.2.3.1-1 DL spectral efficiency for LTE in Rural – eMBB
(Evaluation configuration A, CF=700 MHz)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=10MHz | Number of samples | BW=10MHz |
| 8x2 MU-MIMO Advanced CSI Codebook; gNB Config = (8,4,2,1,1;1,4) | 15 | Average [bit/s/Hz/TRxP] | 3.3 | 1 | 4.66 | 2 | 4.63 |
| 5th-tile [bit/s/Hz] | 0.12 | 0.12 | 0.12 |
| 16x2 MU-MIMO Advanced CSI Codebook; gNB Config = (4,8,2,1,1;1,8) | 15 | Average [bit/s/Hz/TRxP] | 3.3 | 1 | 6.45 | 1 | 6.46 |
| 5th-tile [bit/s/Hz] | 0.12 | 0.16 | 0.15 |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=20MHz | Number of samples | BW=20MHz |
| 16x2 MU-MIMO, Reciprocity based; 2T SRS; gNB Config = (4,8,2,1,1;1,8) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 3.3 | 1 | 11.05 | 1 | 11.22 |
| 5th-tile [bit/s/Hz] | 0.12 | 0.29 | 0.29 |
| 8x2 MU-MIMO, Reciprocity based; 2T SRS; gNB Config = (8,4,2,1,1;1,4) | 15 | DSUDD | Average [bit/s/Hz/TRxP] | 3.3 | 1 | 5.00 | 1 | 5.52 |
| 5th-tile [bit/s/Hz] | 0.12 | 0.18 | 0.19 |

The evaluation results of UL spectral efficiency for LTE FDD and TDD for evaluation configuration A are provided in Table 2.1.2.3.1-2.

It is observed that both LTE FDD and TDD fulfill the UL spectral efficiency requirement for these configurations in evaluation configuration A.

Table 2.1.2.3.1-1 UL spectral efficiency for LTE in Rural – eMBB
(Evaluation configuration A, CF=700 MHz)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=10MHz | Number of samples | BW=10MHz |
| 1x8 SU-MIMO, Codebook based, DFT-S-OFDM; gNB Config = (8,4,2,1,1;1,4) | 15 | Average [bit/s/Hz/TRxP] | 1.6 | 1 | 3.59 | 1 | 3.59 |
| 5th-tile [bit/s/Hz] | 0.045 | 0.10 | 0.10 |
| 2x8 SU-MIMO, Codebook based, DFT-S-OFDM; gNB Config = (8,4,2,1,1;1,4) | 15 | Average [bit/s/Hz/TRxP] | 1.6 | 1 | 4.30 | 2 | 4.75 |
| 5th-tile [bit/s/Hz] | 0.045 | 0.22 | 0.18 |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=20MHz | Number of samples | BW=20MHz |
| 2x8 SU-MIMO, Codebook based, DFT-S-OFDM; gNB Config = (8,4,2,1,1;1,4) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 1.6 | 1 | 3.78 | 1 | 3.80 |
| 5th-tile [bit/s/Hz] | 0.045 | 0.15 | 0.13 |

##### 2.1.2.3.2 Evaluation configuration B (CF = 4 GHz)

The evaluation results of DL spectral efficiency for LTE FDD and TDD for evaluation configuration B are provided in Table 2.1.2.3.2-1.

It is observed that both LTE FDD and TDD fulfill the DL spectral efficiency requirement for these configurations in evaluation configuration B.

Table 2.1.2.3.2-1 DL spectral efficiency for LTE in Rural – eMBB
(Evaluation configuration B, CF=4 GHz)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=10MHz | Number of samples | BW=10MHz |
| 32x4 MU-MIMO Type II Codebook; gNB Config = (8,8,2,1,1;2,8) | 15 | Average [bit/s/Hz/TRxP] | 3.3 | 1 | 9.65 | 1 | 9.63 |
| 5th-tile [bit/s/Hz] | 0.12 | 0.28 | 0.28 |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITURequirement | Channel model A | Channel model B |
| Number of samples | BW=20MHz | Number of samples | BW=20MHz |
| 32x4 MU-MIMO, Reciprocity based; 4T SRS; gNB Config = (8,8,2,1,1;2,8) | 15 | DSUUD | Average [bit/s/Hz/TRxP] | 3.3 | / | / | 1 | 12.25 |
| 5th-tile [bit/s/Hz] | 0.12 | / | 0.43 |
| 32x4 MU-MIMO, Reciprocity based; 4T SRS; gNB Config = (8,8,2,1,1;2,8) | 15 | DSUDD | Average [bit/s/Hz/TRxP] | 3.3 | 1 | 11.59 | 1 | 12.23 |
| 5th-tile [bit/s/Hz] | 0.12 | 0.45 | 0.38 |

