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| **Radiocommunication Study Groups** |  |
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| **English only** |
|  | **TECHNOLOGY ASPECTS** |
| Director, Radiocommunication Bureau[[1]](#footnote-1)\* |
| FINAL Revised evaluation results (SPECTRAL EFFICIENCY FOR DENSE URBAN-EMBB AND RURAL-EMBB) from The Fifth Generation Mobile Communications Promotion Forum on the IMT-2020 proposal in Document IMT-2020/18(rev.1) by “Nufront” IN THE EXTENDED IMT-2020 EVALUATION PROCESS |
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This document describes the final updated evaluation result of 5th percentile user spectral efficiency and average spectral efficiency by 5GMF Evaluation Group regarding the IMT-2020 candidate technology submission in Document [IMT-2020/18(Rev.1)](https://www.itu.int/md/R15-IMT.2020-C-0018/en) by “Nufront”. The candidate technology was evaluated as the reset to Step 4 in the extended IMT-2020 evaluation process. The WG Technology Aspects (Option 2) meeting in August 2021 invited Nufront and 5GMF to continue the dialog on the outstanding issues, according to the agreed actions for closure of the process for Working Party (WP) 5D meeting #39. The agreed actions for the technical performance requirements above are described in [Annex 11 to Document 5D/746](https://www.itu.int/dms_ties/itu-r/md/19/wp5d/c/R19-WP5D-C-0746%21N11%21MSW-E.docx).

# 1 Revised evaluation results of 5th Percentile user and Average spectral efficiencies

## 1.1 Source 3 results

The source 3 evaluation has different models and assumptions in the different versions, as summarized in Table 1 below. The other assumptions are as provided in the evaluation report (Attachment B.1 of Document 5D/740). In the latest evaluation, power control parameters and SU- and MU-MIMO configurations are varied considering suggestions from the proponent, and additionally a model for control channel errors is introduced.

Table 1

Models and assumptions in different versions of the results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Result version | Uplink intercell-interference | Scheduler | Power control | SU-MIMO /MU-MIMO  | Control channel modeling |
| Evaluation report in June 2021 (5D/700) | Underestimated, only one interferer per cell | RR | α = 1SNR target = 16 dB | 2-layer SU-MIMO, 4 users MU-MINO | Only overhead |
| Evaluation report in August 2021 (5D/740) | Corrected for Rural | PF for Rural | α = 1SNR target = 16 dB | 2-layer SU-MIMO, 4 users MU-MINO | Only overhead |
| Re-evaluation according to Annex 11 to 5D/764 | Corrected also for Indoor and Dense Urban | PF also for Indoor and Dense Urban | Alpha and SNR target varied | 2-layer SU-MIMO, 4 users MU-MIMO, and4-layer SU-MIMO, 2 users MU-MINO | Only overhead and explicit |
| The baseline parameters for power control are α=1 and SNR target=16 dB. The baseline MIMO parameters are up to 2-layer SU-MIMO and up to 4 users MU-MIMO. |

Baseline parameters, ideal control channel performance

With the corrected inter-cell interference model, baseline power control and MIMO parameters, and ideal control channel performance, the spectral efficiency results are as presented in Table 2.

For the rural environment, these are the same as provide for the revised evaluation report in August meeting (5D/470). For Indoor and Dense urban, the downlink results have improved due to the use of a PF scheduler. In the uplink direction, despite the use of a PF scheduler, the uplink results have reduced due to the corrected intercell interference modeling.

Table 2

Results with baseline power control and MIMO parameters, ideal control channel performance.

|  |  |  |
| --- | --- | --- |
|  | Average SE [bps/Hz/TRxP] | 5th percentile user SE [bps/Hz] |
| Indoor downlink | 5.91 | 0.109 |
| Indoor uplink | 1.44 | 0.047 |
| Dense urban downlink | 8.52 | 0.250 |
| Dense urban uplink | 3.21 | 0.122 |
| Rural downlink | 9.89 | 0.273 |
| Rural uplink | 3.99 | 0.025 |

