TCOE India Evaluation Report of the 3GPP RIT

*Technical Coordinator*

Name: Prof. R. David Koilpillai

Email: koilpillai@ee.iitm.ac.in

*Administrative Coordinator*

Name: Mr. Anurag Vibhuti

Email: anurag.cc@tcoe.in

Table of Contents

[1 Introduction 3](#_Toc32403077)

[2 Evaluation Summary 3](#_Toc32403078)

[3 Compliance Table 4](#_Toc32403079)

[4 Average and 5th percentile spectral efficiency 8](#_Toc32403080)

[**4.1** Simulation Parameters 8](#_Toc32403081)

[**4.2** Results 13](#_Toc32403082)

[5 Mobility 16](#_Toc32403083)

[**5.1** Simulation assumption of System level simulation (SLS) part for mobility 16](#_Toc32403084)

[**5.2** Simulation assumption of Link level simulation (LLS) part for mobility 18](#_Toc32403085)

[**5.3** Results 20](#_Toc32403086)

[6 Reliability 20](#_Toc32403087)

[**6.1** Simulation assumption of SLS part for Urban Macro - URLLC test environment 20](#_Toc32403088)

[**6.2** Simulation assumption of LLS part for Urban Macro - URLLC test environment 22](#_Toc32403089)

[**6.3** Results 22](#_Toc32403090)

[7 Connection Density 23](#_Toc32403091)

[8 User Experienced Data Rate 24](#_Toc32403092)

[9 Area Traffic Capacity 25](#_Toc32403093)

[10 Peak Spectral Efficiency 26](#_Toc32403094)

[**10.1** DL Peak Spectral Efficiency 27](#_Toc32403095)

[**10.2** UL Peak Spectral Efficiency 27](#_Toc32403096)

[11 Peak data rate 28](#_Toc32403097)

[**11.1** DL Peak Data rate 28](#_Toc32403098)

[**11.2** UL Peak Data rate 28](#_Toc32403099)

[12 User Plane Latency 29](#_Toc32403100)

[**12.1** Evaluation of NR FDD 32](#_Toc32403101)

[**12.2** Evaluation of NR TDD 33](#_Toc32403102)

[13 Control Plane Latency 34](#_Toc32403103)

[**13.1** Control plane latency of FDD 35](#_Toc32403104)

[**13.2** Control plane latency of TDD 36](#_Toc32403105)

[14 Bandwidth and scalability 36](#_Toc32403106)

[15 Energy Efficiency 38](#_Toc32403107)

[**15.1** Network Energy Efficiency 38](#_Toc32403108)

[15.1.1 SS/PBCH block transmission scheme 39](#_Toc32403109)

[15.1.2 RMSI transmission scheme 39](#_Toc32403110)

[15.1.3 Evaluation of sleep ratio 40](#_Toc32403111)

[15.1.4 Evaluation of sleep duration 41](#_Toc32403112)

[**15.2** Device Energy Efficiency 42](#_Toc32403113)

[15.2.1 DRX for UE in idle/inactive mode 42](#_Toc32403114)

[15.2.2 DRX for UE in connected mode 43](#_Toc32403115)

[15.2.3 Evaluation of sleep ratio 44](#_Toc32403116)

[15.2.4 Evaluation of sleep duration 44](#_Toc32403117)

[16 Spectrum 44](#_Toc32403118)

[17 Mobility Interruption Time 47](#_Toc32403119)

[**17.1** Beam mobility 47](#_Toc32403120)

[**17.2** CA Mobility 48](#_Toc32403121)

[18 Link Budget 48](#_Toc32403122)

[19 Calibration Results 48](#_Toc32403123)

# Introduction

This report contains the evaluation results received from TCOE proponents, which are reviewed and harmonized in TCOE meetings and used to summarize the evaluation results for quantitative assessment on 3GPP RIT proposal. All evaluation results were generated by following the IMT‑2020 evaluation methodology as provided in ITU-R M.2412. Table 1 shows the different sources of the evaluation results.

Table 1 Sources for the evaluation results

|  |  |
| --- | --- |
| Source 1 | HUAWEI |

# Evaluation Summary

In this report, the following KPIs have been evaluated.

|  |  |
| --- | --- |
| Test environment | Does the Evaluation Report indicate that the minimum technical performance requirements are met in the test environment? |
| Indoor Hotspot-eMBB | Evaluated. Meets the requirement for the evaluated KPI. |
| Dense Urban-eMBB | Evaluated. Meets the requirement for the evaluated KPI. |
| Rural-eMBB | Evaluated. Meets the requirement for the evaluated KPI. |
| Urban Macro–mMTC | Evaluated. Meets the requirement for the evaluated KPI. |
| Urban Macro–URLLC | Evaluated. Meets the requirement for the evaluated KPI. |

The following KPIs have been evaluated for this report.

|  |  |  |
| --- | --- | --- |
| Simulation | Analytical | Inspection |
| 1. Average spectral efficiency
2. 5th percentile user spectral efficiency
3. Mobility
4. Reliability
5. Connection density
 | 1. Peak data rate
2. Peak spectral efficiency
3. User experienced data rate
4. Area traffic capacity
5. User plane latency
6. Control plane latency
7. Mobility Interruption Time
 | 1. Bandwidth
2. Spectrum
3. Energy efficiency
 |

In the next Table, the summary of the evaluated KPI is provided for quick reference. We observe that the RIT fulfills the requirements for the required KPI.

# Compliance Table

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Minimum technical performance requirements item (5.2.4.3.x), units, and ReportITU-R M.2410-0 section reference(1)** | **Category** | **Required value** | Value as per TCOE evalaution | **Requirement met?** | **Comments(3)** |
|  | **Usage scenario** | **Test environment** | **Downlink or uplink** |  |  |  |   |
| **5.2.4.3.1**Peak data rate (Gbit/s)*(4.1)* | eMBB | Not applicable | Downlink | 20 | 21.34 – 24.35 | Yes |   |
| Uplink | 10 | 10.04 – 12.45 | Yes |
| **5.2.4.3.2**Peak spectral efficiency (bit/s/Hz)*(4.2)* | eMBB | Not applicable | Downlink | 30 | 31.7 - 48.7 | Yes |  |
| Uplink | 15 | 18.2 – 25.1 | Yes |
| **5.2.4.3.3**User experienced data rate (Mbit/s)*(4.3)* | eMBB | Dense Urban – eMBB | Uplink | 50 | 50.4 | Yes |   |
| Downlink | 100 | 136.96 | Yes |   |
| **5.2.4.3.4**5th percentile user spectral efficiency (bit/s/Hz)*(4.4)*  | eMBB | Indoor Hotspot – eMBB | Downlink | 0.3 | 0.344 | Yes |  |
| Uplink | 0.21 | 0.537 | Yes |  |
| eMBB | Dense Urban – eMBB | Downlink | 0.225 | 0.379 | Yes |  |
| Uplink | 0.15 | 0.213 | Yes |  |
| eMBB | Rural – eMBB  | Downlink | 0.12 | 0.213  | Yes |  |
| Uplink | 0.045 | 0.073 | Yes |
| **5.2.4.3.5**Average spectral efficiency (bit/s/Hz/ TRxP)*(4.5)*   | eMBB | Indoor Hotspot – eMBB | Downlink | 9  | 11.31 | Yes |  |
| Uplink | 6.75  | 8.64 | Yes |  |
| eMBB  | Dense Urban – eMBB | Downlink | 7.8  | 11.42  | Yes |  |
| Uplink | 5.4  | 6.50 | Yes |  |
| eMBB | Rural – eMBB | Downlink | 3.3  | 6.54 | Yes |  |
| 7.607 | LMLC |
| Uplink | 1.6  | 4.16 | Yes |  |
| 4.00 | LMLC |
| **5.2.4.3.6**Area traffic capacity (Mbit/s/m2)*(4.6)* | eMBB | Indoor-Hotspot – eMBB | Downlink | 10 | 7.18 | Yes |  |
| **5.2.4.3.7**User plane latency(ms)*(4.7.1)* | eMBB | Not applicable | Downlink  | 4  | 0.23 – 2.48 | Yes |  |
| Uplink | 0.24 – 2.48 | Yes |
|  URLLC | Not applicable | Downlink | 1   | 0.23 – 0.96 | Yes |  |
| Uplink  | 0.24 – 0.96 | Yes |
| **5.2.4.3.8**Control plane latency (ms)*(4.7.2)* | eMBB | Not applicable | Not applicable  | 20 | 12.7 – 16.5 | Yes |  |
| URLLC | Not applicable | Not applicable | 20 | 12.7 – 16.5 | Yes |  |
| **5.2.4.3.9**Connection density (devices/km2)*(4.8)* | mMTC | Urban Macro – mMTC | Uplink  | 1 000 000  | 35,021,000  | Yes | ISD 500m |
|  1,465,000  | Yes | ISD 1732m |
| **5.2.4.3.10**Energy efficiency*(4.9)* | eMBB | Not applicable | Not applicable | Capability to support a high sleep ratio and long sleep duration | 60% - 99.69% | Yes | Network |
| 80% - 99.9% | Device |
| **5.2.4.3.11**Reliability*(4.10)*  | URLLC | Urban Macro –URLLC  | Downlink   | 1-10−5 success probability of transmitting a layer 2 PDU (protocol data unit) of size 32 bytes within 1 ms in channel quality of coverage edge99.999% | 99.9998112% | Yes |  |
| Uplink  | 99.9999997% | Yes |  |
| **5.2.4.3.12**Mobility classes*(4.11)* | eMBB | Indoor Hotspot – eMBB | Uplink | Stationary, Pedestrian | Stationary, Pedestrian | Yes | For all evaluation configurations in Indoor Hotspot – eMBB. |
| eMBB | Dense Urban – eMBB | Uplink | Stationary, Pedestrian, Vehicular (up to 30 km/h) | Stationary, Pedestrian,Vehicular (up to 30 km/h) | Yes | For all evaluation configurations in Dense Urban – eMBB |
| eMBB | Rural – eMBB | Uplink | Pedestrian, Vehicular, High speed vehicular | Pedestrian, Vehicular, High speed vehicular | Yes | For all evaluation configurations in Rural - eMBB |
| **5.2.4.3.13**MobilityTraffic channel link data rates (bit/s/Hz)*(4.11)* | eMBB | Indoor Hotspot – eMBB | Uplink | 1.5 (10 km/h) | 1.75  | Yes |  |
| eMBB | Dense Urban – eMBB | Uplink | 1.12 (30 km/h) | 1.89  | Yes |  |
| eMBB  | Rural – eMBB | Uplink  | 0.8 (120 km/h) | 2.31  | Yes |  |
| 0.45 (500 km/h) | 2.07  | Yes |
| **5.2.4.3.14**Mobility interruption time (ms) *(4.12)* | eMBB and URLLC | Not applicable | Not applicable | 0 | 0 | Yes |  |
| **5.2.4.3.15**Bandwidth and Scalability*(4.13)*  | Not applicable | Not applicable | Not applicable | At least 100 MHz | 800 MHz - 6.4 GHz | Yes |    |
| Up to 1 GHz | Yes |
| Support of multiple different bandwidth values | 3 - 13 different component carrier bandwidth values | Yes |
|   | (1) As defined in Report ITU-R M.2410-0.(2) According to the evaluation methodology specified in Report ITU-R M.2412-0.(3) Proponents should report their selected evaluation methodology of the Connection density, the channel model variant used, and evaluation configuration(s) with their exact values (e.g. antenna element number, bandwidth, etc.) per test environment, and could provide other relevant information as well. For details, refer to Report ITU-R M.2412-0, in particular, § 7.1.3 for the evaluation methodologies, § 8.4 for the evaluation configurations per each test environment, and Annex 1 on the channel model variants.(4) Refer to § 7.3.1 of Report ITU-R M.2412-0. |

# Average and 5th percentile spectral efficiency

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.

The evaluation assumptions are given below.

