## A-1 Results of Peak Data Rate

Three contributions from Ericsson, Intel and Samsung are considered. The results from Ericsson consider FR2 and the ones from Samsung considers both below/above 6 GHz. The results from Intel reflect the data rate with 16 carrier aggregation and also there is a distinction for FDD and TDD cases.

The results from Ericsson are summarized as follows.

DL peak data rates in Gb/s (BW in MHz, SCS in kHz) (Ericsson)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SCS\BW | 50 | 100 | 200 | 400 |
| 60 | 2.11 | 4.32 | 8.73 | NaN |
| 120 | 1.98 | 4.25 | 8.66 | 17.49 |

UL peak data rates in Gb/s (BW in MHz, SCS in kHz) (Ericsson)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SCS\BW | 50 | 100 | 200 | 400 |
| 60 | 1.16 | 2.35 | 4.74 | NaN |
| 120 | 1.08 | 2.31 | 4.71 | 9.50 |

The results from Samsung are summarized as follows.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frequency | SCS (kHz) | Maximum TBS | Peak rate (Gbps) | Spectral efficiency  (bits/s/Hz) |
| Below  6 GHz | 15 | 1,245,544 | 2.5 | 49.8 |
| 30 | 1,277,992 | 5.1 | 51.1 |
| 60 | 622,760 | 5.0 | 49.8 |
| Above  6 GHz | 60 | 1,213,032 | 9.7 | 48.5 |
| 120 | 1,213,032 | 19.4 | 48.5 |

The results from Intel are summarized as follows. The results are separately provided for FR1/FR2 and TDD/FDD.

Definition of frequency ranges

|  |  |
| --- | --- |
| Frequency range designation | Corresponding frequency range |
| FR1 | 450 MHz – 6000 MHz |
| FR2 | 24250 MHz – 52600 MHz |

FDD case

Peak Data Rate (Gbit/sec) for NR in FR1 assuming 16 CA (Intel)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SCS (kHz) | | 5MHz | 10MHz | 15MHz | 20 MHz | 25 MHz | 30 MHz | 40 MHz | 50MHz | 60 MHz | 80 MHz | 100 MHz |
| 15 | DL | 3.42 | 7.12 | 10.82 | 14.52 | 18.22 | 21.91 | 29.58 | 36.98 | - | - | - |
| UL | 1.83 | 3.81 | 5.79 | 7.77 | 9.74 | 11.72 | 15.82 | 19.78 | - | - | - |
| 30 | DL | 3.01 | 6.57 | 10.41 | 13.97 | 17.81 | 21.37 | 29.04 | 36.43 | 44.38 | 59.44 | 74.78 |
| UL | 1.61 | 3.52 | 5.57 | 7.47 | 9.52 | 11.43 | 15.53 | 19.49 | 23.74 | 31.80 | 40.00 |
| 60 | DL |  | 6.03 | 9.86 | 13.15 | 16.98 | 20.82 | 27.94 | 35.61 | 43.28 | 58.62 | 73.96 |
| UL |  | 3.22 | 5.27 | 7.03 | 9.08 | 11.14 | 14.95 | 19.05 | 23.15 | 31.36 | 39.56 |

Peak Data Rate (Gbit/sec) for NR in FR2 assuming 16 CA (Intel)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SCS (kHz) | | 50MHz | 100MHz | 200MHz | 400 MHz |
| 60 | DL | 34.48 | 68.95 | 137.91 | - |
| UL | 18.92 | 37.84 | 75.68 | - |
| 120 | DL | 33.43 | 68.95 | 137.91 | 275.82 |
| UL | 18.35 | 37.84 | 75.68 | 151.36 |

TDD case

Peak Data Rate (Gbit/sec) for NR in FR1 assuming 16 CA (Intel)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SCS (kHz) | | 5MHz | 10MHz | 15MHz | 20 MHz | 25 MHz | 30 MHz | 40 MHz | 50MHz | 60 MHz | 80 MHz | 100 MHz |
| 30 | DL | 1.46 | 3.19 | 5.06 | 6.79 | 8.65 | 10.38 | 14.10 | 17.70 | 21.55 | 28.87 | 36.32 |
| UL | 0.78 | 1.71 | 2.70 | 3.63 | 4.63 | 5.55 | 7.54 | 9.47 | 11.53 | 15.44 | 19.43 |
| 60 | DL | - | 2.93 | 4.79 | 6.39 | 8.25 | 10.11 | 13.57 | 17.30 | 21.02 | 28.47 | 35.92 |
| UL | - | 1.57 | 2.56 | 3.42 | 4.41 | 5.41 | 7.26 | 9.25 | 11.24 | 15.23 | 19.21 |

Peak Data Rate (Gbit/sec) for NR in FR2 assuming 16 CA (Intel)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SCS (kHz) | | 50MHz | 100MHz | 200MHz | 400 MHz |
| 60 | DL | 34.48 | 68.95 | 137.91 | - |
| UL | 18.92 | 37.84 | 75.68 | - |
| 120 | DL | 33.43 | 68.95 | 137.91 | 275.82 |
| UL | 18.35 | 37.84 | 75.68 | 151.36 |

## A-2 Results of Peak Spectral Efficiency

Three contributions from Ericsson, Intel and Samsung are considered. There are slight differences in the consideration of overheads. Combining these three results, peak spectral efficiencies are shown below for FR1/2 and DL/UL.

Definition of frequency ranges

|  |  |
| --- | --- |
| Frequency range designation | Corresponding frequency range |
| FR1 | 450 MHz – 6000 MHz |
| FR2 | 24250 MHz – 52600 MHz |

Peak Spectral Efficiency (bit/s/Hz) for NR in FR1 (Intel+Samsung)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SCS (kHz) | | 5MHz | 10MHz | 15MHz | 20 MHz | 25 MHz | 30 MHz | 40 MHz | 50MHz | 60 MHz | 80 MHz | 100 MHz |
| 15 | DL | 42.80 | 44.51 | 45.08 | 45.37 | 45.54 | 45.66 | 46.23 | 46.23 | - | - | - |
| UL | 22.89 | 23.81 | 24.12 | 24.27 | 24.36 | 24.42 | 24.73 | 24.73 | - | - | - |
| 30 | DL | 37.67 | 41.09 | 43.37 | 43.66 | 44.51 | 44.51 | 45.37 | 45.54 | 46.23 | 46.44 | 46.74,  51.1 |
| UL | 20.15 | 21.98 | 23.20 | 23.35 | 23.81 | 23.81 | 24.27 | 24.36 | 24.73 | 24.84 | 25.00 |
| 60 | DL |  | 37.67 | 41.09 | 41.09 | 42.46 | 43.37 | 43.66 | 44.51 | 45.08 | 45.80 | 46.23,  49.8 |
| UL |  | 20.15 | 21.98 | 21.98 | 22.71 | 23.20 | 23.35 | 23.81 | 24.12 | 24.50 | 24.73 |

Peak Spectral Efficiency (bit/s/Hz) for NR in FR2 (Ericsson+Intel+Samsung)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SCS (kHz) | | 50MHz | 100MHz | 200MHz | 400 MHz |
| 60 | DL | 42.23,  43.10 | 43.10,  43.16 | 43.10,  43.63 | 48.5 |
| UL | 23.65,  23.12 | 23.65,  23.52 | 23.65,  23.72 | - |
| 120 | DL | 39.56,  41.79 | 42.5,  43.10 | 43.10,  43.31 | 43.10,  43.72,  48.5 |
| UL | 21.61,  22.93 | 23.41,  23.65 | 23.54,  23.65 | 23.65,  23.74 |

## A-3 Results of User Experienced Data Rate

Five contributions from Ericsson, Intel, LGE, Nokia and Samsung are considered for the evaluation of User Experienced Data Rate (UEDR). As the DL/UL UEDR requirements are defined for Dense Urban Test scenario, the system-level simulation results of 5th percentile spectral efficiencies are considered with the required bandwidth. All of five contributions show that the 5G NR meets the UEDR requirements.

The results from Ericsson, shown below, indicate that the UEDR requirements are met when the DL/UL bandwidths are larger than 317 and 296 MHz, respectively.

System performance in the 5G DU scenario (Ericsson)

|  |  |  |
| --- | --- | --- |
| Bandwidth, | User experienced data rate, [Mbit/s] | |
| Downlink | Uplink |
| 100 MHz | 31.5 | 16.9 |
| 296 MHz | 92.9 | 50 |
| 317 MHz | 100 | 53.7 |
| 640 MHz | 202 | 108 |
| 1 GHz | 315 | 169 |

The results from Intel, shown below, indicate that at the carrier frequency of 4GHz, DL/UL UEDR requirements are met with 168/98 and 366/206 MHz, respectively for FDD and TDD. The corresponding numbers of resource blocks for each subcarrier spacing are also shown in the table below.

