A 5G AMERICAS WHITE PAPER

NEW DEVELOPMENTS AND ADVANCES IN 5G AND NON-TERRESTRIAL NETWORKS

FEB 2025

Contents

1. Introduction

The satellite industry in partnership with the 3GPP ecosystem has the ability to achieve ubiquitous seamless connectivity around the globe by complementing the coverage of 4G, 5G, and beyond terrestrial networks. The technological advances in the space and satellite communications industry and their integration with terrestrial telecommunications networks will play a significant role in shaping the future of connectivity. The Total Addressable Market for telecommunications revenues via wholesale satellite partnerships is expected to exceed US$28 billion by 2030[1].

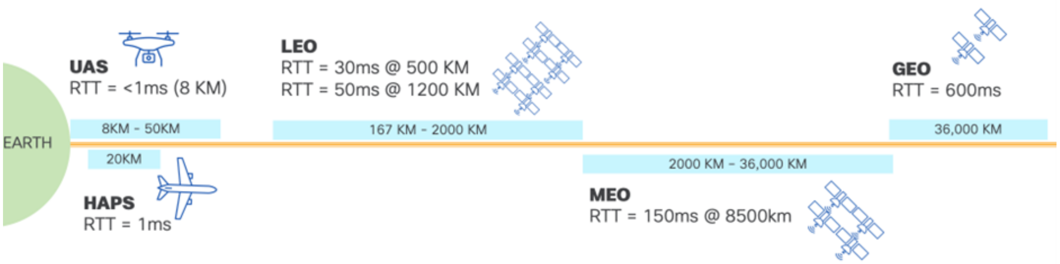
1.1 Purpose of the paper

This paper provides some insights into the ongoing and evolving supplementary services provided by space systems to terrestrial mobile networks. Over the past three years, this nascent service has seen some rudimentary tests and proof of concepts and is now entering into pre-commercial and commercial services. It is expected that there will be various implementations and architectures chosen by the space services partners, and each of these will require some time to shake down and bake. Coverage enhancements and support for the various emergency services such as E911 and WPAS (Wireless Public Alerting Service) or WEA (Wireless Emergency Alerting) will be the initial offering, as the space segment needs time to get assets into the sky to support seamless coverage. In the ramp-up to contiguous coverage, it is expected that intermittent coverage is available, with a period depending on the number of satellites in that orbital plane supporting the virtual cells on the ground. It is important to understand that, unlike the terrestrial network systems where the coverage was always there when a base station was installed, here the satellites move in their orbits and handover to the next satellite, if available, to continue the service.

As mobile operators and their satellite partners work out the bugs in the implementations and coverage, additional services may be added that replicate the existing services, such as voice and data that are offered on terrestrial mobile networks. It is hoped that the regulators in those countries where these services are being planned and/or are in the process of testing, deployment and/or regulatory review, are open to the challenges that will be worked through to provide services. This new service brings key aspirations to regulators in the hope to minimize the digital divide across the vast distances and geographic obstacles that have hindered the feasibility and economical deployment of terrestrial systems.

Given the orbits being used for this supplementary service, many satellites are required to provide national footprints in many countries in the Americas. Enhancement to the deployed satellites and their support services may take some time for future upgrades pending the architecture and model chosen by the space partners. There may be some confusion on NTN (Non-Terrestrial Networks) and Direct-to-Cell or Supplementary services. The supplementary coverage described in this document does not require enhancements for NTN as defined in 3GPP. In fact, there are no 3GPP NR NTN systems in existence today and probably will not be for at least a few years. The work done in those standardization programs may benefit the network and devices in future but are not required for supplementary services. NTN enhancements were aimed at Mobile Satellite Services (MSS) (Primary allocations) and Ancillary Terrestrial Components (ATC) where the operator has a primary allocation of MSS spectrum and has used ATC to build out parts of its network, although they appear the same, they are not.

Figure 1: Non-Terrestrial network Types[2]



NTN encompasses satellites, high altitude platform stations (HAPS), and unmanned aerial systems (UAS)/drones operating in different orbits and ranges as depicted in Figure 1.
The non-terrestrial connectivity is provided by an NTN payload, i.e., a network node (e.g., radio relay unit) on a satellite or HAPS. Ground/terrestrial-based cellular network element components (eNB/gNB, DU/CU, etc.) send the signal via an NTN gateway interconnected by a feeder link to a satellite-based radio access network (RAN) element, to beam the cellular connectivity from space. User equipment accesses NTN cellular network services through the NTN payload via a service link. Feeder link and service link are terms associated with satellite-based communication. The feeder link is used to send instructions and data to the satellite from the ground station and receive information back. The service link is used to send and receive signals between the satellite and devices connected to it.