## Simulation Parameters

**Table 4.1.1: Evaluation assumptions for DL**

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Test environment | Indoor Hotspot – eMBB | Dense Urban – eMBB | Rural - eMBB |
| Evaluation configuration | Configuration A/B | Configuration A | Configuration A/B/C  |
| Channel model | InH\_B | UMa\_B | RMa\_B |
| ISD | 20 m (12TRxP) | 200 m | Configuration A/B: 1732 m Configuration C: 6000 m |
| TDD frame structure | DDDSU | DDDSU | DDDSU |
| Carrier Frequency | Configuration A: 4 GHzConfiguration B: 30 GHz | 4 GHz | Configuration A: 700 MHzConfiguration B: 4 GHzConfiguration C: 700 MHz |
| System bandwidth | TDD:Configuration A: 20MHz ;Configuration B: 80MHz  | TDD: 20MHz | TDD: 20MHz |
| FDD:10MHz | FDD:10MHz | FDD:10MHz |
| Subcarrier spacing | FDD: 15 kHzTDD: 15kHz and 30 kHz for configuration A: 60kHz forconfiguration B  | FDD: 15 kHzTDD: 15kHz and 30 kHz | FDD: 15 kHzTDD: 15kHz and 30 kHz |
| Symbols number per slot | 14 | 14 | 14 |
| Number of antenna elements per TRxP | Configuration A/B: 32Tx cross-polarized antennas(M,N,P,Mg,Ng) = (4,4,2,1,1); | For 32Tx: 128Tx cross-polarized antennas(M,N,P,Mg,Ng) = (8,8,2,1,1)For 64Tx: 192Tx cross-polarized antennas(M,N,P,Mg,Ng) = (12,8,2,1,1) | Configuration A/C: 64Tx cross-polarized antennas(M,N,P,Mg,Ng) = (8,4,2,1,1);Configuration B: 128Tx cross-polarized antennas(M,N,P,Mg,Ng) = (8,8,2,1,1) |
| Number of TXRU per TRxP | Configuration A/B: 32TXRU: Vertical 1-to-1 | 32TXRU: Vertical 2-to-864TXRU: Vertical 4-to-12 | Configuration A/C: 8TXRU Vertical 1-to-8; 16TXRU Vertical 2-to-8.Configuration B: 32TXRU Vertical 2-to-8 |
| Number of antenna elements per UE | Configuration A : 4Rx with 0°,90° polarizationConfiguration B : 8Rx with 0°,90° polarization(M,N,P,Mg,Ng; Mp,Np) = (2,4,2,1,2; 1,2) | 4Rx with 0°,90° polarization | Configuration A: 2Rx Configuration B/C: 4Rxwith 0°,90° polarization |
| Transmit power per TRxP | TDD: Configuration A: 24 dBm Configuration B: 23 dBm | TDD: 44 dBm | TDD: 49 dBm |
| FDD: 21 dBm | FDD: 41 dBm | FDD: 46 dBm |
| TRxP number per site | 1 | 3 | 3 |
| Mechanic tilt | 180deg in GCS (pointing to the ground) | 90deg in GCS (pointing to the horizontal direction) | 90deg in GCS (pointing to the horizontal direction) |
| Electronic tilt | Configuration A: 90deg in LCSConfiguration B: According to Zenith angle in "Beam set at TRxP" | 105deg in LCS | Configuration A/B: 100deg in LCS Configuration C: 92deg in LCS  |
| Beam set at TRxP | Configuration B: Azimuth angle φi = [0],Zenith angle θj = [pi/2] | N/A | N/A |
| Beam set at UE | Configuration B: Azimuth angle φi = [-pi/4, pi/4]; Zenith angle θj = [pi/4, 3\*pi/4] | N/A | N/A |
| UT attachment | Based on RSRP (Eq. (8.1-1) in TR 36.873) from port 0 | Based on RSRP (Eq. (8.1-1) in TR 36.873) from port 0 | Based on RSRP (Eq. (8.1-1) in TR 36.873) from port 0 |
| Scheduling | MU-PF | MU-PF | MU-PF |
| ACK/NACK delay | Next available UL slot | Next available UL slot | Next available UL slot |
| MIMO mode | MU-MIMO with rank 2/4 adaptation per user;Configuration A: Maximum MU layer = 12;Configuration B: Maximum MU layer = 6 | MU-MIMO with rank 2/4 adaptation per user;Maximum MU layer = 12 | MU-MIMO with rank 2/4 adaptation per user;Maximum MU layer = 8 for 8Tx and maximum MU layer = 12 for 16Tx and 32Tx; |
| Guard band ratio | TDD: Configuration A: 8.2% for 30kHz SCS and 4.6% for 15kHz SCS (for 20 MHz);Configuration B: 5.5% (for 80 MHz); | TDD: 8.2% for 30kHz SCS and 4.6% for 15kHz SCS (for 20 MHz) | 8.2% for 30kHz SCS and 4.6% for 15kHz SCS (for 20 MHz) |
| FDD: 6.4% (for 10 MHz) | FDD: 6.4% (for 10 MHz) | FDD: 6.4% (for 10 MHz) |
| BS receiver type | MMSE-IRC | MMSE-IRC | MMSE-IRC |
| CSI feedback | 5 slots period based on non-precoded CSI-RS with delay | For 32Tx: 5 slots period based on non-precoded CSI-RS with delayFor 64Tx: 5 slots period based on precoded CSI-RS with delay | 5 slots period based on non-precoded CSI-RS with delay |
| SRS transmission | Non-precoded SRS for 4Tx ports;Period: 5 slots;2 symbols for 30kHz SCS;4 symbols for 15kHz SCS; | Non-precoded SRS for 4Tx ports;Period: 5 slots;2 symbols for 30kHz SCS;4 symbols for 15kHz SCS; | Non-precoded SRS for 2/4 Tx ports for 2/4 Rx;Period: 5 slots;4 symbols per 5 slots for configuration A/B for 15kHz and 30kHz; 2 symbols for 30kHz SCS and 4 symbols for 15kHz SCS for configuration C; |
| Precoder derivation | TDD: SRS based | TDD: SRS based | TDD: SRS based |
| FDD: NR Type II codebook (4 beams, WB+SB quantization, 8 PSK) | FDD: NR Type II codebook (4 beams, WB+SB quantization, 8 PSK) | FDD: NR Type II codebook (4 beams, WB+SB quantization, 8 PSK) |
| Overhead | PDCCH | 2 complete symbols | 2 complete symbols | 2 complete symbols |
| DMRS | Type II, based on MU-layer (dynamic in simulation) | Type II, based on MU-layer (dynamic in simulation) | Type II, based on MU-layer (dynamic in simulation) |
| CSI-RS | FDD: 32 ports per 5 slots | FDD: 32 ports per 5 slots | FDD: 8/16/32 ports for 8Tx/16Tx/32Tx |
| TDD: 32 ports per 5 slots | TDD: For 64Tx, 4 ports per UE per 5 slots; For 32Tx, 32 ports per 5 slots | TDD: 8/16/32 ports for 8Tx/16Tx/32Tx  |
| CSI-RS for IM | ZP CSI-RS with 5 slots period; 4 RE/PRB/5 slots | ZP CSI-RS with 5 slots period; 4 RE/PRB/5 slots | ZP CSI-RS with 5 slots period; 4 RE/PRB/5 slots |
| SSB | 1 SSB per 20 ms | 1 SSB per 20 ms | 1 SSB per 20 ms |
| TRS | 2 consecutive slots per 20 ms, 1 port, maximal 52 PRBs | 2 consecutive slots per 20ms, 1 port, maximal 52 PRBs | 2 consecutive slots per 20 ms, 1 port, maximal 52 PRBs |
| PTRS | Configuration B: 2 ports PT-RS, (L,K) = (1,4) L is time density and K is frequency density | N/A | N/A |
| Channel estimation | Non-ideal | Non-ideal | Non-ideal |
| Waveform | OFDM | OFDM | OFDM |

**Table 4.1.2: Evaluation assumptions for UL**

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Test environment | Indoor Hotspot – eMBB | Dense Urban – eMBB | Rural - eMBB |
| Evaluation configuration | Configuration A/B | Configuration A | Configuration A/B/C |
| Channel model | InH\_B | UMa\_B | RMa\_B |
| Subcarrier spacing | FDD: 15 kHzTDD: 15kHz and 30 kHz for configuration A: 60kHz forconfiguration B  | FDD: 15 kHzTDD: 15kHz and 30 kHz | FDD: 15 kHzTDD: 15kHz and 30kHz |
| TDD frame structure | DDDSU | DDDSU | DDDSU |
| Symbols number per slot | 14 | 14 | 14 |
| Number of antenna elements per TRxP | Configuration A: 32Rx cross-polarized antenna (M,N,P,Mg,Ng) = (4,4,2,1,1);Configuration B: 64Rx cross-polarized antenna for 16TXRU, (M,N,P,Mg,Ng) = (4,8,2,1,1);32Rx cross-polarized antenna for 32TXRU, (M,N,P,Mg,Ng) = (4,4,2,1,1); | For 32Rx: 128Rx cross-polarized antenna(M,N,P,Mg,Ng) = (8,8,2,1,1)For 64Rx: 192Rx cross-polarized antenna(M,N,P,Mg,Ng) = (12,8,2,1,1) | Configuration A/C: 64Rx cross-polarized antenna(M,N,P,Mg,Ng) = (8,4,2,1,1);Configuration B: 128Rx cross-polarized antenna(M,N,P,Mg,Ng) = (8,8,2,1,1) |
| Number of TXRU per TRxP | Configuration A/B: 32TXRU Vertical 1-to-1;Configuration B: 16TXRU Vertical 2-to-4, Horizontal 4-to-8 | 32TXRU: Vertical 2-to-864TXRU: Vertical 4-to-12 | Configuration A/C: 8TXRU Vertical 1-to-8Configuration B: 32TXRU Vertical 2-to-8 |
| Number of antenna elements per UE | Configuration A : 2Tx/4Tx with 0°,90° polarizationConfiguration B : 8Tx with 0°,90° polarization(M,N,P,Mg,Ng; Mp,Np) = (2,4,2,1,2; 1,2) | 2Tx/4Tx with 0°,90° polarization | Configuration A: 1Tx for FDD, 2Tx with 0°,90° polarization ;Configuration B: 1Tx/4Tx with 0°,90° polarizationConfiguration C: 2Tx/4Tx with 0°,90° polarization |
| UE power class | 23 dBm | 23 dBm | 23 dBm |
| Mechanic tilt | 180deg in GCS (pointing to the ground) | 90deg in GCS (pointing to the horizontal direction) | 90deg in GCS (pointing to the horizontal direction) |
| Electronic tilt | Configuration A: 90deg in LCSConfiguration B: According to Zenith angle in "Beam set at TRxP" | 105deg in LCS | Configuration A/B: 100deg in LCS Configuration C: 92deg in LCS |
| Beam set at TRxP | Configuration B: For 32Rx, Azimuth angle φi = [0],Zenith angle θj = [pi/2];For 16Rx, Azimuth angle φi = [-pi/4,pi/4], Zenith angle θj = [pi/2]; | N/A | N/A |
| Beam set at UE | Configuration B: Azimuth angle φi = [-pi/4, pi/4]; Zenith angle θj = [pi/4, 3\*pi/4] | N/A | N/A |
| UT attachment | Based on RSRP (Eq. (8.1-1) in TR36.873) from port 0 | Based on RSRP (Eq. (8.1-1) in TR36.873) from port 0 | Based on RSRP (Eq. (8.1-1) in TR36.873) from port 0 |
| Scheduling | SU-PF | SU-PF | SU-PF |
| MIMO mode | Configuration A: SU-MIMO with rank 2 adaptation; Configuration B: SU-MIMO with rank 4 adaptation;  | SU-MIMO with rank 2 adaptation | SIMO for 1Tx;SU-MIMO with rank 2 adaptation for 2Tx/4Tx |
| BS receiver type | MMSE-IRC | MMSE-IRC | MMSE-IRC |
| UE precoder scheme | Codebook based | Codebook based | Codebook based |
| UL CSI derivation | Non-precoded SRS based, with delay | Non-precoded SRS based, with delay | Non-precoded SRS based, with delay |
| Power control | $α=0.9， P\_{0}=-86$ dBm | $α=0.6， P\_{0}=-60$ dBm | Configuration A: $α=0.8， P\_{0}=-76$ dBm;Configuration B: $α=0.6， P\_{0}=-60$ dBm;Configuration C: $α=0.6， P\_{0}=-60$ dBm |
| Power backoff model | Continuous RB allocation: follow TS 38.101 in Section 6.2.2;Non-continuous RB allocation: additional 2 dB reduction | Continuous RB allocation: follow TS 38.101 in Section 6.2.2;Non-continuous RB allocation: additional 2 dB reduction | Continuous RB allocation: follow TS 38.101 in Section 6.2.2;Non-continuous RB allocation: additional 2 dB reduction |
| Overhead | PUCCH | 2 RBs and 14 OFDM symbols for FDD and TDD 30kHz SCS;4 RBs and 14 OFDM symbols for TDD 15kHz and 60kHz SCS; | 2 RBs and 14 OFDM symbols for FDD and TDD 30kHz SCS;4 RBs and 14 OFDM symbols for TDD 15kHz SCS; | 2 RBs and 14 OFDM symbols for FDD and TDD 30kHz SCS;4 RBs and 14 OFDM symbols for TDD 15kHz SCS; |
| DMRS | Type II, 2 symbols (including one additional DMRS symbol), multiplexing with PUSCH | Type II, 2 symbols (including one additional DMRS symbol), multiplexing with PUSCH | Type II, 2 symbols (including one additional DMRS symbol), multiplexing with PUSCH |
| SRS | 2 symbols per 5 slots, | 2 symbols per 5 slots, | 2 symbols per 5 slots, |
| PTRS | Configuration B: 2 ports PT-RS, (L,K) = (1,4) L is time density and K is frequency density | N/A | N/A |
| Channel estimation | Non-ideal | Non-ideal | Non-ideal |
| Waveform | OFDM | OFDM | OFDM |

## Results

**Table 4.2.1: FDD DL spectral efficiency evaluation for different system bandwidth in FR1
(Channel model B)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Test env.** | **Evaluation config.** | **Average spectral efficiency (bit/s/Hz/TRxP)** | **5th percentile spectral efficiency(bit/s/Hz)** |
| **BW=10** **MHz** | **BW=20** **MHz** | **BW=50** **MHz** | **Req.** | **BW=10** **MHz** | **BW=20 MHz** | **BW=50 MHz** | **Req.** |
| Indoor Hotspot  | Config. A 32T4R | 11.307 | 12.826 | 13.862 | 9 | 0.344 | 0.39 | 0.422 | 0.3 |
| Dense Urban  | Config. A 32T4R | 11.417 | 12.904 | 13.921 | 7.8 | 0.379 | 0.428 | 0.462 | 0.225 |
| Rural  | Config. A8T2R | 6.537 | 7.32 | 7.858 | 3.3 | 0.13 | 0.146 | 0.156 | 0.12 |
| Config. A16T2R | 7.456 | - | - | 0.156 | - | - |
| Config. B32T4R | 13.533 | 15.299 | 16.506 | 0.345 | 0.39 | 0.421 |
| Config. C8T4R | 7.607 | 8.521 | 9.151 | 0.183 | 0.205 | 0.22 |
| Config. C16T4R | 8.137 | - | - | 0.201 | - | - |