##### 2.1.2.3.3 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.

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 LTE for evaluation configuration C are provided in Table 2.1.2.3.3-1.

It is observed that both LTE fulfills the DL spectral efficiency requirement for these configurations in evaluation configuration C.

Table 2.1.2.3.3-1 DL spectral efficiency for LTE in Rural – eMBB
(Evaluation configuration C, LMLC)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | ITURequirement1 | Channel model A | Channel model B |
| Number of samples | BW=10MHz | Number of samples | BW=10MHz |
| 8x4 MU-MIMO, Type II Codebook; gNB Config = (8,4,2,1,1;1,4) | 15 | Average [bit/s/Hz/TRxP] | 3.3 | 1 | 5.96 | 1 | 5.97 |
| 5th-tile [bit/s/Hz] |  | 0.15 | 0.15 |
| Note 1: According to Report ITU-R M.2410, the 5th percentile user spectral efficiency requriement is not applicable to LMLC. The value shown here is for information only. |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITURequirement1 | Channel model A | Channel model B |
| Number of samples | BW=20MHz | Number of samples | BW=20MHz |
| 8x4 MU-MIMO, Type II Codebook; gNB Config = (8,4,2,1,1;1,4) | 15 | DSUDD | Average [bit/s/Hz/TRxP] | 1.6 | 1 | 6.86 | 1 | 6.68 |
| 5th-tile [bit/s/Hz] |  | 0.30 | 0.27 |
| Note 1: According to Report ITU-R M.2410, the 5th percentile user spectral efficiency requriement is not applicable to LMLC. The value shown here is for information only. |

The evaluation results of UL spectral efficiency for LTE for evaluation configuration C are provided in Table 2.1.2.3.3-2.

It is observed that both LTE fulfills the UL spectral efficiency requirement for these configurations in evaluation configuration C.

Table 2.1.2.3.33-2 UL spectral efficiency for LTE in Rural – eMBB
(Evaluation configuration C, LMLC)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | ITURequirement1 | Channel model A | Channel model B |
| Number of samples | BW=10MHz | Number of samples | BW=10MHz |
| 2x8 SU-MIMO, Codebook based, DFT-S-OFDM; gNB Config = (8,4,2,1,1;1,4); | 15 | Average [bit/s/Hz/TRxP] | 1.6 | 1 | 3.36 | 1 | 3.31 |
| 5th-tile [bit/s/Hz] |  | 0.07 | 0.06 |
| Note 1: According to Report ITU-R M.2410, the 5th percentile user spectral efficiency requriement is not applicable to LMLC. The value shown here is for information only. |

## 2.1.3 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.

User experienced data rate for LTE are evaluated under Dense Urban – eMBB test environment.

#### 2.1.3.1 Dense Urban – eMBB

For Dense Urban – eMBB test environment, single-band single-layer case using evaluation configuration A (carrier frequency = 4 GHz) as defined in Report ITU-R M.2412 is considered in evaluation. Detailed evaluation assumptions for configuration A are based on spectral efficiency evaluation, and can be found in chapter 3.

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

For evaluation configuration A (single-band case), user experienced data rate for LTE 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 user experienced data rate for LTE FDD for evaluation configuration A are provided in Table 2.1.3.1.1-1.

It is assumed that for FDD and TDD with 15 kHz SCS, a component carrier with 20 MHz for FDD and TDD is used. Multiple component carriers are aggregated to achieve the DL target user experienced data rate. The assumed DL/UL aggregated system bandwidth (for FDD) or overall aggregated system bandwidth (for TDD) is given in Table 2.1.3.1.1-1.

It is observed that both LTE FDD and TDD fulfill the DL user experienced data rate requirement in evaluation configuration A.

