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| **Radiocommunication Study Groups** |  |
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| Source: Document IMT-2020-SAT/4Subject: Resolution ITU-R 65 | Document 4B/75-E |
| 3 October 2024 |
| English only |
| Director, Radiocommunication Bureau[[1]](#footnote-1)\* |
| evaluation Report on the proposed candidate IMT-2020 satellite radio interface TECHNOLOGY in document IMT-2020-SAT/4 |

As an Independent Evaluation Group for the satellite component of IMT-2020, SatComForum would like to submit the final evaluation results on IMT-2020 satellite radio interface technology (Satellite IMT-2020 candidate technology) as described in Document [IMT-2020-SAT/4](https://www.itu.int/md/R19-IMT.2020.SAT-C-0004/en).

At the 53rd meeting of ITU-R Working Party 4B, SatComForum submitted the preliminary evaluation results on the IMT-2020 satellite radio interface technology, which included only analytical and inspection-based evaluation results. This document provides an update to the preliminary evaluation result by additionally including simulation-based evaluation results.

The attached evaluation report has been 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

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 (WP) 4B to the 55th meeting of WP 4B has been allocated for the evaluation of satellite IMT-2020 candidate technology by Independent Evaluation Group (IEG).

This document provides the evaluation results for candidate IMT-2020 satellite radio interface technology (RIT) in Document IMT-2020-SAT/4 from SatComForum.

# 2 Administrative information of SatComForum

## 2.1 Background of SatComForum

SatComForum has the following terms of reference regarding the satellite component of IMT:

– Evaluation on candidate technology for satellite IMT:

* preparation of evaluation report
* submission of evaluation report to ITU-R.

– Activities as an IEG:

* coordination and cooperation with other Evaluation Groups; ITU-R WP 4B and other Evaluation Groups.

– Study and analysis on evaluation for satellite IMT

SatComForum 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 SatComForum, which gathered opinions from twenty-one members. These participants represent a diverse range of entities, including manufacturers, service providers, universities and research institutions. The URL for the SatComForm is:

<http://satcomforum.org/en/sub/forum/committee_activity.asp>.

This website provides details of SatComForum such as term of reference and contact point.

## 2.2 Process and method of working by SatComForum

After the 53rd bis ITU-R Working Party 4B meeting, SatComForum held four face-to-face meetings and engaged in continuous email discussions. During these meetings, SatComForum 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:

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

– 15 March 2024: Development of the initial preliminary evaluation report;

– 20 March 2024: Finalization of the preliminary evaluation report;

– 25 March 2024: Submission of the preliminary evaluation report to ITU-R;

– 30 August 2024: 2nd call to the participants for the final evaluation;

– 6 September 2024: Development of the draft final evaluation report;

– 20 September 2024: Completion of the development of the final evaluation report;

– 27 September 2024: Submission of the final evaluation report to ITU-R.

The preliminary and final evaluation reports were developed based on the contributions from Electronics and Telecommunications Research Institute (ETRI). The preliminary and final results were internally presented, and several on/off-line meetings including e-mail discussions were held to reach the consensus on this report. The preliminary evaluation report submitted at the 54th meeting of WP 4B included only analytical and inspection-based evaluation results. Some of simulation-based evaluation results are provided in this final evaluation report, along with minor updates to the analytical evaluation results in the preliminary evaluation report. It is noted that SatComForum does not provide simulation-based evaluation results for some parts (e.g., connection density and reliability) due to a lack of time.

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 or similar configurations and/or assumptions as those used in the self-evaluation of 3GPP 5G NTN.

For the interaction with other evaluation groups, SatComForum maintains close relationships with other evaluation groups such as ATIS, ETSI and 5G India Forum by having several online coordination meetings. During these coordination meetings, SatComForum shared the status of work progress on the evaluation of IMT-2020 satellite RIT, presented the evaluation results, discussed any discrepancies in the results, and sought to reach a consensus on the evaluation report.

