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| **Radiocommunication Study Groups** |  |
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| Received: 16 April 2024Source: Document IMT-2020-SAT/4Subject: Resolution ITU-R 65 | Document 4B/22-E |
| 16 April 2024 |
| English only |
| ETSI |
| Preliminary evaluation Report on the proposed candidate IMT-2020 satellite radio interface TECHNOLOGY in document IMT-2020-SAT/4 |
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This document provides the preliminary evaluation results on IMT-2020 satellite radio interface technology (Satellite IMT-2020 candidate technology) described in Document [IMT-2020-SAT/4](https://www.itu.int/md/R07-IMT.ADV.SAT-C-0004/en) from ETSI as an Independent Evaluation Group (IEG) for the satellite component of IMT-2020.

The attached evaluation report is developed in response to Document [IMT-2020-SAT/2](https://www.itu.int/md/R07-IMT.ADV.SAT-C-0002/en), which provides information regarding the submission and evaluation process and consensus building for the satellite component of IMT-2020.

**Attachment:** 1

Attachment

Preliminary evaluation report on the proposed candidate IMT-2020 satellite radio interface technology in Document IMT-2020-SAT/4

# 1 Introduction

As part of the ongoing process for Satellite IMT-2020, the period from the 54th meeting of Working Party 4B to the 55th meeting of Working Party 4B has been allocated for the evaluation of satellite IMT-2020 candidate technology by Independent Evaluation Groups (IEG).

This document provides the preliminary evaluation results for candidate IMT-2020 satellite radio interface technology in Document [IMT-2020-SAT/4](https://www.itu.int/md/R07-IMT.ADV.SAT-C-0004/en) from ETSI.

# 2 Administrative information of ETSI

## 2.1 Background of ETSI

ETSI has the following terms of reference regarding the satellite component of IMT in the work item DTR/SES-00472 “Satellite Earth Stations & Systems (SES); Independent evaluation of IMT-2020 Satellite Radio Interface proposals” (see <https://portal.etsi.org/webapp/WorkProgram/Report_WorkItem.asp?WKI_ID=69998>):

– Review the Satellite Radio Interface proposals submitted in response to the ITU-R submission and evaluation process for satellite IMT-2020. The proposals may include a self-evaluation report.

– Capture the analytical, inspection and/or simulation evaluation in a Technical Report that would be shared with the ITU-R WP4B in successive versions. The TR should include the work method, the work plan, the simulation calibration approach, and evaluation results.

ETSI was registered as an IEG for the evaluation of satellite IMT-2020 candidate technologies in January 2024. The evaluation tasks for satellite IMT-2020 were conducted by the TC-SES of ETSI, which gathered opinions from multiple participants. These participants represent a diverse range of entities, including are manufacturers, service providers, universities and research institutions. The URL for the TC-SES of ETSI is:

<https://portal.etsi.org/tb.aspx?tbid=162&SubTB=162#/>

This website provides details of the Technical Committee Satellite Earth Stations and Systems of ETSI such as term of reference and contact point.

## 2.2 Process and method of working by ETSI

After the fifty-third bis ITU-R Working Party 4B meeting, ETSI held one face-to-face meeting and engaged in email discussions. During these meetings, ETSI reviewed the self-evaluation report submitted by Alliance for Telecommunications Industry Solutions and discussed evaluation methods and schedules for developing the evaluation report. The detailed schedules for developing the evaluation report were as following:

– 27 March 2024: 1st call to the participants for the preliminary evaluation;

– 17 April 2024: Submission of the preliminary evaluation report to ITU-R.

The preliminary evaluation report was developed based on the contributions from Magister Solutions and Thales. The preliminary results were internally presented, and several on/off-line meetings including e-mail discussions were held to reach the consensus on this report. This preliminary evaluation report provides system simulation based, analytical and inspection based evaluation results. The final evaluation results will be reported at the 55th meeting of Working Party 4B.

This report discusses the discrepancy and validity of the results by comparing them with the self-evaluation results of 3GPP 5G NTN. The results are confirmed by using the same configurations and/or assumptions as those used in the self-evaluation of 3GPP 5G NTN.

For the interaction with other evaluation groups, ETSI will maintain close relationships with other evaluation groups such as SatComForum, ATIS and 5G India Forum by having online or offline discussion meetings. ETSI will present the evaluation results in these on/off-line meetings, and will discuss any discrepancies in the results, and will try to reach the consensus on the evaluation report when the simulation configurations are the same. Based on the discussion results, the evaluation results in this document will be updated, and submitted at the 55th meeting of Working Party 4B.

## 2.3 Contacts for ETSI

For administrative and technical issues related to ETSI, the following individuals can be contacted:

– Administrative contact details:

• Nicolas Chuberre (nicolas.chuberre@thalesaleniaspace.com), Thales, Chairman of Satellite Communication and Navigation working group in TC-SES of ETSI;

– Technical contact details:

• Jani Puttonen (jani.puttonen@magister.fi), Magister Solutions;

• Vesa Hytönen (vesa.hytonen@magister.fi), Magister Solutions;

• Mohamed El Jaafari (mohamed.el-jaafari@thalesaleniaspace.com), Thales.

# 3 Technical evaluation results

## 3.1 Scope of the evaluations

Regarding 3GPP 5G NTN, ETSI performed evaluations on the RIT outlined in the document IMT-2020-SAT/4.