**Table 4.2.2: TDD DL spectral efficiency evaluation for different system bandwidth in FR1 (Channel model B)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Test env.** | **Evaluation config.** | **Average spectral efficiency (bit/s/Hz/TRxP)** | **5th percentile spectral efficiency(bit/s/Hz)** |
| **BW=20** **MHz** | **BW=40** **MHz** | **BW=100 MHz** | **Req.** | **BW=20** **MHz** | **BW=40 MHz** | **BW=100 MHz** | **Req.** |
| Indoor Hotspot  | Config. A (30KHz SCS);32T4R | 12.78 | 14.953 | 16.439 | 9 | 0.385 | 0.45 | 0.495 | 0.3 |
| Config. A (15KHz SCS); 32T4R | 12.53 | - | - | 0.394 | - | - |
| Dense Urban  | Config. A (30KHz SCS);32T4R | 12.581 | 14.646 | 16.061 | 7.8 | 0.385 | 0.448 | 0.491 | 0.225 |
| Config. A (30KHz SCS);64T4R | 15.542 | 18.184 | 19.991 | 0.475 | 0.556 | 0.611 |
| Config. A (15KHz SCS);32T4R | 12.506 | - | - | 0.395 | - | - |
| Config. A (15KHz SCS);64T4R | 15.172 | - | - | 0.483 | - | - |
| Rural  | Config. A(30KHz SCS);8T2R | 7.604 | 8.742 | 9.526 | 3.3 | 0.185 | 0.213 | 0.232 | 0.12 |
| Config. A(30KHz SCS);16T2R | 9.049 | - | - | 0.215 | - | - |
| Config. A(15KHz SCS);8T2R | 7.433 | - | - | 0.156 | - | - |
| Config. A(15KHz SCS);16T2R | 8.783 | - | - | 0.18 | - | - |
| Config. B(30KHz SCS);32T4R | 14.946 | 17.405 | 19.09 | 0.37 | 0.431 | 0.473 |
| Config. B(15KHz SCS);32T4R | 14.901 | - | - | 0.359 | - | - |
| Config. C(30KHz SCS);8T4R | 7.641 | 8.787 | 9.576 | 0.178 | 0.205 | 0.223 |
| Config. C(30KHz SCS);16T4R | 8.429 | - | - | 0.19 | - | - |
| Config. C(15KHz SCS);8T4R | 7.869 | - | - | 0.192 | - | - |
| Config. C(15KHz SCS);16T4R | 8.653 | - | - | 0.211 | - | - |

**Table 4.2.3: FDD UL spectral efficiency evaluation in FR1 (Channel model B)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Test env.** | **Evaluation config.** | **Average spectral efficiency (bit/s/Hz/TRxP)** | **5th percentile spectral efficiency(bit/s/Hz)** |
| **BW=10** **MHz** | **BW=20 MHz** | **BW=40** **MHz** | **Req.** | **BW=10 MHz** | **BW=20** **MHz** | **BW=40 MHz** | **Req.** |
| Indoor Hotspot  | Config. A 2T32R | 8.643 | 8.809  | 9.148  | 6.75 | 0.537 | 0.547  | 0.568  | 0.21 |
| Config. A 4T32R | 9.198 | - | - | 0.572 | - | - |
| Dense Urban  | Config. A 2T16R | 6.499 | 6.624  | 6.879  | 5.4 | 0.213 | 0.217  | 0.225  | 0.15 |
| Config. A 2T32R | 7.874 | 8.025  | 8.334  | 0.315 | 0.321  | 0.333  |
| Config. A 4T32R | 8.568 | - | - | 0.365 | - | - |
| Rural  | Config. A1T8R | 4.184 | 4.264  | 4.428  | 1.6 | 0.125 | 0.127  | 0.132  | 0.045 |
| Config. A2T8R | 6.204 | - | - | 0.133 | - | - |
| Config. B1T32R | 4.161 | 4.241  | 4.404  | 0.142 | 0.145  | 0.150  |
| Config. B4T32R | 7.364 | - | - | 0.209 | - | - |
| Config. C 2T8R | 3.999 | 4.076  | 4.233  | 0.073 | 0.074  | 0.077  |
| Config. C4T8R | 4.675 | - | - | 0.091 | - | - |

**Table 4.2.4: TDD UL spectral efficiency evaluation in FR1 (Channel model B)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Test env.** | **Evaluation Config.** | **Average spectral efficiency (bit/s/Hz/TRxP)** | **5th percentile spectral efficiency(bit/s/Hz)** |
| **BW=20** **MHz** | **BW=40** **MHz** | **BW=100 MHz** | **Req.** | **BW=20** **MHz** | **BW=40** **MHz** | **BW=100 MHz** | **Req.** |
| Indoor Hotspot  | Config. A (30KHz SCS);2T32R | 7.604 | 7.902  | 8.460  | 6.75 | 0.423 | 0.440  | 0.471  | 0.21 |
| Config. A (30KHz SCS);4T32R | 8.277 | - | - | 0.469 | - | - |
| Config. A (15KHz SCS);2T32R | 7.631 | - | - | 0.428 | - | - |
| Config. A (15KHz SCS);4T32R | 8.363 | - | - | 0.476 | - | - |
| Dense Urban | Config. A (30KHz SCS);2T32R | 6.629 | 6.889  | 7.375  | 5.4 | 0.271 | 0.282  | 0.302  | 0.15 |
| Config. A (30KHz SCS);2T64R | 7.601 | 7.899  | 8.457  | 0.353 | 0.367  | 0.393  |
| Config. A (30KHz SCS);4T32R | 7.329 | - | - | 0.336 | - | - |
| Config. A (15KHz SCS);2T32R | 6.813 | - | - | 0.259 | - | - |
| Config. A (15KHz SCS);2T64R | 7.861 | - | - | 0.31 | - | - |
| Config. A (15KHz SCS);4T32R | 7.554 | - | - | 0.303 | - | - |
| Rural  | Config. A(30KHz SCS);2T8R | 5.171 | 5.374  | 5.753  | 1.6 | 0.107 | 0.111  | 0.119  | 0.045 |
| Config. A(15KHz SCS);2T8R | 5.483 | - | - | 0.094 | - | - |
| Config. B(30KHz SCS);1T32R | 3.384 | 3.517  | 3.765  | 0.103 | 0.107  | 0.115  |
| Config. B(30KHz SCS);4T32R | 6.257 | - | - | 0.141 | - | - |
| Config. B(15KHz SCS);1T32R | 3.643 | - | - | 0.104 | - | - |
| Config. B(15KHz SCS);4T32R | 6.349 | - | - | 0.157 | - | - |
| Config. C(30KHz SCS);2T8R | 3.593 | 3.734  | 3.997  | 0.059 | 0.061  | 0.066  |
| Config. C(30KHz SCS);4T8R | 4.153 | - | - | 0.071 | - | - |
| Config. C(15KHz SCS);2T8R | 3.751 | - | - | 0.045 | - | - |
| Config. C(15KHz SCS);4T8R | 4.293 | - | - | 0.056 | - | - |

# Mobility

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. Channel model B is used for all the Mobility evaluations.

## Simulation assumption of System level simulation (SLS) part for mobility

The simulation assumption of system level part for mobility evaluation is listed in Table 5.1.1.

**Table 5.1.1: Simulation assumptions of SLS**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Indoor Hotspot – eMBB | Dense urban - eMBB | Rural - eMBB |
| Evaluation configuration | Configuration A, Configuration B | Configuration A  | Configuration A, Configuration B |
| Carrier frequency for evaluation | 4 GHz | 4 GHz | Configuration A :700 MHzConfiguration B : 4 GHz |
| Multiple access | OFDMA | OFDMA | OFDMA |
| Duplexing  | FDD, TDD | FDD, TDD | FDD, TDD |
| Transmission scheme | UL SIMO | UL SIMO | UL SIMO |
| BS antenna height | 3m | 25 m | 35 m |
| Total transmit power per TRxP | 21 dBm for 10 MHz bandwidth | 41 dBm for 10 MHz bandwidth | 46 dBm for 10 MHz bandwidth |
| UE power class | 23 dBm | 23 dBm | 23 dBm |
| Percentage of high loss and low loss building type | - | 20% high loss, 80% low loss (applies to Channel model B) | 100% low loss (applies to Channel model B) |
| Inter-site distance | 20 m | 200 m | 1732 m |
| Number of antenna elements per TRxP | 32 Tx/Rx, (M,N,P,Mg,Ng) = (4,4,2,1,1), (dH,dV) = (0.5, 0.5)λ+45°, -45° polarization | 64 Tx/Rx, (M,N,P,Mg,Ng) = (8,4,2,1,1), (dH,dV) = (0.5, 0.8)λ+45°, -45° polarization | 32 Tx/Rx, (M,N,P,Mg,Ng) = (8,2,2,1,1), (dH,dV) = (0.5, 0.8)λ+45°, -45° polarization |
| Number of TXRU per TRxP | 8TXRU, (Mp,Np,P,Mg,Ng) = (1,4,2,1,1) | 8TXRU, (Mp,Np,P,Mg,Ng) = (1,4,2,1,1) | 4TXRU, (Mp,Np,P,Mg,Ng) = (1,2,2,1,1) |
| Number of UE antenna elements | 1Tx/Rx, (M,N,P,Mg,Ng) = (1,1,1,1,1) | 1Tx/Rx, (M,N,P,Mg,Ng) = (1,1,1,1,1) | 1Tx/Rx, (M,N,P,Mg,Ng) = (1,1,1,1,1) |
| Device deployment | 100% indoorRandomly and uniformly distributed over the area | 80% indoor, 20% outdoor (in car)Randomly and uniformly distributed over the area under Macro layer | 50% indoor, 50% outdoor (in car)Randomly and uniformly distributed over the area |
| UE speeds of interest | 10 km/h | 30 km/h; | 120 km/h;500km/h; |
| Traffic model | Full buffer | Full buffer | Full buffer |
| Simulation bandwidth | For FDD: 10 MHzFor TDD: 20 MHz | For FDD: 10 MHzFor TDD: 20 MHz | For FDD: 10 MHzFor TDD: 20 MHz |
| UE density | 10 UEs per TRxP | 10 UEs per TRxP | 10 UEs per TRxP |
| UE antenna height | 1.5 m | Outdoor UEs: 1.5 mIndoor UTs: 3(nfl – 1) + 1.5;nfl ~ uniform(1,Nfl) whereNfl ~ uniform(4,8) | 1.5 m |
| Channel model variant | Channel model B | Channel model B | Channel model B |
| TRxP number per site | 1 or 3 | 3 | 3 |
| Mechanic tilt | For 1 TRxP per site:180° in GCS (pointing to the ground)For 3 TRxPs per site: 110° | 90° in GCS (pointing to horizontal direction) | 90° in GCS (pointing to horizontal direction) |
| Electronic tilt | 90° in LCS | 105° in LCS | 100° in LCS |
| Handover margin (dB) | 1 | 1 | 1 |
| TRxP boresight | For 1 TRxP per site::-For 3 TRxP per site: 30 / 150 / 270 degrees | 30 / 150 / 270 degrees | 30 / 150 / 270 degrees |
| UT attachment | Based on RSRP (formula (8.1-1) in TR36.873) from port 0 | Based on RSRP (formula (8.1-1) in TR36.873) from port 0 | Based on RSRP (formula (8.1-1) in TR36.873) from port 0 |
| Wrapping around method | No wrapping around | Geographical distance based wrapping | Geographical distance based wrapping |
| Minimum distance of TRxP and UE | d2D\_min=0m | d2D\_min=10m | d2D\_min=10m |
| Polarized antenna model | Model-2 in TR36.873 | Model-2 in TR36.873 | Model-2 in TR36.873 |
| Power control parameters | **= 0.6, P0 = -60 dBm | **= 0.9, P0 = -86 dBm | For 700 MHz :**= 0.8, P0 = -76 dBmFor 4 GHz :**= 0.6, P0 = -60 dBm |
| Numerology | For FDD: One slot with 15 kHz SCSFor TDD: One slot with 30 kHz SCS | For FDD: One slot with 15 kHz SCSFor TDD: One slot with 30 kHz SCS | For 700 MHz:* 120 km/h: one slot with 15 kHz SCS
* 500 km/h: one slot with 30 kHz SCS

For 4 GHz:* 120 km/h: one slot with 30 kHz SCS
* 500 km/h: one slot with 60 kHz SCS
 |
| Scheduling | PF | PF | PF |
| Receiver | MMSE-IRC | MMSE-IRC | MMSE-IRC |
| Pre-processing SINR calculation | Aligned with Section 2.1.1 in R1-1805643 | Aligned with Section 2.1.1 in R1-1805643 | Aligned with Section 2.1.1 in R1-1805643 |

## Simulation assumption of Link level simulation (LLS) part for mobility

The simulation assumption of link level part for mobility evaluation is listed in Table 5.2.1.

**Table 5.2.1: Simulation assumptions of LLS**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Indoor Hotspot – eMBB | Dense urban - eMBB | Rural – eMBB  |
| Carrier frequency for evaluation | 4 GHz | 4 GHz | Configuration A :700 MHz; Configuration B : 4 GHz |
| RIT | NR | NR | NR |
| Waveform | CP-OFDM | CP-OFDM | CP-OFDM |
| Duplexing  | FDD, TDD | FDD, TDD | FDD, TDD |
| TDD frame structure | DDDSU | DDDSU | DDDSU |
| Evaluated service profiles | Full buffer best effort | Full buffer best effort | Full buffer best effort |
| Simulation bandwidth | 10 MHz | 10 MHz | 10 MHz |
| Number of users in simulation | 1 | 1 | 1 |
| Link-level Channel model | NLOS: CDL-iLOS: CDL-iv | NLOS: CDL-iiiLOS: CDL-v | NLOS: CDL-iiiLOS: CDL-v |
| UE speed | 10 km/h | 30 km/h | 120 km/h, 500 km/h |
| Subcarrier spacing | For FDD: 15 kHzFor TDD: 30 kHz | For FDD: 15 kHzFor TDD: 30 kHz | For 700 MHz:* 120 km/h: 15 kHz
* 500 km/h: 30 kHz

For 4 GHz:* 120 km/h: 30 kHz
* 500 km/h: 60 kHz
 |
| Symbols number per slot | 14 | 14 | 14 |
| Antenna configuration at TRxP | 8R, (4,4,2,1,1; 1,4) | 8R, (8,4,2,1,1; 1,4) | 4R, (8,2,2,1,1; 1,2) |
| Antenna configuration at UE | 1T, (1,1,1,1,1; 1,1) | 1T, (1,1,1,1,1; 1,1) | 1T, (1,1,1,1,1; 1,1) |
| TXRU pattern at TRxP | Option 1: 0dBi Omni-directional | Option 1: 0dBi Omni-directional | Option 1: 0dBi Omni-directional |
| TXRU pattern at UE | Option 1: 0dBi Omni-directional | Option 1: 0dBi Omni-directional | Option 1: 0dBi Omni-directional |
| Transmission mode | SIMO | SIMO | SIMO |
| Transmission rank | Rank 1 | Rank 1 | Rank 1 |
| UL precoder | - | - | - |
| TRxP receiver type | MMSE-IRC | MMSE-IRC | MMSE-IRC |
| Channel estimation | LMMSE | LMMSE | LMMSE |
| Number of subcarriers per PRB | 12 | 12 | 12 |
| Data allocation | 14 symbol slots, with 12 RB allocated | 14 symbol slots, with 12 RB allocated | 14 symbol slots, with 12 RB allocated |
| Channel coding scheme | LDPC | LDPC | LDPC |
| Link adaptation | Yes | Yes | Yes |
| HARQ | Max 4 HARQ transmissions | Max 4 HARQ transmissions | Max 4 HARQ transmissions |
| DMRS configuration | 2 symbol DMRS (front loaded and one additional) with configuration type 2, no FDM with data and full power utilization in DMRS symbols | 2 symbol DMRS (front loaded and one additional) with configuration type 2, no FDM with data and full power utilization in DMRS symbols | - For 4GHz 500km/h: 4 symbol DMRS (front loaded and 3 additional) with configuration type 2, no FDM with data and full power utilization in DMRS symbols- Others: 2 symbol DMRS (front loaded and one additional) with configuration type 2, no FDM with data and full power utilization in DMRS symbols |
| Other overhead | - SRS: 2 symbols per 5 slots. For TDD, the 2 symbols are the 2 uplink symbols in S sub-frame- PUCCH :2 RB in 10MHz bandwidth  | - SRS: 2 symbols per 5 slots. For TDD, the 2 symbols are the 2 uplink symbols in S sub-frame- PUCCH :2 RB in 10MHz bandwidth | - SRS: 2 symbols per 5 slots. For TDD, the 2 symbols are the 2 uplink symbols in S sub-frame- PUCCH :2 RB in 10MHz bandwidth |

Based on the above figures, the 50%-tile point of the CDF for different test environments are listed in Table 5.2.2.