Required Bandwidth to Meet IMT-2020 Target (Intel)

|  |  |  |  |
| --- | --- | --- | --- |
| User Experienced  Data Rate | Minimum  Requirement | Bandwidth (MHz)  Required to Meet Target | |
| FDD | TDD |
| Downlink | 100 Mbit/s | 168 | 366 |
| Uplink | 50 Mbit/s | 96 | 206 |

Maximum transmission bandwidth configuration NRB in FR1 (Intel)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SCS (kHz) | 5MHz | 10MHz | 15MHz | 20 MHz | 25 MHz | 30 MHz | 40 MHz | 50MHz | 60 MHz | 80 MHz | 100 MHz |
| 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 |
| 30 | 11 | 24 | 38 | 51 | 65 | [78] | 106 | 133 | 162 | 217 | 273 |
| 60 | N/A | 11 | 18 | 24 | 31 | [38] | 51 | 65 | 79 | 107 | 135 |

The results from LGE, shown below, indicate that at the carrier frequency of 4GHz, DL/UL UEDR requirements (100/50 MHz) are met when the bandwidths are larger than 350/160 MHz, respectively.

 DL user experienced data rate for Dense Urban-eMBB (4GHz) (LGE)

|  |  |  |
| --- | --- | --- |
| Bandwidth, W (MHz) | 16Tx/4Rx (Mbit/s) | Requirement (Mbit/s) |
| 250 | 74.5 | 100 |
| 300 | 89.4 |
| 350 | 104.3 |
| 400 | 119.2 |

UL user experienced data rate for Dense Urban-eMBB (4GHz) (LGE)

|  |  |  |
| --- | --- | --- |
| Bandwidth, W (MHz) | 2Tx/32Rx (Mbit/s) | Requirement (Mbit/s) |
| 140 | 46.62 | 50 |
| 150 | 49.95 |
| 160 | 53.28 |

The results from Nokia, shown below, indicate that the UEDR requirements are met when the bandwidths are larger than or equal to 300/302/204 MHz for DL FDD/DL TDD/UL FDD, respectively.

User-experienced data rate results (Nokia)

|  |  |
| --- | --- |
| Direction and Duplexing | Minimum Required Bandwidth |
| DL FDD | 300 MHz |
| DL TDD | 302 MHz |
| UL FDD | 204 MHz |

The results from Samsung, shown below, indicate that at the carrier frequency of 4GHz, DL UEDR requirements (100 MHz) are met when the bandwidths are larger than 350 MHz.

User experienced data rate for Dense Urban-eMBB (4GHz) (Samsung)

|  |  |  |
| --- | --- | --- |
| Bandwidth (MHz) | User experienced data rate (Mbit/s) | Requirement (Mbit/s) |
| 250 | 77 | 100 |
| 300 | 92.4 |
| 350 | 107.8 |
| 400 | 123.2 |

## A-4 Results of 5th percentile Spectral Efficiency

These results are captured with the average spectral efficiency.

## A-5 Results of Average Spectral Efficiency

Seven contributions from Korea University, Ericsson, Intel, LG Electronics, Nokia, Qualcomm and Samsung Electronics are considered. The results are obtained from system-level simulation (SLS) and the configurations used SLS are summarized in a different document. The results from these contributions show that 3GPP NR meets the IMT-2020 requirements of the 5th percentile spectral efficiency and average spectral efficiency in all of three test environments of interest – Indoor Hotspot, Dense Urban and Rural. Results are summarized in the following for each test environment.

The simulation results without duplexing note means FDD operation. For the TDD duplexing results, they are noted.

## A-5.1 eMBB Indoor Hotspot Test Environment

Table A-5-1. Evaluation Result of Indoor Hotspot – eMBB (4GHz\_12TRxP)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | 4GHz\_12TRxP | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 9 | 11.450 | 13.160 | 10.124 | MU-MIMO |
| B | 11.470 | - |  |
| Uplink | A | 6.75 | 7.968 | - | 9.570 | SU-MIMO |
| B | 6.927 | - |  |
| A |  |  |  | MU-MIMO |
| B |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 0.3 | 0.339 | 0.330 | 0.719 | MU-MIMO |
| B | 0.343 | - |  |
| Uplink | A | 0.21 | 0.434 | - | 0.493 | SU-MIMO |
| B | 0.431 | - |  |
| A |  |  |  | MU-MIMO |
| B |  |  |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | 4GHz\_12TRxP | | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 9 |  |  | 9.8 fdd  10.054 tdd | 10.627 fdd  8.770 tdd | MU-MIMO |
| B |  |  |  |  |
| Uplink | A | 6.75 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |
| A |  |  | 7.329 | 13.949 fdd  12.913 tdd | MU-MIMO |
| B |  |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 0.3 |  |  | 0.350 fdd  0.452 tdd | 0.398 fdd  0.328 tdd | MU-MIMO |
| B |  |  |  |  |
| Uplink | A | 0.21 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |
| A |  |  | 0.396 | 0.592 fdd  0.548 tdd | MU-MIMO |
| B |  |  |  |  |

Table A-5-2. Evaluation Result of Indoor Hotspot – eMBB (4GHz\_36TRxP)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | 4GHz\_36TRxP | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 9 | 13.230 |  | 9.656 | MU-MIMO |
| B | 13.350 | - |  |
| Uplink | A | 6.75 |  | - | 11.148 | SU-MIMO |
| B |  | - |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 0.3 | 0.380 |  | 0.468 | MU-MIMO |
| B | 0.368 | - |  |
| Uplink | A | 0.21 |  | - | 0.434 | SU-MIMO |
| B |  | - |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | 4GHz\_36TRxP | | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 9 |  |  |  | 12.586 fdd  10.385 tdd | MU-MIMO |
| B |  |  |  |  |
| Uplink | A | 6.75 |  |  |  | 15.172 fdd  14.045 tdd | MU-MIMO |
| B |  |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 0.3 |  |  |  | 0.406 fdd  0.335 tdd | MU-MIMO |
| B |  |  |  |  |
| Uplink | A | 0.21 |  |  |  | 0.467 fdd  0.432 tdd | MU-MIMO |
| B |  |  |  |  |

Table A-5-3. Evaluation Result of Indoor Hotspot – eMBB (30GHz\_12TRxP)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | 30GHz\_12TRxP | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A/B | 9 |  | 8.495 | 11.402 | MU-MIMO |
| Uplink | A/B | 6.75 |  |  | 7.192 | SU-MIMO |
|  | 7.657 fdd |  | MU-MIMO |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A/B | 0.3 |  | 0.313 | 0.921 | MU-MIMO |
| Uplink | A/B | 0.21 |  |  | 0.416 | SU-MIMO |
|  | 0.394 fdd |  | MU-MIMO |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | 30GHz\_12TRxP | | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A/B | 9 | 12.034 tdd | 13.900 tdd |  | 8.474 tdd | MU-MIMO |
| Uplink | A/B | 6.75 | 6.900 tdd |  |  |  | SU-MIMO |
|  | 10.190 tdd |  | 11.439 tdd | MU-MIMO |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A/B | 0.3 | 0.486 tdd | 0.348 tdd |  | 0.343 tdd | MU-MIMO |
| Uplink | A/B | 0.21 | 0.300 tdd |  |  | 0.425 tdd | SU-MIMO |
|  | 0.312 tdd |  |  | MU-MIMO |

Table A-5-4. Evaluation Result of Indoor Hotspot – eMBB (30GHz\_36TRxP)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **eMBB - Indoor Hotspot** | | | **30GHz\_36TRxP** | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A/B | 9 |  |  |  | MU-MIMO |
| Uplink | A/B | 6.75 |  |  |  | SU-MIMO |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A/B | 0.3 |  |  |  | MU-MIMO |
| Uplink | A/B | 0.21 |  |  |  | SU-MIMO |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **eMBB - Indoor Hotspot** | | | **30GHz\_36TRxP** | | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A/B | 9 |  |  |  | 8.687 tdd | MU-MIMO |
| Uplink | A/B | 6.75 |  |  |  | 10.383 tdd | SU-MIMO |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A/B | 0.3 |  |  |  | 0.293 tdd | MU-MIMO |
| Uplink | A/B | 0.21 |  |  |  | 0.310 tdd | SU-MIMO |

Table A-5-5. Evaluation Result of Indoor Hotspot – eMBB (4GHz\_LargerBW\_12TRxP)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | | 4GHz\_LargerBW\_12TRxP | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 10 | 9 | 11.450 | 13.160 |  | MU-MIMO |
| 20 | 13.010 | 14.953 |  |
| 40 | 13.937 | 16.019 |  |
| B | 10 | 11.470 | - |  |
| 20 | 13.033 | - |  |
| 40 | 13.962 | - |  |
| Uplink | A |  | 6.75 | 7.968 |  |  | SU-MIMO |
| B |  | 6.927 |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 10 | 0.3 | 0.339 | 0.330 |  | MU-MIMO |
| 20 | 0.385 | 0.375 |  |
| 40 | 0.413 | 0.402 |  |
| B | 10 | 0.343 | - |  |
| 20 | 0.390 | - |  |
| 40 | 0.418 | - |  |
| Uplink | A |  | 0.21 | 0.434 |  |  | SU-MIMO |
| B |  | 0.431 |  |  |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | | 4GHz\_LargerBW\_12TRxP | | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 10 | 9 |  |  | 9.800 | 10.627 | MU-MIMO |
| 20 |  |  | 10.987 fdd  10.054 tdd | 12.078 fdd  8.770 tdd |
| 40 |  |  | 11.703 fdd  11.580 tdd | 12.941 fdd  10.427 tdd |
| B | 10 |  |  |  |  |
| 20 |  |  |  |  |
| 40 |  |  |  |  |
| Uplink | A |  | 6.75 |  |  |  | 13.949 fdd  12.913 tdd | MU-MIMO |
| B |  |  |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 10 | 0.3 |  |  | 0.350 | 0.398 fdd | MU-MIMO |
| 20 |  |  | 0.392 fdd  0.452 tdd | 0.452 fdd  0.328 tdd |
| 40 |  |  | 0.418 fdd  0.520 tdd | 0.485 fdd  0.390 tdd |
| B | 10 |  |  |  |  |
| 20 |  |  |  |  |
| 40 |  |  |  |  |
| Uplink | A |  | 0.21 |  |  |  | 0.592 fdd  0.548 tdd | MU-MIMO |
| B |  |  |  |  |  |

