ASIA-PACIFIC TELECOMMUNITY
The 32nd Meeting of the APT Wireless Group (AWG-32)
4–8 March 2024, Pattaya, Thailand

Document No:
AWG-32/INP-89
26 February 2024

ITU-APT Foundation of India (IAFI[1])

PROPOSED UPDATES TO WORKING DOCUMENT TOWARDS A DRAFT NEW REPORT ON TECHNOLOGY AND REGULATORY DEVELOPMENTS FOR THE DELIVERY OF 5G/IMT-2020 APPLICATIONS IN THE MOBILE SATELLITE SERVICE

1 Introduction

WRC-23 adopted following agenda item 1.13 for WRC-27 "to consider studies on possible new allocations to the mobile-satellite service for direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage, in accordance with Resolution **253 (WRC-23)**" Based on these studies, WRC-27 is expected to consider appropriate regulatory actions, including possible new allocations to the MSS for direct connectivity between space stations and IMT user equipment to complement terrestrial IMT network coverage.

2 Proposal

IAFI through this contribution proposes to update on "Proposed updates to working document towards a draft new report on technology and regulatory developments for the delivery of 5G/IMT-2020 applications in the mobile satellite service" by adding suitable references of agenda item 1.13 of WRC-27 as shown in Attachment-1.

Attachment: As above

[1] ITU-APT FOUNDATION OF INDIA (IAFI)

Contact: **Email:**

WORKING DOCUMENT TOWARDS A DRAFT NEW REPORT ON TECHNOLOGY AND REGULATORY DEVELOPMENTS FOR THE DELIVERY OF 5G/IMT-2020 APPLICATIONS IN THE MOBILE SATELLITE SERVICE

1. Introduction

[Editor's note: This section provides the raison d'etre for the report and a brief summary of the key points contained herein]

Mobile satellite communications are an effective method to deliver mobile communication applications to rural, remote, and underserved areas where it is uneconomic or unfeasible to provide these applications by terrestrial means. The Mobile Satellite Service thereby serves alongside the Mobile Service as a means to reduce the digital divide and support the widespread adoption of digital economies.

As one of the potential radio access technologies of IMT-2020, 5G NTN satellite access will support mobility through integration at the terminal, network, and service level. Satellite network components are envisioned to provide worldwide ubiquitous coverage to end user equipment to meet the usage scenarios defined for the satellite component of IMT-2020.

The use and objective of 5G NTN satellite radio interfaces will complement terrestrial IMT-2020 operations, given satellites' unique ability to address coverage challenges and complex use-cases. The vast footprints and inherently global operation of satellite systems make global harmonization of spectrum even more critical than for terrestrial systems.

Whilst the complementary role and integration of satellite and terrestrial IMT systems has been contemplated since the 1990's[2]. The development and deployment of the terrestrial IMT systems proceeded well in advance of satellite systems. However, in the past few years radio technology, satellite design and manufacturing techniques, satellite launch and deployment options have improved to the point where the satellite component of IMT may be fully realized.

The evolution and large-scale deployment of fifth generation "5G" wireless networks over the next few years will require complementary 5G services by offering ubiquitous and reliable coverage across numerous geographies. Terrestrial networks are currently focusing on delivery of 5G services to areas already being served by existing cellular technologies, but the unique capabilities of non-terrestrial networks can help expand the reach of 5G technology in the realization of new use cases.

The satellite communications industry is picking up pace with new constellations of satellite deployments available today that are offering services to consumers, in addition to ongoing research into making these deployments serve larger footprints, providing more reliable service

[2] Recommendation ITU-R M.818-1 Satellite operation within International Mobile Telcommunications-200 (IMT-2000) (1992 – 1994)

and becoming more cost-effective as more satellite are deployed. Currently, there is increasing interest and participation in industry forums from the satellite communication industry, with companies and organizations convinced of the market potential for an integrated satellite and terrestrial network infrastructure in the context of 5G communications.

2. Scope

[Editor's note: This section describes in one or two paragraphs the scope of the report]

This report serves to inform APT members on recent developments and the current state of technology, regulation related to 3GPP 5G NTN and satellite component of IMT-2020 applications in the mobile satellite service.