**Table 5.2.2: The 50%-tile point of SINR CDF for different test environments**

|  |  |  |  |
| --- | --- | --- | --- |
| Test environment | Evaluation configuration | UE mobility | 50%-tile point of SINR CDF (dB) |
| Channel model B |
| Rural – eMBB | Config. A (700 MHz) | 120 km/h | 10.14 |
| 500 km/h | 9.65 |
| Rural - eMBB | Config. B (4 GHz) | 120 km/h | 4.50 |
| 500 km/h | 2.72 |
| Dense Urban – eMBB | Config. A (4 GHz) | 30 km/h | 5.32 |
| Indoor Hotspot – eMBB (12 TRxP) | Config. A (4 GHz) | 10 km/h | 3.95 |

## Results

**Table 5.3.1: The uplink link level evaluation results for different test environments for NR**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Test environment | ITU requirement (bit/s/Hz) | Evaluation configuration | Channel Model | 50%-tile point of SINR CDF (dB) | Uplink SE (bit/s/Hz) |
| FDD | TDD |
| NLOS | LOS | NLOS | LOS |
| Indoor Hotspot –eMBB (12 TRxP) | 1.5 | Config. A(4 GHz) | Channel model B | 3.95 | 1.75  | 2.07  | 1.60  | 1.95  |
| Dense Urban – eMBB | 1.12 | Config. A(4 GHz) | Channel model B | 5.32 | 1.89  | 2.19  | 1.79  | 2.06  |
| Rural –eMBB (120 km/h) | 0.8 | Config. A(700 MHz) | Channel model B | 10.14 | 2.31  | 2.90  | 2.09  | 2.63  |
| Config. B(4 GHz) | Channel model B | 4.50 | 1.28  | 1.68  | 1.16  | 1.52  |
| Rural –eMBB (500 km/h) | 0.45 | Config. A(700 MHz) | Channel model B | 9.65 | 2.07  | 2.64  | 1.87  | 2.39  |
| Config. B(4 GHz) | Channel model B | 2.72 | 0.91  | 1.33  | 0.83  | 1.22  |

# Reliability

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 is evaluated under Urban Macro – URLLC test environment.

## Simulation assumption of SLS part for Urban Macro - URLLC test environment

The simulation assumption for system level part of Urban Macro – URLLC test environment is listed in Table 6.1.1.

**Table 6.1.1: Simulation assumptions for SLS**

|  |  |
| --- | --- |
|  | Urban Macro - URLLC |
| Evaluation configuration | Configuration A, Configuration B |
| Carrier frequency for evaluation | Configuration A : 4 GHz 60KHz SCSConfiguration B :700 MHz 30KHz SCS |
| Multiple access (DL/UL) | OFDMA |
| Duplexing | FDD |
| Transmission scheme | DL: SU-MIMO with rank 1UL: SIMO |
| BS antenna height | 25 m |
| Total transmit power per TRxP | 46 dBm for 10 MHz bandwidth |
| UE power class | 23 dBm |
| Percentage of high loss and low loss building type | 100% low loss (applies to Channel model B) |
| Inter-site distance | 500m |
| Number of antenna elements per TRxP | Configuration A DL: 64 Tx/Rx, (M,N,P,Mg,Ng) = (8,4,2,1,1), (dH,dV) = (0.5, 0.8)λ+45°, -45° polarizationConfiguration B DL: 16 Tx/Rx, (M,N,P,Mg,Ng) = (8,1,2,1,1), (dH,dV) = (0.5, 0.8)λ+45°, -45° polarizationConfiguration A UL: 128 Tx/Rx, (M,N,P,Mg,Ng) = (8,8,2,1,1), (dH,dV) = (0.5, 0.8)λ+45°, -45° polarizationConfiguration B UL: 64 Tx/Rx, (M,N,P,Mg,Ng) = (8,4,2,1,1), (dH,dV) = (0.5, 0.8)λ+45°, -45° polarization |
| Number of TXRU per TRxP | Configuration A DL: 8TXRU, (Mp,Np,P,Mg,Ng) = (1,4,2,1,1)Configuration B DL: 2TXRU, (Mp,Np,P,Mg,Ng) = (1,1,2,1,1)Configuration A UL: 16TXRU, (Mp,Np,P,Mg,Ng) = (1,8,2,1,1)Configuration B UL: 8TXRU, (Mp,Np,P,Mg,Ng) = (1,4,2,1,1) |
| Number of UE antenna elements | 1Tx, 2Rx, (M,N,P,Mg,Ng) = (1,1,2,1,1) |
| Number of TXRU per UE | 1TXU, 2RXU  |
| Device deployment | 80% outdoor ,20% indoorRandomly and uniformly distributed over the area |
| UE speeds of interest | 3 km/h for indoor and 30 km/h for outdoor |
| Traffic model | Full buffer |
| Simulation bandwidth | 10 MHz |
| UE density | 10 UEs per TRxP |
| UE antenna height | 1.5 m |
| Channel model variant | Channel model B |
| TRxP number per site | 3 |
| Mechanic tilt | 90° in GCS (pointing to horizontal direction) |
| Electronic tilt | Configuration A : 99° in LCSConfiguration B : 100° in LCS |
| Handover margin (dB) | 1 |
| TRxP boresight | 30 / 150 / 270 degrees |
| UT attachment | Based on RSRP (formula (8.1-1) in TR36.873) from port 0 |
| Wrapping around method | Geographical distance based wrapping |
| Minimum distance of TRxP and UE | d2D\_min=10m |
| Polarized antenna model | Model-2 in TR36.873 |
| Power control parameters | Configuration A :**= 0.8, P0 = -86 dBmConfiguration B :**= 0.9, P0 = -86 dBm |
| Scheduling | PF |
| Receiver | MMSE-IRC |
| Pre-processing SINR calculation | Aligned with Section 2.1.1 in R1-1805643 |

## Simulation assumption of LLS part for Urban Macro - URLLC test environment

The simulation assumption for link level part of Urban Macro – URLLC test environment is listed in Table 6.2.1.

**Table 6.2.1:** **Simulation assumptions for LLS**

|  |  |
| --- | --- |
|  | Urban Macro - URLLC |
| Evaluation configuration | Configuration A,Configuration B |
| Carrier frequency | Configuration A :4GHzConfiguration B :700MHz |
| Waveform | DL/UL: CP-OFDM |
| System Bandwidth | 10MHz |
| Channel model | TDL-iii (NLOS) |
| Scaled delay spread | 363ns(NLOS) |
| UE Speed | 3km/h |
| Sub-carrier spacing | Configuration A :60 kHzConfiguration B :30 kHz |
| Number of symbols per slot | 14 |
| Antenna configuration at TRxP | Configuration A: 16TRXU (8 Tx port and 16 Rx port)Configuration B: 8TRXU (2 Tx port and 8 Rx port) |
| Antenna configuration at UE | 1 Tx port, 2Rx port |
| TXRU pattern at TRxP | 0dBi Omni-directional |
| TXRU pattern at UE | 0dBi Omni-directional |
| Data Transmission mode | DL SU-MIMO with rank 1UL: SIMO |
| Channel estimation | Realistic |
| PDCCH transmission scheme | Polar code. 64bit payload includes CRC.  |
| Data coding | LDPC, BG2 |
| Packet size  | 256bit |
| DMRS configuration | Type 1, 2 symbol DMRS |

## Results

**Table 6.3.1 DL reliability evaluation result**

|  |  |  |  |
| --- | --- | --- | --- |
| Test environment | Evaluation configuration | Transmission scheme |  5%-tile point of SINR CDF (dB) |
| Channel model B |
| Urban Macro – URLLC | Config. A (4 GHz) | One PDCCH + 2 PDSCH | 99.99990561% |
| Urban Macro – URLLC | Config. B (700 MHz) | One shot | 99.9998112% |

**Table 6.3.2: UL reliability evaluation result**

|  |  |  |  |
| --- | --- | --- | --- |
| Test environment | Evaluation configuration | Transmission scheme |  5%-tile point of SINR CDF (dB) |
| Channel model B |
| Urban Macro – URLLC | Config. A (4 GHz) | One shot | 99.9999924% |
| Urban Macro – URLLC | Config. B (700 MHz) | One shot | 99.9999997% |

# Connection Density

The connection density of NB-IoT, eMTC and NR are evaluated using full buffer system level simulation with link level simulation as defined in Report ITU-R M.2412. The simulation assumptions are given below.

**Table 7.1: Simulation assumption for NR**

|  |  |
| --- | --- |
| Urban Macro – eMTC | Parameter |
| Simulation bandwidth | 5MHz |
| Sub-carrier spacing for PDCCH, PDSCH | 15 kHz |
| Sub-carrier spacing for PUSCH | 15 kHz |
| UL DMRS | 12 symbols per RB |
| PUSCH scheduling unit | 180kHz |
| Simulation bandwidth | 5 MHz |
| Power control  | ISD 1732m: Alpha = 1, P0 = -113 dBm on 180kHzISD 500m: Alpha = 1, P0 = -103 dBm on 180kHz |

**Table 7.2: Link level simulation assumption**

|  |  |
| --- | --- |
|  | NR Parameter |
| Simulation bandwidth | 180kHz |
| Sub-carrier spacing | 15 kHz |
| Modulation order | QPSK/16QAM |
| Number of Resource unit | - |
| Number of TTI | 1 |
| Number of repetitions | - |
| Channel model | TDL-iii |
| Delay spread | 363ns |
| TBS | 40,48,64,80,96,144,152,168,184,208,240,256 |
| Channel estimation | Realistic |

 The evaluation results are provided in Table 7.3. The 99% latency derived by SINR could fulfill the 10s latency requirement.

**Table 7.3: Evaluation result of full buffer system-level followed by link-level simulation**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Config A (ISD=500m)Channel mode A | Config B (ISD=500m)Channel mode B | Config B (ISD=1732m)Channel mode A | Config B (ISD=1732m)Channel mode B |
| Devices supported per km2 per 180kHz | 36,574,000 | 35,021,000 | 1,138,000 | 1,465,000 |
| Connection efficiency (#of devices/Hz/TRxP) | 14.663 | 14.041 | 5.475 | 7.048 |

# User Experienced Data Rate

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 user experienced data rate, Ruser is given by:

 Ruser = W(Effective Bandwidth) × SEuser (5th Percentile)

**Table 8.1: UL user experienced data rate**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Evaluated features | Evaluation configuration | Carrier frequency for *fi* (*i*=1 or 2) | Simulation bandwidth *SBWi* on *fi* | Simulated user throughput *SRk* |
| NR FDD  | Configuration A | *f*1=4 GHz | 10 MHz | 5%-tile: 3.15 Mbps |
| NR FDD | Configuration A | f1=4 GHz | 160 MHz | 50.4 Mbps |

**Table 8.2: DL user experienced data rate**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Evaluated features | Evaluation configuration | Carrier frequency for *fi* (*i*=1 or 2) | Simulation bandwidth *SBWi* on *fi* | Simulated user throughput *SRk* |
| NR FDD  | Configuration A | *f*1=4 GHz | 20 MHz | 5%-tile: 8.56 Mbps |
| NR FDD | Configuration A | f1=4 GHz | 320 MHz | 136.96 Mbps |

# 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.

The area traffic capacity of the RIT is evaluated using analytical way based on the downlink average spectral efficiency evaluation for Indoor Hotspot – eMBB test environment. Let W denote the channel bandwidth and $ρ$ the TRxP density (TRxP/m2). The area traffic capacity Carea is related to average spectral efficiency SEavg through equation Carea = ρ × W × SEavg.

The results are provided in Table 8.1.

**Table 9.1: Downlink area traffic capacity (Mbit/s/m2) in Indoor Hotspot-eMBB at 4GHz
(12 TRxP, Channel model B)**

|  |  |  |
| --- | --- | --- |
| System bandwidth (MHz) | Average spectral efficiency SE*avg* [bps/Hz/TRxP] | 12TRxP (TRxP density $ρ$=0.002TRxP/m2) |
| FDD 50 MHz bandwidth per CC with 15 kHz SCS | TDD100 MHz bandwidth per CC with 30 kHz SCS | FDD | TDD(DDDSU) |
| *W =*300 | 11.968 | 13.675 | 7.18 | 6.33 |
| *W* = 350 | 8.38 | 7.38 |
| *W* = 400 | 9.57 | 8.34 |
| *W* = 450 | 10.77 | 9.49 |
| *W* = 500 | 11.97 | 10.55 |

# Peak Spectral Efficiency

Peak spectral efficiency is the maximum data rate under ideal conditions divided 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).