Table A-5-6. Evaluation Result of Indoor Hotspot – eMBB (4GHz\_LargerBW\_36TRxP)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | | 4GHz\_LargerBW\_36TRxP | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 10 | 9 | 13.230 |  |  | MU-MIMO |
| 20 | 15.033 |  |  |
| B | 10 | 13.350 |  |  |
| 20 | 15.169 |  |  |
| Uplink | A |  | 6.75 |  |  |  | SU-MIMO |
| B |  |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 10 | 0.3 | 0.380 |  |  | MU-MIMO |
| 20 | 0.432 |  |  |
| B | 10 | 0.368 |  |  |
| 20 | 0.418 |  |  |
| Uplink | A |  | 0.21 |  |  |  | SU-MIMO |
| B |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | |  | 4GHz\_LargerBW\_36TRxP | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 10 | 9 |  |  |  | 12.586 fdd | MU-MIMO |
| 20 |  |  |  | 14.305 fdd  10.385 tdd |
| 40 |  |  |  | 12.348 tdd |
| B | 10 |  |  |  |  |
| 20 |  |  |  |  |
| Uplink | A |  | 6.75 |  |  |  | 15.172 fdd  14.045 tdd | MU-MIMO |
| B |  |  |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 10 | 0.3 |  |  |  | 0.406 fdd | MU-MIMO |
| 20 |  |  |  | 0.461 fdd  0.335 tdd |
| 40 |  |  |  | 0.398 tdd |
| B | 10 |  |  |  |  |
| 20 |  |  |  |  |
| Uplink | A |  | 0.21 |  |  |  | 0.467 fdd  0.432 tdd | MU-MIMO |
| B |  |  |  |  |  |

Table A-5-7. Evaluation Result of Indoor Hotspot – eMBB (30GHz\_LargerBW\_12TRxP)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | | 30GHz\_Larger\_BW\_12TRxP | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A/B | 40 | 9 | - | 8.495 fdd |  | MU-MIMO |
| Uplink | A/B |  | 6.75 | - | 7.657 fdd |  | MU-MIMO |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A/B | 40 | 0.3 | - | 0.313 tdd |  | MU-MIMO |
| Uplink | A/B |  | 0.21 |  |  |  | SU- MIMO |
| - | 0.394 fdd |  | MU-MIMO |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | | 30GHz\_Larger\_BW\_12TRxP | | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A/B | 100  200  400 | 9 | 12.034 tdd(80)  14.399 tdd(200)  14.966 tdd(400) | 13.900 tdd(80)  16.875 tdd(200) |  | 8.474 tdd  9.796 tdd  10.457 tdd | MU-MIMO |
| Uplink | A/B |  | 6.75 |  |  |  |  |  |
| 6.900 fdd | 10.190 tdd |  | 11.439 tdd | MU-MIMO |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A/B | 100  200  400 | 0.3 | 0.486 tdd (80)  0.582 tdd (200)  0.604 tdd (400) | 0.348 tdd (80)  0.422 tdd (200) |  | 0.343 tdd  0.396 tdd  0.423 tdd | MU-MIMO |
|  |  |  |  |  |  |  |  | SU-MIMO |
| Uplink | A/B |  | 0.21 | 0.300 fdd | 0.312 tdd |  | 0.425 tdd | MU-MIMO |

Table A-5-8. Evaluation Result of Indoor Hotspot – eMBB (30GHz\_LargerBW\_36TRxP)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | | 30GHz\_Larger\_BW\_36TRxP | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A/B |  | 9 | - |  |  | MU-MIMO |
| Uplink | A/B |  | 6.75 | - |  |  | MU-MIMO |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A/B |  | 0.3 | - |  |  | MU-MIMO |
| Uplink | A/B |  | 0.21 | - |  |  | MU-MIMO |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB - Indoor Hotspot | | | | 30GHz\_Larger\_BW\_36TRxP | | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A/B | 100  200  400 | 9 |  |  |  | 8.687 tdd  10.042 tdd  10.720 tdd | MU-MIMO |
| Uplink | A/B |  | 6.75 |  |  |  | 10.383 tdd | MU-MIMO |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A/B | 100  200  400 | 0.3 |  |  |  | 0.293 tdd  0.338 tdd  0.361 tdd | MU-MIMO |
| Uplink | A/B |  | 0.21 |  |  |  | 0.310 tdd | MU-MIMO |

## A-5.2 eMBB Dense Urban Test Environment

Table A-5-9. Evaluation Result of Dense Urban – eMBB (4GHz)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Dense Urban | | | 4GHz | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 7.8 | 9.710 | 10.650 | 8.966 | MU-MIMO |
| B | 9.630 | - |  |
| Uplink | A | 5.4 | 6.502 fdd | - | 6.720 | SU-MIMO |
| B | 6.431 fdd | - |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 0.225 | 0.289 | 0.308 | 0.443 | MU-MIMO |
| B | 0.309 | - |  |
| Uplink | A | 0.15 | 0.343 fdd | - | 0.201 | SU-MIMO |
| B | 0.310 fdd | - |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Dense Urban | | | 4GHz | | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 7.8 |  | 12.200 tdd | 9.200 | 14.814 fdd  12.245 tdd | MU-MIMO |
| B | 10.776 tdd |  |  |  |
| Uplink | A | 5.4 |  | 7.280 tdd | 6.735 fdd | 22.479 fdd  20.808 tdd | MU-MIMO |
| B | 5.513 tdd |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 0.225 |  | 0.296  tdd | 0.330 | 0.537 fdd  0.443 tdd | MU-MIMO |
| B | 0.361 tdd |  |  |  |
| Uplink | A | 0.15 |  | 0.163 tdd | 0.277 fdd | 0.528 fdd  0.488 tdd | MU-MIMO |
| B | 0.174 tdd |  |  |  |

Table A-5-10. Evaluation Result of Dense Urban – eMBB (4GHz\_LargerBW)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Dense Urban | | | | 4GHz\_LargerBW | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 10 | 7.8 | 9.710 | 10.650 |  | MU-MIMO |
| 20 | 11.033 | 12.101 |  |
| 40 | 11.819 | 12.964 |  |
| B | 10 | 9.630 |  |  |
| 20 | 10.942 |  |  |
| 40 | 11.722 |  |  |
| Uplink | A |  | 5.4 | 6.502 fdd |  |  | SU-MIMO |
| B |  | 6.431 |  |  |
| A |  |  |  |  | MU-MIMO |
| B |  |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 10 | 0.225 | 0.289 | 0.308 |  | MU-MIMO |
| 20 | 0.328 | 0.350 |  |
| 40 | 0.352 | 0.375 |  |
| B | 10 | 0.309 |  |  |
| 20 | 0.351 |  |  |
| 40 | 0.376 |  |  |
| Uplink | A |  | 0.15 | 0.343 fdd |  |  | SU-MIMO |
| B |  | 0.310 |  |  |
| A |  |  |  |  | MU-MIMO |
| B |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Dense Urban | | | | 4GHz\_LargerBW | | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 10 | 7.8 |  |  | 9.200 tdd | 14.814 | MU-MIMO |
| 20 |  | 12.200 tdd | 10.315 tdd | 16.837 fdd  12.245 tdd |
| 40 |  | 14.823 tdd | 10.987 tdd | 18.039 fdd  14.560 tdd |
| B | 10 |  |  |  |  |
| 20 | 10.776 tdd |  |  |  |
| 40 | 12.562 tdd  13.778 tdd (100) |  |  |  |
| Uplink | A |  | 5.4 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |  |
| A |  |  | 7.280 tdd | 6.735 fdd | 22.479 fdd  20.808 tdd | MU-MIMO |
| B |  | 5.513 tdd |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 10 | 0.225 |  |  | 0.330 tdd | 0.537 | MU-MIMO |
| 20 |  | 0.296 tdd | 0.370 tdd | 0.611 fdd  0.443 tdd |
| 40 |  | 0.359 tdd | 0.394 tdd | 0.654 fdd  0.527 tdd |
| B | 10 |  |  |  |  |
| 20 | 0.361 tdd |  |  |  |
| 40 | 0.421 tdd  0.462 tdd (100) |  |  |  |
| Uplink | A |  | 0.15 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |  |
| A |  |  | 0.163 tdd | 0.277 fdd | 0.528 fdd  0.488 tdd | MU-MIMO |
| B |  | 0.174 tdd |  |  |  |

