|  |  |
| --- | --- |
| **Radiocommunication Study Groups** |  |
|  |  |
|  |  |
| Received: 4 October 2024Source: Document IMT-2020-SAT/4Subject: Resolution ITU-R 65 | Document 4B/78-E |
| 4 October 2024 |
| English only |
| ETSI |
| FINAL evaluation Report on the proposed candidate IMT-2020 satellite radio interface technoLogy in document IMT-2020-SAT/4 |
|  |

This document provides the final evaluation results on IMT-2020 satellite radio interface technology (Satellite IMT-2020 candidate technology) described in document IMT-2020-SAT/4 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, which provides information regarding the submission and evaluation process and consensus building for the satellite component of IMT-2020.

**Attachment**: 1

Attachment

Final 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 final evaluation results for candidate IMT-2020 satellite radio interface technology in Document IMT-2020-SAT/4 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 Technical Committee-Satellite Earth Station and systems (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 points.

## 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 (ATIS) 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;

– 11 April 2024: Submission of the preliminary evaluation report to ITU-R;

– 28 August 2024: Review of a revised preliminary evaluation report for ITU-R;

– 16 September 2024: Start review by correspondence of a pre final evaluation report for ITU-R;

– 30 September 2024: Agreement on a final evaluation report for ITU-R;

– 4th October 2024: Submission of the final evaluation report to ITU-R.

The final evaluation report was developed based on the contributions from Magister Solutions and Thales (with support of the European Space Agency), as well as from Ericsson. 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 evaluation report provides system simulation based, analytical and inspection based evaluation results. The final evaluation results are 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 has maintained close relationships with other evaluation groups such as SatComForum, ATIS and 5G India Forum by having online or offline discussion meetings. ETSI has presented the evaluation results in these on/off-line meetings, discussed any discrepancies in the results, and reached the consensus on the evaluation report when the simulation configurations are the same. Based on the discussion results, the evaluation results in this document have been 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, Chair of Satellite Communication and Navigation working group in TC-SES of ETSI.

– Technical contact details:

• Kimmo Kaario (kimmo.kaario@magister.fi), Magister Solutions

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

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

• Sebastian Euler (sebastian.euler@ericsson.com), Ericsson

• Stefano Cioni (stefano.cioni@esa.int), European Space Agency.

# 3 Collaboration between Independent Evaluation Groups

In total four parties registered with the ITU as an IEG: ETSI, ATIS Evaluation Group, 5G India Forum and SatComForum (Korea). Close online and offline collaboration between the IEGs has been conducted to capture any discrepancies in the evaluations and to coordinate the work, with three online meetings:

– IEG coordination #1: 28th March 2024.

– IEG coordination #2: 15th May 2024.

– IEG coordination #3: 28th August 2024.

# 4 Technical evaluation results

## 4.1 Scope of the evaluations

Regarding 3GPP 5G NTN, ETSI performed evaluations on the Radio Interface Technology (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 the present final report, assessments conducted through link level and system level simulations, analysis and inspection are included.

## 4.2 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.

## 4.3 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 submission’s “completeness” according to Section 8.2 of Report ITU-R M.2514.

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

### 4.4.1 Compliance template for Services

|  | Service related minimum capabilities within the RIT/SRIT | Evaluator’s comments |
| --- | --- | --- |
| **4.4.1.1** | **Support of a wide range of services**Does the proposal support a wide range of services?:****YES / NO | *See Annex 2 subclause A2.1* |

### 4.4.2 Compliance template for Spectrum

|  |  |  |
| --- | --- | --- |
|  | Spectrum capability requirements | Evaluator’s comments |
| **4.4.2.1** | **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* |

### 4.4.3 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 | 111.339 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 | 64416 devices/km2 (for FRF3 and 1 message/day/device) | Yes | *See Annex 1 subclause A1.12*  |
| Energy efficiency | eMBB-s | N/A | N/A | High sleep ratio and long sleep duration | N/A | Yes | See Annex 2 subclause A2.3 |
| Reliability | HRC-s | Rural | N/A | 99.9% (1-10−3) | 99.987% (DL) & 99.955% (UL) for FRF3 | Yes | *See Annex 1 subclause A1.11* |
| Mobility – UE speed | eMBB-s | Rural | N/A | 250 km/h | See row below | Yes | *See Annex 1 subclause A1.10* |
| Mobility - Traffic channel link data rate | eMBB-s | Rural | N/A | 0.005 bit/s/Hz | 0.14 bit/s/Hz for FRF3 and 250 km/h speed | Yes | *See Annex 1 subclause A1.10* |
| 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* |

## 4.5 Questions and feedback to WP 4B and/or the proponents or other Independent Evaluation Groups

No further question.