2. Progress and adoption of NTN

Table 1: IoT/D2C service providers as of Oct 31st, 2024 (Not Comprehensive)

Operator	Satellite system (deployed)	Spectrum	Technology	Operational	Services
Dedicated providers					
Space X	2016 LEO (257)	MNO spectrum/ 2GHz MSS	Pre Rel-17 3GPP	2024	Messaging, speech, broadband
AST SpaceMobile	243 LEO (5)	MNO spectrum	Pre Rel-17 3GPP	2024	Messaging, speech, broadband
Lynk	5000 LEO (3)	MNO spectrum	Pre Rel-17 3GPP	2Q2023	Messaging, LDR (low-data rate)
Sateliot	250 LEO (5)	2.0GHz MSS	Rel-17 NB-IoT (NB-NTN)	TBD	NB-IoT
Iridium	66 LEO (66)	L-band	Proprietary	Yes	LDR/Messaging
Orbcomm	31 LEO	137-150 MHz	Proprietary	Yes	Assets tracking
GlobalStar	48 LEO (25)	L/S-band	Proprietary	Yes	Assets tracking
Ligado	1 GEO	L-band	Rel-17 NB-IoT (NB-NTN)	TBD	NB-IoT
Partnerships					
T-Mobile/SpaceX	2016 LEO (257)	MNO spectrum	3GPP-Rel 12	2024	Messaging, Data, Voice, Video
AT&T/AST	243 LEO (5)	MNO spectrum	3GPP-Rel 12	2024	Messaging, Data, Voice, Video
Verizon/Kuiper	3236 (0)	Ka band	Proprietary	TBD	Ground sites backhaul - LTE and 5G
Apple/Globalstar	24 LEO	L-band, S-band	Proprietary	4Q2022	Emergency Messaging
Mediatek/ Skylo/Bullitt	6 GEO (Inmarsat)	L-band	3GPP-NTN	1Q2023	Messaging
Skylo/Ligado/ Viasat/Verizon	1 GEO (Ligado)	L-band	3GPP-NTN	2H2023	NB-IoT, Messaging, LDR
Rogers/SpaceX	2016 LEO (257)	MNO Spectrum	3GPP-Rel 12	2024	Messaging, Data, Voice, Video
Rogers/Lynk	5000 LEO (3)	MNO Spectrum	3GPP-Rel 12	2024	Messaging, Data, Voice, Video

New partnerships for both D2C pre-Release17, NB-NTN and proprietary technologies have been announced over the last couple of years as mentioned in Table 1. These partnerships will help drive adoption of these technologies into the device and IoT ecosystem.

2.1 Current deployment and partnership updates

Supplemental Coverage from Space (SCS) or Direct-to-Cell (D2C), direct-to-device (D2D) are forms of NTN, where the satellites act as cell towers distributing coverage. These can look like IaaS (Infrastructure as a Service). The model here is sometimes possible for many mobile operators to share the satellites to provide coverage in their home territory, which is a bit different than sharing on an existing terrestrial tower. Virtual Cells are created for coverage in the home network for MNO, but the actual satellite it uses are moving, and the virtual cell is imposed on satellites that are currently in the right spatial location of the virtual cell. Other MNO in other countries will have their own virtual cells.

With SCS/ D2C deployments, the location of earth stations will play a key role in providing the regulatory frameworks required by those countries. The location of an earth station in the beginning will be driven by the aggregate capacity required to be supported by the space element among its terrestrial partners and its access to the skies. Some satellite providers may use GEO and/or in-orbit communication links between the satellites, but each of these may add some delay, and the space segment partners will vet and choose what works for them, including how many earth stations to deploy.

Pending these architecture choices will drive implementation issues. Additional methods of interconnection to the earth station may require MNO operations such as knowledge of who is using or attempting to use the services in their service areas. Barring devices in support of police for stolen handsets, and monitoring devices for security reasons, lawful access support, cyber control on access to WEA, access to PSAP data-bases, and resiliency support for other MNO disasters that may be mandated in the serving country, they may not be mandated or have different requirements where the host earth station is located.

Some proposals suggest a roaming architecture from the space segment (S8) providers, however, to meet the above requirements it is also suggested that various business interfaces between the space segment and the associated MNO to meet their country's regulatory requirements are required. Some implementations may also use mobile network sharing but are predicated on the architecture provided by the space segment and their abilities to manage the various relationships.