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

 $SE\_{p\_{j}}=\frac{v\_{Layers}^{\left(j\right)}Q\_{m}^{\left(j\right)}f^{\left(j\right)}R\_{max}\frac{N\_{PRB}^{BW\left(j\right),μ}12}{T\_{s}^{μ}}\left(1-OH^{\left(j\right)}\right)}{BW^{\left(j\right)}}$

Wherein,

* Rmax = 948/1024
* For the j-th CC,
	+  is the maximum number of layers
	+  is the maximum modulation order
	+ is the scaling factor
		- * The scaling factor can at least take the values 1 and 0.75.
			* is signalled per band and per band per band combination as per UE capability signaling
	+  is the numerology (as defined in TS38.211)
	+  is the average OFDM symbol duration in a subframe for numerology , i.e. . Note that normal cyclic prefix is assumed.
	+  is the maximum RB allocation in bandwidth  with numerology , as given in TS38.104 section 5.3.2, where  is the UE supported maximum bandwidth in the given band or band combination.
	+ is the overhead calculated as the average ratio of the number of REs occupied by L1/L2 control, Synchronization Signal, PBCH, reference signals and guard period (for TDD), etc. with respect to the total number of REs in effective bandwidth time product as given by α(j).BW(j).(14\*Tsu)

− α(j) is the normalized scalar considering the downlink/uplink ratio; for FDD α(j)=1 for DL and UL; and for TDD and other duplexing α(j) for DL and UL is calculated based on the DL/UL configuration.

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

## DL Peak Spectral Efficiency

The DL peak spectral efficiencies for FDD and TDD are given below.

Table 10.1.1: NR FDD DL peak spectral efficiency (bit/s/Hz)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SCS [kHz] | 5MHz | 10MHz | 15MHz | 20 MHz | 25 MHz | 30MHz | 40 MHz | 50 MHz | 60 MHz | 80 MHz | 90MHz | 100 MHz | Req. |
| FR1 | 15 | 40.8 | 44.5 | 45.9 | 46.5 | 46.9 | 47.2 | 48.0 | 48.1 | - | - | - | - | 30 |
| 30 | 32.7 | 39.4 | 43.0 | 43.9 | 45.2 | 45.5 | 46.7 | 47.1 | 47.9 | 48.3 | 48.5 | 48.7 | 30 |
| 60 | - | 32.7 | 38.4 | 39.6 | 41.8 | 43.2 | 44.1 | 45.3 | 46.2 | 47.2 | 47.6 | 47.9 | 30 |

Table 10.1.2: NR TDD DL peak spectral efficiency (bit/s/Hz)
(Frame structure: DDDSU, DL:UL=4:1)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SCS [kHz] | 5MHz | 10MHz | 15MHz | 20 MHz | 25 MHz | 30MHz | 40 MHz | 50 MHz | 60 MHz | 80 MHz | 90MHz | 100 MHz | 200 MHz | 400 MHz | Req. |
| FR1 | 15 | 39.6 | 43.6 | 44.9 | 45.6 | 46.1 | 46.3 | 47.1 | 47.2 | - | - | - | - | - | - | 30 |
| 30 | 31.7 | 38.4 | 42.1 | 43.1 | 44.4 | 44.6 | 45.9 | 46.3 | 47.1 | 47.5 | 47.7 | 47.9 | - | - | 30 |
| 60 | - | 31.8 | 37.5 | 38.7 | 40.9 | 42.3 | 43.3 | 44.5 | 45.4 | 46.4 | 46.8 | 47.1 | - | - | 30 |
| FR2 | 60 | - | - | - | - | - | - | - | 33.7 | - | - | - | 34.5 | 34.9 | - | 30 |
| 120 | - | - | - | - | - | - | - | 31.7 | - | - | - | 34.0 | 34.7 | 35.0 | 30 |

## UL Peak Spectral Efficiency

The UL peak spectral efficiencies for FDD and TDD are given below.

Table 10.2.1: NR FDD UL peak spectral efficiency (bit/s/Hz)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SCS [kHz] | 5MHz | 10MHz | 15MHz | 20 MHz | 25 MHz | 30MHz | 40 MHz | 50 MHz | 60 MHz | 80 MHz | 90MHz | 100 MHz | Req. |
| FR1 | 15 | 22.9 | 23.8 | 24.1 | 24.3 | 24.4 | 24.4 | 24.8 | 24.8 | - | - | - | - | 15 |
| 30 | 20.1 | 22.0 | 23.3 | 23.4 | 23.4 | 23.9 | 24.4 | 24.5 | 24.5 | 24.8 | 25.1 | 25.1 | 15 |
| 60 | - | 20.2 | 22.0 | 22.1 | 22.8 | 23.3 | 23.5 | 24.0 | 24.3 | 24.3 | 24.8 | 24.9 | 15 |

The TDD UL peak spectral efficiency for NR TDD for different bandwidth and SCS parameters is shown in Table 2.1.2-2. In this evaluation, the DL dominant frame structure “DDDSU” is selected.

Table 10.2.2: NR TDD UL peak spectral efficiency (bit/s/Hz) for DL dominant frame structure

(Frame structure: DDDSU, DL:UL = 4:1)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **SCS [kHz]** | **5****MHz** | **10****MHz** | **15****MHz** | **20 MHz** | **25 MHz** | **30****MHz** | **40 MHz** | **50 MHz** | **60 MHz** | **80 MHz** | **90****MHz** | **100 MHz** | **200 MHz** | **400 MHz** | **Req.** |
| FR1 | 15 | 20.6 | 21.5 | 21.8 | 22.0 | 22.0 | 22.1 | 22.1 | 22.4 | - | - | - | - | - | - | 15 |
| 30 | 18.2 | 20.0 | 21.1 | 21.3 | 21.7 | 21.7 | 22.2 | 22.2 | 22.6 | 22.7 | 22.8 | 22.8 | - | - | 15 |
| 60 | - | 18.3 | 20.0 | 20.1 | 20.8 | 20.8 | 21.4 | 21.8 | 22.1 | 22.5 | 22.6 | 22.7 | - | - | 15 |
| FR2 | 60 | - | - | - | - | - | - | - | 20.9 | - | - | - | 21.0 | 21.0 | - | 15 |
| 120 | - | - | - | - | - | - | - | 20.4 | - | - | - | 21.1 | 21.2 | 21.2 | 15 |

# 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).

## DL Peak Data rate

The DL peak data rate for NR is shown in Table 11.1.1.

Table 11.1.1: NR FDD DL peak data rate

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Duplexing | SCS [kHz] | Per CC BW (MHz) | Peak data rate per CC (Gbit/s) | Number of CC | Total bandwidth (MHz) | Aggregated peak data rate (Gbit/s) | Req. (Gbit/s) |
| FDD | FR1 | 15 | 50 | 2.405 | 9 | 450 | 21.65 | 20 |
| 30 | 100 | 4.87 | 5 | 500 | 24.35 |
| 60 | 100 | 4.79 | 5 | 500 | 23.95 |
| TDD (DDDSU，$α\_{DL}^{\left(j\right)}=0.7643$) | FR1 | 15 | 50 | 1.804  | 12 | 600 | 21.65  |
| 30 | 100 | 3.661  | 6 | 600 | 21.97  |
| 60 | 100 | 3.60 | 6 | 600 | 21.6  |
| FR2 | 60 | 200 | 5.335  | 4 | 800 | 21.34 |
| 120 | 400 | 10.7 | 2 | 800 | 21.4  |

## UL Peak Data rate

.

Table 11.2.1: NR UL peak data rate

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Duplexing** | **SCS [kHz]** | **Per CC BW (MHz)** | **Peak data rate per CC (Gbit/s)** | **Number of CC** | **Total bandwidth (MHz)** | **Aggregated peak data rate (Gbit/s)** | **Req. (Gbit/s)** |
| FDD | FR1 | 15 | 50 | 1.24 | 9 | 450 | 11.16 | 10 |
| 30 | 100 | 2.51 | 4 | 400 | 10.04 |
| 60 | 100 | 2.49 | 5 | 400 | 12.45 |

# User Plane Latency

According to 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). It is defined as the one-way time it takes to successfully deliver an application layer packet/message from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface in either uplink or downlink in the network for a given service in unloaded conditions, assuming the mobile station is in the active state.

This requirement is defined for the purpose of evaluation in the eMBB and URLLC usage scenarios.

The minimum requirements for user plane latency are

– 4 ms for eMBB

– 1 ms for URLLC

assuming unloaded conditions (i.e., a single user) for small IP packets (e.g., 0 byte payload + IP header), for both downlink and uplink.

Based on the definition and the evaluation method provided in Report ITU-R M.2412, the BS-to-UE data transmission procedure is illustrated in Figure 12.1. Also, the detailed procedure of user plane latency are listed in Table 12.1 and Table 12.2 for UL and DL, with value of each component.



Figure 12.1: Illustration of UP latency components

For NR UL evaluation, grant free transmission is assumed.

Table 12.1: UL user plane procedure parameter for NR

|  |  |  |  |
| --- | --- | --- | --- |
| Step | Component | Notations | Value |
| 1 | UL data transfer | *T*1 = (*t*UE,tx + *t*FA,UL)+ *t*UL\_duration + *t*BS,rx |  |
| 1.1 | UE processing delay | *t*UE,txThe time interval between the data is arrived, and packet is generated;  | Tproc,2/2, with d2,1= d2,2= d2,3=0 |
| 1.2 | UL Frame alignment (transmission alignment) | *t*FA,ULIt includes frame alignment time, and the waiting time for next available UL slot  | *T*FA + *T*wait,*T*FA is the frame alignment time within the current UL slot; *for the first transmission, frame alignment time includes the waiting time for the starting symbol (see below).**T*wait is the waiting time for next available UL slot if the current slot is not UL slot. |
| 1.3 | TTI for UL data packet transmission | *t*UL\_duration | Length of one slot (14 OFDM symbol length) or non-slot (2/4/7 OFDM symbol length) |
| 1.4 | BS processing delay | *t*BS,rx The time interval between the PUSCH is received and the data is decoded; | Tproc,1/2, d1,1=0; d1,2 is selected according to resource mapping type and UE capability. *N*1*=*the value with “No additional PDSCH DM-RS configured”NOTE: A strong BS capability is assumed: BS processing delay is equal to UE processing delay as for receiving PDSCH |
| 2 | HARQ retransmission | *T*HARQ = *T*2 + *T*1*T*2 = (*t*BS,tx + *t*FA,DL) + *t*DL\_duration + *t*UE,rx (For Steps 2.1 to 2.4) |  |
| 2.1 | BS processing delay | *t*BS,tx The time interval between the data is decoded, and PDCCH preparation | Tproc,1/2, d1,1=0; d1,2 is selected according to resource mapping type and UE capability. *N*1*=*the value with “No additional PDSCH DM-RS configured”. |
| 2.2 | DL Frame alignment (transmission alignment) | *t*FA,DLIt includes frame alignment time, and the waiting time for next available DL slot  | *T*FA + *T*wait,*T*FA is the frame alignment time within the current DL slot; *T*wait is the waiting time for next available DL slot if the current slot is not DL slot |
| 2.3 | TTI for PDCCH transmission | *t*DL\_duration | 1 OFDM symbols for PDCCH scheduling the retransmission. |
| 2.4 | UE processing delay | *t*UE,rx The time interval between the PDCCH is received and the decoded. | Tproc,2/2, with d2,1= d2,2= d2,3=0  |
| 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*HARQwhere *n* is the number of re-transmissions (*n*≥0)*Average T*UP*= T*1 *+* *p*×*T*HARQwhere *p* is the probability of re-transmissions |

In the evaluation, the grant free transmission uses the following start symbols:

* 1. For 2-symbol PUSCH, the start symbol can be symbols {0,2,4,6,8,10,12} for PUSCH resource mapping type B
	2. For 4-symbol PUSCH, the start symbol can be:
		1. For PUSCH resource mapping type B: symbols **{0,7}**
		2. For PUSCH resource mapping type A: symbol 0;
	3. For 7-symbol PUSCH, the start symbol can be:
		1. For PUSCH resource mapping type B: symbols {0, 7}
		2. For PUSCH resource mapping type A: symbol 0;
	4. For 14-symbol PUSCH, the start symbol can be at symbol #0 for PUSCH resource mapping type A and B.

Table 12.2: DL user plane procedure parameter for NR

|  |  |  |  |
| --- | --- | --- | --- |
| ID | Component | Notations | Value |
| 1 | DL data transfer | *T*2 = (*t*BS,tx + *t*FA,DL) + *t*DL\_duration + *t*UE,rx |  |
| 1.1 | BS processing delay | *t*BS,txThe time interval between the data is arrived, and packet is generated. | Tproc,2/2, with d2,1= d2,2= d2,3=0.  |
| 1.2 | DL Frame alignment (transmission alignment) | *t*FA,DLIt includes frame alignment time, and the waiting time for next available DL slot | *T*FA + *T*wait,*T*FA is the frame alignment time within the current DL slot;*T*wait is the waiting time for next available DL slot if the current slot is not DL slot.  |
| 1.3 | TTI for DL data packet transmission | *t*DL\_duration | Length of one slot (14 OFDM symbol length) or non-slot (2/4/7 OFDM symbol length). |
| 1.4 | UE processing delay | *t*UE,rx The time interval between the PDSCH is received and the data is decoded; | Tproc,1/2, d1,1=0; d1,2 is selected according to resource mapping type and UE capability. *N*1*=*the value with “No additional PDSCH DM-RS configured”. |
| 2 | HARQ retransmission | *T*HARQ = *T*1 + *T*2*T*1 = (*t*UE,tx + *t*FA,UL)+ *t*UL\_duration + *t*BS,rx (For Steps 2.1 to 2.4) |  |
| 2.1 | UE processing delay | *t*UE,tx The time interval between the data is decoded, and ACK/NACK packet is generated. | Tproc,1/2, d1,1=0; d1,2 is selected according to resource mapping type and UE capability. *N*1*=*the value with “No additional PDSCH DM-RS configured”. |
| 2.2 | UL frame alignment (transmission alignment) | *t*FA,ULIt includes frame alignment time, and the waiting time for the next available UL slot | *T*FA + *T*wait,*T*FA is the frame alignment time within the current UL slot;*T*wait is the waiting time for next available UL slot if the current slot is not UL slot |
| 2.3 | TTI for ACK/NACK transmission | *t*UL\_duration | 1 OFDM symbol as starting point; |
| 2.4 | BS processing delay | *t*BS,rx The time interval between the ACK is received and the ACK is decoded. | Tproc,2/2 with d2,1= d2,2= d2,3=0. |
| 2.5 | Repeat DL data transfer from 1.1 to 1.4 | *T*2 |  |
| - | Total one way user plane latency for DL | *T*UP= *T*2 + *n*×*T*HARQwhere *n* is the number of re-transmissions (*n*≥0)*Average T*UP*= T*2 *+* *p*×*T*HARQwhere *p* is the probability of re-transmissions |

It is noted that the values of the components are related to frame structure and numerology, UE processing capability, as well as PDSCH/PUSCH mapping type. These impact factors are further subject to duplexing schemes like FDD, TDD. Therefore, in the following we consider the user plane latency for in terms of the above aspects.