## 2.3 Contacts for SatComForum

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

– Administrative contact details:

* Joon Gyu Ryu (jgryurt@etri.re.kr), ETRI, Chairman of SatComForum Technical Committee;

– Technical contact details:

* Hee Wook Kim (prince304@etri.re.kr), ETRI, Principal researcher;
* Sooyoung Kim (sookim@jbnu.ac.kr), Jeonbuk National University.

# 3 Technical evaluation results

## 3.1 Scope of the evaluations

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

SatComForum 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 report, assessments through analysis, inspection and simulations are included. Specifically, the simulations were conducted based on the same configuration as outlined in the self-evaluation report of 3GPP 5G NTN.

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

SatComForum performed the evaluations according to the 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.

SatComForum agrees with the WP 4B’s view and also confirms that the submission is “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* §*A1.1 of Annex 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* §*A1.2 of Annex 1* |

### 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 | 2.67Mbit/s | Yes | *See* §*A2.1 of Annex 2* |
| Downlink | 70 Mbit/s | 111.34Mbit/s | Yes |
| Peak spectral efficiency | eMBB-s | N/A | Uplink | 1.5 bit/s/Hz | 1.85bit/s/Hz | Yes | *See* §*A2.2 of Annex 2* |
| Downlink | 3 bit/s/Hz | 3.71bits/Hz | Yes |
| User experienced data rate | eMBB-s | Rural | Uplink | 100 kbit/s | - | - | - |
| Downlink | 1 Mbit/s | 1.2 Mbit/s | Yes | *See* §*A3.1 of Annex 3*  |
| 5th percentile user spectral efficiency | eMBB-s | Rural | Uplink | 0.003 bit/s/Hz | - | - | - |
| Downlink | 0.03 bit/s/Hz | 0.04 bit/s/Hz | Yes | *See* §*A3.2 of Annex 3*  |
| Average spectral efficiency | eMBB-s | Rural | Uplink | 0.1 bit/s/Hz | - | - | - |
| Downlink | 0.5 bit/s/Hz | 0.57 bit/s/Hz | Yes | *See* §*A3.3 of Annex 3*  |
| Area traffic capacity | eMBB-s | Rural | Uplink | 1.5 kbit/s/km² | - | - | - |
| Downlink | 8 kbit/s/km² | 12.1 kbit/s/km2 | Yes | *See* §*A3.4 of Annex 3*  |
| User Plane latency | eMBB-s | N/A | N/A | 10 ms | 6.64 ms | Yes | *See* §*A2.3 of Annex 2* |
| Control Plane latency | eMBB-s | N/A | N/A | 40 ms | 22.36 ms | Yes | *See* §*A2.4 of Annex 2* |
| Connection density | mMTC-s | Rural | N/A | 500 devices/km² | - | - | - |
| Energy efficiency | eMBB-s | N/A | N/A | High sleep ratio and long sleep duration | Support | Yes | *See* §*A1.3 of Annex 1* |
| Reliability | HRC-s | Rural | N/A | 1-10−3 | - | - | - |
| Mobility – UE speed | eMBB-s | Rural | N/A | 250 km/h | - | - | - |
| Mobility - Traffic channel link data rate | eMBB-s | Rural | N/A | 0.005 bit/s/Hz | - | - | - |
| Mobility interruption time | eMBB-s | N/A | N/A | 50 ms | 0 | Yes | *See* §*A2.5 of Annex 2* |
| Bandwidth | N/A | N/A | N/A | At least up to and including 30 MHz | 30 MHz | Yes | *See* §*A1.4 of Annex 1* |

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

SatComForum has no further question.