Table 2.1.3.1.1-1 DL user experienced data rate for LTE in Dense Urban – eMBB
(Evaluation configuration A, CF=4 GHz)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing | ITURequirement [Mbps] | Channel model A | Channel model B |
| Number of samples | Assumed DL system bandwidth [MHz] | User exp. data rate [Mbps] | Number of samples | Assumed DL system bandwidth [MHz] | User exp. data rate [Mbps] |
| 32x4 MU-MIMO Advanced CSI Codebook; gNB Config = (8,8,2,1,1;2,8) | 15 | 100 | 1 | 360 | 101.52 | 1 | 360 | 101.52 |
| 32x4 MU-MIMO Advanced CSI Codebook; gNB Config = (16,8,2,1,1;2,8) | 15 | 100 | 1 | 360 | 105.48 | 1 | 360 | 103.68 |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing | Frame structure | ITURequirement [Mbps] | Channel model A | Channel model B |
| Number of samples | Assumed system bandwidth [MHz] | User exp. data rate [Mbps] | Number of samples | Assumed system bandwidth [MHz] | User exp. data rate [Mbps] |
| 64x2 MU-MIMO, Reciprocity based; 2T SRS; gNB Config = (12,8,2,1,1;4,8) | 15 | DSUDD,S slot =10DL:2GP:2UL | 100 | 1 | 540 | 102.21 | 1 | 520 | 100.79 |
| 32x4 MU-MIMO, Reciprocity based; 4T SRS; gNB Config = (16,8,2,1,1;2,8) | 15 | DSUUD,S slot =11DL:1GP:2UL | 100 | 1 | 460 | 100.19 | 1 | 480 | 102.93 |
| 64x4 MU-MIMO, Reciprocity based; 4T SRS; gNB Config = (12,8,2,1,1;4,8) | 15 | DSUUD,S slot =11DL:1GP:2UL | 100 | 1 | 360 | 105.43 | 1 | 360 | 102.38 |
| 64x4 MU-MIMO, Reciprocity based; 4T SRS; gNB Config = (16,8,2,1,1;4,8) | 15 | DSUUD,S slot =11DL:1GP:2UL | 100 | 1 | 340 | 100.53 | 1 | 340 | 100.34 |
| 32x2 MU-MIMO, Reciprocity based; 2T SRS; gNB Config = (16,8,2,1,1;4,4) | 15 | DSUUD,S slot =6DL:2GP:6UL | 100 | 1 | 620 | 102.39 | 1 | 600 | 102.00 |

The evaluation results of UL user experienced data rate for LTE FDD and TDD for evaluation configuration A are provided in Table 2.1.3.1.1-2.

It is assumed that for FDD and TDD with 15 kHz SCS, a component carrier with 20 MHz for FDD and TDD is used. Multiple component carriers are aggregated to achieve the UL target user experienced data rate. The assumed DL/UL aggregated system bandwidth (for FDD) or overall aggregated system bandwidth (for TDD) is given in Table 2.1.3.1.1-2.

It is observed that both LTE FDD and TDD fulfill the UL user experienced data rate requirement in evaluation configuration A.

Table 2.1.3.1.1-2 UL user experienced data rate for LTE in Dense Urban – eMBB
(Evaluation configuration A, CF=4 GHz)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing | ITURequirement [Mbps] | Channel model A | Channel model B |
| Number of samples | Assumed UL system bandwidth [MHz] | User exp. data rate [Mbps] | Number of samples | Assumed UL system bandwidth [MHz] | User exp. data rate [Mbps] |
| 4x32 SU-MIMO, DFT-S-OFDM; gNB Config = (16,8,2,1,1;2,8) | 15 | 50 | 1 | 140 | 54.46 | 1 | 140 | 56.98 |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing | Frame structure | ITURequirement [Mbps] | Channel model A | Channel model B |
| Number of samples | Assumed system bandwidth [MHz] | User exp. data rate [Mbps] | Number of samples | Assumed system bandwidth [MHz] | User exp. data rate [Mbps] |
| 4x32 SU-MIMO, Codebook based, DTF-S-OFDM; gNB Config = (16,8,2,1,1;2,8) | 15 | DSUUDS slot =11DL:1GP:2UL | 50 | 1 | 380 | 50.00 | 1 | 360 | 50.19 |
| 2x32 SU-MIMO, Codebook based, DTF-S-OFDM; gNB Config = (16,8,2,1,1;4,4) | 15 | DSUUDS slot =6DL:2GP:6UL | 50 | 1 | 280 | 53.04 | 1 | 320 | 51.33 |