Table A-5-10-1. Evaluation Result of Dense Urban – eMBB (30GHz\_LargerBW)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Dense Urban | | | 30GHz\_LargerBW | | | | | |
| Performance Requirement | Category | Bandwidth | Req. | Source #51) | Source #42) | Source #23) | Source #34) | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | 80 | 7.8 | 21.6  16.9 | 9.38 | 8.37 | 8.03 | MU-MIMO  TDD |
| 200 | 24.2  18.9 | 10.77 | 9.62 |  |
| 400 | 25.4  19.8 | 11.36 | 10.15 |  |
| Uplink | 80 | 5.4 | 11.3 | 5.52 | 5.75 |  | MU-MIMO  TDD |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | 80 | 0.225 | 0.58  0.44 | 0.28 | 0.26 | 0.30 | MU-MIMO  TDD |
| 200 | 0.65  0.49 | 0.32 | 0.30 |  |
| 400 | 0.68  0.51 | 0.34 | 0.32 |  |
| Uplink | 80 | 0.15 | 0.41 | 0.16 | 0.22 |  | MU-MIMO  TDD |
| Note 1) 100 % low loss penetration is considered.  Note 2) 3) Admission control, where UE’s with path loss larger than 128 and 125 dB are excluded, respectively  Note 4) All outdoor UEs are assumed. | | | | | | | | |

## A-5.3 eMBB Rural Test Environment

Table A-5-11. Evaluation Result of Rural – eMBB (700MHz)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Rural | | | 700MHz | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 3.3 | 9.420 | 7.040 | 7.098 | MU-MIMO |
| B | 9.080 |  |  |
| Uplink | A | 1.6 | 2.948 fdd |  | 3.530 | SU-MIMO |
| B | 2.917 fdd |  |  |
| A |  |  |  | MU-MIMO |
| B |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 0.12 | 0.160 | 0.180 | 0.386 | MU-MIMO |
| B | 0.171 |  |  |
| Uplink | A | 0.045 | 0.132 fdd |  | 0.0733 | SU-MIMO |
| B | 0.123 fdd |  |  |
| A |  |  |  | MU-MIMO |
| B |  |  |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Rural | | | 700MHz | | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 3.3 |  |  |  | 15.284 fdd  12.611 tdd | MU-MIMO |
| B | 6.606  tdd |  |  |  |
| Uplink | A | 1.6 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |
| A |  |  |  | 15.550 fdd  14.396 tdd | MU-MIMO |
| B | 4.190 tdd |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 0.12 |  |  |  | 0.472 fdd  0.390 tdd | MU-MIMO |
| B | 0.132  tdd |  |  |  |
| Uplink | A | 0.045 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |
| A |  |  |  | 0.632 fdd  0.585 fdd | MU-MIMO |
| B | 0.223 tdd |  |  |  |

Table A-5-12. Evaluation Result of Rural – eMBB (4GHz)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Rural | | | 4GHz | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 3.3 | 12.580 |  | 10.499 | MU-MIMO |
| B | 11.960 | 12.290 |  |
| Uplink | A | 1.6 | 3.525 fdd(1x32)  6.267 fdd(2x32) |  | 4.317 | SU-MIMO |
| B | 6.160 fdd |  |  |
| A |  |  |  | MU-MIMO |
| B |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 0.12 | 0.120 |  | 0.657 | MU-MIMO |
| B | 0.126 | 0.290 |  |
| Uplink | A | 0.045 | 0.140 fdd(1x32)  0.234 fdd(2x32) |  | 0.0549 | SU-MIMO |
| B | 0.187 fdd |  |  |
| A |  |  |  | MU-MIMO |
| B |  |  |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Rural | | | 4GHz | | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 3.3 |  | 17.375 tdd | 9.700 fdd  8.658 tdd | 18.007 fdd  14.857 tdd | MU-MIMO |
| B | 10.361 tdd |  |  |  |
| Uplink | A | 1.6 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |
| A |  | 10.731 tdd | 8.913 fdd | 23.009 fdd  21.301 tdd | MU-MIMO |
| B | 9.204 tdd |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 0.12 |  | 0.425 tdd | 0.269 fdd  0.190 tdd | 0.471 fdd  0.389 tdd | MU-MIMO |
| B | 0.129 tdd |  |  |  |
| Uplink | A | 0.045 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |
| A |  | 0.073 tdd | 0.123 fdd | 0.283 fdd  0.262 tdd | MU-MIMO |
| B | 0.110 tdd |  |  |  |

Table A-5-13. Evaluation Result of Rural – eMBB (LMLC)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Rural | | | LMLC | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 3.3 | 9.530 |  | 6.417 | MU-MIMO |
| B | 9.457 | 8.180 |  |
| Uplink | A | 1.6 | 4.298 fdd |  |  | SU-MIMO |
| B | 4.226 fdd |  |  |
| A |  |  |  | MU-MIMO |
| B |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 0.12 | 0.220 |  | 0.259 | MU-MIMO |
| B | 0.211 | 0.210 |  |
| Uplink | A | 0.045 | 0.188 fdd |  |  | SU-MIMO |
| B | 0.179 fdd |  |  |
| A |  |  |  | MU-MIMO |
| B |  |  |  |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Rural | | | LMLC | | | | | |
| Performance Requirement | Category | Channel model | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 3.3 |  | 6.011 | 5.400 fdd  5.241 tdd | 12.650 fdd  10.437 tdd | MU-MIMO |
| B |  |  |  |  |
| Uplink | A | 1.6 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |
| A |  | 4.824 tdd | 4.754 fdd | 11.443 fdd | MU-MIMO |
| B |  |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 0.12 |  |  | 0.179 fdd  0.160 tdd | 0.421 fdd  0.347 tdd | MU-MIMO |
| B |  |  |  |  |
| Uplink | A | 0.045 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |
| A |  | - | 0.119 fdd | 0.087 fdd | MU-MIMO |
| B |  |  |  |  |

Table A-5-14. Evaluation Result of Rural – eMBB (700MHz\_LargerBW)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Rural | | | | 700MHz\_LargerBW | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 10 | 3.3 | 9.420 | 7.040 |  | MU-MIMO |
| 20 | 10.658 | 7.965 |  |
| 40 | 11.397 | 8.517 |  |
| B | 10 | 9.080 |  |  |
| 20 | 10.273 |  |  |
| 40 | 10.985 |  |  |
| Uplink | A |  | 1.6 | 2.948 fdd |  |  | SU-MIMO |
| B |  | 2.917 fdd |  |  |
| A |  |  |  |  | MU-MIMO |
| B |  |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 10 | 0.12 | 0.160 | 0.180 |  | MU-MIMO |
| 20 | 0.181 | 0.204 |  |
| 40 | 0.194 | 0.218 |  |
| B | 10 | 0.171 |  |  |
| 20 | 0.193 |  |  |
| 40 | 0.207 |  |  |
| Uplink | A |  | 0.045 | 0.132 fdd |  |  | SU-MIMO |
| B |  | 0.123 fdd |  |  |
| A |  |  |  |  | MU-MIMO |
| B |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Rural | | | | 700MHz\_LargerBW | | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 10 | 3.3 |  |  |  | 15.284 | MU-MIMO |
| 20 |  |  |  | 17.371 fdd  12.611 tdd |
| 40 |  |  |  | 18.611 fdd  14.994 tdd |
| B | 10 |  |  |  |  |
| 20 | 6.606 tdd |  |  |  |
| 40 | 7.701 tdd  8.446 tdd (100) |  |  |  |
| Uplink | A |  | 1.6 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |  |
| A |  |  |  |  | 15.550 fdd  14.396 tdd | MU-MIMO |
| B |  | 4.190 tdd |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 10 | 0.12 |  |  |  | 0.472 | MU-MIMO |
| 20 |  |  |  | 0.536 fdd  0.390 tdd |
| 40 |  |  |  | 0.574 fdd  0.463 tdd |
| B | 10 |  |  |  |  |
| 20 | 0.132 tdd |  |  |  |
| 40 | 0.153 tdd  0.168 tdd (100) |  |  |  |
| Uplink | A |  | 0.045 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |  |
| A |  |  |  |  | 0.632 fdd  0.585 tdd | MU-MIMO |
| B |  | 0.233 tdd |  |  |  |