## 4.6 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.

# 5 List of acronyms and abbreviations

|  |  |
| --- | --- |
| **3GPP** | 3rd Generation Partnership Project |
| **5QI** | 5G QoS Identifier |
| **AMC** | Adaptive Modulation and Coding |
| **BLER** | Block Error Rate |
| **BS** | Base Station |
| **BW** | Bandwidth |
| **CDF** | Cumulative Distribution Function |
| **CORESET** | COntrol REsourceSET |
| **DCI** | Downlink Control Information |
| **DL** | Downlink |
| **DRX** | Discontinuous Reception |
| **eMBB-s** | Enhanced Mobile Broadband - satellite |
| **FDD** | Frequency Division Duplex |
| **FR1** | Frequency Range 1 (up to 7.125 GHz) |
| **FRF** | Frequency-Reuse Factor |
| **GBR** | Guaranteed Bit Rate |
| **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 |
| **NR** | New Radio |
| **NTN** | Non-Terrestrial Network |
| **OFDM** | Orthogonal Frequency Division Multiplexing |
| **PBCH** | Physical Broadcasting Channel |
| **PDB** | Packet Delay Budget |
| **PDCCH** | Physical Downlink Control Channel |
| **PDSCH** | Physical Downlink Shared Channel |
| **PO** | Paging Occasion |
| **PRACH** | Physical Random Access Channel |
| **PRB** | Physical Resource Block |
| **PUCCH** | Physical Uplink Control Channel |
| **PUSCH** | Physical Uplink Shared Channel |
| **QAM** | Quadrature Amplitude Modulation |
| **QoS** | Quality of Service |
| **RA** | Random Access |
| **RACH** | Random Access Channel |
| **RB** | Resource Block |
| **RIT** | Radio Interface Technology |
| **RRC** | Radio Resource Control |
| **RRM** | Radio Resource Management |
| **RTD** | Round Trip Delay |
| **SAN** | Satellite Access Network |
| **SCS** | Sub-Carrier Spacing |
| **SDU** | Service Data Unit |
| **SES** | Satellite Earth Stations & Systems |
| **SIB1** | System Information Block 1 |
| **SINR** | Signal-to-Interference-plus-Noise Ratio |
| **SIR** | Signal-to-Interference Ratio |
| **SRI** | Sounding Reference Signal Resource Indication |
| **SRIT** | Set of Radio Interface Technologies |
| **SRS** | Sounding Reference Signal |
| **SS** | Synchronization Signal |
| **SSB** | Synchronization Signal Block (it refers to Synchronization/PBCH or SS/PBCH Block) |
| **TCI** | Transmission Configuration Indication |
| **TCP** | Transport Control Protocol |
| **TD** | Transmission Delay |
| **TRxP** | Transmission Reception Point |
| **TTI** | Transmission Time Interval |
| **UE** | User Equipment |
| **UL** | Uplink |
| **WP4B** | Working Party 4B |
| **WRC** | World Radio Conference |

# Annex 1

Analytical & simulation evaluation results

## A1.1 Peak spectral efficiency calculation

|  |
| --- |
|  *According to ITU-R Report 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 the ITU-R Report 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

|  |
| --- |
| *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:*$$3.7113 [SE\_{peak}]×30 \left[BW\right]=111.339 Mbit/s$$*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

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to ITU-R Report 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 ITU-R Report 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* |

 |

Based on the above evaluation results as well as independent 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

|  |
| --- |
| *According to ITU-R Report 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 the ITU-R Report 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

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to ITU-R Report 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 ITU-R Report 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 ITU-R Report 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* |

 |

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

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to ITU-R Report 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 1415 km2 (corresponding to approximately 50 km diameter beam foot print). Detailed evaluation assumptions can be found in Annex 4.* *Based on the definition in ITU-R Report 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* |

 |

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 ITU-R Report 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 ITU-R Report 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 40ms.

## A1.9 Mobility Interruption Time

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to ITU-R Report 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.