## 2.1.4 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.

LTE evaluation for area traffic capacity is conducted for Indoor Hotspot – eMBB test environment. A wide range of antenna configurations and transmission schemes are considered. Detailed evaluation assumptions are according to spectral efficiency evaluation, which can be found in chapter 3.

#### 2.1.4.1 Indoor Hotspot – eMBB

The area traffic capacity of LTE is evaluated using analytical way based on the downlink average spectral efficiency evaluation for LTE in Indoor Hotspot – eMBB test environment. The analytical way is defined in Report ITU-R M.2412.

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

The evaluation results of area traffic capacity for LTE FDD and LTE TDD for evaluation configuration A with 12TRxP are provided in Table 2.1.4.1.1-1.

It is assumed that for FDD and TDD with 15 kHz SCS, a component carrier with 20 MHz for FDD and TDD is used. The assumed aggregated DL system bandwidth (for FDD) and overall system bandwidth (for TDD) are given in Table 2.1.4.1.1-1.

Table 2.1.4.1.1-1 Area traffic capacity for LTE in Indoor Hotspot – eMBB
(Evaluation configuration A, CF=4 GHz, for 12TRxP)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing | ITURequirement [Mbps/m2] | Channel model A | Channel model B |
| Number of samples | Assumed DL systembandwidth [MHz] | Area traffic capacity [Mbps/m2] | Number of samples | Assumed DL system bandwidth [MHz] | Area traffic capacity [Mbps/m2] |
| 32x4 MU-MIMO Advanced CSI CodebookgNB Config = (4,4,2,1,1;4,4) | 15 | 10 | 1 | 520 | 10.20 | 1 | 520 | 10.25 |

## 2.1.5 Mobility

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

Several configurations are evaluated for LTE. Detailed evaluation assumptions and results can be found in chapter 3.

#### 2.1.5.1 Dense Urban – eMBB

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

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

The evaluation results of mobility for LTE FDD and TDD for evaluation configuration A are provided in Table 2.1.5.1.1-1.

It is observed that LTE fulfills the mobility requirement in evaluation configuration A.

Table 2.1.5.1.1-1 LTE mobility in Dense Urban – eMBB
(Evaluation configuration A, CF=4 GHz)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | ITURequirement (bit/s/Hz) | Channel model A | Channel model B |
| Channel condition | Number of samples | Normalized traffic channel link data rate (bit/s/Hz) | Channel condition | Number of samples | Normalized traffic channel link data rate (bit/s/Hz) |
| 1x8 SIMO | 15 | 1.12 | LOS | 1 | 1.99 | LOS | 1 | 1.88 |
| NLOS | 1 | 1.81 | NLOS | 1 | 1.77 |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITURequirement (bit/s/Hz) | Channel model A | Channel model B |
| Channel condition | Number of samples | Normalized traffic channel link data rate (bit/s/Hz) | Channel condition | Number of samples | Normalized traffic channel link data rate (bit/s/Hz) |
| 1x8 SIMO | 15 | DSUUD | 1.12 | LOS | 1 | 1.91 | LOS | 1 | 1.81 |
| NLOS | 1 | 1.74 | NLOS | 1 | 1.70 |

#### 2.1.5.2 Rural – eMBB

Evaluation configuration A (carrier frequency = 700 MHz) is applied for the evaluations of Rural – eMBB test environment for LTE. Both LTE FDD and TDD are evaluated. The mobility class of 120 km/h and 500 km/h are considered.

##### 2.1.5.2.1 Evaluation configuration A (CF = 700 MHz)

The evaluation results of mobility for LTE FDD and TDD for evaluation configuration A for mobility class of 120km/h are provided in Table 2.1.5.2.1-1.