Baseline parameters, non-ideal control channel performance, normal mode

In the above evaluations, control channels were modeled by means of the overhead they consume. The errors occurring on the control channels and impact of those on spectral efficiency were not taken into account but considered ideal without any errors. This is an acceptable simplification if control channels are very robust, e.g. use very strong channel coding. In the EUHT normal mode, control channels use BPSK or QPSK modulation and are coded with rate ½ or 4/7. To verify if this is robust enough, and the potential impact on spectral efficiency, the downlink SCH and the uplink feedback / signaling channel have been modelled explicitly. In the simulator, the SINRs on these channels are measured, an efficient SNR metric after antenna combination is calculated and mapped to an error probability, and error events are generated. For the CCH, in case of error, the data in the following downlink or uplink frame is also assumed to be in error. For the feedback / signaling channel, the impact on the user plane, and thereby spectral efficiency, is more complex. Anyway, as an option, a simple model where an in the feedback results in an error in the data is used.

Already when including the CCH impact, very large drops are observed in 5th percentile user spectral efficiency for all environments, as well as significant drops in cell average spectral efficiency for the indoor and dense urban environments. None of the 5th percentile user spectral efficiency requirements are reached, and neither are the cell-average spectral efficiencies for Indoor and Dense Urban. When including the impact also on the feedback / signalling channel, the results are further reduced.

Table 3

Results with baseline power control and MIMO parameters, explicit CCH model.

|  |  |  |
| --- | --- | --- |
|  | Average SE [bps/Hz/ TRxP]New result (Baseline result) | 5th percentile user SE [bps/Hz]New result (Baseline result) |
| Indoor downlink | 4.04 (5.91) | 0.000 (0.109) |
| Indoor uplink | 0.78 (1.44) | 0.000 (0.047) |
| Dense urban downlink | 7.55 (8.52) | 0.000 (0.250) |
| Dense urban uplink | 2.45 (3.21) | 0.000 (0.122) |
| Rural downlink | 9.42 (9.89) | 0.004 (0.273) |
| Rural uplink | 3.75 (3.99) | 0.001 (0.025) |

Table 4

Results with baseline power control and MIMO parameters, explicit CCH and feedback/signaling model.

|  |  |  |
| --- | --- | --- |
|  | Average SE [bps/Hz/TRxP]New result (Baseline result) | 5th percentile user SE [bps/Hz]New result (Baseline result) |
| Indoor downlink | 2.26 (5.91) | 0.000 (0.109) |
| Indoor uplink | 0.50 (1.44) | 0.000 (0.047) |
| Dense urban downlink | 5.96 (8.52) | 0.000 (0.250) |
| Dense urban uplink | 2.05 (3.21) | 0.000 (0.122) |
| Rural downlink | 8.33 (9.89) | 0.000 (0.273) |
| Rural uplink | 3.51 (3.99) | 0.000 (0.025) |

### 1.1.1 Rural-eMBB UL (source 3, 4GHz)

Alternative power control parameters, ideal control channel performance

In addition to using the baseline power control parameters, a case with increased SNR target, 26 dB or 62 dB and fractional pathloss compensation, alpha = 0.6 is evaluated. The MIMO configuration is set to the baseline (2-layer SU-MIMO layer and 4 users MU-MIMO). The results are provided in Table 5 below. For comparison the results with baseline power control parameters are also included.

Table 5

Results with alternative power control configuration, ideal control channel performance.

|  |  |  |
| --- | --- | --- |
|  | Average SE [bps/Hz/TRxP] | 5th percentile user SE [bps/Hz] |
| Rural uplink (baseline) | 3.99 | 0.025 |
| Rural uplink (SNR target = 26 dB, 0.6) | 3.97 | 0.015 |
| Rural uplink (SNR target = 62 dB, 0.6) | 3.91 | 0.012 |

Alternative MIMO configurations, ideal control channel performance

In addition to using the baseline MIMO configurations, up to 2-layer SU-MIMO and up to 4 users MU-MIMO (for a total of 2 × 4 = 8 spatial layers), A case with up to 4-layer SU-MIMO and up to 2 users MU-MIMO is evaluated. The power control parameters are set to the baseline. The results are provided in Table 6 below.