## 3.6 Conclusion

The evaluation results in this report showed that 3GPP NTN RIT meets the minimum requirement of satellite IMT-2020 technology for the evaluated items. Therefore, SatComForum 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 |
| **BW** | Bandwidth |
| **CDW** | Cumulative Distribution Function |
| **DL** | Downlink |
| **EIRP** | Equivalent Isotropic Radiated Power |
| **eMBB-s** | Enhanced Mobile Broadband - satellite |
| **FDD** | Frequency Division Duplex |
| **FR1** | Frequency Range 1 |
| **FRF** | Frequency Reuse Factor |
| **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 |
| **MMSE-IRC** | Minimum Mean Square Error - Interference Rejection Combining |
| **NTN** | Non-Terrestrial Network |
| **NR** | New Radio |
| **OFDM** | Orthogonal Frequency Division Modulation |
| **PBCH** | Physical Broadcasting Channel |
| **PDSCH** | Physical Downlink Shared Channel |
| **PF** | Proportional Fair |
| **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 |
| **SINR** | Signal-to-Interference-plus-Noise Ratio |
| **SIR** | Signal-to-Interference Ratio |
| **SRIT** | Set of Radio Interface Technologies |
| **SRS** | Sounding Reference Signal |
| **TD** | Transmission Delay |
| **TR** | Technical Report |
| **TTI** | Transmission Time Interval |
| **UE** | User Equipment |
| **UL** | Uplink |

Annex 1

Inspection-based evaluation results

## A1.1 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 meet the minimum technical performance requirement for the three test environments of 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. 5QI values in Table A-7:*Table A-75QI (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 message, 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).

## A1.2 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-8Operating 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. |

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Based on the above evaluation results, it is 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.

## A1.3 Energy Efficiency

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| ***Energy efficiency by the RIT****Energy efficiency of the network and the device can relate to the support for the following two aspects:** *Efficient data transmission in a loaded case;*
* *Low energy consumption when there is no data.*

*Regarding efficient data transmission in a loaded case, the 3GPP NR NTN RIT can support adaptive modulation and coding (AMC) schemes depending on channel conditions for spectral efficient transmission.**On the other hand, for low energy consumption when there is no data, the 3GPP NR NTN RIT has the capability to support a high sleep ratio and long sleep duration.**The sleep ratio is the fraction of unoccupied time resources (for the network) or sleeping time (for the device) in a period of time corresponding to the cycle of the control signalling (for the network) or the cycle of discontinuous reception (for the device) when no user data transfer takes place. The sleep duration is the continuous period of time with no transmission (for network and device) and reception (for the device).* |

Based on the above evaluation results, it is confirmed by inspection that the proposed RIT supports the energy efficiency capability.

## A1.4 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-9Transmission bandwidth configuration NRB in Frequency Range 1 (FR1) (NRB: the number of Resource Blocks)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 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 |

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

Annex 2

Analytical evaluation results

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## A2.2 Peak spectral efficiency calculation

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| *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).**Based on the definition in ITU-R Report M.2514 and system configuration information provided by the proponent, calculations of the peak spectral efficiency values are given in the below, taking the following aspects into account:** *L1/L2 control, Synchronization Signal, PBCH, reference signal, etc are considered as overhead*
	+ *Overhead radio for downlink is assumed to 14 %*
	+ *Overhead radio for uplink is assumed to 8 %*
* *NR NTN FDD is considered*
* *Maximum number of layers is one*
* *Considering the satellite system is a link budget-limited system, highest modulation schemes are 64QAM and 16QAM in downlink and uplink, respectively.*
* *A subcarrier spacing of 15 kHz is considered.*
* *Considering UE has limitation on maximum Tx power, it is assumed that only 8 RBs are allocated to the UE while SAN use whole assignable radio resources for total bandwidth up to 30 MHz.*

*Calculation of peak spectral efficiency****DL 1 layer spatial multiplexing (3GPP NR NTN SAN 30 MHz is assumed):****1(layers)* × *6(64QAM)* × *1(scaling factor)* × *822/1024(max. coding rate)* × *(1-0.14(Overhead))* × *160(RBs)* × *12(subcarriers)* × *14 / 10-3(ms) / (30* × *106)(BW)= 3.71 bps/Hz****UL 1 layer spatial multiplexing (3GPP NR NTN UE 1.44 MHz is assumed):****1(layers)* × *4(16QAM)* × *1(scaling factor)* × *533/1024(max. coding rate)* × *(1-0.08(Overhead))* × *8(RBs)* × *12(subcarriers)* × *14 / 10-3(ms) / (1.44* × *106)(BW)= 1.85 bps/Hz* |