3. References

[Editor's note: A list of external references relevant to the contents of the report – is expected to contain references to documents from organizations such as 3GPP and ITU-R as well as other organizations undertaking work related to 5G/IMT-2020 relevant to the Mobile Satellite Service]

3GPP TS 38.101-5 V17.0.0 (2022-06) User Equipment (UE) radio transmission and reception; Part 5: Satellite access Radio Frequency (RF) and performance requirements

Recommendation 206 (Rev. WRC-19) Studies on the possible use of integrated mobile-satellite service and ground component systems in the frequency bands 1 525-1 544 MHz, 1 545-1 559 MHz, 1 626.5-1 645.5 MHz and 1 646.5-1 660.5 MHz

Resolution 716 (Rev. WRC-12) Use of the frequency bands 1 980-2 010 MHz and 2 170-2 200 MHz in all three Regions and 2 010-2 025 MHz and 2 160-2 170 MHz in Region 2 by the fixed and mobile satellite services and associated transition arrangement

Resolution 212 (Rev. WRC-19) Implementation of International Mobile Telecommunications in the frequency bands 1 885-2 025 MHz and 2 110-2 200 MHz

Resolution 225 (Rev. WRC-12) Use of additional frequency bands for the satellite component of IMT

Report ITU-R M.2514-1 (09-2022) Vision, requirements and evaluation guidelines for satellite radio interface(s) of IMT-2020

Circular Letter ITU-R LCCE "Invitation for submission of proposals for candidate radio interface technologies for the satellite component of the radio interface(s) for IMT-2020 and invitation to participate in their subsequent evaluation", 23 November 2022

5G & Non-Terrestrial networks, 5G Americas, February 2022

4. Background

[Editor's note: this section includes information that supports content in later sections of the report, for example and not limited to; economic considerations, the importance of

standardization, harmonization and identification for ecosystem and technology development as it pertains to the scope of this report]

Over the past several years, the world has witnessed resurging interest for broadband provisioned by LEO satellite constellations. To benefit from the economies of scale of the 5G ecosystem[3], the satellite industry has engaged in the 3GPP process to integrate satellite networks into the 5G ecosystem.

Throughout 2021, 5G deployments have been steadily ramping up across the globe with dozens of terrestrial network operators. While initially, 5G services have been offered to consumers with smart phones, there is also a significant desire by network operators to offer 5G services to enterprise and massive IoT (internet of Things) and MTC (machine type communication) devices. Demand for service continuity is expected to further drive the network evolution and expansion into non-traditional areas. Non-Terrestrial Networks, or NTN, have been part of gradual shift of research focus and the industrial push towards 5G-Advanced leading into sixth generation (6G) systems.

Satellite-based communication can potentially play an important role in leveraging communication infrastructure to deliver 5G services in the future and bridge the digital divide. Generally, satellite-based architecture leverages Geostationary Earth Orbit (GEO), Medium Earth Orbit (MEO), and Low Earth Orbit (LEO) systems which can collectively provide coverage across altitudes ranging from 36,000 km to 400 km. These satellites can be either stationary or can orbit around the Earth in the form of constellations to provide services. Overall, there are tradeoffs in performance and deployment cost among different satellite systems (LEO, MEO, GEO) that need to be taken into consideration.

5. Regulatory Status and Considerations

[Editor's note: this section addresses international and national regulatory developments relevant to 5G/IMT-2020 in the MSS, it will include spectrum related information and may contain other related information e.g. the Radio Regulations and WRC Resolutions, relevant information on the status and contents of ITU-R Reports and Recommendations, the progress and processes with the ITU-R, national allocations and spectrum planning and policy decisions, it may also address best practices in national allocation and policy development]

5.1. International developments

WARC-92 allocated the bands 1 980-2 010 MHz and 2 170-2 200 MHz for the mobile-satellite service (MSS) with a date of entry into force of 1 January 2005, these allocations being co-primary with fixed and mobile service allocations.

The use of the frequency bands 1 980-2 010 MHz and 2 170-2 200 MHz in all three Regions and 2 010-2 025 MHz and 2 160-2 170 MHz in Region 2 by the MSS, in accordance with the provisions of Nos. 5.389A and 5.389C of the Radio Regulations, as adopted by WRC-95 and WRC-97.

The frequency bands 1 518-1 544 MHz, 1 545-1 559 MHz, 1 610-1 626.5 MHz, 1 626.5-1 645.5 MHz, 1 646.5-1 660.5 MHz, 1 668-1 675 MHz and 2 483.5-2 500 MHz may be used by administrations wishing to implement the satellite component of IMT, subject to the regulatory provisions related to the mobile-satellite service in these frequency bands.

[3] EMEA Satellite Operators Association, "ESOA satellite action plan for 5G standards," white paper. Available at https://www.esoa.net/cms- data/positions/1771%20ESOA%205G%20standards.pdf

The bands 2 500-2 520 MHz and 2 670-2 690 MHz as identified for IMT in No. 5.384A and allocated to the mobile-satellite service in Region 3 may be used by administrations in that Region wishing to implement the satellite component of IMT.