ETSI has evaluated the 3GPP 5G NTN technology to verify the minimum requirements of satellite IMT-2020 as described in Report ITU-R M.2514. In this preliminary report, assessments conducted through system level simulations, analysis and inspection are included. The evaluation results will be incorporated into the final report and submitted to the next WP 4B meeting.

## 3.2 Conformance to Report ITU-R M.2514

ETSI performed the evaluations according to the evaluation methodologies defined in Report ITU‑R M.2514. There are no additionally identified evaluation methodologies.

## 3.3 Qualitative assessment of 3GPP 5G NTN RIT

In Document IMT-2020-SAT/4, WP 4B acknowledges the receipt of the candidate technology submission from Alliance for Telecommunications Industry Solutions. WP 4B has reviewed this candidate submission under the satellite IMT‑2020 process and has determined that the submission is “complete” according to Section 8.2 of Report ITU-R M.2514.

ETSI agrees with the WP 4B view and also confirms the submissions “complete” according to Section 8.2 of Report ITU-R M.2514.

## 3.4 Quantitative assessment of 3GPP 5G NTN RIT

### 3.4.1 Compliance template for Services

|  | Service related minimum capabilities within the RIT/SRIT | Evaluator’s comments |
| --- | --- | --- |
| **3.4.1.1** | **Support of a wide range of services**Does the proposal support a wide range of services?:****YES / ¨NO | *See Annex 2 subclause A2.1* |

### 3.4.2 Compliance template for Spectrum

|  |  |  |
| --- | --- | --- |
|  | Spectrum capability requirements | Evaluator’s comments |
| **3.4.2.1** | **Spectrum bands**Is the proposal able to utilize at least one band identified for IMT?: ****YES / ¨NOSpecify in which band(s) the candidate satellite radio interface(s) can be deployed. | *See Annex 2 subclause A2.2* |

### 3.4.3 Compliance template for Technical Performance

| Minimum technical requirements items | Category | Required value  | Value  | Requirement met? | Comments |
| --- | --- | --- | --- | --- | --- |
| Usage scenario | Test environment | Downlink or uplink |
| Peak data rate | eMBB-s | N/A | Uplink | 2 Mbit/s | 2.6711 Mbit/s | Yes | *See Annex 1 subclause A1.1* |
| Downlink | 70 Mbit/s | 111.330 Mbit/s | Yes |
| Peak spectral efficiency | eMBB-s | N/A | Uplink | 1.5 bit/s/Hz | 1.8549 bit/s/Hz | Yes | *See Annex 1 subclause A1.2* |
| Downlink | 3 bit/s/Hz | 3.7113 bit/s/Hz | Yes |
| User experienced data rate | eMBB-s | Rural | Uplink | 100 kbit/s | 162.55 kbit/s | Yes | *See Annex 1 subclause A1.3* |
| Downlink | 1 Mbit/s | 1.32 Mbit/s | Yes | *See Annex 1 subclause A1.3* |
| 5th percentile user spectral efficiency | eMBB-s | Rural | Uplink | 0.003 bit/s/Hz | 0.0054 bit/s/Hz | Yes | *See Annex 1 subclause A1.4* |
| Downlink | 0.03 bit/s/Hz | 0.044 bit/s/Hz | Yes | *See Annex 1 subclause A1.4* |
| Average spectral efficiency | eMBB-s | Rural | Uplink | 0.1 bit/s/Hz/TRxP | 0.22 bit/s/Hz/TRxP | Yes | *See Annex 1 subclause A1.5* |
| Downlink | 0.5 bit/s/Hz/TRxP | 0.65 bit/s/Hz/TRxP | Yes | *See Annex 1 subclause A1.5* |
| Area traffic capacity | eMBB-s | Rural | Uplink | 1.5 kbit/s/km² | 4.61 kbit/s/ km² | Yes | *See Annex 1 subclause A1.6* |
| Downlink | 8 kbit/s/km² | 13.73 kbit/s/ km² | Yes | *See Annex 1 subclause A1.6* |
| User Plane latency | eMBB-s | N/A | N/A | 10 ms | 6.71 ms | Yes | *See Annex 1 subclause A1.7* |
| Control Plane latency | eMBB-s | N/A | N/A | 40 ms | 22.36 ms | Yes | *See Annex 1 subclause A1.8* |
| Connection density | mMTC-s | Rural | N/A | 500 devices/km² | [TBD] | [TBD] | [TBD] |
| Energy efficiency | eMBB-s | N/A | N/A | High sleep ratio and long sleep duration | [TBD] | [TBD] | [TBD] |
| Reliability | HRC-s | Rural | N/A | 1-10−3 | [TBD] | [TBD] | [TBD] |
| Mobility – UE speed | eMBB-s | Rural | N/A | 250 km/h | [TBD] | [TBD] | [TBD] |
| Mobility - Traffic channel link data rate | eMBB-s | Rural | N/A | 0.005 bit/s/Hz | [TBD] | [TBD] | [TBD] |
| Mobility interruption time | eMBB-s | N/A | N/A | 50 ms | 0 ms | Yes | See Annex 1 subclause A1.9 |
| Bandwidth | N/A | N/A | N/A | At least up to and including 30 MHz | 30 MHz | Yes | *See Annex 2 subclause A2.4* |

## 3.5 Questions and feedback to Working Party 4B and/or the proponents or other Independent Evaluation Groups

No further question.