Table A-5-15. Evaluation Result of Rural – eMBB (4GMHz\_LargerBW)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Rural | | | | 4GHz\_LargerBW | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 10 | 3.3 | 12.580 |  |  | MU-MIMO |
| 20 | 14.233 |  |  |
| 40 | 15.220 |  |  |
| B | 10 | 11.960 | 12.290 |  |
| 20 | 13.532 | 13.945 |  |
| 40 | 14.470 | 14.931 |  |
| Uplink | A |  | 1.6 | 3.525 fdd  (1x32)  6.267 fdd  (2x32) |  |  | SU-MIMO |
| B |  | 6.160 fdd  (2x32) |  |  |
| A |  |  |  |  | MU-MIMO |
| B |  |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 10 | 0.12 | 0.120 |  |  | MU-MIMO |
| 20 | 0.138 |  |  |
| 40 | 0.145 |  |  |
| B | 10 | 0.126 | 0.290 |  |
| 20 | 0.143 | 0.329 |  |
| 40 | 0.152 | 0.352 |  |
| Uplink | A |  | 0.045 | 0.140 fdd  (1x32)  0.234 fdd  (2x32) |  |  | SU-MIMO |
| B |  | 0.187 fdd  (2x32) |  |  |
| A |  |  |  |  | MU-MIMO |
| B |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Rural | | | | 4GHz\_LargerBW | | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 10 | 3.3 |  |  | 9.700 | 18.007 | MU-MIMO |
| 20 |  | 17.375 tdd NR  14.745 tdd LTE | 10.875 fdd  8.658 tdd | 20.466 fdd  14.857 tdd |
| 40 |  | 21.111 tdd NR | 11.584 fdd  9.972 tdd | 21.927 fdd  17.666 tdd |
| B | 10 |  |  |  |  |
| 20 | 10.360 tdd |  |  |  |
| 40 | 12.077 tdd  13.246 tdd (100) |  |  |  |
| Uplink | A |  | 1.6 |  | 10.731 tdd |  |  | SU-MIMO |
| B |  |  |  |  |  |
| A |  |  |  | 8.913 fdd | 23.009 fdd  21.301 tdd | MU-MIMO |
| B |  | 9.204 tdd |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 10 | 0.12 |  |  | 0.269 | 0.471 | MU-MIMO |
| 20 |  | 0.425 tdd NR  0.357 tdd LTE | 0.302 fdd  0.190 tdd | 0.535 fdd  0.389 tdd |
| 40 |  | 0.517 tdd NR | 0.321 fdd  0.219 tdd | 0.573 fdd  0.462 tdd |
| B | 10 |  |  |  |  |
| 20 | 0.129 tdd |  |  |  |
| 40 | 0.150 tdd  0.164 tdd (100) |  |  |  |
| Uplink | A |  | 0.045 |  | 0.073 tdd |  |  | SU-MIMO |
| B |  |  |  |  |  |
| A |  |  |  | 0.123 fdd | 0.283 fdd  0.262 tdd | MU-MIMO |
| B |  | 0.110 tdd |  |  |  |

Table A-5-16. Evaluation Result of Rural – eMBB (LMLC\_LargerBW)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Rural | | | | LMLC\_LargerBW | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #1 | Source #2 | Source #3 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 10 | 3.3 | 9.530 |  |  | MU-MIMO |
| 20 | 10.782 |  |  |
| 40 | 11.530 |  |  |
| B | 10 | 9.457 | 8.180 |  |
| 20 | 10.700 | 9.255 |  |
| 40 | 11.441 | 9.896 |  |
| Uplink | A |  | 1.6 | 4.298 fdd |  |  | SU-MIMO |
| B |  | 4.226 fdd |  |  |
| A |  |  |  |  | MU-MIMO |
| B |  |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 10 | 0.12 | 0.220 |  |  | MU-MIMO |
| 20 | 0.249 |  |  |
| 40 | 0.266 |  |  |
| B | 10 | 0.211 | 0.210 |  |
| 20 | 0.239 | 0.238 |  |
| 40 | 0.255 | 0.254 |  |
| Uplink | A |  | 0.045 | 0.188 fdd |  |  | SU-MIMO |
| B |  | 0.179 fdd |  |  |
| A |  |  |  |  | MU-MIMO |
| B |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMBB – Rural | | | | LMLC\_LargerBW | | | | | |
| Performance Requirement | Category | Channel model | Bandwidth | Req. | Source #4 | Source #5 | Source #6 | Source #7 | Note |
| Average spectral efficiency (bps/Hz/TRxP) | Downlink | A | 10 | 3.3 |  |  | 5.400 | 12.650 | MU-MIMO |
| 20 |  | 6.011 tdd | 6.054 fdd  5.241 tdd | 14.378 fdd  10.437 tdd |
| 40 |  | 7.303 fdd | 6.449 fdd  6.037 tdd | 15.404 fdd  12.410 tdd |
| B | 10 |  |  |  |  |
| 20 |  |  |  |  |
| 40 |  |  |  |  |
| Uplink | A |  | 1.6 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |  |
| A |  |  | 4.824 fdd | 4.754 fdd | 11.443 fdd | MU-MIMO |
| B |  |  |  |  |  |
| 5th percentile user spectral efficiency (bps/Hz) | Downlink | A | 10 | 0.12 |  |  | 0.179 | 0.421 | MU-MIMO |
| 20 |  |  | 0.201 fdd  0.160 tdd | 0.479 fdd  0.347 tdd |
| 40 |  |  | 0.214 fdd  0.184 tdd | 0.513 fdd  0.413 tdd |
| B | 10 |  |  |  |  |
| 20 |  |  |  |  |
| 40 |  |  |  |  |
| Uplink | A |  | 0.045 |  |  |  |  | SU-MIMO |
| B |  |  |  |  |  |
| A |  |  | - | 0.119 fdd | 0.087 fdd | MU-MIMO |
| B |  |  |  |  |  |

## A-6 Results of Area Traffic Capacity

Five contributions from Ericsson, Intel, LGE, Nokia and Samsung are considered for the evaluation of Area Traffic Capacity (ATC). As the ATC requirement is defined only for the Indoor Hotspot-eMBB Test scenario, the system-level simulation results from the corresponding test scenario are considered with the required bandwidth. All of five contributions show that the 5G NR meets the ATC requirement.

The results from Ericsson, shown below, indicate that the ATC requirement is met when the bandwidths are larger than 219 MHz.

System performance in the 5G InH scenario (Ericsson)

|  |  |
| --- | --- |
| Bandwidth, | Area traffic capacity, [Mbit/s/m2] |
| 100 MHz | 4.5 |
| 219 MHz | 10 |
| 1 GHz | 45 |

The results from Intel, shown below, consider the carrier frequencies of 4GHz and 30GHz with 12/36 TRxP and FDD/TDD configurations. The ATC requirements are met if the bandwidth is larger than of 119 – 641 MHz, depending upon the configurations. Details can be found in the table shown below.

Carrier frequency of 4 GHz (Intel)

Average Cell Spectral Efficiency

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Downlink  Spectral Efficiency  (bits/s/Hz) | Indoor Hotspot eMBB Configuration A  CF = 4GHz, SCS = 15kHz, Channel Model A | | | |
| 12 TRxP | | 36 TRxP | |
| FDD | TDD | FDD | TDD |
| Average () | 11.832 | 11.163 | 14.011 | 13.219 |

Required Bandwidth to Meet IMT-2020 Target Area Traffic Capacity

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| IMT-2020 Minimum  Requirement | Bandwidth (MHz) Required to Satisfy  Minimum Requirement | | | |
| 12 TRxP | | 36 TRxP | |
| FDD | TDD | FDD | TDD |
| 10 Mbit/sec/m2 | 423 | 592 | 119 | 167 |

Maximum transmission bandwidth configuration NRB in FR1

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SCS (kHz) | 5MHz | 10MHz | 15MHz | 20 MHz | 25 MHz | 30 MHz | 40 MHz | 50MHz | 60 MHz | 80 MHz | 100 MHz |
| 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 |
| 30 | 11 | 24 | 38 | 51 | 65 | [78] | 106 | 133 | 162 | 217 | 273 |
| 60 | N/A | 11 | 18 | 24 | 31 | [38] | 51 | 65 | 79 | 107 | 135 |

Carrier frequency of 30 GHz (Intel)

Average Cell Spectral Efficiency

|  |  |  |
| --- | --- | --- |
| Downlink  Spectral Efficiency  (bits/s/Hz) | Indoor Hotspot eMBB Configuration B  CF = 30GHz, SCS = 120kHz,  Channel Model B, TDD | |
| 12 TRxP | 36 TRxP |
| Average () | 10.308 | 10.567 |

Required Bandwidth to Meet IMT-2020 Target Area Traffic Capacity

|  |  |  |
| --- | --- | --- |
| IMT-2020 Minimum  Requirement | Bandwidth (MHz) Required to Satisfy  Minimum Requirement | |
| 12 TRxP | 36 TRxP |
| 10 Mbit/sec/m2 | 641 | 209 |

Maximum transmission bandwidth configuration NRB in FR2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SCS (kHz) | 50MHz | 100MHz | 200MHz | 400 MHz |
| NRB | NRB | NRB | NRB |
| 60 | 66 | 132 | 264 | N/A |
| 120 | 32 | 66 | 132 | 264 |

The results from LGE, shown below, indicate that at the carrier frequency of 4 GHz, the ATC requirement is met when the bandwidth are larger than 450 MHz, respectively.

Area traffic capacity for Indoor Hotspot-eMBB with 12 Site (4GHz) (LGE)

|  |  |  |
| --- | --- | --- |
| Bandwidth, W (MHz) | 12 TRxP (ρ=0.002) (Mbit/s/m2) | Requirement (Mbit/s/m2) |
| 350 | 8.015 | 10 |
| 400 | 9.16 |
| 450 | 10.305 |
| 500 | 11.45 |

The results from Nokia, shown below, indicate that the ATC requirement is met when the bandwidths are larger than or equal to 510 and 459 MHz for DL FDD and DL TDD configurations, respectively.

Area Traffic Capacity (Nokia)

|  |  |
| --- | --- |
| Direction and Duplexing | Minimum Required Bandwidth |
| DL FDD | 510 MHz |
| DL TDD | 459 MHz |

The results from Samsung, shown below, indicate that at the carrier frequency of 4 GHz, the ATC requirement is met when the bandwidths are larger than 130 and 400 MHz for 36 and 12 TRxP configurations, respectively.