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

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### A2.3 User plane latency calculation

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to ITU-R Report M.2514, user plane latency 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.**Based on the definition in ITU-R Report M.2514 and system configuration information provided by the proponent, calculations of user plane latency are given in the below, taking the following aspects into account:** *It is assumed that the packet arrives at any time of any OFDM symbol. In this case, a symbol length of 0.5 is added as the “average symbol alignment time” 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 slot-based scheduling is used.*
* *A subcarrier spacing of 15 kHz is considered.*
* *The resource mapping type A is considered, which impact the start timing of a transmission.*
* *UE processing capability 1 is assumed.*
* *It is assumed that transparent satellite processing delay is negligible.*
* *It is assumed that the propagation delay between BS and satellite and propagation delay between satellite and UE are the same, and it is denoted as Td.*

Table A-1User plan latency calculation in downlink with No HARQ

|  |  |  |
| --- | --- | --- |
| *Component* | *Description* | *Time (ms)* |
| *1* | *BS processing delay**(The time interval between the data is arrived and packet is generated)**(=10*×*(2048+144)*×*64*×*Tc/2), where Tc is basic time unit defined in 3GPP NTN NR and , and defined in Section 6.4 of TS 38.214 are assumed.* | *0.36* |
| *2* | *DL frame alignment (transmission alignment)**(The time interval between packet generation and the next Tx opportunity)* | *1* |
| *3* | *TTI for DL packet transmission* | *1* |
| *4* | *One way propagation delay**(Propagation delay between BS and satellite + Propagation delay between satellite and UE + satellite processing delay)* | *2Td* |
| *5* | *UE processing delay (=8*×*(2048+144)*×*64*×*Tc/2), where Tc is basic time unit defined in 3GPP NTN NR and , and defined in Section 5.3 of TS 38.214 are assumed.* | *0.28* |
|  | ***Total delay*** | ***2.64+2Td*** |
|  | ***In case of LEO satellite at 600 km and UE at elevation angle of 90o*** | ***6.64*** |
|  | ***In case of GEO satellite and UE at elevation angle of 90o*** | ***242.64*** |

Table A-2User plan latency calculation in uplink with no HARQ

|  |  |  |
| --- | --- | --- |
| *Component* | *Description* | *Time (ms)* |
| *1* | *UE processing delay (=10*×*(2048+144)*×*64*×*Tc/2)), where Tc is basic time unit defined in 3GPP NTN NR and , and defined in Section 6.4 of TS 38.214 are assumed.* | *0.36* |
| *2* | *UL frame alignment (transmission alignment)**(The time interval between packet generation and the next Tx opportunity)* | *1* |
| *3* | *TTI for UL packet transmission* | *1* |
| *4* | *One way propagation delay**(Propagation delay between UE and satellite + Propagation delay between satellite and BS + satellite processing delay)* | *2Td* |
| *5* | *BS processing delay**(The time interval between the data is arrived and packet is generated)**(=8*×*(2048+144)*×*64*×*Tc/2), where Tc is basic time unit defined in 3GPP NTN NR and , and defined in Section 5.3 of TS 38.214 are assumed.* | *0.28* |
|  | ***Total delay*** | ***2.64+2Td*** |
|  | ***In case of LEO satellite at 600 km and UE at elevation angle of 90o*** | ***6.64*** |
|  | ***In case of GEO satellite and UE at elevation angle of 90o*** | ***242.64*** |

Table A-3User plan latency calculation in downlink with HARQ

|  |  |  |
| --- | --- | --- |
| *Component* | *Description* | *Time (ms)* |
| *1* | *HARQ retransmission**(User plane latency in downlink + User plane latency in uplink)* | *5.28+4T\_d* |
| *2* | *Repeat DL or UL data transfer* | *2.64+2T\_d* |
|  | ***Total delay where p is the probability of retransmission*** | ***2.64+2Td +******p* x *(5.28+4Td)*** |
|  | ***In case of LEO satellite at 600 km, UE at elevation angle of 90o and 10% HARQ BLER*** | ***7.97*** |
|  | ***In case of GEO satellite, UE at elevation angle of 90o and 10% HARQ BLER*** | ***291.17*** |

 |

Based on the above evaluation results, it is confirmed that in LEO satellite configuration, the proposed RIT meets the minimum requirements for user plane latency which are 10 ms for both downlink and uplink.