Resolution 212 (Rev. WRC-19), inter alia, provides guidance to concerned administrations on the following technical, operational and other applicable measures in the deployment of terrestrial and satellite components of International Mobile Telecommunications (IMT) for reducing the potential of harmful interference between the terrestrial and satellite components of IMT in the frequency bands 1 980-2 010 MHz and 2 170-2 200 MHz.

5.2. National Policy Considerations

[Editor's note: APT members are invited to provide information related to national policy, licensing experience (for UE uplink transmissions and Satellite downlinks or "landing rights") for inclusion in this section]

6. **Status and planning for Technology Specification and Standardization**

[Editor's note: this section describes the status of standards and specification and plans for their further development in relevant organizations, for example 3GPP and Release 17 and subsequent releases]

3GPP is a primary international body responsible for defining the technical specifications for mobile wireless networks. 3GPP was initially formed in December 1998 when the European Telecommunications Standards Institute (ETSI) partnered with other standard development organizations (SDOs) from around the world to develop new technologies (or more specifically, technology specifications) for the third generation (3G) of cellular networks. Each round of technical specifications work culminates in a release.

After initial delivery in late 2017 of 'Non-Stand-Alone' (NSA) NR new radio specifications for 5G, much effort focused in 2018 on timely completion of 3GPP Release-15 – the first full set of 5G standards – and on work to pass the first milestones for the 3GPP submission towards IMT-2020. 3GPP 5G standards continue to advance as the organization works toward 3GPP Release 17 and 18 in future years.

3GPP work on NR NTN started in 2017, with a Rel-15 study focused on deployment scenarios and channel models. The study was documented in 3GPP TR 38.811. The key scenarios and models included:

- Frequency ranges,
- GEO satellites, LEO satellites, as well as HAPS
- Earth-fixed beams (i.e., beams that are steered towards an area of earth as long as possible) and moving beams (i.e., beams that move over the Earth's surface following the motion of the satellite)
- Typical footprint sizes and minimum elevation angles for GEO, LEO, and HAPS deployments
- Two types of NTN terminals: handheld terminals and Very Small Aperture Terminals (VSAT) (equipped with parabolic antennas and typically mounted on buildings or vehicles)
- Antenna models for the satellite and HAPS antennas

The second main objective of the study was to develop NTN channel models based on the terrestrial 3GPP channel models. The channel models developed supports a range of deployment scenarios including urban, suburban, and rural.

Multipath is a typical phenomenon in terrestrial propagation environments. For NTN, the large distance to the satellite causes different paths to be almost parallel, and the angular spread is thus close to zero. The large-scale parameters (line- of-sight probability, angular spread, delay spread, etc.) are therefore different from the terrestrial case and depend on the elevation angle of the serving satellite.
Modeling of the path loss mainly relies on free-space path loss but adds components for clutter loss and shadow fading to account for the attenuation by surrounding buildings and objects. Values for clutter loss and shadow fading are tabulated for different elevation angles and for the two frequency ranges of S-band and Ka-band. The channel models also include parameters to account for absorption by atmospheric gases, as well as ionospheric and tropospheric scintillation losses. These losses may be of interest only for low elevation angles and/or in certain other conditions (e.g., at low latitudes, during periods with high solar activity, etc.).
The study developed two fast fading models. A more generic and frequency-selective model is based on the terrestrial model but adjusted to the satellite geometry with different values and correlations for delay and arrival angles. Similar to clutter loss and shadow fading, values are tabulated for different elevation angles and for the two frequency ranges. Alternatively, a simpler two-state model assuming flat fading can be used to study certain situations (e.g., low frequencies, large elevation angles, and near-line-of-sight).
In addition, the study developed clustered delay line and tapped delay line channel models for NTN link-level simulations.
After this initial study, the 3GPP SA (Systems Aspects) workgroup started to discuss the use cases for Satellite-based NTN as part of the Study Item on Satellite Access in 5G. The study identified three main categories of use cases for satellite-based NTN:

- Service Continuity: Use cases where 5G services cannot be offered by terrestrial networks alone, and how a combination of terrestrial and non- terrestrial networks combined provides service continuity for such cases. Some examples are airborne platforms (e.g., a commercial or a private jet) and maritime platforms (e.g., a maritime vessel).
- Service Ubiquity: Use cases address unserved or under-served geographical areas, where terrestrial networks may not be available. Examples of ubiquity use cases are IoT (e.g., agriculture, asset tracking, metering), public safety (i.e., emergency networks), and home access.
- Service Scalability: Use cases that leverage the large coverage area of satellites and uses multicasting or broadcasting a similar content over a large area. An example of such use case is the distribution of rich TV content (i.e., Ultra High-Definition TV).