## Evaluation of NR FDD

For NR FDD, the user plane latency is calculated. It is noted that in NR DL, the start and length indicator SLIV can be used to indicate the starting symbol relative to the start of the slot, and the number of consecutive symbols counting from the symbol allocated for the PDSCH. Similar mechanism is also introduced for PUSCH. Note that in this paper, grant free based UL transmission is considered in order to derive the lower bound of user plane latency performance.

The DL and UL user plane latency results for NR FDD are presented below.

Table 12.1.1 DL user plane latency for FDD

|  |  |  |
| --- | --- | --- |
| DL user plane latency – NR FDD | UE capability 1 | UE capability 2 |
| SCS | SCS |
| 15 kHz | 30 kHz | 60 kHz | 15 kHz | 30 kHz | 60 kHz |
| **Resource mapping Type A** | M=4 (4OS non-slot) | p=0 | 1.37  | 0.76  | 0.53  | 0.98  | 0.55  | 0.35  |
| p=0.1 | 1.57  | 0.86  | 0.63  | 1.09  | 0.65  | 0.40  |
| M=7 (7OS non-slot) | p=0 | 1.49  | 0.82  | 0.56  | 1.10  | 0.61  | 0.38  |
| p=0.1 | 1.69  | 0.93  | 0.66  | 1.23  | 0.71  | 0.43  |
| M=14 (14OS slot) | p=0 | 2.18  | 1.16  | 0.73  | 1.79  | 0.96  | 0.55  |
| p=0.1 | 2.48  | 1.31  | 0.83  | 1.99  | 1.06  | 0.63  |
| **Resource mapping Type B** | M=2 (2OS non-slot) | p=0 | 1.00  | 0.57  | 0.44  | 0.50  | 0.31  | 0.23  |
| p=0.1 | 1.18  | 0.68  | 0.52  | 0.59  | 0.37  | 0.28  |
| M=4 (4OS non-slot) | p=0 | 1.14  | 0.64  | 0.47  | 0.67  | 0.40  | 0.28  |
| p=0.1 | 1.33  | 0.75  | 0.56  | 0.77  | 0.46  | 0.32  |
| M=7 (7OS non-slot) | p=0 | 1.32  | 0.73  | 0.52  | 0.93  | 0.53  | 0.34  |
| p=0.1 | 1.51  | 0.84  | 0.61  | 1.05  | 0.60  | 0.39  |

Table 12.1.2 UL user plane latency for FDD

|  |  |  |
| --- | --- | --- |
| UL user plane latency – NR FDD | UE capability 1 | UE capability 2 |
| SCS | SCS |
| 15 kHz | 30 kHz | 60 kHz | 15 kHz | 30 kHz | 60 kHz |
| **Resource mapping Type A** | M=4 (4OS non-slot) | p=0 | 1.57  | 0.86  | 0.58  | 1.18  | 0.65  | 0.40  |
| p=0.1 | 1.77  | 1.01  | 0.68  | 1.38  | 0.75  | 0.45  |
| M=7 (7OS non-slot) | p=0 | 1.68  | 0.91  | 0.61  | 1.29  | 0.71  | 0.43  |
| p=0.1 | 1.88  | 1.06  | 0.71  | 1.49  | 0.81  | 0.48  |
| M=14 (14OS slot) | p=0 | 2.18  | 1.16  | 0.73  | 1.79  | 0.96  | 0.55  |
| p=0.1 | 2.48  | 1.31  | 0.83  | 1.99  | 1.11  | 0.63  |
| **Resource mapping Type B** | M=2 (2OS non-slot) | p=0 | 1.04  | 0.59  | 0.45  | 0.54  | 0.33  | 0.24  |
| p=0.1 | 1.21  | 0.69  | 0.53  | 0.62  | 0.38  | 0.28  |
| M=4 (4OS non-slot) | p=0 | 1.32  | 0.73  | 0.52  | 0.86  | 0.49  | 0.32  |
| p=0.1 | 1.51  | 0.84  | 0.60  | 0.96  | 0.55  | 0.37  |
| M=7 (7OS non-slot) | p=0 | 1.43  | 0.79  | 0.54  | 1.04  | 0.58  | 0.37  |
| p=0.1 | 1.62  | 0.90  | 0.63  | 1.17  | 0.65  | 0.42  |

## Evaluation of NR TDD

For NR TDD, the user plane latency is calculated.

Table 12.2.1 DL User plane latency results for NR TDD (DDDSU)

Table 12.2.1 DL user plane latency for TDD (DDDSU)

|  |  |  |
| --- | --- | --- |
| DL user plane latency – NR TDD (DDDSU) | UE capability 1 | UE capability 2 |
| SCS | SCS |
| 15 kHz | 30 kHz | 60 kHz | 15 kHz | 30 kHz | 60 kHz |
| **Resource mapping Type A** | M=4 (4OS non-slot) | p=0 | 1.47  | 0.81  | 0.56  | 1.08  | 0.60  | 0.38  |
| p=0.1 | 1.85  | 1.00  | 0.68  | 1.46  | 0.79  | 0.47  |
| M=7 (7OS non-slot) | p=0 | 1.69  | 0.92  | 0.61  | 1.30  | 0.71  | 0.43  |
| p=0.1 | 2.07  | 1.11  | 0.73  | 1.67  | 0.90  | 0.53  |
| M=14 (14OS slot) | p=0 | 2.38  | 1.26  | 0.78  | 1.99  | 1.06  | 0.60  |
| p=0.1 | 2.78  | 1.46  | 0.93  | 2.37  | 1.25  | 0.70  |
| **Resource mapping Type B** | M=2 (2OS non-slot) | p=0 | 1.16  | 0.65  | 0.48  | 0.66  | 0.39  | 0.27  |
| p=0.1 | 1.52  | 0.83  | 0.59  | 1.02  | 0.57  | 0.36  |
| M=4 (4OS non-slot) | p=0 | 1.28  | 0.71  | 0.51  | 0.82  | 0.47  | 0.31  |
| p=0.1 | 1.64  | 0.90  | 0.63  | 1.17  | 0.65  | 0.40  |
| M=7 (7OS non-slot) | p=0 | 1.49  | 0.82  | 0.56  | 1.10  | 0.61  | 0.38  |
| p=0.1 | 1.86  | 1.01  | 0.69  | 1.47  | 0.80  | 0.47  |

Table 12.2.2 UL user plane latency for TDD (DDDSU)

|  |  |  |
| --- | --- | --- |
| UL user plane latency – NR TDD (DDDSU) | UE capability 1 | UE capability 2 |
| SCS | SCS |
| 15 kHz | 30 kHz | 60 kHz | 15 kHz | 30 kHz | 60 kHz |
| **Resource mapping Type A** | M=4 (4OS non-slot) | p=0 | 3.46  | 1.80  | 1.05  | 3.07  | 1.60  | 0.87  |
| p=0.1 | 3.96  | 2.05  | 1.18  | 3.57  | 1.85  | 1.00  |
| M=7 (7OS non-slot) | p=0 | 3.68  | 1.91  | 1.11  | 3.29  | 1.71  | 0.93  |
| p=0.1 | 4.18  | 2.16  | 1.23  | 3.79  | 1.96  | 1.05  |
| M=14 (14OS slot) | p=0 | 4.18  | 2.16  | 1.23  | 3.79  | 1.96  | 1.05  |
| p=0.1 | 4.68  | 2.41  | 1.36  | 4.29  | 2.21  | 1.18  |
| **Resource mapping Type B** | M=2 (2OS non-slot) | p=0 | 2.58  | 1.36  | 0.83  | 2.08  | 1.10  | 0.63  |
| p=0.1 | 3.07  | 1.60  | 0.95  | 2.57  | 1.35  | 0.75  |
| M=4 (4OS non-slot) | p=0 | 3.12  | 1.63  | 0.97  | 2.66  | 1.39  | 0.77  |
| p=0.1 | 3.62  | 1.88  | 1.09  | 3.15  | 1.64  | 0.90  |
| M=7 (7OS non-slot) | p=0 | 3.23  | 1.69  | 0.99  | 2.84  | 1.48  | 0.82  |
| p=0.1 | 3.72  | 1.93  | 1.12  | 3.33  | 1.73  | 0.94  |

# Control Plane Latency

According to Report ITU-R M.2410, control plane latency refers to the transition time from a most “battery efficient” state (e.g. Idle state) to the start of continuous data transfer (e.g. Active state).

This requirement is defined for the purpose of evaluation in the eMBB and URLLC usage scenarios. The minimum requirement for control plane latency is 20 ms.

Different from LTE Rel-14, it was agreed in NR that a new state, i.e. “inactive state”, should be supported. This state is a most battery efficient state, where the UE does not need to monitor the physical channels all the time.

In addition, NR defines the connection resume signals which allow to fetch RRC context from gNB without information exchanging between gNB and NG-CN. Therefore, the signaling between gNB and NG-CN can be skipped. Based on this understanding, it is appropriate to evaluate NR control plane latency from inactive state to connected state.

The control plane latency analysis for NR is shown in Table 13.1. It is noted that, the delay values shown below does not include the waiting time for DL/UL subframe. It is only gNB or UE processing delay. The waiting time will be calculated and it depends on the detailed DL/UL configuration.

Table 13.1 Control plane latency analysis

|  |  |  |
| --- | --- | --- |
| Component | Description | Time (# of non-slot of *M* OFDM symbols) |
| 1 | Delay due to RACH scheduling period | 0 |
| 2 | Transmission of RACH Preamble | Length of the preamble according to the PRACH format as specified in [6 38.211] For format A0: Length of 2 OFDM symbols For format 0: 1 *ms*  |
| 3 | Preamble detection and processing in gNB | Tproc,2 (assuming d2,1= d2,2= d2,3=0)  |
| 4 | Transmission of RA response | Ts (the length of 1 slot / non-slot) |
| 5 | UE Processing Delay (decoding of scheduling grant, timing alignment and C-RNTI assignment + L1 encoding of RRC Connection Resume Request) | *NT,1+NT,2+0.5 ms* |
| 6 | Transmission of RRC Connection Resume Request | Ts (the length of 1 slot / non-slot) |
| 7 |  Processing delay in gNB (L2 and RRC)  | *3 ms* |
| 8 | Transmission of RRC Connection Resume | Ts (the length of 1 slot / non-slot) |
| 9 | Processing delay in UE of RRC Connection Resume including grant reception | *7 ms* |
| 10 | Transmission of RRC Connection Resume Complete and UP data | 0 |

## Control plane latency of FDD

The control plane latency results are given below. Note that different PRACH format, UE capability and resource mapping types are taken into account. It is worth mentioning that since PRACH format A1 lasts a short duration in the time domain, which is more suitable for a latency critical scenario, thus the non-slot duration is assumed under this PRACH format configuration. Also noted that 2OS non-slot and 14OS slot are not supported for resource mapping type A and B, respectively.

Table 13.1.1 Control plane latency results for FDD with PRACH format ‘A1’

|  |  |  |  |
| --- | --- | --- | --- |
| **Resource mapping type** | **Non-slot duration** | **UE capability1** | **UE capability2** |
| **15kHz SCS** | **30kHz SCS** | **15kHz SCS** | **30kHz SCS** |
| Type A | *M* =4(4OS non-slot) | 15.4 | 12.8 | 14.9 | 12.5 |
| *M* =7(7OS non-slot) | 15.6 | 13.4 | 15.1 | 13.2 |
| Type B | *M*=2(2OS non-slot) | 13.1 | 12 | 12.8 | 11.8 |
| *M* =4(4OS non-slot) | 13.6 | 12.3 | 13.2 | 12.1 |
| *M* =7(7OS non-slot) | 14.5 | 12.7 | 14.1 | 12.6 |

Table 13.1.2 Control plane latency results for NR FDD with PRACH format ‘0’

Table 13.1.2 Control plane latency results for FDD with PRACH format ‘0’

|  |  |  |  |
| --- | --- | --- | --- |
| **Resource mapping type** | **Slot / non-slot duration** | **UE capability1** | **UE capability2** |
| **15kHz SCS** | **30kHz SCS** | **15kHz SCS** | **30kHz SCS** |
| Type A | *M* =4(4OS non-slot) | 16.3  | 13.6 | 16.3  | 13.6 |
| *M* =7(7OS non-slot) | 16.5 | 14.3 | 16.5 | 14.3 |
| Type B | *M*=2(2OS non-slot) | 14 | 12.9 | 13.6 | 12.7 |
| *M* =4(4OS non-slot) | 14.6 | 13.3 | 14 | 12.9 |
| *M* =7(7OS non-slot) | 15.5 | 13.8 | 15 | 13.3 |

## Control plane latency of TDD

The control plane latency results are given below. Note that the downlink dominated frame structure DDDSU is used for evaluation. The frame structure DDDSU is employed herein due to the consideration that the IMT-2020 network needs to adapt to the asymmetric traffic pattern that are observed in many deployment scenarios.