### A2.4 Control plane latency calculation

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to ITU-R Report M.2514, control plane latency is defined as* *the transition time from a most “battery efficient” state (e.g., Idle state) to the start of continuous data transfer (e.g., Active state).**Based on the definition in ITU-R Report M.2514 and system configuration information provided by the proponent, calculations of control plane latency are given in the below, taking the following aspects into account:** *It is assumed that control plane latency is calculated from RRC Inactive state to RRC Connected state.*
* *Four-step and Two-step RACH based transitions are considered.*
* *A subcarrier spacing of 15 kHz is considered.*
* *PRACH preamble format with a length of 1m is considered.*
* *UE processing capability 1 is assumed.*
* *It is assumed that transparent satellite processing delay is negligible.*
* *It is assumed that the waiting time for DL/UL subframe is not included in the calculated delay values.*
* *It is assumed that the propagation delay between BS and satellite and propagation delay between satellite and UE are the same, and it is denoted as Td.*
* *The transmission duration of Step 2 and 4 cannot cross the boundary of a slot;*
* *The CP procedure can start from the OFDM symbols within the slot that PRACH preamble can be transmitted.*
* *One-slot duration is considered for RA response, RRC resume request and RRC resume.*
* *PDSCH processing capability 1 and PUSCH processing capability 2 are considered*
* *It is assumed that transparent satellite processing delay is negligible.*
* *It is assumed that in two-step RACH, the length of the transmission interval between PRACH and PUSCH is 1ms.*

Table A-4Control plan latency calculation based on four-step RACH based transmission

|  |  |  |
| --- | --- | --- |
| *Component* | *Description* | *Time (ms)* |
| *1* | *Delay due to RACH scheduling period (1TTI)* | *0* |
| *2* | *Transmission of RACH preamble* | *1* |
| *3* | *One way propagation delay**(Propagation delay between UE and satellite + Propagation delay between satellite and BS + satellite processing delay)* | *2Td* |
| *4* | *Preamble detection and processing in gNB**(=10*× *(2048+144)* ×*64*×*Tc) , where Tc is basic time unit defined in 3GPP NTN NR and , and defined in Section 6.4 of 3GPP TS 38.214 are assumed.* | *0.71* |
| *5* | *Transmission of RA response* | *1* |
| *6* | *One way propagation delay**(Propagation delay between UE and satellite + Propagation delay between satellite and BS + satellite processing delay)* | *2Td* |
| *7* | *UE processing delay (decoding of scheduling grant, timing alignment and C-RNTI assignment + L1 encoding of RRC Resume Request)**(NT,1+NT,2+0.5 ms), where NT,1=0.3568 ms and NT,2=0.7135 according to Section 8.3 of 3GPP TS 38.213.* | *1.07* |
| *8* | *Transmission of RRC Resume Request* | *1* |
| *9* | *One way propagation delay**(Propagation delay between UE and satellite + Propagation delay between satellite and BS + satellite processing delay)* | *2Td* |
| *10* | *Processing delay in gNB (L2 and RRC)* | *3* |
| *11* | *Transmission RRC Resume* | *1* |
| *12* | *One way propagation delay**(Propagation delay between UE and satellite + Propagation delay between satellite and BS + satellite processing delay)* | *2Td* |
| *13* | *Processing delay in UE of RRC Resume including grant reception* | *7* |
| *14* | *Transmission of RRC Resume Complete and UP data* | *0* |
|  |  |  |
|  | ***Total delay*** | ***15.78+8Td*** |
|  | ***In case of LEO satellite at 600 km with elevation angle of 90o*** | ***31.78*** |
|  | ***In case of GEO satellite with elevation angle of 90o*** | ***975.78*** |