Area traffic capacity for Indoor Hotspot-eMBB with 36 Site (4GHz) (Samsung)

|  |  |  |
| --- | --- | --- |
| Bandwidth, W (MHz) | 36 TRxP (ρ=0.006) (Mbit/s/m2) | Requirement (Mbit/s/m2) |
| 100 | 7.938 | 10 |
| 130 | 10.3194 |
| 150 | 11.907 |

Area traffic capacity for Indoor Hotspot-eMBB with 12 Site (4GHz) (Samsung)

|  |  |  |
| --- | --- | --- |
| Bandwidth (MHz) | 12 TRxP | Requirement (Mbit/s/m2) |
| 350 | 9.21 | 10 |
| 400 | 10.53 |
| 450 | 11.84 |

## A-7 Results of User Plane Latency

Contributions from Ericsson and Nokia are considered for the evaluation of User Plane Latency (UPL). There are two UPL requirements – 1 ms for URLLC and 4ms eMBB. UPLs are obtained by analysis for several different configurations including sub-carrier spacing, retransmission and TTI in terms of OFDM symbols. All the contributions show that the 5G NR meets the UPL requirements.

The results from Ericsson, shown below, indicate that the following observations.

* NR FDD can fulfill the 4ms UP latency target with 15kHz SCS.
* NR FDD can fulfill the 1ms UP latency target with 15kHz SCS, mini-slots, and UL configured grants.
* NR TDD can fulfill the 4ms UP latency target with 15 kHz SCS, mini-slot and configured UL grants.
* NR TDD can fulfill the 1ms UP latency target with 120 kHz SCS, mini-slots and configured UL grants.
* From the above, the conclusion from Ericsson is that NR fulfills the IMT-2020 requirements on latency.

FDD UP one-way latency for data transmission with HARQ-based retransmission, compared to the 1ms (green) and 4ms (pink) requirements. (Ericsson)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Latency (ms) | HARQ | 15kHz SCS | | | | 30kHz SCS | | | | 120kHz SCS | | | |
| 14-os TTI | 7-os TTI | 4-os TTI | 2-os TTI | 14-os TTI | 7-os TTI | 4-os TTI | 2-os TTI | 14-os TTI | 7-os TTI | 4-os TTI | 2-os TTI |
| **DL data** | 1st tx | 3.2 | 1.7 | 1.3 | 0.86 | 1.7 | 0.91 | 0.7 | 0.48 | 0.55 | 0.43 | 0.38 | 0.31 |
| 1 retx | 6.2 | 3.2 | 2.6 | 1.7 | 3.1 | 1.6 | 1.3 | 0.96 | 1.1 | 0.87 | 0.76 | 0.63 |
| 2 retx | 9.2 | 4.7 | 3.6 | 2.6 | 4.7 | 2.4 | 2 | 1.5 | 1.6 | 1.3 | 1.1 | 0.96 |
| 3 retx | 12 | 6.2 | 4.6 | 3.4 | 6.1 | 3.1 | 2.7 | 2 | 2.1 | 1.7 | 1.5 | 1.3 |
| **UL data (SR)** | 1st tx | 5.5 | 3 | 2.5 | 1.8 | 2.8 | 1.5 | 1.3 | 0.93 | 1.2 | 1.1 | 1 | 0.89 |
| 1 retx | 9.4 | 4.9 | 3.9 | 2.6 | 4.7 | 2.4 | 2 | 1.4 | 1.9 | 1.7 | 1.6 | 1.3 |
| 2 retx | 12 | 6.4 | 4.9 | 3.5 | 6.2 | 3.2 | 2.6 | 1.9 | 2.6 | 2.3 | 2.1 | 1.8 |
| 3 retx | 15 | 7.9 | 5.9 | 4.4 | 7.7 | 3.9 | 3.3 | 2.3 | 3.2 | 2.8 | 2.6 | 2.2 |
| **UL data (CG)** | 1st tx | 3.4 | 1.9 | 1.4 | 0.93 | 1.7 | 0.95 | 0.7 | 0.48 | 0.7 | 0.57 | 0.52 | 0.45 |
| 1 retx | 6.4 | 3.4 | 2.6 | 1.8 | 3.2 | 1.7 | 1.4 | 0.93 | 1.3 | 1.1 | 1.1 | 0.89 |
| 2 retx | 9.4 | 4.9 | 3.9 | 2.6 | 4.7 | 2.4 | 2 | 1.4 | 1.9 | 1.7 | 1.6 | 1.3 |
| 3 retx | 12 | 6.4 | 4.9 | 3.5 | 6.2 | 3.2 | 2.6 | 1.9 | 2.6 | 2.3 | 2.1 | 1.8 |

TDD UP one-way latency for data transmission with alternating DL-UL slot pattern, compared to the 1ms (green) and 4ms (pink) requirements. (Ericsson)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Latency (ms) | HARQ | 15kHz SCS | | | 30kHz SCS | | | 120kHz SCS | | |
| 14-os TTI | 7-os TTI | 4-os TTI | 14-os TTI | 7-os TTI | 4-os TTI | 14-os TTI | 7-os TTI | 4-os TTI |
| **DL data** | 1st tx | 4.2 | 2.7 | 2.3 | 2.2 | 1.4 | 1.2 | 0.68 | 0.55 | 0.51 |
| 1 retx | 8.2 | 4.7 | 4.3 | 4.1 | 2.4 | 2.2 | 1.4 | 1.1 | 1 |
| 2 retx | 12 | 6.7 | 6.3 | 6.2 | 3.4 | 3.2 | 2.2 | 1.6 | 1.5 |
| 3 retx | 16 | 8.7 | 8.3 | 8.1 | 4.4 | 4.2 | 2.9 | 2.1 | 2 |
| **UL data (SR)** | 1st tx | 7.5 | 4.5 | 4.1 | 3.8 | 2.3 | 2.1 | 1.5 | 1.2 | 1.2 |
| 1 retx | 12 | 6.9 | 6.4 | 6.2 | 3.4 | 3.2 | 2.3 | 1.9 | 1.7 |
| 2 retx | 16 | 8.9 | 8.4 | 8.2 | 4.5 | 4.2 | 3.1 | 2.5 | 2.2 |
| 3 retx | 20 | 11 | 10 | 10 | 5.4 | 5.2 | 3.8 | 3.2 | 2.7 |
| **UL data (CG)** | 1st tx | 4.4 | 2.9 | 2.4 | 2.2 | 1.4 | 1.2 | 0.82 | 0.7 | 0.64 |
| 1 retx | 8.4 | 4.9 | 4.4 | 4.2 | 2.5 | 2.2 | 1.6 | 1.3 | 1.2 |
| 2 retx | 12 | 6.9 | 6.4 | 6.2 | 3.4 | 3.2 | 2.3 | 1.9 | 1.7 |
| 3 retx | 16 | 8.9 | 8.4 | 8.2 | 4.5 | 4.2 | 3.1 | 2.5 | 2.2 |

The results from Nokia show several observations from **four configurations**. Results and observations are different depending upon the UE capabilities (the non-latency optimized UE category 1 and the latency optimized UE category 2) and the DL/UL configurations (FDD, dynamic TDD and static TDD).

For the non-latency optimized UE category 1 in FDD and dynamic TDD allocations, following observations and conclusions are drawn.

* 4 ms eMBB latency target with 10% average retransmission probability:
  + For downlink, operating with a full 14-symbol (or shorter) scheduling allocation, with an average retransmission probability of 10%, all supported subcarrier spacings meet the eMBB latency requirement of 4 ms.
  + For grant-based uplink, operating with full 14-symbol (or shorter) scheduling allocation, with an average retransmission probability of 10%, SCSs of 30, 60 and 120 kHz subcarrier spacings meet the eMBB latency requirement of 4 ms, while with 15 kHz SCS, either a 7-symbol allocation or grant-free operation is needed to meet the 4 ms requirement.
* 1 ms URLLC latency target with 1 HARQ retransmission and the worst-case timing:
* For downlink, operating with 120 kHz subcarrier spacing and 7-symbol (or shorter) scheduling allocation, the worst-case latency with 1 HARQ retransmission meets the URLLC latency requirement of 1 ms.
* For uplink, operating with 120 kHz subcarrier spacing and 7-symbol (or shorter) grant free scheduling allocation, the worst-case latency with 1 HARQ retransmission meets the URLLC latency requirement of 1 ms.

For the latency optimized UE category 2 UP in FDD and dynamic TDD allocations, following observations and conclusions are drawn.