## 3.6 Conclusion

The evaluation results in this report show that 3GPP NTN RIT [meets] the minimum requirement of satellite IMT-2020 technology. Therefore, ETSI confirms that the 3GPP NTN RIT proposed by Alliance for Telecommunications Industry Solutions [meets] the minimum requirements of satellite IMT-2020 technology.

# 4 List of acronyms and abbreviations

|  |  |
| --- | --- |
|  |  |
| 3GPP | 3rd Generation Partnership Project |
| AMC | Adaptive Modulation and Coding |
| BLER | Block Error Rate |
| BS | Base Station |
| DL | Downlink |
| eMBB-s | Enhanced Mobile Broadband - satellite |
| FDD | Frequency Division Duplex |
| GBR | Grant Bit Rates  |
| GEO | Geostationary Earth Orbit |
| HARQ | Hybrid Automatic Request |
| HO | Handover |
| HRC-s | High Reliable Communication - satellite |
| IEG | Independent Evaluation Group |
| IMT | International Mobile Telecommunications |
| ITU-R | International Telecommunication Union – Radiocommunication Sector  |
| L1 | Layer 1 |
| L2 | Layer 2 |
| LEO | Low Earth Orbit |
| mMTC-s | Massive Machine Type Communication - satellite |
| NTN | Non-Terrestrial Network |
| NR | New Radio |
| OFDM | Orthogonal Frequency Division Modulation |
| PBCH | Physical Broadcasting Channel |
| PDSCH | Physical Downlink Shared Channel |
| PRACH | Physical Random Access Channel |
| PUSCH | Physical Uplink Shared Channel |
| QAM | Quadrature Amplitude Modulation |
| QoS | Quality of Service |
| RB | Resource Block |
| RA | Random Access |
| RIT | Radio Interface Technology |
| RRC | Radio Resource Control |
| SAN | Satellite Access Network |
| SDU | Service Data Unit |
| SRIT | Set of Radio Interface Technologies |
| SRS | Sounding Reference Signal |
| TD | Transmission Delay |
| TTI | Transmission Time Interval |
| UE | User Equipment |
| UL | Uplink |

Annex 1

Analytical evaluation results

## A1.1 Peak spectral efficiency calculation

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| *According to Report ITU-R M.2514, peak spectral efficiency is defined as the maximum data rate under ideal conditions normalized by the assigned bandwidth (in bit/s/Hz), where the maximum data rate is the received data bits assignable to a single mobile station, when up to 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 and guard bands).**The peak spectral efficiency can be calculated by the following formula:*$$SE\_{peak}=\frac{v\_{layers}×Q\_{m}×f×R\_{max}×(1-R\_{OH})×N\_{PRB}×N\_{SC}×\frac{10^{-3}}{N\_{sym}×2^{μ}}}{BW}$$*The system configuration and assumptions based on Report ITU-R M.2514 are provided below:**– Control overhead is the ratio of resource elements (REs) used for L1/L2 control, Synchronization Signal, PBCH, reference signal, etc.over the total number of the Res for the effective bandwidth. Overhead ratio is 0.14 for downlink and 0.08 for uplink (*$R\_{OH}$*)**– Duplexing mode is FDD**– Maximum number of layers is one* ($v\_{layers}$)*– Modulation order is 64QAM for downlink and 16QAM for uplink (*$Q\_{m}$*). The respective maximum code rates are 822/1024 for downlink and 553/1024 for uplink (*$R\_{max}$*)**– Numerology is 0 (*$μ$*), i.e. 12 subcarriers/PRB (*$N\_{SC}$*), 14 symbols/slot (*$N\_{sym}$*) and 1 ms slot duration**– Total system bandwidth per physical layer shared channel is 30 MHz /160 PRBs. The evaluation assumes the whole bandwidth of 160 PRBs/30 MHz (*$N\_{PRB}$*/* $BW$*) is assigned to UE in downlink, while for uplink, the assignable bandwidth is 8 PRBs/1.44 MHz due to transmission power limitation of the UE.**– The scaling factor is 1.0 (*$f$*)**By using the above formula and assumptions, the peak spectral efficiency for downlink and uplink are provided below:**Downlink:*$$\frac{1 [v\_{layers}]×6 [Q\_{m}]×1 [f]×\frac{822}{1024}[R\_{max}]×(1-0.14 [R\_{OH}])×160 [N\_{PRB}]×12 [N\_{SC}]× \frac{10^{-3}}{14 [N\_{sym}]×2^{0 [μ]}}}{30×10^{6}}$$$$=3.7113 bit/s/Hz$$*Uplink:*$$\frac{1 [v\_{layers}]×4 [Q\_{m}]×1 [f]×\frac{553}{1024}[R\_{max}]×(1-0.08 [R\_{OH}])×8 [N\_{PRB}]×12 [N\_{SC}]× \frac{10^{-3}}{14 [N\_{sym}]×2^{0 [μ]}}}{1.44×10^{6}}$$$$=1.8549 bit/s/Hz$$ |

Based on the above evaluation results, it is confirmed that the proposed RIT meets the minimum requirement for peak spectral efficiency which is 3 bit/s/Hz for DL and 1.5 bit/s/Hz for UL, respectively.