The work in Release-16 also included a study in Radio Access Network (RAN) working groups on solutions for New Radio (NR) to support non- terrestrial networks with the objective to determine the necessary features to enable NR support for NTN. These studies provided a baseline for NR functionalities needed to support LEO and GEO satellites.

The approval of normative activities on Non-Terrestrial Networks (NTN) for 3GPP Rel-17 generated growing interest in the topic. The Rel-17 NTN work items are supported by a wide range of vendors (terminal, chipset, network), as well as service providers from both the mobile and space industries and user groups including GSOA.

The Rel-17 NTN and satellite work items in Technical Specification Group. Radio Access Networks (RAN) and Service and System Aspects (SA) completed satellite inclusion in 3GPP technical specifications in June 2022. The focus was on transparent payload architecture with FDD systems where all UEs were assumed to have GNSS capabilities. The normative phase included adaptation to the physical & access layer aspects, radio access network and system architecture, radio resource management, and RF requirements for targeted satellite networks operating at LEO, MEO or GEO orbits.

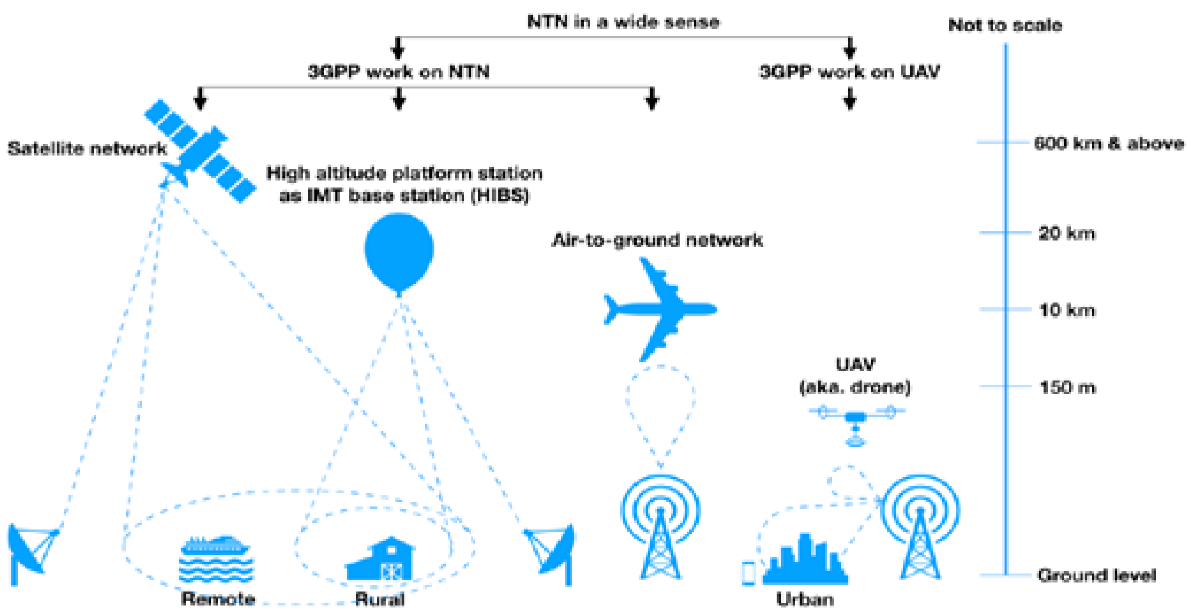
The 3GPP Rel-17 specifications support New Radio (NR) based satellite access deployed in Frequency Range 1 (FR1), which encapsulates bands below 6 GHz, serving handheld devices for global service continuity. The specification also supports NB-IoT and eMTC based satellite access to address massive Internet of Things (IoT) use cases in areas such as agriculture, transport, and logistics etc.

This joint effort between mobile and satellite industries is leading to full integration of satellite in the 3GPP ecosystem and the definition of a global standard for future satellite networks. Thus addressing the challenges of reachability and service continuity for areas unserved/underserved by terrestrial networks, enhancing reliability through connectivity between various access technologies, and improving network resilience and dependability in responding to natural and man-made disasters.