Table 6

Results with alternative MIMO configuration, ideal control channel performance.

|  |  |  |
| --- | --- | --- |
|  | Average SE [bps/Hz/TRxP] | 5th percentile user SE [bps/Hz] |
| Rural uplink (baseline) | 3.99 | 0.025 |
| Rural uplink (4-layer SU-MIMO and 2 users MU-MIMO) | 3.89 | 0.026 |

### 1.1.2 Dense Urban-eMBB UL (source 3, 4 GHz)

Alternative power control parameters, ideal control channel performance

In addition to using the baseline power control parameters, a case with increased SNR target, 26 dB or 62 dB and fractional pathloss compensation, alpha = 0.6 is evaluated. The MIMO configuration is set to the baseline (2-layer SU-MIMO and 4 users MU-MIMO). The results are provided in Table 7 below. For comparison the results with baseline power control parameters are also included.

Table 7

Results with alternative power control configuration, ideal control channel performance.

|  |  |  |
| --- | --- | --- |
|  | Average SE [bps/Hz/TRxP] | 5th percentile user SE [bps/Hz] |
| Dense urban uplink (baseline) | 3.21 | 0.122 |
| Dense urban uplink (SNR target=26 dB, 0.6) | 3.54 | 0.018 |
| Dense urban uplink (SNR target=62 dB, 0.6) | 3.23 | 0.000 |

Alternative MIMO configurations, ideal control channel performance

In addition to using the baseline MIMO configurations, up to 2-layer SU-MIMO and up to 4 users MU-MIMO (for a total of 2 × 4 = 8 spatial layers), A case with up to 4-layer SU-MIMO and up to 2 users MU-MIMO is evaluated. The power control parameters are set to the baseline. The results are provided in Table 8 below.

Table 8

Results with alternative MIMO configuration, ideal control channel performance.

|  |  |  |
| --- | --- | --- |
|  | Average SE [bps/Hz/TRxP] | 5th percentile user SE [bps/Hz] |
| Dense urban uplink (baseline) | 3.21 | 0.122 |
| Dense urban uplink (4-layer SU-MIMO and 2 users MU-MIMO) | 3.09 | 0.123 |

### 1.1.3 Dense Urban-eMBB DL (source 3, 4GHz)

Alternative power control parameters, ideal control channel performance

The downlink results are not affected.

Alternative MIMO configurations, ideal control channel performance

In addition to using the baseline MIMO configurations, up to 2-layer SU-MIMO and up to 4 users MU-MIMO (for a total of 2 × 4 = 8 spatial layers), A case with up to 4-layer SU-MIMO and up to 2 users MU-MIMO is evaluated. The power control parameters are set to the baseline. The results are provided in Table 9 below.

Table 9

Results with alternative MIMO configuration, ideal control channel performance.

|  |  |  |
| --- | --- | --- |
|  | Average SE [bps/Hz/TRxP] | 5th percentile user SE [bps/Hz] |
| Dense urban downlink (baseline) | 8.52 | 0.250 |
| Dense urban downlink (4-layer SU-MIMO and 2 users MU-MIMO) | 4.92 | 0.155 |

In the downlink, a large reduction of both cell-average and 5th percentile user spectral efficiency is seen with the alternative MIMO configuration (4-layer SU-MIMO, 2-users MU-MIMO). This is likely because the reduction in the multi-user domain, which leads to halved scheduling opportunities, is not compensated by an increase in data rate when scheduled, which in turn is because the SINR is too low for 4 layers to have an advantage over 2 layers.

## 1.2 Source 4 results

### 1.2.1 Rural-eMBB UL (source 4, 700 MHz)

Alternative power control parameters

In addition to using the baseline power control parameters (P0 −60 dBm, alpha = 0.6) in 5GMF evaluation report (5D/740), a case with increased P0, −46 dBm and fractional pathloss compensation, alpha = 0.6 is evaluated. The other parameters are the same with source 4 in “03 Rural-eMBB-v03.xlsx” in 5GMF evaluation report (5D/740). Please note that the control channel modeling in source 4 does not consider the impact of control channel overhead. The results are provided in Table 10 and Table 11 below. For comparison the results with baseline power control parameters are also included.