## A1.2 Peak data rate calculation

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| *According to ITU-R Report M.2514, peak data rate is defined as the maximum achievable data rate under ideal conditions, which is the received data bits assignable to a single mobile station, when up to 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).**For the peak data rate calculation, based on the system configuration in ITU-R M.2514, the same assumptions can be used as in the calculation of the peak spectral efficiency. Thus, the peak data rate can be calculated by:*$$R\_{peak}=SE\_{peak}×BW$$*where:*$SE\_{peak}$ *is the peak spectral efficiency calculated in subclause A1.1* *BW is the assignable system bandwidth, namely 30 MHz for downlink and 1.44 MHz for uplink.**By using the above formula and assumptions, the peak data rate for downlink and uplink are provided below:**Downlink:*$$3.7113 [SE\_{peak}]×30 \left[BW\right]=111.330 Mbit/s$$*Uplink:*$$1.8549 [SE\_{peak}]×1.44 \left[BW\right]=2.6711 Mbit/s$$ |

Based on the above evaluation results, it is confirmed that the proposed RIT meets the minimum requirement for peak data rate which is 70 Mbit/s for DL and 2 Mbit/s for UL, respectively.

## A1.3 User experienced data rate

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| *According to Report ITU-R M.2514, user experienced data rate is the 5% point of the cumulative distribution function (CDF) of the user throughput. User throughput (during active time) is defined as the number of correctly received bits, i.e. the number of bits contained in the service data units (SDUs) delivered to Layer 3, over a certain* *period of time.**User experienced data rate for NR satellite access is evaluated under Rural – eMBB test environment. Detailed evaluation assumptions can be found in ANNEX 4 Evaluation assumptions*.*Based on the definition in Report ITU-R M.2514 and system configuration information provided by the proponent, the results of the peak data rate are given in the below tables A-1 and A-2 for DL and UL, respectively.**Table A-1**Evaluation results of DL user experienced data rate for NR satellite access*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Scintillation loss*** | ***Number of UE antennas*** | ***Frequency reuse factor*** | ***ITU Requirement (Mbit/s)*** | ***DL user experienced data rate (Mbit/s)*** |
| *2.2 dB* | *2* | *FRF = 1* | *1* | *1.264* |
| *FRF = 3* | *1* | *1.000* |
| *0 dB* | *2* | *FRF = 1* | *1* | *1.319* |
| *FRF = 3* | *1* | *1.097* |

*Table A-2**Evaluation results of UL user experienced data rate for NR satellite access*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Scintillation loss*** | ***Number of UE antennas*** | ***Frequency reuse factor*** | ***ITU Requirement (Mbit/s)*** | ***UL user experienced data rate (Mbit/s)*** |
| *2.2 dB* | *2* | *FRF = 1* | *0.1* | *0.121* |
| *FRF = 3* | *0.1* | *0.243* |
| *0 dB* | *2* | *FRF = 1* | *0.1* | *0.163* |
| *FRF = 3* | *0.1* | *0.334* |

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Based on the above evaluation results as well as independent preliminary simulation results provided in Annex 4 – *Evaluation assumptions*, it is confirmed that the proposed RIT meets the minimum requirement for user experienced data rate which is at least 1 Mbps for DL and 0.1 Mbps for UL, respectively.

## A1.4 5th percentile user spectral efficiency

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| *According to Report ITU-R M.2514, the 5th percentile user spectral efficiency is the 5% point of the CDF of the normalized user throughput. The normalized user throughput is defined as the number of correctly received bits, i.e.* *the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time, divided by the channel bandwidth, and is measured in bit/s/Hz.**As requested by Report ITU-R M.2514, the 5th percentile user spectral efficiency should be assessed together with the average spectral efficiency. Therefore, the joint results are provided in subclause A1.5.* |

## A1.5 Average spectral efficiency

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| *According to Report ITU-R M.2514, the average spectral efficiency is the aggregate throughput of all users (the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time) divided by the channel bandwidth of a specific band divided by the number of TRxPs and is measured* *in bit/s/Hz/TRxP.**As per Report ITU-R M.2514, a TRxP (transmission and reception point) refers to a beam generated by the satellite and the channel bandwidth for average spectral efficiency evaluation is defined as the effective bandwidth times the frequency reuse factor.**The 5th percentile user spectral efficiency and the user experienced data rate for NR satellite access are evaluated under Rural – eMBB test environment. Detailed evaluation assumptions can be found in Annex 4.**Based on the definition in Report ITU-R M.2514 and system configuration information provided by the proponent, the results of the 5th percentile user spectral efficiency and the average spectral efficiency are given in the below Tables A-3 and A-4 for DL and UL, respectively.**Table A-3**Evaluation results of DL spectral efficiency for NR satellite access*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Scintillation loss*** | ***Number of UE antennas*** | ***Frequency reuse factor*** | ***ITU Requirement*** | ***DL Spectral efficiency*** |
| *2.2 dB* | *2* | *FRF = 1* | *Average [bit/s/Hz/TRxP]* | *0.500* | *0.634* |
| *5th percentile [bit/s/Hz]* | *0.030* | *0.042* |
| *FRF = 3* | *Average [bit/s/Hz/TRxP]* | *0.500* | *0.513* |
| *5th percentile [bit/s/Hz]* | *0.030* | *0.033* |
| *0 dB* | *2* | *FRF = 1* | *Average [bit/s/Hz/TRxP]* | *0.500* | *0.648* |
| *5th percentile [bit/s/Hz]* | *0.030* | *0.044* |
| *FRF = 3* | *Average [bit/s/Hz/TRxP]* | *0.500* | *0.547* |
| *5th percentile [bit/s/Hz]* | *0.030* | *0.037* |