Table A-5Control plan latency calculation based on two-step RACH based transmission

|  |  |  |
| --- | --- | --- |
| *Component* | *Description* | *Time (ms)* |
| *1* | *Delay due to RACH scheduling period (1TTI)* | *0* |
| *2* | *UE processing delay (L1 encoding of RRC Resume Request) for MsgA**(=10*× *(2048+144)* ×*64*×*Tc/2) , where Tc is basic time unit defined in 3GPP NTN NR and , and defined in Section 6.4 of TS 38.214 are assumed.* | *0.36* |
| *3* | *Transmission of RACH preamble* | *1* |
| *4* | *Transmission interval between PRACH and PUSCH* | *1* |
| *5* | *Transmission of PUSCH payload* | *1* |
| *3* | *One way propagation delay**(Propagation delay between UE and satellite + Propagation delay between satellite and BS + satellite processing delay)* | *2Td* |
| *4* | *MsgA detection and processing delay in gNB (preamble, L2 and RRC)* | *3* |
| *5* | *Transmission of MsgB (RA response)* | *1* |
| *6* | *One way propagation delay**(Propagation delay between UE and satellite + Propagation delay between satellite and BS + satellite processing delay)* | *2Td* |
| *12* | *Processing delay in UE of RRC Resume including RA response* | *7* |
| *13* | *Transmission of RRC Resume Complete and UP data* | *0* |
|  |  |  |
|  | ***Total delay*** | ***14.36+4Td*** |
|  | ***In case of LEO satellite at 600 km with elevation angle of 90o*** | ***22.36*** |
|  | ***In case of GEO satellite with elevation angle of 90o*** | ***494.36*** |

 |

Based on the above evaluation results, it is confirmed that in LEO satellite configuration, the proposed RIT meets the minimum requirement for control plane latency, which is 40 ms.

**A2.5 Mobility Interruption Time**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to ITU-R Report M.2514, mobility interruption time is defined as* *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.**Based on the definition in ITU-R Report M.2514 and system configuration information provided by the proponent, calculations of mobility interruption time are given in the below, taking the following aspects into account:**For 3GPP NR NTN, the mobility without cell and satellite change is supported for the beam mobility scenario. When moving within the same cell, the transmit-receive beam pair of the UE may need to be changed.**For DL data transmission during UE mobility, gNB can configure different beams for the UE at different slots. It ensures appropriate transmit beam allocation to the UE for continuous DL transmission. Therefore, DL data packet transmission is kept during beam pair switching at different slots.**For UL data transmission, PUSCH is sent using the beam configured by SRI (SRS resource indicator) by gNB. Accordingly, an appropriate gNB-side beam is selected for UL data reception. gNB may select different beams at different slots depending on the UE mobility. Therefore, UL data packet transmission is kept during beam pair switching at different slots.**Based on the above analysis, the UE can always exchange user plane packets with gNB during the mobility transition. Therefore, the mobility interruption time of 0 ms is achieved by NR NTN for this scenario.**On the other hand, the Break-before-Make handover (HO) procedure of 3GPP NR NTN is described as follow:** *Once the HO command has been processed by the UE, it leaves the source cell and stops receiving data. This is the point in time where data interruption starts. The first step after that is the radio synchronisation, which consists of:*
	+ *Frequency synchronization time: Typically, the time taken for frequency synchronisation depends on whether the target cell is operating on the same carrier frequency as the currently served frequency or not. Since the UE has already identified and measured a signal from the target cell, this delay is negligible.*
	+ *DL synchronization time: Although baseband and RF alignments always take some time, since the UE has already acquired DL synchronisation to the target cell in conjunction with previous measurement and can relate the target cell DL timing to the source cell DL timing with an offset, the corresponding delay is less than 1 ms.*
	+ *DL synchronization time: Although baseband and RF alignments requires processing time, the UE typically acquires DL synchronisation with the target cell, having delay less than 1 ms. This is because the synchronization is made in conjunction with previous measurement and can relate the target cell DL timing to the source cell DL timing with an offset.*
* *Because forwarding is initiated before the UE moves and establishes connection to the target cell and because the backhaul is faster than the radio interface, forwarded data is already awaiting transmission in the target when the UE is ready to receive. This component therefore does not affect the overall delay.*
* *A subcarrier spacing of 15 kHz is considered.*
* *UE processing capability 1 is assumed.*
* *PRACH preamble format with a length of 1m is considered.*
* *It is assumed that RACH scheduling duration is 1 ms.*
* *Transparent satellite is assumed.*
* *SSB post processing time is assumed to be 1 ms.*
* *It is assumed that the propagation delay between BS and satellite and propagation delay between satellite and UE are the same, and it is denoted as Td.*