* 4 ms eMBB latency target with 10% average retransmission probability:
  + For both UL and DL grant-based operation with full 14 symbol (or shorter) scheduling allocations and with all subcarrier spacings the eMBB latency requirement of 4 ms is met.
* 1 ms URLLC latency target with 1 HARQ retransmission and worst-case timing:
  + 120 kHz subcarrier spacing does not define the latency optimized UE processing category, but the requirement can be met even with the non-latency optimized UE processing category 1.
  + the URLLC latency requirement of 1 ms with subcarrier spacings 30 and 60 kHz using 2-symbol slot scheduling and 1 HARQ retransmission is met with the worst- case timing
  + With larger scheduling allocations, the URLLC latency requirement can be met with subcarrier spacings 30 and 60 kHz for 10% HARQ retransmission probability.
  + The average latency for DL and grant-free UL at 30 kHz can meet the URLLC latency requirement when there is no retransmission even with full 14-symbols slot-based scheduling.
  + The average latency for DL and grant-free UL at 60 kHz can meet the URLLC latency requirement when there is 10% HARQ retransmission or without retransmission even with full 14-symbols slot-based scheduling.
  + For 4-symbols and 2-symbols slot schedulings, the URLLC latency requirement can be met with 10% HARQ retransmission or without retransmission even with 15 kHz subcarrier spacing.

For the non-latency optimized UE category 1 (eMBB) in a 5-slot long static TDD configuration of DDDXU, which naturally severely limits the worst-case latency, following observations and conclusions are drawn.

* 4 ms eMBB latency target with 10% average retransmission probability:
* For downlink, operating with a full 14-symbol (or shorter) scheduling allocation, with an average retransmission probability of 10%, 30, 60 and 120 kHz SCS meet the eMBB latency requirement of 4 ms.
* For grant-based uplink, operating with a full 14-symbol (or shorter) scheduling allocation, with an average retransmission probability of 10%, 30, 60 and 120 kHz SCS meet the eMBB latency requirement of 4 ms, while grant-free uplink meets the requirement also with 15 kHz SCS.

For the latency optimized UE category 2 (URLLC) in 5-slot long static TDD configuration of DDDXU, which naturally severely limits the worst-case latency, following observations and conclusions are drawn.

* The analysis in this contribution indicates that the 3GPP specifications can meet the URLLC latency requirement of 1 ms for the analysed static TDD configuration, but not for the worst-case packet with 1 HARQ retransmission. For downlink and grant-free uplink, the requirement can be met on average with subcarrier spacings 30 and 60 kHz using even full 14-symbol slot scheduling and taking 10% HARQ retransmission into account. With shorter data allocation durations, the 1 ms latency requirement can be met on average for subcarrier spacings 30 and 60 kHz and taking 10% HARQ retransmission into account.

## A-8 Results of Control Plane Latency

Contributions from Ericsson and Nokia are considered for the evaluation of Control Plane Latency (CPL). The CPL requirement is 20 ms. Several configurations are considered for the CPL analysis. All the contributions show that the 5G NR meets the CPL requirement.

The results from Ericsson, shown below, indicate that the CPL requirement is met in the following configurations.

Achievable CP latency for NR Rel-15 in ms for TDD with alternating UL-DL pattern (Ericsson)

|  |  |  |  |
| --- | --- | --- | --- |
| CP latency (ms) | 15kHz SCS | 30kHz SCS | 120kHz SCS |
| 14-symbol TTI | 20 | 13 | 8.5 |
| 7-symbol TTI | 13 | 9.5 | 7.3 |
| 4-symbol TTI | 10 | 8.0 | 6.7 |

Achievable CP latency for NR Rel-15 in ms for TDD with UL-DL-DL-DL pattern (Ericsson)

|  |  |  |  |
| --- | --- | --- | --- |
| CP latency (ms) | 15kHz SCS | 30kHz SCS | 120kHz SCS |
| 14-symbol TTI | 18 | 12 | 9.3 |
| 7-symbol TTI | 12 | 9.0 | 7.6 |
| 4-symbol TTI | 9.4 | 7.7 | 6.9 |

The results from Nokia, shown below, indicate that the CPL requirement is met in the following configurations.

C-plane latency calculation for TDD

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SCS | Case 1 (DL-UL) | | Case 2 (DL-DL-DL-DL-UL) | |
| TTI = 7 | TTI = 14 | TTI = 7 | TTI = 14 |
| 15 kHz | 24 TTI = 12 ms | 15 TTI = 15 ms | 29 TTI = 14.5 ms | 18 TTI = 18 ms |
| 30 kHz | 42 TTI = 10.5 ms | 24 TTI = 12 ms | 41 TTI = 10.25 ms | 23 TTI = 11.5 ms |
| 60 kHz | 72 TTI = 9 ms | 38 TTI = 9.5 ms | 76 TTI = 9.5 ms | 41 TTI = 10.25 ms |
| 120 kHz | 130 TTI = 8.125 ms | 68 TTI = 8.5 ms | 133 TTI = 8.3125 ms | 71 TTI = 8.875 ms |

C-plane latency calculation for FDD

|  |  |  |
| --- | --- | --- |
| SCS | Latency [ms] | |
| TTI = 7 | TTI = 14 |
| 15 kHz | 12.0686 | 13.5686 |
| 30 kHz | 10.1043 | 10.8543 |
| 60 kHz | 8.7721 | 9.1471 |
| 120 kHz | 8.0211 | 8.2086 |

## A-9 Results of Connection Density

Contributions from Ericsson and Nokia are considered for the evaluation of Connection Density. The requirement of the connection density is 1,000,000 connections per km2. Full buffer simulation (by Ericsson) results and non-full buffer simulation (by Nokia) results are considered. All the results show that the 5G NR meets the Connection Density requirement.

The results of full buffer simulation for 5G NR by Ericsson are summarized as follows. The bandwidth of 180kHz is assumed.

99th percentile delay D recorded in Step 3 defined in Report ITU-R M.2412 (Ericsson)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Conf A, UMA A | Conf A, UMA B | Conf B, UMA A | Conf B, UMA B |
| NR | 0,008 | 0,009 | 0,101 | 0,093 |

Connection density C recorded in Step defined in Report ITU-R M.2412 (Ericsson)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Conf A, UMA A | Conf A, UMA B | Conf B, UMA A | Conf B, UMA B |
| NR | 30 066 283 | 29 844 621 | 1 269 767 | 1 575 368 |

The conclusions of the non-full buffer simulation for 5G NR by Nokia are drawn as follows. The packet delay PDF in terms of the number of HARQ attempts required for successful transmission is obtained. It shows that all packet transmissions were successful in fewer than 1000 HARQ attempts for both configurations. Since a HARQ retransmission can occur in less than 10 ms, the maximum delay time is less than 10 seconds and the packet outage rate at these loading levels is zero. Therefore, the results place a lower bound on the number of supported connections at the required connection density.

From these, Nokia’s observation is that NR can meet the connection density requirement in both Configuration A and B in the Urban Macro – mMTC environment.

## A-10 Results of Energy Efficiency

Contributions from Ericsson and Nokia are considered for the evaluation of Energy Efficiency. The requirement of the Energy Efficiency is to have a “***Capability to support a high sleep ratio and long sleep duration***”. Observations expressed in Ericsson and Nokia’s contributions indicate that 5G NR has a “***Capability to support a high sleep ratio and long sleep duration***”, and therefore the Energy Efficiency requirement is met.

Observations from Ericsson is summarized as follow:

LTE networks are dominated by idle mode power consumption. NR supports significantly longer network DTX durations and have a significantly larger DTX duration. We conclude that this result in significantly lower idle mode power consumption as well. As an example, a stand-alone LSAS (large scale antenna system) base station can have a 6 times lower power consumption if we use NR compared to LTE (assuming 20 ms SSB periodicity) and more than 10 times lower power consumption is achievable for larger SSB periodicities.

For traditional 2TX macro base stations the energy saving gains with NR compared to LTE are even larger. The energy consumption can be reduced with a factor of 9 in a stand-alone case (20 ms SSB periodicity) and close to 19 times for a non-stand-alone case (SSB periodicity 160 ms).

The energy savings enabled by NR will result in significant energy cost savings for operators. It will help to reduce the carbon footprint of cellular networks even further. Lower energy consumption is of importance in off-grid areas where base stations need to be powered by on-site generated power, such as solar panels. The size of backup batteries is reduced proportionally to the average energy consumption. Also, reduced energy consumption result is reduced heat dissipation which is a major hurdle for product miniaturization. The combined techno economic effects of such large improvements in network energy performance are difficult to overestimate.

Nokia’s contribution shows some analysis on the sleep duration of 5G NR base station for several configurations of SS/PBCH block’s periodicity. After the analysis, the following conclusions are drawn:

It can be concluded that the NR can support a very high sleep ratio and long sleep duration for the 5G NR base station, and the NR specification meets the IMT-2020 network energy efficiency requirement.

## A-11 Results of Reliability

Three contributions from Ericsson, Intel and Nokia are considered. System-level simulation is performed to obtain the SINR of the 5th percentile UE. Then, 1-10-5 probability of success transmission is evaluated. Simulation results and observations from these three contributors indicate that 5G NR meets the reliability requirements.

Ericsson draws the following observations regarding the Reliability evaluation.

* Observation 1: The cell-edge SINR for URLLC Conf. A is approximately 1.98 dB (DL) and 0.81 dB (UL) for channel model UMa A, and 1.93 dB (DL) and 1.77 dB (UL) for channel model UMa B.
* Observation 2: The cell-edge SINR for URLLC Conf. B is approximately 0.16 dB (DL) and 0.83 dB (UL) for channel model UMa A, and -0.06 dB (DL) and 0.65 dB (UL) for channel model UMa B.
* Observation 3: With 1 transmission using MCS1 the reliability target of 10-5 error can be met in DL and in UL with configured grant.
* Observation 4: With MCS1 and a 7-os mini-slot, 46 PRBs are required for a 32B packet.
* Observation 5: With 30kHz SCS and 7-os mini-slot 1 transmission can be made in FDD within 1ms.