Table 13.2.1 Control plane latency results for TDD (DDDSU) with PRACH format ‘A1’

|  |  |  |  |
| --- | --- | --- | --- |
| **Resource mapping type** | **Non-slot duration** | **UE capability1** | **UE capability2** |
| **15kHz SCS** | **30kHz SCS** | **15kHz SCS** | **30kHz SCS** |
| Type A | *M* =4(4OS non-slot) | 17.9 | 14.0 | 17.9 | 14.0 |
| *M* =7(7OS non-slot) | 18.1 | 14.4 | 18.1 | 14.2 |
| Type B | *M*=2(2OS non-slot) | 16.8 | 13.4 | 16.8 | 13.4 |
| *M* =4(4OS non-slot) | 17.2 | 13.6 | 17.2 | 13.6 |
| *M* =7(7OS non-slot) | 17.6 | 13.8 | 17.6 | 13.8 |

Table 13.2.2 Control plane latency results for TDD (DDDSU) with PRACH format ‘0’

|  |  |  |  |
| --- | --- | --- | --- |
| **Resource mapping type** | **Slot / non-slot duration** | **UE capability1** | **UE capability2** |
| **15kHz SCS** | **30kHz SCS** | **15kHz SCS** | **30kHz SCS** |
| Type A | *M* =4(4OS non-slot) | 18.3 | 16.6 | 18.3 | 16.6 |
| *M* =7(7OS non-slot) | 18.5 | 16.8 | 18.5 | 16.8 |
| Type B | *M*=2(2OS non-slot) | 17.1 | 13.9 | 17.1 | 13.7 |
| *M* =4(4OS non-slot) | 17.6 | 16.3 | 17.6 | 14.0 |
| *M* =7(7OS non-slot) | 18.0 | 16.5 | 18.0 | 14.3 |

# 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.

According to Section 5.3.2 of TS.38.104, the maximum bandwidth related to specific sub-carrier spacing (SCS) and frequency range (FR) for a component carrier is provided in Table 14.1. Besides, according to Section 6.4 of TS.38.331, carrier aggregation of up to sixteen component carriers is supported. Accordingly, the capability of maximum aggregated system bandwidth is presented in Table 14.1. It is observed that the maximum aggregated bandwidth for FR 1 is 800 MHz to 1600 MHz; while for FR 2, the maximum aggregated bandwidth is 3200 MHz to 6400 MHz. Therefore, the bandwidth requirement of at least 100 MHz is met by the RIT under all frequency ranges for all sub-carrier spacing values.

 **Table 14.1 RIT capability on bandwidth**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **SCS [kHz]**  | **Maximum bandwidth for one component carrier (MHz)** | **Maximum number of component carriers for carrier aggregation** | **Maximum aggregated bandwidth (MHz)** |
| FR1 | 15 | 50 |  16 | 800 |
| 30 | 100 | 16 | 1600 |
| 60 | 100 | 16 | 1600 |
| FR2  | 60 | 200 | 16 | 3200 |
| 120 | 400 | 16 | 6400 |

According to Section 5.3.2 of TS38.104, different bandwidths are supported for a component carrier at given SCS as listed in Table 14.2. Accordingly, the bandwidth scalability capability of the RIT is summarized in Table 14.3. It is observed that up to 13 different bandwidths are supported for FR 1, and up to 4 different bandwidths are supported for FR 2. Therefore bandwidth scalability capability is fulfilled by the RIT.

**Table 14.2 Transmission bandwidth configuration NRB**(a) For FR1

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **SCS (kHz)** | **5MHz** | **10MHz** | **15MHz** | **20 MHz** | **25 MHz** | **30 MHz** | **40 MHz** | **50MHz** | **60 MHz** | **70****MHz** | **80 MHz** | **90 MHz** | **100 MHz** |
| **NRB** | **NRB** | **NRB** | **NRB** | **NRB** | **NRB** | **NRB** | **NRB** | **NRB** | **NRB** | **NRB** | **NRB** | **NRB** |
| 15 | 25 | 52 | 79 | 106 | 133 | 160 | 216 | 270 | N/A | N.A | N/A | N/A | N/A |
| 30 | 11 | 24 | 38 | 51 | 65 | 78 | 106 | 133 | 162 | 189 | 217 | 245 | 273 |
| 60 | N/A | 11 | 18 | 24 | 31 | 38 | 51 | 65 | 79 | 93 | 107 | 121 | 135 |

 (b) For FR2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SCS [kHz]** | **50 MHz** | **100 MHz** | **200 MHz** | **400 MHz** |
| **NRB** | **NRB** | **NRB** | **NRB** |
| 60 | 66 | 132 | 264 | N.A |
| 120 | 32 | 66 | 132 | 264 |
|  |  |  |  |  |

**Table 14.2 Bandwidth scalability capability**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **SCS [kHz]**  | **Minimum component carrier bandwidth (MHz)** | **Maximum component carrier bandwidth (MHz)** | **Maximum Number of supported bandwidth for a component carrier** |
| FR1 | 15 | 5 | 50 | 8 |
| 30 | 5 | 100 | 13 |
| 60 | 10 | 100 | 12 |
| FR2 | 60 | 50 | 200 | 3 |
| 120 | 50 | 400 | 4 |
|  |  |  |  |  |

# Energy Efficiency

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.

Low energy consumption when there is no data can be estimated by the sleep ratio. 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 signalling (for the network) or the cycle of discontinuous reception (for the device) when no user data transfer takes place. Furthermore, the sleep duration, i.e. the continuous period of time with no transmission (for network and device) and reception (for the device), should be sufficiently long.

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

## Network Energy Efficiency

From the definition and evaluation methodology of energy efficiency, we can see that sleep ratio and sleep duration are two important metrics to measure the performance of energy efficiency in unloaded case. When no data transmission occurs, the network still needs to keep the capability for UE to detect, access and get served. Therefore, the dominant power consumption in this stage is for the initial access signals and related reference signals. In NR, SS/PBCH-block based initial access is used, where BS needs to transmit SS/PBCH blocks and RMSI periodically.

### SS/PBCH block transmission scheme

In both single beam and multi-beam scenarios, time division multiplexing of NR-PSS, NR-SSS, and NR-PBCH is supported. These initial access signals can be transmitted within an SS/PBCH block. One or multiple SS/PBCH block(s) compose an “SS burst set” (SSB set).

The configuration of “SSB set” transmission is as follows.

* One SS/PBCH block occupies 4 OFDM symbols with 20 RBs in one slot.
* SSB set is confined to a 5 ms window
* UE assumed a default SSB set periodicity (*P*SSB): 20 ms, network can configure {5, 10, 20, 40, 80, 160} ms
* The following mapping to slots in a half radio frame is used for 15, 30, 120 and 240kHz SCS
	+ *L* is the number of SS/PBCH blocks in an SSB set, where *L* can be 1~ 64. For below 3 GHz, the maximum value of *L* is 4; for below 6 GHz, the maximum value of *L* is 8.
	+ One slot can transmit up to 2 SS/PBCH blocks. And the *L* SS/PBCH blocks in an SSB set can be transmitted in successive slots from the first slot in one SSB set period.

In energy efficiency evaluation, the above transmission scheme of SS/PBCH block can be employed.

### RMSI transmission scheme

RMSI transmission scheme can be assumed based on SS/PBCH block transmission. The following configuration can be used

* One RMSI transmission occupies 2 OFDM symbols in one slot.
* Multiplexing with SS/PBCH block:
	+ For FR1 (below 6 GHz), RMSI is time division multiplexed (TDMed) with SS/PBCH block.
	+ For FR2 (above 24 GHz), RMSI can be frequency division multiplexed (FDMed) with SS/PBCH block.
	+ SS/PBCH block and RMSI could be transmitted in the same slot for both TDM and FDM.
* RMSI periodicity (*P*RMSI):
	+ 20ms for SSB set periodicity less than or equal to 20ms;
	+ Otherwise RMSI periodicity equals to SSB set periodicity.
* The following mapping to slots is used
	+ One RMSI transmission corresponds to one SS/PBCH block
		- If *L* SS/PBCH block is transmitted, then *L* RMSI transmissions are required.
	+ One slot can accommodate up to 2 RMSI transmissions.
	+ The offset of RMSI transmission can be set as {0, 2, 5, 7}ms with respect to every 20ms time point. The offset value that allows the closest RMSI transmission to SS/PBCH block transmission is selected.

Note that the UE in RRC\_idle state needs to monitor the paging occasion which is time interval over which a paging messaging is transmitted by the gNB. According to RAN2 agreement, the length of one paging occasion in case of beam sweeping is one period of beam sweeping, and it can be TDMed or FDMed with an SS block. Therefore in the following, we assume that the periodicity of paging occasion is the same as that of SSB set, and it is FDMed with an SS block, thus the paging occasion is expected to have ignorable impact on the overall energy efficiency performance.

The above SS/PBCH block and RMSI transmission scheme is illustrated in Figure 15.1.2.1 as one example. In this example, the number of SS/PBCH block in one “SSB set” is *L*=4. The first two slots are used for SS/PBCH block transmission, and 4 accompanying RMSI transmission occurs in the two slots right after the SS/PBCH block transmission by setting appropriate offset.

Half frame

(

5

ms

)

SS block

SS block

SS block

SS block

“SSB set”

“SSB set”

periodicity

Half frame

(

5

ms

)

RMSI

RMSI

RMSI

RMSI

Figure 15.1.2.1 Illustration of SS/PBCH block and RMSI transmission

### Evaluation of sleep ratio

Based on the above mechanisms, the sleep ratio (per slot basis) can be calculated as follows,



where  is the numerology (as defined in TS38.211, e.g., **=0 for 15 kHz SCS, **=1 for 30 kHz SCS, **=3 for 120 kHz SCS, and **=4 for 240 kHz SCS), *L* is the number of SS/PBCH blocks in one SSB set, *P*SSB is the SSB set periodicity, *P*RMSI is the RSMI periodicity.

For the number of SS/PBCH blocks in one SSB set, *L*, it is considered to have *L*= 1 for FR1 (below 6 GHz), and *L*=16 for FR2 (above 24 GHz). The 16 SS/PBCH blocks correspond to 16 beam directions for FR2 considering the need of 3D coverage (both vertical and horizontal).

**Table 15.1.3.1 Sleep ratio (%) performance of NR with different SSB set periodicity**

|  |  |
| --- | --- |
| **SSB configuration** | **SSB set periodicity** *P*SSB |
| **SCS [kHz]** | **Number of SS/PBCH block per SSB set,** *L* | 5ms | 10ms | 20ms | 40ms | 80ms | 160ms |
| 15kHz  | 1 | 90.00% | 95.00% | 97.50% | 98.75% | 99.38% | 99.69% |
| 2 | 80.00% | 90.00% | 95.00% | 97.50% | 98.75% | 99.38% |
| 30kHz  | 1 | 95.00% | 97.50% | 98.75% | 99.38% | 99.69% | 99.84% |
| 4 | 80.00% | 90.00% | 95.00% | 97.50% | 98.75% | 99.38% |
| 120kHz  | 8 | 90.00% | 95.00% | 97.50% | 98.75% | 99.38% | 99.69% |
| 16 | 80.00% | 90.00% | 95.00% | 97.50% | 98.75% | 99.38% |
| 32 | 60.00% | 80.00% | 90.00% | 95.00% | 97.50% | 98.75% |
| 240kHz  | 16 | 90.00% | 95.00% | 97.50% | 98.75% | 99.38% | 99.69% |
| 32 | 80.00% | 90.00% | 95.00% | 97.50% | 98.75% | 99.38% |
| 64 | 60.00% | 80.00% | 90.00% | 95.00% | 97.50% | 98.75% |

The results in Table 15.1.3.1 demonstrate the sleep ratio of NR is highly dependent on the different SS/PBCH block and SSB set periodicity configuration, with different sub-carrier spacing (SCS) values. To be specific, we can see that longer SSB set periodicity could lead to larger sleep ratio due to self-contained initial access signal design principle. Note that for larger SSB set periodicity, e.g., 80ms or 160ms, the sleep ratio could be higher than 97%. For high frequency range, multi-beam based initial access is necessary due to the use of narrow beam to compensate the coverage, thus beam sweeping is introduced. In this case, multiple SS/PBCH blocks need to be configured, thus the sleep ratio would decrease to some extent. For example, for 120 kHz SCS and 32 SS/PBCH blocks per “SSB set”, the sleep ratio is about 80% if the SSB set periodicity is 10ms.

### Evaluation of sleep duration

The sleep duration can also be evaluated based on the proposed SS/PBCH block and RMSI transmission scheme. The appropriate offset is selected for RMSI transmission corresponding to one SS/PBCH block to maximize the longest sleep duration of the gNB.

**Table 15.1.4.1Sleep duration (ms) performance of NR with different SSB set periodicity**

|  |  |
| --- | --- |
| **SSB configuration** | **SSB set periodicity** *P*SSB |
| **SCS [kHz]** | **Number of SS/PBCH block per SSB set,** *L* | 5ms | 10ms | 20ms | 40ms | 80ms | 160ms |
| 15kHz  | 1 | 4.00  | 9.00  | 19.00  | 39.00  | 79.00  | 159.00  |
| 2 | 4.00  | 9.00  | 19.00  | 39.00  | 79.00  | 159.00  |
| 4 | 3.00  | 8.00  | 18.00  | 38.00  | 78.00  | 158.00  |
| 30kHz  | 1 | 4.50  | 9.50  | 19.50  | 39.50  | 79.50  | 159.50  |
| 4 | 4.00  | 9.00  | 19.00  | 39.00  | 79.00  | 159.00  |
| 8 | 3.00  | 8.00  | 18.00  | 38.00  | 78.00  | 158.00  |
| 120kHz  | 8 | 4.50  | 9.72  | 18.92  | 39.03  | 78.97  | 158.99  |
| 16 | 4.00  | 9.88  | 18.77  | 39.05  | 78.96  | 158.99  |
| 32 | 3.00  | 9.95  | 18.34  | 39.08  | 78.93  | 158.99  |
| 240kHz  | 16 | 4.50  | 9.86  | 18.90  | 39.04  | 78.97  | 158.99  |
| 32 | 4.00  | 9.94  | 18.76  | 39.06  | 78.96  | 158.99  |
| 64 | 3.00  | 9.98  | 18.34  | 39.08  | 78.93  | 158.99  |

We can see that similarly longer SS burst set periodicity could help to get longer sleep duration. It is because the initial access signals can be transmitted in adjacent symbols instead of distributed uniformly in the time domain. In this way, as long as the initial access signals are transmitted, the RF chains and connected PA components can be turned off to save energy. Combining the high sleep ratio and long sleep duration together, significantly energy saving is expected when the system is working in unloaded case.