The completion in June 2022 of Rel-17, commercial 5G NTN product availability is expected sometime in 2024[4]. Including satellite as part of the 3GPP specifications will support the promise of worldwide access to 5G services and drive explosive growth in the satellite industry.

Looking ahead, NTN stakeholders have started discussions on 3GPP Rel-18 and are working on enhancements for both NR-NTN and IoT-NTN for Rel-18. Plans are also underway to further define the enablers for NR based satellite access in bands above 10 GHz to serve fixed and moving platforms (e.g., aircraft, vessels, UAVs) as well as building- mounted devices (e.g., businesses and premises) (See xx). The goal of these efforts is to further optimize satellite access performance, address new bands with their specific regulatory requirements, and support new capabilities and services as part of the ongoing evolution of 5G NR.

Figure 1: Different types of non-terrestrial networks



According to 3GPP TR 38.821, the two typical scenarios, transparent and regenerative payloads, of a satellite-based NTN providing access to user equipment are depicted below:

[4] NTN & Satellite in Rel.17 & 18 by Munira Jaffar & Nicolas Chuberre, July 2022, https://www.3gpp.org/news-events/partner-news/ntn-rel17

Figure 2: Satellite NTN scenario based on transparent payload

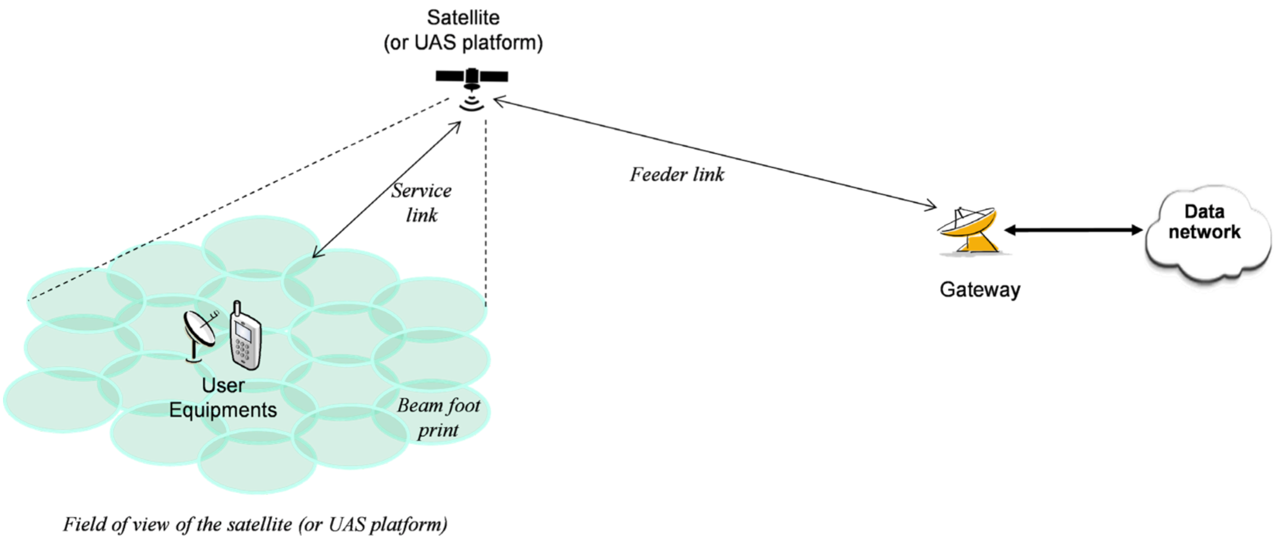
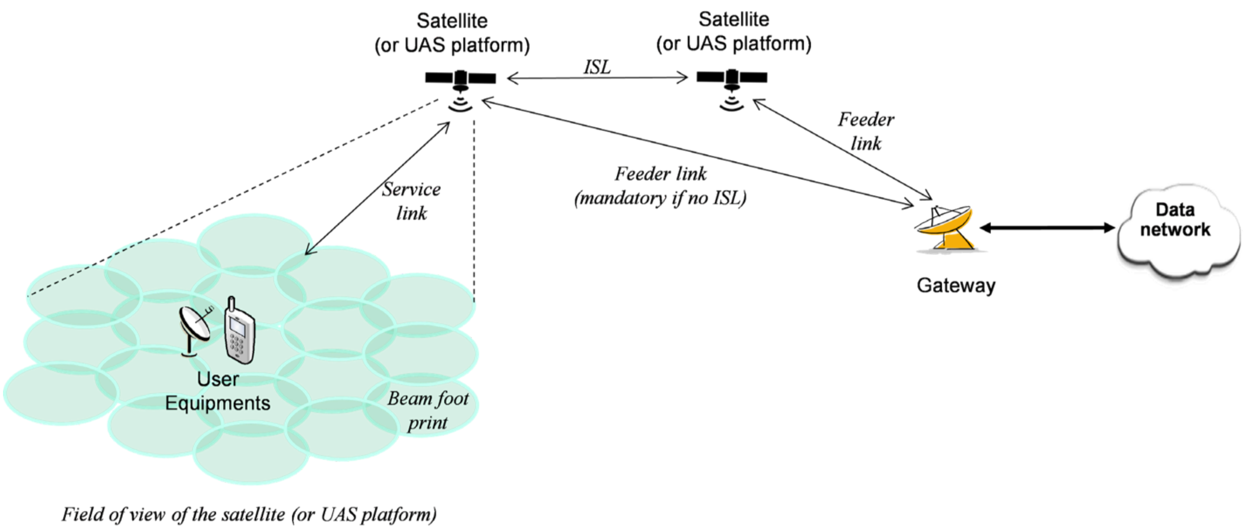