**A1.10 Mobility**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to ITU-R Report M.2514, the mobility requirement refers to the maximum device speed at which a defined QoS can be achieved. In other words, to pass the requirement, a certain spectral efficiency or “Normalized traffic channel link data rate” (in bit/s/Hz) has to be reached while the device is moving at the maximum speed of 250 km/h.* *In addition, ITU-R Report M.2412, which describes the evaluations for the terrestrial component of IMT-2020, and on which the evaluations of the satellite component are based, requires that the residual decoded packet error ratio is less than 1%.**Mobility is evaluated in the Rural-eMBB-s test environment.* *Based on the definition in ITU-R Report M.2514 and system configuration information provided by the proponent, the results of the mobility evaluation are given in the below table A-13.**Table A-13****Evaluation results of mobility for NR satellite access***

|  |  |  |  |
| --- | --- | --- | --- |
| ***Frequency reuse factor*** | ***ITU Requirement (bit/s/Hz)*** | ***Normalized traffic channel link data rate (bit/s/Hz)*** | ***Residual packet error ratio*** |
| *FRF = 1* | *0.005* | *0.013* | *0.48%* |
| *FRF = 3* | *0.075* | *0.15%* |

 |

Based on the above evaluation results, it is confirmed that the proposed RIT meets the minimum requirement for mobility which is 0.005 bit/s/Hz. Also, the residual packet error ratio is below the required 1%.

**A1.11 Reliability**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to ITU-R Report M.2514, reliability is the success probability of transmitting a layer 2/3 packet at a certain channel quality. For the satellite component of IMT-2020 there is no requirement on the maximum time for a successful transmission, in contrast to the terrestrial component.* *The reliability is evaluated in the Rural-HRC-s test environment.* *Based on the definition in ITU-R Report M.2514 and system configuration information provided by the proponent, the results of the reliability evaluation are given in the below tables A-14 and A-15 for DL and UL, respectively.**Table A-14****Evaluation results of DL reliability for NR satellite access***

|  |  |  |  |
| --- | --- | --- | --- |
| ***Frequency reuse factor*** | ***ITU Requirement*** | ***DL reliability*** | ***Maximum required delay (ms)*** |
| *FRF = 1* | *99.9% (1-10-3)* | *99.985%* | *24.2* |
| *FRF = 3* | *99.987%* | *24.2* |

*Table A-15****Evaluation results of UL reliability for NR satellite access***

|  |  |  |  |
| --- | --- | --- | --- |
| ***Frequency reuse factor*** | ***ITU Requirement*** | ***UL reliability*** | ***Maximum required delay (ms)*** |
| *FRF = 1* | *99.9% (1-10-3)* | *99.927%* | *129* |
| *FRF = 3* | *99.955%* | *32.2* |

 |

Based on the above evaluation results, it is confirmed that the proposed RIT meets the minimum requirement for reliability which is 99.9% (1-10-3), in both DL and UL.

## A1.12 Connection density

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to ITU-R Report M.2514, the connection density is the total number of devices fulfilling a specific quality of service (QoS) per unit area (per km2).* *The connection density is evaluated in the Rural-mMTC-s test environment. ITU-R Report M.2412 suggests two different traffic models (1 message/day/device and 1 message/2* *hours/device); we evaluate both. Report M.2412 also provides two possible evaluation methods (non-full buffer system-level simulation and full-buffer system-level simulation followed by link-level simulation); we adopt the full-buffer methodology based on a combination of system- and link-level simulation.**Based on the definition in ITU-R Report M.2514 and system configuration information provided by the proponent, the results of the connection density evaluation are given in the below table A-16.**Table A-16**Evaluation results of connection density for NR satellite access*

|  |  |  |  |
| --- | --- | --- | --- |
| *Traffic model* | *Frequency reuse factor* | *ITU Requirement (devices/km2)* | *Connection density (devices/km2)* |
| *1 message/day/device* | *FRF = 1* | *500* | *3792* |
| *FRF = 3* | *64416* |
| *1 message/2* *hours/device* | *FRF = 1* | *316* |
| *FRF = 3* | *5368* |

 |

Based on the above evaluation results, it is confirmed that the proposed RIT meets the minimum requirement for connection density which is 500 devices/km2, since this criteria is met for at least one RIT configuration.