## Device Energy Efficiency

From UE’s perspective, energy efficiency capability can be reflected by its capability of discontinuous reception (DRX) especially when there is no user data transferred. Here two cases need to be considered, one is the DRX in idle mode, e.g., paging, and the other is DRX in connected mode. In NR, DRX is supported for UEs in idle, inactive and connected states. Similarly, we present the capability of NR in terms of DRX and provide the evaluation results as follows.

### DRX for UE in idle/inactive mode

The UE monitors one paging occasion (PO) per DRX cycle. A PO is a set of PDCCH monitoring occasions and can consist of multiple time slots (e.g. subframe or OFDM symbol) where paging DCI can be sent. One Paging Frame (PF) is one Radio Frame and may contain one or multiple PO(s) or starting point of a PO.

PF, PO are determined by the following formulae:

SFN for the PF is determined by:

(SFN + PF\_offset) mod T = (T div N)\*(UE\_ID mod N)

Index (i\_s), indicating the start of a set of PDCCH monitoring occasions for the paging DCI, is determined by:

i\_s = floor (UE\_ID/N) mod Ns; where, Ns = max (1, nB/T)

The following parameters defined are used for the calculation of PF and i\_s above:

T: DRX cycle of the UE (T is determined by the shortest of the UE specific DRX value, if configured by RRC or upper layers, and a default DRX value broadcast in system information. If UE specific DRX is not configured by upper layers, the default value is applied)

nB: number of total paging occasions in T

N: min(T,nB)

PF\_offset: offset used for PF determination

UE\_ID: IMSI mod 1024

**Table 15.2.1.1 The definitions and values of paging related key parameters for NR**

|  |  |  |
| --- | --- | --- |
| Parameters | Definitions | Values |
| *defaultPagingCycle* | Default paging cycle, used to derive ‘T’ in TS 38.304. | rf32, rf64, rf128, rf256. Value rf32 corresponds to 32 radio frames, rf64 corresponds to 64 radio frames and so on. |
| *n* | Number of total paging frames in T. | halfT, quarterT, oneEighthT,oneSixteenthT. |
| *ns* | Number of paging occasions in paging frame. | four, two, one. |
| *pf-Offset* | Paging frame offset, corresponding to parameter PF\_offset in TS 38.304. | 0..255. |

### DRX for UE in connected mode

Similar DRX mechanism as LTE is adopted in NR, and the key parameters that impact the energy efficiency performance at UE side are drx-onDurationTimer, drx-ShortCycle and drx-ShortCycleTimer. The definitions and values of these parameters are listed as below.

**Table 15.2.2.1 The definitions and values of DRX related key parameters for NR**

|  |  |  |
| --- | --- | --- |
| Parameters | Definitions | Values |
| *drx-onDurationTimer* | Timer for DRX. Value in ms. | ms1-32, ms2-32, ms3-32, ms4-32, ms5-32, ms6-32, ms7-32, ms8-32, ms9-32, ms10-32, ms11-32, ms12-32, ms13-32, ms14-32, ms15-32, ms16-32, ms17-32, ms18-32, ms19-32, ms-20-32, ms21-32, ms22-32, ms23-32, ms24-32, ms25-32, ms26-32, ms27-32, ms28-32, ms29-32, ms30-32, ms31-32, ms1, ms2, ms3, ms4, ms5, ms6, ms8, ms10, ms20, ms30, ms40, ms50, ms60, ms80, ms100, ms200, ms300, ms400, ms500, ms600, ms800, ms1000, ms1200, ms1600. ms1-32 corresponds to 1/32ms, ms2-32 corresponds to 2/32ms, and so on. ms1 corresponds to 1ms, ms2 corresponds to 2ms, and so on. |
| *drx-ShortCycle* | *Short DRX cycle length*. Value in ms. | ms2, ms3, ms4, ms5, ms6, ms7, ms8, ms10, ms14, ms16, ms20, ms30, ms32, ms35, ms40, ms64, ms80, ms128, ms160, ms256, ms320, ms512, ms640. ms1 corresponds to 1ms, ms2 corresponds to 2ms, and so on. |
| *drx-ShortCycleTimer* | *Short Cycle timer, value in multiples of drx-ShortCycle.* | INTEGER (1..16). A value of 1 corresponds to drx-ShortCycle, a value of 2 corresponds to 2 \* drx-ShortCycle and so on. |

### Evaluation of sleep ratio

For UE in idle mode, the sleep ratio is dependent on the paging cycle as  where  is the paging cycle in unit of radio frames. Similar to the analysis of sleep ratio above, the sleep ratio of NR UE in connected mode can be expressed as



Where  is the short cycle length in ms,  is the short cycle timer and  is the on duration time in ms.

According to the specification, the sleep ratio of NR UE in connected mode is shown in Table 15.2.3.1, from which we can see that with short duration length and long cycle length, very high sleep ratio for UE in connected mode can be achieved.

**Table 15.2.3.1 The sleep ratio of NR UE in connected mode with different DRX parameters**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| onDurationTimer (ms) | 1/32 | 1/32 | 1/32 | 800 | 1600 |
| drx-ShortCycle (ms) | 2 | 320 | 640 | 640 | 640 |
| drx-ShortCycleTimer | 16 | 16 | 16 | 16 | 16 |
| FDD (=1) | 99.90% | ~100.00% | ~100.00% | 92.19% | 84.38% |
| TDD (=0.8) | 99.88% | ~100.00% | ~100.00% | 90.23% | 80.47% |
| TDD (=0.5) | 99.80% | ~100.00% | ~100.00% | 84.38% | 68.75% |

### Evaluation of sleep duration

Based on the discussion of sleep ratio, we can get the sleep duration for UE in idle mode as  in sub-frames, which is about 2.56s. Similarly, the sleep duration of NR UE in connected mode can be expressed as  in ms. According to the specification, the longest sleep duration of NR UE in connected mode can be as long as 640ms\*16 = 10.24s.

# Spectrum

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

* 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 bands in which the RIT can be deployed are given in Table 16.1, Table 16.2 and Table 16.3. It is observed that the RIT supports at least one frequency band for IMT, as well as to utilize the higher frequency range/bands above 24.25 GHz. Therefore the RIT fulfils the spectrum requirement.

**Table 16.1: Operating bands in FR1**

|  |  |  |  |
| --- | --- | --- | --- |
| ***Operating band*** | **Uplink (UL) *operating band*BS receive / UE transmit****FUL\_low   – FUL\_high** | **Downlink (DL) *operating band*BS transmit / UE receive** **FDL\_low   – FDL\_high** | **Duplex Mode** |
| n1 | 1920 MHz – 1980 MHz | 2110 MHz – 2170 MHz | FDD |
| n2 | 1850 MHz – 1910 MHz | 1930 MHz – 1990 MHz | FDD |
| n3 | 1710 MHz – 1785 MHz | 1805 MHz – 1880 MHz | FDD |
| n5 | 824 MHz – 849 MHz | 869 MHz – 894 MHz | FDD |
| n7 | 2500 MHz – 2570 MHz | 2620 MHz – 2690 MHz | FDD |
| n8 | 880 MHz – 915 MHz | 925 MHz – 960 MHz | FDD |
| n12 | 699 MHz – 716 MHz | 729 MHz – 746 MHz | FDD |
| n20 | 832 MHz – 862 MHz | 791 MHz – 821 MHz | FDD |
| n25 | 1850 MHz – 1915 MHz | 1930 MHz – 1995 MHz | FDD |
| n28 | 703 MHz – 748 MHz | 758 MHz – 803 MHz | FDD |
| n34 | 2010 MHz – 2025 MHz | 2010 MHz – 2025 MHz | TDD |
| n38 | 2570 MHz – 2620 MHz | 2570 MHz – 2620 MHz | TDD |
| n39 | 1880 MHz – 1920 MHz | 1880 MHz – 1920 MHz | TDD |
| n40 | 2300 MHz – 2400 MHz | 2300 MHz – 2400 MHz | TDD |
| n41 | 2496 MHz – 2690 MHz | 2496 MHz – 2690 MHz | TDD |
| n51 | 1427 MHz – 1432 MHz | 1427 MHz – 1432 MHz | TDD |
| n66 | 1710 MHz – 1780 MHz | 2110 MHz – 2200 MHz | FDD |
| n70 | 1695 MHz – 1710 MHz | 1995 MHz – 2020 MHz | FDD |
| n71 | 663 MHz – 698 MHz | 617 MHz – 652 MHz | FDD |
| n75 | N/A | 1432 MHz – 1517 MHz | SDL |
| n76 | N/A | 1427 MHz – 1432 MHz | SDL |
| n77 | 3300 MHz – 4200 MHz | 3300 MHz – 4200 MHz | TDD |
| n78 | 3300 MHz – 3800 MHz | 3300 MHz – 3800 MHz | TDD |
| n79 | 4400 MHz – 5000 MHz | 4400 MHz – 5000 MHz | TDD |
| n80 | 1710 MHz – 1785 MHz | N/A | SUL  |
| n81 | 880 MHz – 915 MHz | N/A | SUL  |
| n82 | 832 MHz – 862 MHz | N/A | SUL  |
| n83 | 703 MHz – 748 MHz | N/A | SUL |
| n84 | 1920 MHz – 1980 MHz | N/A | SUL |
| n86 | 1710 MHz – 1780 MHz | N/A | SUL |

**Table 16.2: Operating bands in FR2**

|  |  |  |
| --- | --- | --- |
| ***operating band*** | **Uplink (UL) and Downlink (DL) *operating band*BS transmit/receiveUE transmit/receive****FUL\_low   – FUL\_high****FDL\_low   – FDL\_high** | **Duplex Mode** |
| n257 | 26500 MHz – 29500 MHz | TDD |
| n258 | 24250 MHz – 27500 MHz | TDD |
| n260 | 37000 MHz – 40000 MHz | TDD |
| n261 | 27500 MHz – 28350 MHz | TDD |

**Table 16.3 : mMTC Operating Bands**

|  |  |  |  |
| --- | --- | --- | --- |
| **Operating Band** | **Uplink (UL) operating bandBS receiveUE transmit** | **Downlink (DL) operating bandBS transmit UE receive** | **Duplex Mode** |
| **FUL\_low   – FUL\_high** | **FDL\_low  – FDL\_high** |
| 1 | 1920 MHz | – | 1980 MHz  | 2110 MHz | – | 2170 MHz | HD-FDD |
| 2 | 1850 MHz | – | 1910 MHz | 1930 MHz | – | 1990 MHz | HD-FDD |
| 3 | 1710 MHz | – | 1785 MHz | 1805 MHz | – | 1880 MHz | HD-FDD |
| 4 | 1710 MHz | – | 1755 MHz  | 2110 MHz | – | 2155 MHz | HD-FDD |
| 5 | 824 MHz | – | 849 MHz | 869 MHz | – | 894MHz | HD-FDD |
| 8 | 880 MHz | – | 915 MHz | 925 MHz | – | 960 MHz | HD-FDD |
| 11 | 1427.9 MHz | – | 1447.9 MHz  | 1475.9 MHz | – | 1495.9 MHz  | HD-FDD |
| 12 | 699 MHz | – | 716 MHz | 729 MHz | – | 746 MHz | HD-FDD |
| 13 | 777 MHz | – | 787 MHz | 746 MHz | – | 756 MHz | HD-FDD |
| 17 | 704 MHz | – | 716 MHz | 734 MHz | – | 746 MHz | HD-FDD |
| 18 | 815 MHz | – | 830 MHz | 860 MHz | – | 875 MHz | HD-FDD |
| 19 | 830 MHz | – | 845 MHz | 875 MHz | – | 890 MHz | HD-FDD |
| 20 | 832 MHz | – | 862 MHz | 791 MHz – 821 MHz | HD-FDD |
| 21 | 1447.9 MHz | – | 1462.9 MHz | 1495.9 MHz | – | 1510.9 MHz | HD-FDD |
| 25 | 1850 MHz | – | 1915 MHz | 1930 MHz | – | 1995 MHz | HD-FDD |
| 26 | 814 MHz | – | 849 MHz | 859 MHz | – | 894 MHz | HD-FDD |
| 28 | 703 MHz | – | 748 MHz | 758 MHz | – | 803 MHz | HD-FDD |
| 31 | 452.5 MHz | – | 457.5 MHz | 462.5 MHz | – | 467.5 MHz | HD-FDD |
| 41 | 2496 MHz |  | 2690 MHz | 2496 MHz |  | 2690 MHz | TDD |
| 66 | 1710 MHz | – | 1780 MHz  | 2110 MHz | – | 2200 MHz | HD-FDD |
| 70 | 1695 MHz | – | 1710 MHz  | 1995 MHz | – | 2020 MHz | HD-FDD |
| 71 | 663 MHz | – | 698 MHz  | 617 MHz | – | 652 MHz | HD-FDD |
| 72 | 451 MHz | – | 456 MHz  | 461 MHz | – | 466 MHz | HD-FDD |
| 74 | 1427 MHz | – | 1470 MHz  | 1475 MHz | – | 1518 MHz  | HD-FDD |

# Mobility Interruption Time

The mobility interruption time is evaluated for the following scenarios:

## Beam mobility

When moving within the same cell, the transmit-receive beam pair of the UE may need to be changed.

For DL data transmission during UE mobility, gNB can configure different beams for this UE at different slots. It ensures appropriate transmit beam allocation to the UE for continuous DL transmission. Therefore DL data packet transmission is kept during beam pair switching at different slots.

For UL data transmission, PUSCH is sent using the beam configured by SRI (SRS resource indicator) by gNB. Accordingly, an appropriate gNB-side beam is selected for UL data reception. gNB may select different beams at different slots depending on the UE mobility. Therefore UL data packet transmission is kept during beam pair switching at different slots.

Based on the above analysis, the UE can always exchange user plane packets with gNB during the mobility transitions. Therefore, 0ms mobility interruption time is achieved by the RIT for this scenario.

## CA Mobility

When moving within the same PCell with CA enabled, the set of configured SCells of the UE may change. The SCell addition procedure and SCell release procedures can occur.

During these procedures, the UE can always exchange user plane packets with the gNB during transitions, because the data transmission between the UE and the PCell is kept. Therefore, 0ms mobility interruption time is achieved by the RIT for this case.

# Link Budget

We have carefully looked at the link budgets of the required test environments and found them to be in order.

# Calibration Results

Calibration of the simulators used by the members of TCOE was done. As an example, the CDF for coupling gain for rural 4 GHz scenario is shown below.