Figure 3: Satellite-based NTN typical scenario based on regenerative payload



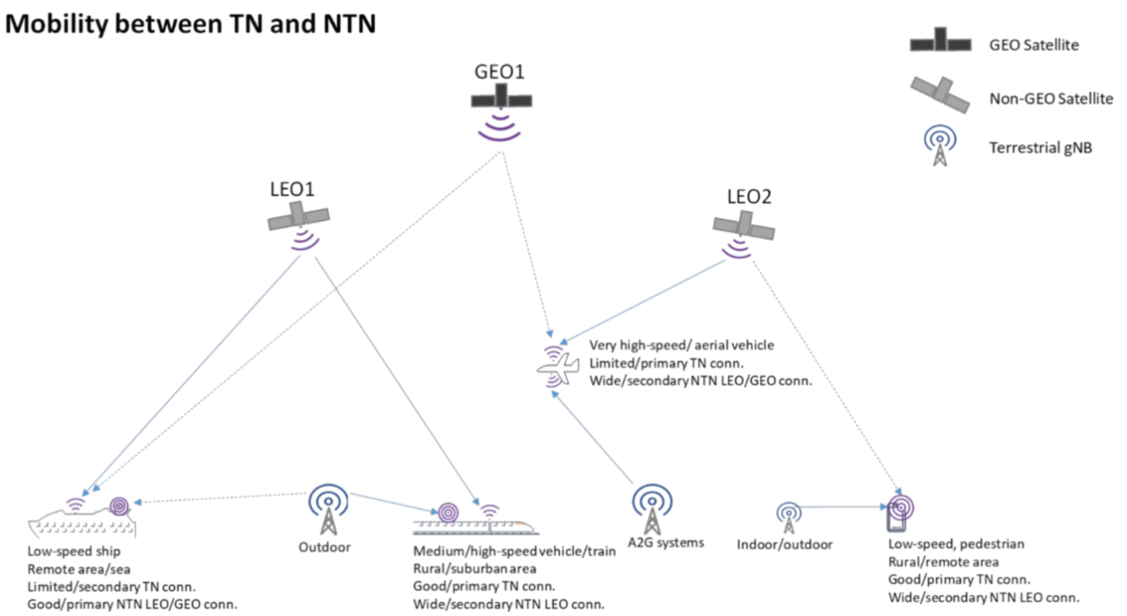
A satellite-based Non-Terrestrial Network typically features the following elements:

- One or several satellite gateways that connect the Non-Terrestrial Network to a public data network:
  - o A GEO satellite is fed by one or several sat-gateways which are deployed across the satellite targeted coverage (e.g., regional, or even continental coverage). We assume that UEs in a cell are served by only one satellite gateway
  - o A Non-GEO satellite served successively by one or several sat-gateways at a time. The system ensures service and feeder link continuity between the successive serving sat-gateways with sufficient time duration to proceed with mobility anchoring and hand-over
- A feeder link or radio link between a sat-gateway and the satellite
- A service link or radio link between the user equipment and the satellite

- A satellite which may implement either a transparent or a regenerative (with on board processing) payload. The satellite typically generate several beams over a given service area bounded by its field of view. The footprints of the beams are typically of elliptical shape. The field of view of a satellite depends on the on-board antenna diagram and minimum elevation angle.
    - A transparent payload: Radio frequency filtering, frequency conversion and amplification only at the satellite. Hence, the waveform signal repeated by the payload is unchanged.
    - A regenerative payload: Radio frequency filtering, frequency conversion and amplification as well as demodulation/ decoding, switch and/or routing, coding/modulation at the satellite. This is effectively equivalent to having all or part of base station functions (e.g., gNodeB or "gNB") on board the satellite.
- Inter-satellite links (ISL) are optional in case of a constellation of satellites. This will require regenerative payloads on board the satellites. ISL may operate in RF frequency or optical bands.
- User Equipment are served by the satellite within the targeted service area.