# Annex 2

Inspection evaluation results

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

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Services**According to Report ITU-R M.2514-0, the IMT-2020 satellite component is expected to support wide range of services, namely eMBB-s, mMTC-s and HRC-s usage scenarios, to provide scalable and efficient network solutions.**Based on the evaluations presented in Annex 1 and Annex 2, 3GPP NR NTN RIT can meet the minimum technical performance requirement for the three test environments 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 PDU session is the level of granularity for QoS control. Each session can be associated with several QoS parameters according to Table 5.7.4-1 in TS 23.501, which maps standardized 5QI values to certain 5G QoS parameters. Table 2 presents an example of the mapping:*Table A-135QI (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* |
| *…* | *…* | *…* | *…* |
| *10* | *Non-GBR* | *1100 ms* | *10-6* | *Video (Buffered Streaming), TCP-based (e.g. www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.) and any service that can be used over satellite access type with these characteristics* |
| *…* |  | *…* | *…* | *…* |
| *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* |
| *…* | *…* | *…* | *…* |

*It should be noted that the table aggregates various QoS levels that are mainly designed for Terrestrial Network (TN) communication. Due to constraints from inherently long Round-Trip Delay (RTD) of the satellite communication, only a selection of the listed QoS levels is relevant for the 3GPP NR NTN RIT. According to TR 38.821, the RTD in GEO-based scenario is at maximum 541.46 ms, considering service and feeder links, and in LEO-600km scenario it is 25.77 ms. In general, the PDB should accommodate uplink scheduling delay (i.e. one RTD) and at least a single end-to-end delay which already rules out from NR NTN some QoS levels with stringent PDB targets. Moreover, to realistically reach the low Packet Error Loss Rate targets may require retransmissions of packets, further affecting the fulfillment of PDB target for NTN. In Release 17, 3GPP introduced a new 5QI (5QI = 10) with a packet delay budget (PDB) going up to 1100ms. This large PDB value is defined to support non-guaranteed bit rate (non-GBR) services provisioned via satellite that can accommodate the worst case latencies when GEO satellites are used.* |

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 of services).

## 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 No.* **5.388** *and Resolution* **212** *(***Rev.WRC-07***).*Table A-14Operating bands in FR1

|  |  |  |  |
| --- | --- | --- | --- |
| **Satellite *operating band*** | **Uplink (UL) *operating band*SAN receive / UE transmit****FUL,low – FUL,high** | **Downlink (DL) *operating band*SAN transmit / UE receive****FDL,low – FDL,high** | **Duplex mode** |
| n256 | 1980 MHz – 2010 MHz | 2170 MHz – 2200 MHz | FDD |
| n255 | 1626.5 MHz – 1660.5 MHz | 1525 MHz – 1559 MHz | FDD |
| n254 | 1610 MHz – 1626.5 MHz | 2483.5 MHz – 2500 MHz | FDD |
| NOTE: Satellite bands are numbered in descending order from n256. |

*Note: additional bands are considered in 3GPP releases beyond Rel-17.* |

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

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| According to ITU-R Report M.2514, network energy efficiency is the capability of a RIT/SRIT to minimize the radio access network energy consumption in relation to the traffic capacity provided and the device energy efficiency is the capability of the RIT/SRIT to minimize the power consumed by the device modem in relation to the traffic characteristics.Energy efficiency of the network and the device can relate to the support for the following two aspects:1. Efficient data transmission in a loaded case;
2. Low energy consumption when there is no data.

Efficient data transmission in a loaded case is demonstrated by the average spectral efficiency. Low energy consumption when there is no data can be estimated by the sleep ratio.The sleep ratio will be evaluated below, separately for network and device. In addition, sleep duration is discussed which, according to ITU-R Report M.2514, should be sufficiently long.**Network side**Sleep ratio of the network side when there is no data can be defined by the sleep duration, i.e. the proportion of time without any transmission and reception of mandatory downlink and uplink control signaling, respectively.The following assumptions are used for the evaluation:* Mandatory signaling in downlink consists of SS/PBCH block (SSB) and SIB1 transmissions and paging configured over CORESET-0.
* Paging configured over CORESET-0 is assumed to be transmitted in the same slot with the SSB.
* L SSBs are included in an SS burst set (SSB set) transmitted with a periodicity of 5, 10, 20, 40, 80 and 160 ms.
* SSBs in an SSB set are transmitted in consecutive slots within a 5 ms window, i,e, half radio frame.
* Two SSBs can be transmitted in a single slot, with each SSB occupying 4 consecutive OFDM symbols.
* One SIB1 is mapped to a single SSB. It is assumed SSB and the respective SIB1 can be transmitted in the same slot.
* Mandatory signaling in uplink that the network monitors, consists of PRACH occasions which can be configured in the same slot with the respectively mapped SSB.
* Slot-level accuracy is assumed in the evaluation, i.e. a slot is either fully active or fully inactive. Evaluation in symbol-level accuracy is not included, however it is assumed that the symbol-level evaluation would allow slightly higher sleep ratio compared to the slot-level evaluation.
* Numerology 0 and 1 are assumed.
* Number of SSBs per SSB set is 1, 2 and 4, which are specified for sub-3 GHz carrier frequency in the 5G NR standard.