Table A-6U-Plane interruption in case of hard HO

|  |  |  |
| --- | --- | --- |
| *Component* | *Description* | *Time (ms)* |
| *1* | *Radio Synchronisation to the target cell* | *1* |
| *2* | *Average delay due to RACH scheduling period (1ms periodicity)* | *0.5* |
| *3* | *RACH Preamble + One way propagation delay* | *1+2Td* |
| *4* | *Preamble detection and processing in gNB**(=10*×*(2048+144)*×*64*×*Tc) , where Tc is basic time unit defined in 3GPP NTN NR and , and defined in Section 6.4 of TS 38.214 are assumed.* | *0.71* |
| *5* | *Transmission of RA response* | *1* |
| *6* | *One way propagation delay**(Propagation delay between UE and satellite + Propagation delay between satellite and BS + satellite processing delay)* | *2Td* |
| *6* | *UE processing delay (decoding of scheduling grant and timing alignment)**(NT,1+NT,2+0.5 ms)* | *1.07* |
|  | ***Total delay*** | ***5.28+4Td*** |
|  | ***In case of LEO satellite at 600 km with elevation angle of 90o*** | ***13.28*** |
|  | ***In case of GEO satellite with elevation angle of 90o*** | ***485.28*** |

 |

Based on the above evaluation results, it is confirmed that in LEO satellite configuration, the proposed RIT meets the minimum requirement for mobility interruption time, which is 50 ms.

Annex 3

Simulation-based evaluation results

## A3.1 User experienced data rate

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *According to ITU-R Report M.2514, user experienced data rate is defined as the 5% point of the cumulative distribution function of the user throughput. The throughput for each UE is calculated as the number of correctly received bits, i.e., the number of bits contained in the service data units delivered to Layer 3, over a certain period of time.**The user experienced data rate for NR NTN is evaluated under the eMBB-s and rural scenario where the detailed simulation assumptions are given in ANNEX 4.**Based on the definition in ITU-R Report M.2514 and system configuration information provided by the proponent, the simulation results of the user experienced data rate for DL are given in Table A-7.* Table A-7Evaluation results of user experienced data rate for DL

|  |  |  |
| --- | --- | --- |
| *IMT-2020 requirement* | *Frequency reuse factor* | *Evaluateduser experienced data rate* |
| *1 Mbit/s* | *1* | *1.2022 Mbit/s* |
| *3* | *1.1188 Mbit/s* |

 |

Based on the above evaluation results, it is confirmed that the proposed RIT meets the minimum requirement for the user experienced data rate for DL, which is 1 Mbps.

## A3.2 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.**Based on the definition in ITU-R Report M.2514 and system configuration information provided by the proponent, the simulation results of the 5th percentile user spectral efficiency for DL are given in Table A-8.*Table A-8Evaluation results of 5th percentile user spectral efficiency for DL

|  |  |  |
| --- | --- | --- |
| *IMT-2020 requirement* | *Frequency reuse factor* | *Evaluated 5th percentile user spectral efficiency* |
| *0.03 bit/s/Hz* | *1* | *0.0401 bit/s/Hz* |
| *3* | *0.0373 bit/s/Hz* |

 |

Based on the above evaluation results, it is confirmed that the proposed RIT meets the minimum requirement for the 5th percentile user spectral efficiency for DL, which is 0.03 bit/s/Hz.