Intel draws the following conclusions regarding the Reliability evaluation.

* It is showed that at least for Configuration A the requirements are fulfilled with single-shot transmission of PDCCH+PDSCH.

Nokia draws the following observations regarding the Reliability evaluation.

* Observation 1: The 5th percentile (cell edge) SINR’s in the Urban Macro – URLLC environment for Configuration A (4 GHz) are 9.41 dB in DL and 8.04 dB in UL. The 5th percentile SINR’s for Configuration B (700 MHz) are 14.52 dB in DL and 10.61 dB in UL.
* Observation 2: NR can meet the IMT-2020 reliability requirements for Configuration A (4 GHz) DL with a single transmission attempt with a NLoS channel.
* Observation 3: NR can meet the IMT-2020 reliability requirements for Configuration A (4 GHz) UL with a single transmission attempt with a LoS channel.
* Observation 4: NR can meet the IMT-2020 reliability requirements for Configuration B (700 MHz) DL and UL with a single transmission attempt with a NLoS channel.

## A-12 Results of Mobility

Support of a mobility class in a certain eMBB test environment is determined based on the traffic channel link data rate on the uplink, normalized by bandwidth. The traffic channel link data rate is obtained by system-level and link-level simulations. We have contributions from Ericsson, Intel, Nokia and Samsung for this evaluation.

Based on these contributions, whose results are shown in A-13 Results of Mobility Traffic channel link data rates, following mobility classes are supported in each of eMBB test environment.

* For Indoor Hotspot eMBB, mobility classes of stationary and pedestrian are supported.
* For Dense Urban eMBB, mobility classes of Stationary, Pedestrian and Vehicular (up to 30 km/h) are supported.
* For Rural eMBB, Pedestrian, Vehicular, High speed vehicular are supported.

## A-13 Results of Mobility – Traffic Channel Link Data Rates

Four contributions from Ericsson, Intel, Nokia and Samsung are considered. System-level simulation is performed to obtain SINR CDF and the median SINR value is used for the link-level simulation to get the traffic channel link data rate on the uplink, normalized by bandwidth. All of four contributions show that the 5G NR meets the requirements of mobility in all of three eMBB test environments.

The results from Ericsson are summarized as follows.

Required and achieved SNR values for the case without OH for DL/UL switching (Ericsson)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test environment | Requirement | Required SNR  (NLOS/LOS) | Achieved median downlink SINR [model A/B] | Achieved median uplink SINR [model A/B] |
| Indoor Hotspot eMBB, 1sector/site | 1.5bps/Hz at 10km/h | 8.2dB / 6.5dB | 14.5dB / 14.1dB | 14.2dB / 13.8dB |
| Indoor Hotspot eMBB,  3sectors/site | 1.5bps/Hz at 10km/h | 8.2dB / 6.5dB | 11.0dB / 10.7 dB | 14.8dB / 14.5dB |
| Dense Urban eMBB | 1.12bps/Hz at 30km/h | 7dB / 3.5dB | 13.0dB / 12.8dB | 8.6dB / 8.8dB |
| Rural eMBB | 0.8bps/Hz at 120km/h | 7dB / 1dB | 14.9dB / 15.3dB | 8.6dB / 8.6dB |
| 0.45bps/Hz at 500km/h | 4.5dB / -1dB | 14.9dB / 15.3dB | 8.6dB / 8.6dB |

Note that unlike other contributions, they obtained the required SNRs in the link-level simulation to achieve the required traffic channel link data rates and then, compared them with the achieved SINRs. As shown below, the achieved SINRs are higher than the required SNRs, the traffic channel link data rates can be higher than 1.5, 1.12, 0.8 and 0.45 bps/Hz.

The results from Intel, shown below, indicate that there are several configuration at which the traffic channel link data rate on the uplink, normalized by bandwidth, exceeds the requirements for each of eMBB test environments.

System and Link Level Evaluation Results for Mobility (Intel)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Test Environ-ment | CF | SCS  (kHz) | System Level Results | | | Link Level Results | | |
| 50th % Pre-Processing SINR (dB) | gNB Antenna Configuration  (M,N,P,Mp,Np) | Power Control | Tx Ports (UE) | Rx Ports  (gNB) | Normalized Link Rate  (bits/s/Hz) |
| Indoor Hotspot  10 km/hr | 4 GHz,  12 TRxP  (Config. A) | 15 | 9.5 | (8,8,2,2,2)  DFT beam switching | (0.9,-90) | 2 | 8 | 3.207 |
| 30 | 9.19 | 2.991 |
| 4 GHz,  36 TRxP  (Config. A) | 15 | 3.29 | (16,4,2,2,2)  Single Beam  110 downtilt | 1.776 |
| 30 | 3.18 | 1.773 |
| 30 GHz,  12 TRxP  (Config. B) | 60 | 16.76 | (4,4,2,2,2)  DFT beam switching | (0.8,-70) | 4.484 |
| 120 | 16.43 | 4.270 |
| 30 GHz,  36 TRxP  (Config. B) | 60 | 13.91 | (8,4,2,2,2)  DFT beam switching | (0.7,-80) | 4.127 |
| 120 | 13.29 | 3.905 |
| Dense Urban  30 km/hr | 4 GHz  (Config. A) | 15 | 4.02 | (16,2,2,2,2)  Single Beam  102 downtilt | (0.9,-90) | 1.923 |
| 30 | 3.93 | 1.925 |
| 30 GHz  (Config. B) | 60 | 10.56 | (16,8,2,2,2,2)  DFT beam  switching | (0.7,-80) | 3.216 |
| 120 | 7.82 | 2.665 |
| Rural Macro  120 km/hr | 700 MHz  (Config. A) | 15 | 7.34 | (8,2,2,2,2)  Single Beam  100 downtilt | (0.9,-90) | 2.464 |
| 30 | 7.17 | 2.464 |
| 4 GHz  (Config. B) | 15 | 7.97 | (16,2,2,2,2)  Single Beam  100 downtilt | 2.750 |
| 30 | 7.1 | 2.462 |
| Rural Macro  500 km/hr | 700 MHz  (Config. A) | 15 | 7.34 | (8,2,2,2,2)  Single Beam  100 downtilt | (0.9,-90) | 2.730 |
| 30 | 7.17 | 2.463 |
| 4 GHz  (Config. B) | 15 | 7.97 | (16,2,2,2,2)  Single Beam  100 downtilt | 2.093 |
| 30 | 7.1 | 2.463 |

The results from Nokia, shown below, indicate that the traffic channel link data rate on the uplink, normalized by bandwidth, exceeds the requirements for each of eMBB test environments.

Extracted 50th Percentile SINR , Link SE, and Residual BLER Values (Nokia)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Environment | UE Speed | 50th Percentile SINR | Link SE [bit/s/Hz] | | Residual BLER [%] |
| FDD | TDD |
| Indoor Hotspot – eMBB | 10 km/h | 7.08 dB | 1.84 | 1.50 | 0.2 |
| Dense Urban – eMBB  (1,4,2) Rx Config | 30 km/h | 6.51 dB | 1.56 | 1.28 | < 0.1 |
| Dense Urban – eMBB  (1,2,2) Rx Config | 30 km/h | 6.09 dB | 1.48 | 1.21 | < 0.1 |
| Rural – eMBB | 120 km/h  500km/h | 6.96 dB 6.03 dB | 1.02  0.87 | 0.80  0.68 | 0.1  0.1 |

The results from Samsung, shown below, indicate that the traffic channel link data rate on the uplink, normalized by bandwidth, exceeds the requirements for the Indoor Hotspot-eMBB and Dense Urban-eMBB test environment in 30GHz.

Downlink/Uplink normalized traffic channel link data rate (Samsung)

|  |  |  |
| --- | --- | --- |
| Test environment | Normalized traffic channel link data rate (Bit/s/Hz) | |
| LOS | NLOS |
| Indoor Hotspot – eMBB (DL) | 4.85 | 2.98 |
| Indoor Hotspot – eMBB (UL) | 4.76 | 3.01 |
| Dense Urban – eMBB (DL) | 3.69 | 2.21 |
| Dense Urban – eMBB (UL) | 0.92 | 0.48 |

## A-14 Results of Mobility Interruption Time

Ericsson’s contribution is considered for the evaluation of mobility interruption time. It includes how 0ms mobility interruption time can be achieved in 5G NR.

* In intra-cell beam mobility
* For CA operation, during addition and release of an SCell in response to mobility (no change to PCell).

## A-15 Results of Bandwidth and Scalability

Ericsson’s contribution is considered for the evaluation of bandwidth and scalability. It includes the observation that several 5G NR configurations support bandwidths of 100 MHz and above. The largest component carrier bandwidth is 400 MHz. 5G NR supports carrier aggregation of up to 16 component carriers in which case the supported 5G NR carrier bandwidth exceeds 1 GHz.

Therefore, 3GPP 5G NR meets the 100 MHz and 1 GHz bandwidth requirement and the bandwidth scalability requirement.