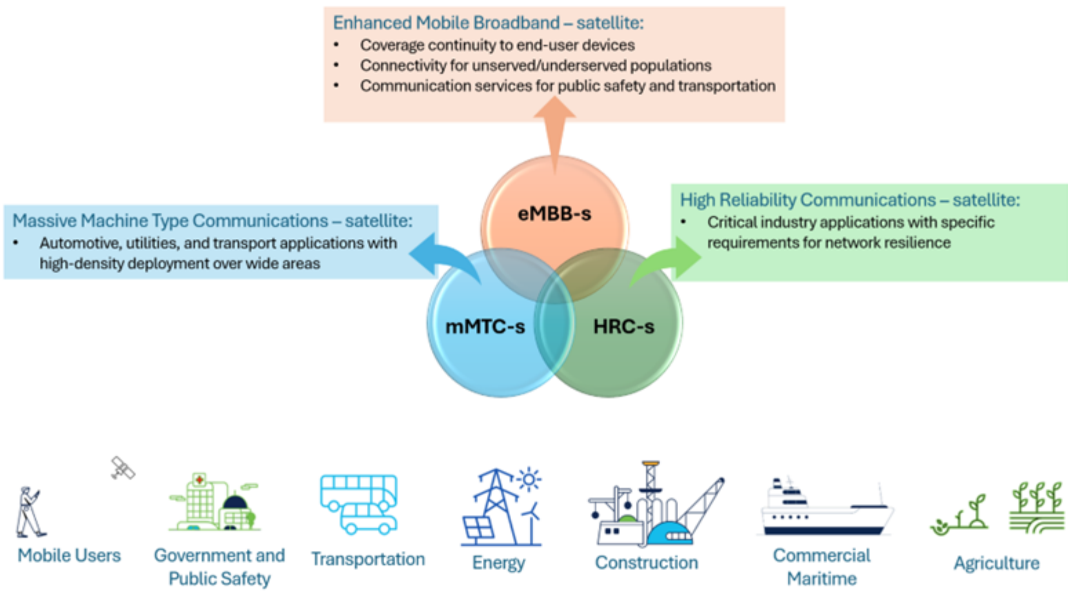
2.2 Use cases

While the NTN bring supplemental coverage from Space, the satellite radio interfaces are expected to complement the terrestrial operations with existing smartphone devices (LTE) and higher compliant 5GNR devices, using satellites' unique ability to address coverage continuity issues and support challenging use cases in remote and underserved areas, also including aerial and maritime environments. Some aspects of NTN are not expected to be served by the satellite radio interface due to the distance between the satellites and the associated earth terminals that increases latency compared to terrestrial operations. Taking these aspects into consideration, new satellite-based service categories that are reflected through the definition of eMBB-s, mMTC-s, and HRC-s usage scenarios for the satellite component of IMT-2020[3] along with some of the key industries targeted by NTN providers are outlined in Fig. 2. Although these new service categories with the suffix -s are specific to the key requirements related to the minimum technical performance of the satellite component of IMT-2020, it is to be noted that eMBB, mMTC, and HRC can be provided by various other satellite technologies providing supplemental coverage.

While NTN Release-17 is 5G NR based, satellite-based direct-to-device service offering, like AST-Space Mobile, SpaceX/Starlink are aiming to provide direct-to-device connection from satellite-based "LTE" Radio Access using Operator Spectrum to offer services to unmodified LTE smartphones. They may consider deploying a transparent eNB/gNB architecture or a regenerative eNB//gNB with some components of gNB L2 functionality incorporated on satellite payload. eNB functionality, algorithms are expected to handle all connectivity and service requirement related changes as they are expected to work with unmodified smartphone devices.

Using existing LTE spectrum (after consent by the terrestrial licensee and regulatory approval) and Pre-Release-17 LTE based NTN Access Network Solution to provide direct-to-device connectivity* for unmodified smartphone can take advantage of enormous number of incumbent LTE smart phone users. This also needs minimal changes in Core Network. NTN

Figure 2. Non-terrestrial network use cases and key industry target sectors[4]



Release-17 and above based solution using newly assigned spectrum need both device chipset ecosystem and spectrum support on newer mobile devices.