*Table A-4**Evaluation results of UL spectral efficiency for NR satellite access*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Scintillation loss*** | ***Number of UE antennas*** | ***Frequency reuse factor*** | ***ITU Requirement*** | ***UL Spectral efficiency*** |
| *2.2 dB* | *2* | *FRF = 1* | *Average [bit/s/Hz/TRxP]* | *0.100* | *0.175* |
| *5th percentile [bit/s/Hz]* | *0.003* | *0.004* |
| *FRF = 3* | *Average [bit/s/Hz/TRxP]* | *0.100* | *0.202* |
| *5th percentile [bit/s/Hz]* | *0.003* | *0.008* |
| *0 dB* | *2* | *FRF = 1* | *Average [bit/s/Hz/TRxP]* | *0.100* | *0.217* |
| *5th percentile [bit/s/Hz]* | *0.003* | *0.005* |
| *FRF = 3* | *Average [bit/s/Hz/TRxP]* | *0.100* | *0.256* |
| *5th percentile [bit/s/Hz]* | *0.003* | *0.011* |

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Based on the above evaluation results, it is confirmed that the proposed RIT meets the minimum requirement for 5th percentile user spectral efficiency which is 0.03 bits/s/Hz for DL and 0.003 bits/s/Hz for UL, respectively. Moreover, the proposed RIT meets the minimum requirement for average spectral efficiency which is 0.5 bits/s/Hz/TRxP for DL and 0.1 bits/s/Hz/TRxP for UL, respectively.

## A1.6 Area traffic capacity

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| *According to Report ITU-R M.2514, the area traffic capacity is the total traffic throughput served per geographic area (in Mbit/s/km2). 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 is evaluated under Rural – eMBB test environment, based on the total traffic throughput of the network and a beam coverage area of 1 415 km2 (corresponding to approximately 50 km diameter beam footprint). Detailed evaluation assumptions can be found in Annex 4.* *Based on the definition in Report ITU-R M.2514 and system configuration information provided by the proponent, the results of the area traffic capacity are given in the below tables A-5 and A-6 for DL and UL, respectively.**Table A-5**Evaluation results of DL area traffic capacity for NR satellite access*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Scintillation loss*** | ***Number of UE antennas*** | ***Frequency reuse factor*** | ***ITU Requirement (kbit/s/km2)*** | ***DL area traffic capacity (kbit/s/km2)*** |
| *2.2 dB* | *2* | *FRF = 1* | *8* | *13.44* |
| *FRF = 3* | *8* | *10.87* |
| *0 dB* | *2* | *FRF = 1* | *8* | *13.73* |
| *FRF = 3* | *8* | *11.60* |

*Table A-6**Evaluation results of uL area traffic capacity for NR satellite access*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Scintillation loss*** | ***Number of UE antennas*** | ***Frequency reuse factor*** | ***ITU Requirement (kbit/s/km2)*** | ***UL area traffic capacity (kbit/s/km2)*** |
| *2.2 dB* | *2* | *FRF = 1* | *1.5* | *3.71* |
| *FRF = 3* | *1.5* | *4.28* |
| *0 dB* | *2* | *FRF = 1* | *1.5* | *4.61* |
| *FRF = 3* | *1.5* | *5.12* |

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Based on the above evaluation results, it is confirmed that the proposed RIT meets the minimum requirement for area traffic capacity which is 8 kbit/s/km2 for DL and 1.5 kbit/s/km2 for UL respectively.

## A1.7 User plane latency calculation

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to Report ITU-R M.2514, 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.**For the NR satellite access user plane latency evaluation, the following assumptions are considered:**– It is assumed that the packet arrives at any time of any OFDM symbol. For the maximum symbol alignment time, one symbol length is added at the beginning of the procedure.* *– The transmission of PDCCH, PDSCH, PUCCH, PUSCH cannot be across the slot. Otherwise, the transmission will wait for the next slot.**– The PDSCH/PUSCH allocation assumes slot-based scheduling.**– Resource mapping type A is considered.**– UE processing capability 1 is considered.**– The subcarrier spacing is 15 kHz.**– It is assumed that PDCCH monitoring occasion occurs at every OFDM symbol in the evaluation.**– It is assumed that HARQ feedback is disabled, i.e., packet retransmissions are not considered.**– It is assumed that an initial error probability is 0.**– It is assumed that satellite on-board delay can be considered negligible.**– Grant-free allocation is assumed in uplink.**The calculation of the user plane latency in downlink direction is provided in Table A-7, based on the above assumptions.**Table A-7**Downlink user plane latency for NR satellite access for LEO satellite at 600 km altitude*

|  |  |
| --- | --- |
| ***Description*** | ***Duration (ms)*** |
| *Initial symbol alignment* | *0.0714* |
| *gNB processing delay:*$t\_{BS,tx}=T\_{proc,2}/2$*, where* $T\_{proc,2}$ *is defined in TS 38.214, Section 6.4, with* $N\_{2}=10$ *,* $d\_{2,1}=d\_{2}=d\_{2,2}=T\_{ext}=T\_{switch}=0$ *and* $κ=64.$ | *0.3568* |
| *Downlink frame alignment, assuming 1 ms slot duration:* $t\_{FA,DL}$ | *1* |
| *TTI for downlink data packet transmission:* $t\_{DL\\_duration}$ | *1* |
| *One way propagation delay:* $t\_{prop}=RTD/2$*, where* $RTD=8 ms$ *as per minimum round-trip delay for LEO satellite at 600 km altitude, transparent payload, defined in TR 38.821, Table 7.1.1*  | *4* |
| *UE processing delay:*$t\_{UE,rx}=T\_{proc,1}/2$*, where* $T\_{proc,1}$ *is defined in TS 38.214, Section 5.3, with* $N\_{1}=8$ *,* $d\_{1,1}=d\_{2}=T\_{ext}=0$ *and* $κ=64.$ | *0.2854* |
| *Total one-way user plane latency:* $T\_{1}=t\_{BS,tx}+t\_{FA,DL}+t\_{DL\\_duration}+t\_{prop}+t\_{UE,rx}$ | *6.7136* |