## A3.3 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.**Based on the definition in ITU-R Report M.2514 and system configuration information provided by the proponent, the simulation results of the average spectral efficiency for DL are given in Table A-9.*Table A-9Evaluation results of average spectral efficiency for DL

|  |  |  |
| --- | --- | --- |
| *IMT-2020 requirement* | *Frequency reuse factor* | *Evaluated average spectral efficiency* |
| *0.5 bit/s/Hz* | *1* | *0.5707 bit/s/Hz* |
| *3* | *0.5134 bit/s/Hz* |

 |

Based on the above evaluation results, it is confirmed that the proposed RIT meets the minimum requirement for the average spectral efficiency for DL, which is 0.5 bit/s/Hz.

## A3.4 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.**Based on the definition in ITU-R Report M.2514 and system configuration information provided by the proponent, the simulation results of the area traffic capacity for DL are given in Table A-10.*Table A-10Evaluation results of area traffic capacity for DL

|  |  |  |
| --- | --- | --- |
| *IMT-2020 requirement* | *Frequency reuse factor* | *Evaluated area traffic capacity* |
| *8 kbit/s/km²* | *1* | *12.0990 kbit/s/km²* |
| *3* | *10.8855 kbit/s/km²* |

 |

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

Annex 4

Assumptions used in the Simulations

## A4.1 Simulation models and assumptions

In order to evaluate system-level performance, study case 9 (LEO 600 km, FRF=1) and study case 10 (LEO 600 km, FRF=3) were considered with the assumptions based on the 3GPP TR 38.821 specification. The detailed parameters that were used in the simulations are given in Table A-11.

Table A-11

Assumptions for system-level simulations

|  |  |
| --- | --- |
| Parameters | Assumptions |
| Satellite altitude | 600 km (LEO) |
| Satellite payload | Transparent  |
| Terminal type | Handheld  |
| Frequency band | S-band (2 GHz) |
| Bandwidth | 30 MHz |
| Channel model | Frequency selective fading |
| Deployment scenario | Rural |
| Propagation conditions | Line-of-sight |
| UEs outdoor/indoor distribution | 100% outdoor distribution |
| FRF | 1 and 3 |
| Total number of beams  | 61 (FRF=1) and 127 (FRF=3) |
| Beams of interests | 7 inner beams |
| Number of UEs per beam | 10 |
| Central beam elevation angle | 90 degrees |
| Satellite EIRP density | 34 dBW/MHz |
| Satellite Tx antenna gain (max) | 30 dBi |
| Satellite 3dB beamwidth | 4.4127 |
| Antenna type and configuration |  (1,2,2) with omnidirectional antenna elements |
| UE polarization | Linear (±45 degrees) |
| UE Rx antenna gain | 0 dBi per element |
| UE antenna temperature | 290 K |
| UE noise figure | 7 dB |
| UE orientation | Random  |
| UE attachment | RSRP-based |
| Scintillation loss | 2.2 dB |
| Depolarization loss | 3 dB |
| Receiver type | MMSE-IRC |
| Scheduler | PF |
| Traffic model | Full buffer |
| Overhead | 14 % |

Annex 5

Assumptions for channel calibrations and results

## A5.1 Calibration assumptions

Channel calibrations are performed based on the assumptions for simulation-based evaluations, which are provided in ANNEX 3, with the following exceptions: a large-scale channel model was assumed, and scintillation loss is ignored. The calibration metrics are DL coupling loss, and geometry SIR/SINR.

## A5.2 Calibration results

The calibration results (shown as “Evaluation” in the legend of the following figures) are approximated to the average calibration results provided by different 3GPP entities (shown as “Mean”) for the self-evaluation towards IMT-2020.







FIGURE A-1 Calibration results for LEO 600 km, FRF=1 (study case 9)







FIGURE A-2 Calibration results for LEO 600 km, FRF=3 (study case 10)

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1. \* Submitted on behalf of SatComForum. [↑](#footnote-ref-1)