Table 10

Results with alternative power control configuration, Channel Mode A.

|  |  |  |
| --- | --- | --- |
|  | Average SE [bps/Hz/TRxP] | 5th percentile user SE [bps/Hz] |
| Rural uplink (P0= −60 dBm, 0.6) | 3.14 | 0.04 |
| Rural uplink (P0= −46 dBm, 0.6) | 4.47 | 0.02 |

Table 11

Results with alternative power control configuration, Channel Mode B.

|  |  |  |
| --- | --- | --- |
|  | Average SE [bps/Hz/TRxP] | 5th percentile user SE [bps/Hz] |
| Rural uplink (P0= −60 dBm, 0.6) | 3.16 | 0.04 |
| Rural uplink (P0=−46 dBm, 0.6) | 4.51 | 0.01 |

# 2 5GMF Observation

In the source 3 re-evaluation, it is seen that the variations in power control and MIMO configurations do not significantly improve the results. The modelling of control channel errors leads to dramatically reduce results, especially for the 5th percentile user spectral efficiency.

In the source 4 re-evaluation, it is seen that the new parameter in power control does not significantly improve the results. One of reasons is that the more inter-cell interference caused by higher transmit power, leads to dramatically reduce the 5th percentile user spectral efficiency.

# 3 Conclusion

5GMF had evaluated again the average spectral efficiency and 5th percentile user spectral efficiency of the candidate technology IMT-2020/18(Rev.1) proposed by “Nufront proponent” after WG Technology Aspects (Option 2) meeting in August 2021. 5GMF provides revised compliance template for the relevant KPIs of average spectral efficiency and 5th percentile user spectral efficiency in Attachment as the conclusion of Step 4 in WP 5D #39.

ATTACHMENT

Revised compliance template for 5th percentile spectral efficiency and Average spectral efficiency

– Only the relevant KPIs for re-evaluation are shown in the compliance template for technical performance (Section 5.2.4.3 of Report ITU-R M.2411-0) below.

 For Source 3 re-evaluation, the results with baseline power control and MIMO parameters, explicit CCH and feedback/signaling model are considered.

| Minimum technical performance requirements item (5.2.4.3.x), units, and ReportITU-R M.2410-0 section reference(1) | Category | Required value | Value(2) | Requirement met? | Comments(3) |
| --- | --- | --- | --- | --- | --- |
| Usage scenario | Test environment | Downlink or uplink |
| 5.2.4.3.45th percentile user spectral efficiency (bit/s/Hz)*(4.4)* |  |  |  |  |  |  |  |
|  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |
| eMBB | Dense Urban – eMBB | Downlink | 0.225 | 0.00~0.284 |  Yes No(Inconclusive) | For evaluation configuration of 4 GHz, Channel model A/B. |
| Uplink | 0.15 | 0.00~0.1 |  Yes🗹 No |
|  |  |  |   |  |
|  |  |  |  |
| eMBB | Rural – eMBB |  |  |  |  | For evaluation configuration of 700 MHz, Channel model A/B. |
| Uplink | 0.045 | 0.04~0.04 |  Yes🗹 No |
|  |  |  |  | For evaluation configuration of 4 GHz, Channel model A/B. |
| Uplink | 0.045 | 0.000~0.002 |  Yes🗹 No |
| 5.2.4.3.5Average spectral efficiency (bit/s/Hz/ TRxP)*(4.5)* |  |  |  |  |  |  |  |
|  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |
| eMBB | Dense Urban – eMBB | Downlink | 7.8  | 6.42~7.74 |  Yes🗹 No | For evaluation configuration of 4 GHz, Channel model A/B. |
| Uplink | 5.4  | 2.05~3.71 |  Yes🗹 No |
|  |  |  |  |  |
|  |  |  |  |
| eMBB | Rural – eMBB |  |  |  |  | For evaluation configuration of 700 MHz, Channel model A/B. |
| Uplink | 1.6 | 3.14~3.16 | 🗹 Yes No |
|  |  |  |  | For evaluation configuration of 4 GHz, Channel model A/B. |
| Uplink | 1.6  | 2.67~3.60 | 🗹 Yes No |

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1. \* Submitted on behalf of The Fifth Generation Mobile Communications Promotion Forum (5GMF). [↑](#footnote-ref-1)