*The calculation of the user plane latency in uplink direction is provided in Table A-8, based on the above assumptions.**Table A-8**Uplink user plane latency for NR satellite access for LEO satellite at 600 km altitude*

|  |  |
| --- | --- |
| ***Description*** | ***Duration (ms)*** |
| *Initial symbol alignment* | *0.0714* |
| *UE processing delay:*$t\_{UE,tx}=T\_{proc,2}/2$*, where* $T\_{proc,2}$ *is defined in TS 38.214, Section 6.4, with* $N\_{2}=10$ *,* $d\_{2,1}=d\_{2}=d\_{2,2}=T\_{ext}=T\_{switch}=0$ *and* $κ=64.$ | *0.3568* |
| *Uplink frame alignment, assuming 1 ms slot duration:* $t\_{FA,UL}$ | *1* |
| *TTI for uplink data packet transmission:* $t\_{UL\\_duration}$ | *1* |
| *One way propagation delay:* $t\_{prop}=RTD/2$*, where* $RTD=8 ms$ *as per minimum round-trip delay for LEO satellite at 600 km altitude, transparent payload, defined in TR 38.821, Table 7.1.1*  | *4* |
| *gNb processing delay:*$t\_{BS,rx}=T\_{proc,1}/2$*, where* $T\_{proc,1}$ *is defined in TS 38.214, Section 5.3, with* $N\_{1}=8$ *,* $d\_{1,1}=d\_{2}=T\_{ext}=0$ *and* $κ=64.$ | *0.2854* |
| *Total one-way user plane latency:* $T\_{1}=t\_{UE,tx}+t\_{FA,UL}+t\_{UL\\_duration}+t\_{prop}+t\_{BS,rx}$ | *6.7136* |

*In addition to the above calculations for the 600 km altitude LEO satellite, the calculations for the user plane latency for GEO satellite with transparent payload at 35786 km altitude are provided in Table A-9 and A-10 for downlink and uplink, respectively.**Table A-9**Downlink user plane latency for NR satellite access for GEO satellite at 35786 km altitude*

|  |  |
| --- | --- |
| ***Description*** | ***Duration (ms)*** |
| *One way propagation delay:* $t\_{prop}=RTD/2$*, where* $RTD=477.48 ms$ *as per minimum round-trip delay for GEO satellite at 35786 km altitude, transparent payload, defined in TR 38.821, Table 7.1.1*  | *238.74* |
| *Total one-way user plane latency:* $T\_{1}=t\_{BS,tx}+t\_{FA,DL}+t\_{DL\\_duration}+t\_{prop}+t\_{UE,rx}$ | *241.4536* |

*Table A-10**Uplink user plane latency for NR satellite access for GEO satellite at 35786 km altitude*

|  |  |
| --- | --- |
| ***Description*** | ***Duration (ms)*** |
| *One way propagation delay:* $t\_{prop}=RTD/2$*, where* $RTD=477.48 ms$ *as per minimum round-trip delay for GEO satellite at 35786 km altitude, transparent payload, defined in TR 38.821, Table 7.1.1*  | *238.74* |
| *Total one-way user plane latency:* $T\_{1}=t\_{BS,tx}+t\_{FA,DL}+t\_{DL\\_duration}+t\_{prop}+t\_{UE,rx}$ | *241.4536* |

 |

Based on the above evaluation results, it is confirmed that with LEO satellite at 600 km altitude, the proposed RIT meets the minimum requirement for user plane latency which is 10ms for both downlink and uplink.

## A1.8 Control plane latency calculation

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to Report ITU-R M.2514, 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).**In the context of 5G NR satellite access, the respective states are RRC\_IDLE or RRC\_INACTIVE and RRC\_CONNECTED. The control plane latency is evaluated from RRC\_INACTIVE to RRC\_CONNECTED transition. The following additional assumptions are considered in the evaluation:**– Resource mapping type A is assumed.**– UE processing capability 1 is assumed.**– The subcarrier spacing is 15 kHz.**– 2-step random access is used.**– Satellite on-board delay is considered negligible.**The calculation of the control plane latency based on the assumptions above is provided in Table A-11.**Table A-11**Control plane latency for NR satellite access for LEO satellite at 600 km altitude*