Table 2.1.5.2.1-1 LTE mobility in Rural – eMBB
(Evaluation configuration A, CF=700 MHz, Mobility class of 120km/h)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | ITURequirement (bit/s/Hz) | Channel model A | Channel model B |
| Channel condition | Number of samples | Normalized traffic channel link data rate (bit/s/Hz) | Channel condition | Number of samples | Normalized traffic channel link data rate (bit/s/Hz) |
| 1x4 SIMO | 15 | 0.8 | LOS | 1 | 2.79 | LOS | 1 | 2.79 |
| NLOS | 1 | 2.20 | NLOS | 1 | 2.19 |
| 1x8 SIMO | 15 | LOS | 1 | 2.91 | LOS | 1 | 2.90 |
| NLOS | 1 | 2.75 | NLOS | 1 | 2.73 |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITURequirement (bit/s/Hz) | Channel model A | Channel model B |
| Channel condition | Number of samples | Normalized traffic channel link data rate (bit/s/Hz) | Channel condition | Number of samples | Normalized traffic channel link data rate (bit/s/Hz) |
| 1x4 SIMO | 15 | DSUDD | 0.8 | LOS | 1 | 2.49 | LOS | 1 | 2.49 |
| NLOS | 1 | 1.96 | NLOS | 1 | 1.94 |
| 1x8 SIMO | 15 | DSUUD | LOS | 1 | 2.79 | LOS | 1 | 2.79 |
| NLOS | 1 | 2.64 | NLOS | 1 | 2.63 |

The evaluation results of mobility for LTE FDD and TDD for evaluation configuration A for mobility class of 500km/h are provided in Table 2.1.5.2.1-2.

It is observed that LTE fulfills the mobility requirement under both 120km/h and 500km/h.

Table 2.1.5.2.1-2 LTE mobility in Rural – eMBB
(Evaluation configuration A, CF=700 MHz, Mobility class of 500km/h)

(a) LTE FDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | ITURequirement (bit/s/Hz) | Channel model A | Channel model B |
| Channel condition | Number of samples | Normalized traffic channel link data rate (bit/s/Hz) | Channel condition | Number of samples | Normalized traffic channel link data rate (bit/s/Hz) |
| 1x4 SIMO | 15 | 0.45 | LOS | 1 | 2.59 | LOS | 1 | 2.59 |
| NLOS | 1 | 1.94 | NLOS | 1 | 1.93 |
| 1x8 SIMO | 15 | LOS | 1 | 2.39 | LOS | 1 | 2.38 |
| NLOS | 1 | 1.82 | NLOS | 1 | 1.82 |

(b) LTE TDD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Scheme and antenna configuration** | Sub-carrier spacing (kHz) | Frame structure | ITURequirement (bit/s/Hz) | Channel model A | Channel model B |
| Channel condition | Number of samples | Normalized traffic channel link data rate (bit/s/Hz) | Channel condition | Number of samples | Normalized traffic channel link data rate (bit/s/Hz) |
| 1x4 SIMO | 15 | DSUDD | 0.45 | LOS | 1 | 2.31 | LOS | 1 | 2.31 |
| NLOS | 1 | 1.73 | NLOS | 1 | 1.72 |
| 1x8 SIMO | 15 | DSUUD | LOS | 1 | 2.29 | LOS | 1 | 2.29 |
| NLOS | 1 | 1.75 | NLOS | 1 | 1.75 |

## 2.2 Evaluation of mMTC technical performance

## 2.2.1 Connection density for NB-IoT

As specified in Report ITU-R M.2410, connection density is the system capacity metric defined as the total number of devices fulfilling a specific quality of service (QoS) per unit area (per km2) with 99% grade of service (GoS).

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

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 of NB-IoT is evaluated using both the full buffer, and the non-full buffer system level simulation as defined in Report ITU-R M.2412.

As indicated in Section 7.1.1, the full buffer system level simulation method targets to evaluate the connection density in terms of the capability of uplink data transmission. It does also not model synchronization and system information acquisition. control channel and downlink data channel performance. It assumes ideal resource allocation among the multiple uplink packets and users (e.g., there is no collision on resource allocation), and the delays introduced by access procedure are not considered.

In the non-full buffer system level simulation, the idle mode synchronization and system information acquisition performance and delays are taken into account. The chosen system access procedure, the uplink data transmission and the connection release procedures are modelled. The link level performance of all relevant physical channels and signals are modelled, and the system level resource allocation and the delays associated with the modeled protocols are considered. The connection density is recorded at the user arrival rate at which 99% of all uplink packet is successfully received within 10 s.