The 5G system is expected to support service continuity between 5G terrestrial access network and 5G satellite access networks owned by the same operator or owned by two different operators having an agreement. NTN as currently defined only supports standalone deployments (SA).

Figure 4: Typical example of NTN-TN interworking



3GPP Rel-17 specified the enhancements identified for 5G NR NTN LEO and GEO satellites. RAN features in physical layers were enhanced to address long propagation delays, large Doppler effects and moving cells in NTN. This includes timing relationships, UL time and frequency synchronization and HARQ procedures.

Increased delays can also cause Channel Quality Indicator (CQI) reporting and Modulation Coding Scheme (MCS) assignment delays as channel conditions like rain fade on DL and UL can change. Therefore, the gNB needs to have robust algorithms to maintain the throughput performance to compensate for higher Block Error Rate (BLER) at the UE or gNB. The scheduler needs to compensate MCS and resource block (RB) assignment for various signal to noise (SNR) conditions.

5G NTNs re-use the existing 5G Core Network functionality as much as possible without impact on the core network's procedures or functional elements. However, certain timers involved in session and mobility management required adjustment to cope with longer delays introduced with satellite access.

The Core network for 5G satellite (NTN) communication is expected to reuse the 5G NR terrestrial core network. Due to the unique nature of satellite communication that can cover multiple countries, the system needs to be able to support a mix of national roaming and RAN sharing and also have the possibility to support scenarios where the satellite operator has its own subscribers and where it does not.

For 3GPP, spectrum has been generally defined in two different frequency range (FR) groups: FR1 - frequency range from 450Mhz to 6GHz, and FR2 – frequency range from 24.25GHz to 52.6GHz. For FR1, 3GPP reached an agreement for the following NTN bands (See Table 1):

Table 1: 3GPP defined NTN satellite bands in FR1

NTN satellite operating band	Uplink (UL) operating band Satellite Access Node receive / UE transmit F_{UL_low} – F_{UL_high}	Downlink (DL) operating band Satellite Access Node transmit / UE receive F_{DL_low} – F_{DL_high}	Duplex mode
n256	1980MHz – 2010 MHz	2170 MHz – 2200 MHz	FDD
n255	1626.5 MHz – 1660.5 MHz	1525 MHz – 1559 MHz	FDD
NOTE: NTN satellite bands are numbered in descending order from n256.			

The maximum transmission bandwidth configuration N_{RB} for each UE channel bandwidth and subcarrier spacing (SCS) is specified in Table 2.

Table 2: Maximum transmission bandwidth configuration

SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz
	N_{RB}	N_{RB}	N_{RB}	N_{RB}
15	25	52	79	106
30	11	24	38	51
60	N/A	11	18	24

It should be noted that bands n256 and n255 correspond to spectrum identified in the ITU Radio Regulations and associated resolutions for the satellite component of IMT.

In 2022, the ITU-R approved Report ITU-R M.2514 "Vision, requirements and evaluation guidelines for satellite radio interface(s) of IMT-2020". The purpose of this Report is to build a vision, the requirements and evaluation guidelines for the satellite component of IMT-2020 including use cases, application scenarios, capabilities, system, radio interface, and the considered specific features, particularly with respect to service and technical requirements.

On the 23 November 2022, via circular letter 4/LCCE/134, the ITU-R invited the submission of proposals for candidate radio interface technologies (RITs) or Set of RITs (SRITs) for the satellite component of the radio interface(s) for IMT-2020 and invitation to participate in their subsequent evaluation[5].