|  |  |
| --- | --- |
| ***Description*** | ***Duration (ms)*** |
| *Delay due to RACH scheduling period. It is assumed that the transition procedure begins from the transmission of RACH preamble, thus RACH scheduling period can be ignored.* | *0* |
| *UE processing delay for L1 encoding of RRC Resume Request:*$t\_{UE,tx}=T\_{proc,2}/2$*, where* $T\_{proc,2}$ *is defined in TS 38.214, Section 6.4, with* $N\_{2}=10$ *,* $d\_{2,1}=d\_{2}=d\_{2,2}=T\_{ext}=T\_{switch}=0$ *and* $κ=64.$ | *0.3568* |
| *Transmission of RACH preamble:* $t\_{tx,preamble}$ | *1* |
| *PRACH-to-PUSCH offset:* $t\_{PUSCH\\_offset}$*Given that the RACH preamble transmission is 14 symbols and the minimum time between PRACH and PUSCH for MsgA is 2 OFDM symbols for* $μ=0$*, at least one slot offset should be considered between PRACH and PUSCH, as defined by* *msgA-PUSCH-TimeDomainOffset.* | *1* |
| *Transmission of PUSCH payload:* $t\_{tx,PUSCH}$ | *1* |
| *One way propagation delay, UE  gNB:* $t\_{prop}=RTD/2$*, where* $RTD=8 ms$ *as per minimum round-trip delay for LEO satellite at 600 km altitude, transparent payload, defined in TR 38.821, Table 7.1.1*  | *4* |
| *MsgA detection and processing delay in gNB (preamble, L2 and RRC):* $t\_{BS,rx}$ | *3* |
| *Transmission of MsgB:* $t\_{tx,MsgB}$ | *1* |
| *One way propagation delay, gNB  UE:* $t\_{prop}=RTD/2$ | *4* |
| *UE processing delay of RRC Resume, including RA Response:* $t\_{UE,rx}$ | *7* |
| *Transmission of RRC Resume Complete and data* | *0* |
| *Total control plane latency:*$$T=t\_{UE,tx}+t\_{tx,preamble}+t\_{PUSCH\\_offset}+t\_{tx,PUSCH}+t\_{prop}+t\_{BS,rx}+t\_{tx,MsgB}+t\_{prop}+t\_{UE,rx}$$ | *22.3568* |

 |

Based on the above evaluation results, it is confirmed that with LEO satellite at 600 km altitude, the proposed RIT meets the minimum requirement for control plane latency which is 40 ms.

## A1.9 Mobility Interruption Time

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to Report ITU-R M.2514, mobility interruption time is the shortest time duration supported by the system during which a user terminal cannot exchange user plane packets with any satellite and/or gateway node during* *transitions.**The mobility interruption time includes the time required to execute any radio access network procedure, radio resource control signalling protocol, or other message exchanges between the mobile station and the radio access network, as applicable to the candidate RIT/SRIT.**Beam-based mobility without cell and satellite switch is controlled by the beam management procedure standardized for 5G NR and is applicable to NR-NTN. Beam management allows the gNB to dynamically change the beam used for user plane communication, without involvement of higher layer signalling. For downlink data transmission on PDSCH, the gNB configures used beam on per-slot basis via Transmission Configuration Indication (TCI), which enables interruption-free service for intra-cell mobility. For uplink data transmission on PUSCH, the gNB can indicate a Sounding Reference Signal Resource Indication (SRI) in each uplink resource grant separately, which is used for dynamic beam selection per-slot basis.**In case a conventional break-before-make handover procedure is used, the connection to the source cell is first terminated by the terminal upon reception of a handover command from the gNB, followed by a synchronization and random access signaling with the target cell. The mobility interruption time spans from the connection termination to the transmission of RRC Reconfiguration Complete message towards the target cell, indicating the end of the handover process. The following assumptions are used for evaluation of the mobility interruption time for break-before-make handover:**– For cell synchronization, SSB periodicity is assumed 20 ms.**– Two-step random access is assumed, reusing the parameters given in subclause A1.8.**– User plane data is buffered in the target cell prior the completion of the handover process.**Table A-12**Mobility interruption time for break-before-make handover*

|  |  |
| --- | --- |
| ***Description*** | ***Duration (ms)*** |
| *Synchronization with the target cell:* $t\_{synch}$ | *20* |
| *Random access procedure, obtained from subclause A1.9:* $t\_{RA}$ | *22.3568* |
| *UE processing delay for L1 encoding of RRC Connection Complete:*$t\_{UE,tx}=T\_{proc,2}/2$*, where* $T\_{proc,2}$ *is defined in TS 38.214, Section 6.4, with* $N\_{2}=10$ *,* $d\_{2,1}=d\_{2}=d\_{2,2}=T\_{ext}=T\_{switch}=0$ *and* $κ=64.$ | *0.3568* |
| *Transmission of RRC Connection Complete:* $t\_{tx}$ | *1* |
| *One way propagation delay, UE  gNB:* $t\_{prop}=RTD/2$*, where* $RTD=8 ms$ *as per minimum round-trip delay for LEO satellite at 600 km altitude, transparent payload, defined in TR 38.821, Table 7.1.1*  | *4* |
| *gNb processing delay:*$t\_{BS,rx}=T\_{proc,1}/2$*, where* $T\_{proc,1}$ *is defined in TS 38.214, Section 5.3, with* $N\_{1}=8$ *,* $d\_{1,1}=d\_{2}=T\_{ext}=0$ *and* $κ=64.$ | *0.2854* |
| *Total mobility interruption time:* $t\_{synch}+t\_{RA}+t\_{UE,tx}+t\_{tx}+t\_{prop}+t\_{BS,rx}$ | *47.999* |

 |

Based on the above evaluation results, it is confirmed that with LEO satellite at 600 km altitude, the proposed RIT meets the minimum requirement for mobility interruption time which is 50 ms.