The sleep ratio is calculated as follows:$R\_{sleep}=1-\frac{\left⌈L/2\right⌉}{2^{μ}×P\_{SSBset}}$,where$R\_{sleep}$ is the sleep ratio.$L$ is the number of SSBs per SSB set.$μ$ is the 5G numerology, i.e. 0 for 15 kHz subcarrier spacing and 1 for 30 kHz subcarrier spacing.$\left⌈L/2\right⌉$ is the ceiling value expressing the number of slots required for the transmission of all the SSBs when assuming two SSBs can be transmitted in the same slot.$P\_{SSBset}$ is the periodicity of the SSB set.The sleep ratios assuming slot-level granularity are provided in the table below.Table A-15Network side sleep ratio $R\_{sleep}$

|  |  |  |  |
| --- | --- | --- | --- |
| Numerology | L |  | SSB set periodicity $P\_{SSBset}$ |
| 5 ms | 10 ms | 20 ms | 40 ms | 80 ms | 160 ms |
| 0 | 1 | 0.8 | 0.9 | 0.95 | 0.975 | 0.9875 | 0.9938 |
| 2 | 0.8 | 0.9 | 0.95 | 0.975 | 0.9875 | 0.9938 |
| 4 | 0.6 | 0.8 | 0.9 | 0.95 | 0.975 | 0.9875 |
| 1 | 1 | 0.9 | 0.95 | 0.975 | 0.9875 | 0.9938 | 0.9969 |
| 2 | 0.9 | 0.95 | 0.975 | 0.9875 | 0.9938 | 0.9969 |
| 4 | 0.8 | 0.9 | 0.95 | 0.975 | 0.9875 | 0.9938 |

It is expected that for carrier frequency below 3 GHz, the number of SSBs in an SSB set is 1 or 2 especially for numerology 0, and the periodicity of the SSB set can be specified longer than 5 ms to reduce signaling overhead while still allowing adequate accessibility. With these assumptions the sleep ratio can be above 90% depending on the parameterization and thus a high energy-efficiency can be achieved for the network side.The sleep duration depends on the SSB set periodicity, numerology and number of SSBs in an SSB set. Assuming slot-level granularity, the sleep duration can be calculated by$$T\_{sleep}=P\_{SSBset}×R\_{sleep}$$The sleep durations for the above configurations are provided in the table below.Table A-16Network side sleep duration $T\_{sleep}$ [ms]

|  |  |  |  |
| --- | --- | --- | --- |
| Numerology | L |  | SSB set periodicity $P\_{SSBset}$ |
| 5 ms | 10 ms | 20 ms | 40 ms | 80 ms | 160 ms |
| 0 | 1 | 4 | 9 | 19 | 39 | 79 | 159 |
| 2 | 4 | 9 | 19 | 39 | 79 | 159 |
| 4 | 3 | 8 | 18 | 38 | 78 | 158 |
| 1 | 1 | 4.5 | 9.5 | 19.5 | 39.5 | 79.5 | 159.5 |
| 2 | 4.5 | 9.5 | 19.5 | 39.5 | 79.5 | 159.5 |
| 4 | 4 | 9 | 19 | 39 | 79 | 159 |

**Device side**Sleep ratio of the device side can be defined by the inactive time of the discontinuous reception (DRX) cycle in an unloaded case when there is no user data transfer. In the 5G standard, supported also by the NR-NTN, this is achieved by the inactivity time of connected mode DRX cycle when user is in RRC\_CONNECTED mode, or idle mode DRX cycle when user is in RRC\_IDLE or RRC\_INACTIVE mode. During the inactive time, the user can switch to power saving mode.The following assumptions are used for the sleep ratio calculation when the user is in RRC\_CONNECTED mode:* Slot-level accuracy is assumed for the sleep ratio evaluation.
* Numerology is 0.
* Before the On-duration period, the user monitors SSB for synchronization. The duration of the SSB set monitoring and synchronization process is assumed to take 10 ms.
* During the On-duration period, the user monitors PDCCH for incoming downlink transmissions
* After the On-duration period, the user performs RRM measurements which is assumed to take 3 ms.
* RRM measurements are followed by an Off-duration period when the user is not required to monitor and can switch to power-saving mode.
* The transition between sleep and active states is not instantaneous. It is assumed the total transition time is 10 ms for single DRX cycle.
* The length of On-duration period is set to 2 ms, 10 ms and 100 ms for DRX cycle lengths 320 ms, 640 ms and 1024 ms, respectively.