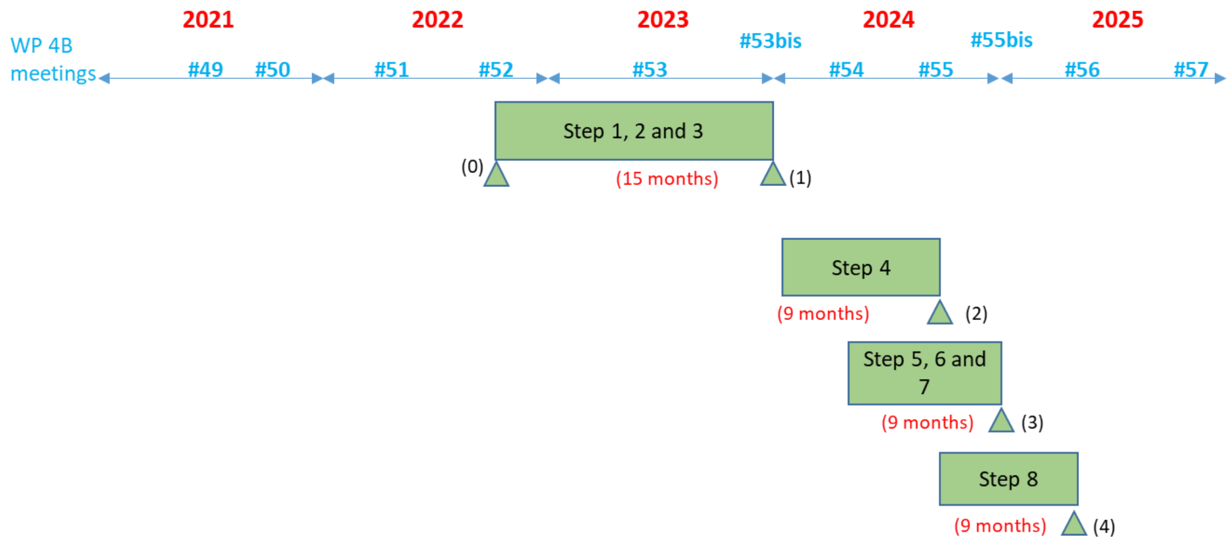
The Circular Letter also initiates an ongoing process to evaluate the candidate RITs or SRITs for the satellite component of IMT-2020 and invites the formation of independent evaluation groups and the subsequent submission of evaluation reports on these candidate RITs or SRITs.

The Radiocommunication Bureau has established a "Web page for the satellite IMT-2020 submission and evaluation process" to facilitate the development of proposals and the work of the evaluation groups. The satellite IMT-2020 web page will provide details of the process for the submission of proposals, and will include the RIT and SRIT submissions, evaluation group registration and contact information, evaluation reports and other relevant information on the development of IMT-2020 satellite radio interface(s).

Candidate RITs or SRITs will be evaluated by the ITU membership, standards organizations and other independent evaluation groups. Evaluation groups are requested to register with ITU-R[6], preferably before the end of 2022. The evaluation groups are kindly requested to submit evaluation reports to the ITU-R in accordance with the evaluation process delineated on the satellite IMT-2020 web page. The evaluation reports will be considered in the development of the ITU-R Recommendation describing the radio interface specifications.

The detailed schedule for the evaluation process can be found in Figure 5 below.

Figure 5: Schedule for the development of IMT-2020 satellite radio interface Recommendations



Steps in radio interface development process:
Step 1: Issuance of the circular letter
Step 2: Development of candidate RITs and SRITs
Step 3: Reception of the RIT and SRIT submissions and acknowledgement of receipt
Step 4: Evaluation of candidate RITs and SRITs by independent evaluation groups
Step 5: Review and coordination of outside evaluation activities
Step 6: Review to access compliance with minimum requirements
Step 7: Consideration of evaluation results, consensus building and decision

[5] https://www.itu.int/en/ITU-R/study-groups/rsg4/Pages/imt-2020-sat-submission-eval.aspx and https://www.itu.int/md/R00-SG04-CIR-0134/en

[6] Evaluation group registration forms will be made available at: Satellite IMT-2020 submission and evaluation process.

Step 8: Development of radio interface Recommendation(s)

Critical milestones in radio interface development process:

(0): Issue an invitation to propose RITs	September 2022
(1): ITU proposed cut off for submission of candidate RIT proposals	December 2023
(2): Cut off for evaluation report to ITU	September 2024
(3): WP 4B decides framework and key characteristics of IMT-2020-Sat RITs and SRITs	End 2024
(4): WP 4B completes development of radio interface specification Recommendation(s)	May 2025

3GPP is currently undertaking efforts to prepare its NTN specifications for submission to the ITU-R evaluation process.

The reader may notice that the process leading to the publication of radio interface specification Recommendation(s) in May 2025 coincides roughly with the expected availability of equipment.

7. **Industry Activities and Developments**

[Editor's note: this section contains information on the development and deployment of 5G/IMT-2020 technology in the MSS, for example, in may include information on current research initiatives and partnerships, ecosystem development, deployment status and plans, case studies etc.]