Annex 2

Inspection evaluation results

## A2.1 Support of a wide range of services

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Services**3GPP NR NTN RIT can support eMBB-s, HRC-s and mMTC-s usage scenarios, considering that self-evaluation results show it can meet the minimum technical performance requirement for the three test environment in eMBB-s, HRC-s and mMTC-s.**Furthermore, the Quality of Service (QoS) framework of NR NTN RIT allows the support of a wide range of services. In the NR NTN RIT, a bearer is the level of granularity for QoS control. Each bearer can be associated with several QoS parameters, e.g.:**Table A-13**5QI (5G QoS Identifier) Example*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***5QI*value** | ***Resource*type** | ***Packet delay budget*** | ***Packet error loss rate*** | ***Example services*** |
| *1* | *GBR* | *100 ms* | *10-2* | *Conversational Voice* |
| *2* | *150 ms* | *10-3* | *Conversational Video (Live Streaming)* |
| *3* | *50 ms* | *10-3* | *Real time gaming, V2X messge, etc* |
| *4* | *300 ms* | *10-6* | *Non-Conversational Video (Buffered Streaming)* |
| *…* | *…* | *…* | *…* |
| *5* | *Non-GBR* | *100 ms* | *10-6* | *IMS Signalling* |
| *6* | *300 ms* | *10-6* | *Video (Buffered Streaming), TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)* |
| *7* | *100 ms* | *10-3* | *Voice, Video (Live Streaming), Interactive Gaming* |
| *8* | *300 ms* | *10-6* | *Video (Buffered Streaming), TCP-based (e.g., www, e-mail, chat, ftp, p2p file* |
| *…* | *…* | *…* | *…* |
| *82* | *Delay Critical GBR* | *10 ms* | *10-4* | *Discrete Automation, V2X message* |
| *83* | *10 ms* | *10-4* | *Intelligent transport systems* |
| *84* | *30 ms* | *10-5* | *Electricity Distribution High Voltage* |
| *…* | *…* | *…* | *…* |

*The configuration of those QoS parameters, allows the 3GPP NR NTN RIT to support a wide range of services. In particular, it can support basic conversational service class, rich conversational service class and conversational low delay service class. In addition, it is also able to support the service classes of interactive high delay, interactive low delay, streaming live, streaming non-live and background under the consideration of satellite-specific transmission delay.* |

Based on the above information provided by the proponent, it is confirmed by inspection that the proposed RIT meets the requirements for the service related minimum capabilities (the support of a wide range service).

## A2.2 Spectrum bands

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***The frequency bands supported by the RIT****The following frequency band is currently mentioned by the proponent. The frequency bands are identified for the use by the satellite component of IMT through provisions of RR No.* ***5.388*** *and Resolution* ***212*** *(****Rev.WRC-07****).**Table A-14**Operating bands in FR1*

|  |  |  |  |
| --- | --- | --- | --- |
| ***Satellite operating band*** | ***Uplink (UL) operating bandSAN receive / UE transmitFUL,low – FUL,high*** | ***Downlink (DL) operating bandSAN transmit / UE receiveFDL,low – FDL,high*** | ***Duplex mode*** |
| *n256* | *1 980 MHz – 2 010 MHz* | *2 170 MHz – 2 200 MHz* | *FDD* |
| *n255* | *1 626.5 MHz – 1 660.5 MHz* | *1 525 MHz – 1 559 MHz* | *FDD* |
| *n254* | *1 610 MHz – 1 626.5 MHz* | *2 483.5 MHz – 2 500 MHz* | *FDD* |
| *NOTE: Satellite bands are numbered in descending order from n256.* |

 |

Based on the above evaluation results, it was confirmed by inspection that the proposed RIT supports deployment in one of bands identified for satellite IMT in ITU-R Radio Regulations and meets the spectrum capability requirements.

## A2.3 Energy efficiency

Yet to be evaluated

## A2.4 Bandwidth

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Channel bandwidth scalability**One component carrier in the NR NTN RIT supports a scalable bandwidth, 5, 10, 15, 20 and 30 MHz. By aggregating multiple component carriers, more transmission bandwidths are supported to provide the highest data rates. Component carriers can be either contiguous or non-contiguous in the frequency domain. The number of component carriers transmitted and/or received by a mobile terminal can vary over time depending on the instantaneous data rate.**Table A-15**Transmission bandwidth configuration NRB in FR1*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***SCS (kHz)*** | ***5 MHz*** | ***10 MHz*** | ***15 MHz*** | ***20 MHz*** | ***30 MHz*** |
| ***NRB*** | ***NRB*** | ***NRB*** | ***NRB*** | ***NRB*** |
| *15* | *25* | *52* | *79* | *106* | *160* |
| *30* | *11* | *24* | *38* | *51* | *78* |
| *60* | *N/A* | *11* | *18* | *24* | *38* |

 |

Based on the above evaluation results, it is confirmed by inspection that the proposed RIT supports up to and including 30 MHz bandwidth.

Annex 3

Calibration assumptions and results

In order to validate the system level simulator performance, calibration of the models was performed for scenario 9 (FRF-1) and scenario 10 (FRF-3) with the assumptions based on the 3GPP TR 38.821 specification. The calibration metrics used for the evaluation were DL geometry SINR and SIR and coupling loss. The results were compared to a set of calibration results provided by different 3GPP entities for the self-evaluation towards IMT-2020.

The calibration assumptions and the results can be found in the attached document **A.3\_Calibration.xlsx**.

Annex 4

Evaluation assumptions

The detailed evaluation assumptions and the results can be found in the attached document **A.4\_eMBB\_SE\_UserExpDataRate\_AreaTrafCap.xlsx**.

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