The sleep ratio is defined by$R\_{sleep}=1-\frac{T\_{SSB}+T\_{OnDuration}+T\_{RRM}+T\_{transition}}{T\_{DRXCycle}}$,Where:$R\_{sleep}$ is the sleep ratio.$T\_{SSB}$ is the SSB monitoring period.$T\_{OnDuration}$ is the On-duration time used for PDCCH monitoring and RRM measurements.$T\_{RRM}$ is the time used for RRM measurements.$T\_{transition}$ is the time spent for transition to and from active state.$T\_{DRXcycle}$ is the length of the DRX cycle.The sleep ratios assuming slot-level granularity are provided in the table below.Table A-17Device side sleep ratio $R\_{sleep}$ in RRC\_CONNECTED mode

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| DRX cycle [ms] | On-duration [ms] | SSB monitoring [ms] | RRM measurements [ms] | Transition time [ms] | Sleep ratio $R\_{sleep}$ |
| 320 | 2 | 10 | 3 | 10 | 0.9219 |
| 640 | 10 | 0.9484 |
| 1024 | 100 | 0.8799 |

In RRC\_CONNECTED, sleep ratios close to or above 90% can be achieved with the current assumptions. The sleep duration with the above configuration is 295 ms, 607 ms and 901 ms for DRX cycle lengths 320 ms, 640 ms and 1024 ms, respectively.In RRC\_IDLE and RRC\_INACTIVE, the sleep ratio depends on the idle mode DRX parameterization. In idle mode DRX, the user monitors paging occasion (PO) for incoming downlink transmissions during a DRX cycle, then falls into power saving mode during the inactive periods. The PO may last several slots in one DRX cycle and consist of one or multiple PDCCH monitoring occasions. Like in the connected mode DRX, the user needs to perform synchronization and RRM measurements when in idle mode DRX.The following assumptions are used for the sleep ratio calculation when the user is in RRC\_IDLE or RRC\_INACTIVE mode:* Slot-level accuracy is assumed for the sleep ratio evaluation.
* Numerology is 0.
* DRX cycle length is 2560 ms.
* Before the paging occasion, the user monitors SSB for synchronization. The duration of the SSB set monitoring and synchronization process is assumed to take 10 ms.
* One PO is assumed per DRX cycle and paging frame.
* Paging PDCCH monitoring is assumed to last for one slot, including processing of the paging DCI.
* RRM measurement is assumed to take place after the PO.
* The transition between sleep and active states is not instantaneous. It is assumed the total transition time is 10 ms for single DRX cycle.

The sleep ratio is defined by$R\_{sleep}=1-\frac{T\_{SSB}+T\_{PO}+T\_{RRM}+T\_{transition}}{T\_{DRXCycle}}$,where$R\_{sleep}$ is the sleep ratio.$T\_{SSB}$ is the SSB monitoring period.$T\_{PO}$ is the paging PDCCH monitoring period$T\_{RRM}$ is the time used for RRM measurements.$T\_{transition}$ is the time spent for transition to and from active state.$T\_{DRXcycle}$ is the length of the DRX cycle.With the assumptions above, the sleep ratio is$R\_{sleep}=1-\frac{10+1+3+10}{2560}=0.9906$.Thus, it can be concluded that a high sleep ratio, around 99.06%, can be achieved in RRC\_IDLE and RRC\_INACTIVE mode.The sleep duration with the aforementioned assumptions is 2536 ms. |

Based on the above analysis, it is confirmed that the proposed RIT supports high energy efficiency at both network side and device side.

## 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-18Transmission 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 |

 |

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 documents:

**4.2** **eMBB\_SE\_UserExpDataRate\_AreaTrafCap.xlsx**



**4.3 Mobility\_Reliability\_ConnectionDensity.xlsx**



\_\_\_\_\_\_\_\_\_\_\_\_\_\_