Since the non-full buffer system level simulation provides a more detailed level of modelling the evaluation results are, as expected, different from the full buffer system level simulation.

For both evaluation methods, the Urban Macro – mMTC test environment is used. Both evaluation configuration A (ISD=500 m) and evaluation configuration B (ISD=1732 m) are considered.

The evaluation results of NB-IoT is shown in Table 7.1.2-1 for full buffer system level simulation, and in Table 7.1.2-2 for non-full buffer system level simulation, respectively. For non-full buffer system level simulation, both the Early Data Transmission (EDT) and the RRC Resume procedures are evaluated. Since EDT procedure is shortened compared to RRC Resume procedure, the evaluation results are different.

Overhead from (N)PSS, (N)SSS, (N)PBCH or (N)PDSCH system information broadcast is also not accounted for in the reported bandwidths. For NB‑IoT a reasonable assumption is that the overhead from NPSS, NSSS, NPBCH and SIB1-NB transmissions constitutes ~30% of one downlink PRB.

It is observed that NB-IoT fulfills connection density requirement under either evaluation method, using either system access procedures.

Detailed simulation assumptions and results can be found in chapter 3.

Table 2.2.1-1 Evaluation results of connection density for NB-IoT
(Full buffer system level simulation followed by link level simulation
packet arrival rate: 1 packet / 2 hour / device)

(a) Evaluation configuration A (ISD=500 m)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Technical feature | Scheme and antenna configuration | Sub-carrier spacing | ITURequirement (device/km2) | Channel model A | Channel model B |
| Number of samples | Connection density (device/km2) | Required bandwidth (kHz) | Number of samples | Connection density (device/km2) | Required bandwidth (kHz) |
| NB-IoT | 1x2 SIMO  | 15 kHz | 1,000,000 | 1 | 41325000 | 180 | 1 | 41981000 | 180 |

(b) Evaluation configuration B (ISD=1 732 m)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Technical feature | Scheme and antenna configuration | Sub-carrier spacing | ITURequirement (device/km2) | Channel model A | Channel model B |
| Number of samples | Connection density (device/km2) | Required bandwidth (kHz) | Number of samples | Connection density (device/km2) | Required bandwidth (kHz) |
| NB-IoT | 1x2 SIMO  | 15 kHz | 1,000,000 | 2 | 2384315.5 | 180 | 2 | 2447084 | 180 |

Table 2.2.2-2 Evaluation results of connection density for NB-IoT
(Non-full buffer system level simulation
packet arrival rate: 1 packet / 2 hour / device)

(a) Evaluation configuration A (ISD=500 m)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Technical feature | Scheme and antenna configuration | Sub-carrier spacing | ITURequirement (device/km2) | Channel model A | Channel model B |
| Number of samples | Connection density (device/km2) | Required bandwidth (kHz) | Number of samples | Connection density (device/km2) | Required bandwidth (kHz) |
| NB-IoT (EDT) | 1x2 SIMO, Single-tone | 15 kHz | 1,000,000 | 1 | 8,047,087 | 180 | 1 | 8,077,017 | 180 |

(b) Evaluation configuration B (ISD=1 732m)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Technical feature | Scheme and antenna configuration | Sub-carrier spacing | ITURequirement (device/km2) | Channel model A | Channel model B |
| Number of samples | Connection density (device/km2) | Required bandwidth (kHz) | Number of samples | Connection density (device/km2) | Required bandwidth (kHz) |
| NB-IoT (EDT) | 1x2 SIMO, Single-tone | 15 kHz | 1,000,000 | 1 | 1,198,000 | 360 | 1 | 1,203,880 | 360 |

# 3 Detailed evaluation results

During evaluation phase, all ChEG members participated in evaluation and 8 members provided LTE results, i.e. CAICT, CATT, CMCC, China Telecom, Huawei, OPPO, VIVO and ZTE.

Detailed simulation results of 5th percentile user spectral efficiency, Average spectral efficiency, User experienced data rate, Area traffic capacity, Mobility and Connection density of LTE can be found in the attached document.