Regenerative gNB is not in the scope of Release 17, however it is included in Release 19. In the regenerative gNB architecture, the satellite carries an entire gNB, which makes it possible to decode and process packets on the satellite. The regenerative architecture provides more flexibility and better performance. Mobile Network Operators are expected to integrate with Non-Terrestrial network provider infrastructure, using standard roaming interconnectivity based on Home Routed Model. MNO subscribers with NTN access will roam into NTN network during idle-mode network selection, or other network and eSIM/SIM/Device based mechanisms to prioritize the selection of Non-Terrestrial network based on preconfigured rules.

One of the largest benefits of satellite systems is their ability to provide coverage over large geographical areas that terrestrial systems just do not cover today. As of 2023, in the US 99.6%[5] of the population is covered by mobile wireless, while only 84%[6] of the land geography is covered. In Canada about 99.9 % of the 40 Million[7] population is covered by mobile wireless service, however that only represented about 30 %[8] of the land mass. (See appendix)

Natural disasters like hurricanes can wreak havoc on communications. Yet, government agencies, cellular carriers, and the overall industry historically have worked together to help those in need during these difficult times. In early October 2024, T-Mobile and SpaceX received permission from the Federal Communications Commission (FCC) to temporarily provide pre-commercial Direct-to-Cell SMS services on a best effort basis to support the impacted areas of Hurricane Milton and Hurricane Helene. Hurricane Milton made landfall near Tampa Florida and impacted those areas on its path to Orlando Florida. Over a 48 hours period both in advance of Milton and when it made landfall Direct-to-Cell service was used to broadcast over 120 WEA from public safety agencies and enabled over 100K SMS messages to be sent and received. Direct-to-Cell services inherently do not offer the same capacity as terrestrial networks, however they may be able to provide some critical communications during national disasters while terrestrial networks recover.

2.3 Spectrum/territorial regulation issues

Currently the FCC has issued initial rules, frequency bands for consideration of SCS in the United States. It is currently limited to FR1 band, and those that are FDD in nature. The FCC rules look at mechanism to get SCS service operational over a vast number of MNO using the same band. In Canada a consultation was issue in early June, in general it mirrors the objectives and concerns of the FCC. It however also includes discussion on coastal water ways which is a sperate FCC NOI[9]. The Canadian Consultation does not include public safety at this time as the band has yet to be licensed.

Of concern to both the US and Canadian spectrum considerations is the lack of TDD spectrum. Here there may be an erroneous thought that TDD on a particular frequency can not handle the space link time delay, or coordinate the up and down in the same channel, however many carriers are pairing TDD spectrum with carrier aggregation. With carrier aggregation it is possible to have data sent in one band and the uplink in another band, thus making TDD with carrier aggregation with either FDD and or TDD spectrum appear as FDD to the user, and thus alleviates any time delay questions, and any in band collisions. TDD issues like TX/RX duty cycles can still be maintained on these deployments, but are better to be flexible from 0 to 100 percent for either mode

3GPP has already anticipated bands that may be used for NTN and supplementary coverage. The NTN bands that have been defined in 3GPP are utilizing MSS spectrum. Direct-to-Cell Spectrum pre-Release-17 is using terrestrial spectrum which is not defined as NTN in 3GPP. For 3GPP R17 NTN and beyond spectrum bands are specified in 3GPP 38.101. As of Q3 2024 there is currently three FR1NTN bands standardized to support L-Band and S-Band spectrum. The channel bandwidths are defined as 5, 10, 15 & 20MHz in DL and UL for FDD paired spectrum for SCS (Subcarrier Spacing) of 15kHz.

Table 2: NTN satellite bands in FR1-NTN

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 receive/ UE receive $F_{UL,low}$ – $F_{UL,high}$	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 – 1626.5 MHz	2483.5 – 2500 MHz	FDD
NOTE: NTN satellite bands are numbered in descending order from n256.			

If TDD band are considered, 2.6 GHz.and in future C band could be considered; as multiple TDD allocation can be configured as FDD via carrier aggregation.

2.4 Public Safety use of NTN

Public Safety is paramount, and SCS, D2C should be envisioned for public safety broadband services. In the US, FirstNet is interested in SCS to enhance coverage especially in areas where terrestrial cellular coverage may be lacking.

If regulators provide access to coastal waterways, MNO interaction with public safety is likely to change to include Coastguard and polices around routing emergency calls to specific virtual cells located in these coastal waters. Law Enforcement Agencies (LEA) will also need to understand that these virtual cells in coastal water ways will effect how they deal with targets under lawful authorizations.

2.5 Supplementary Services Impact on stakeholders

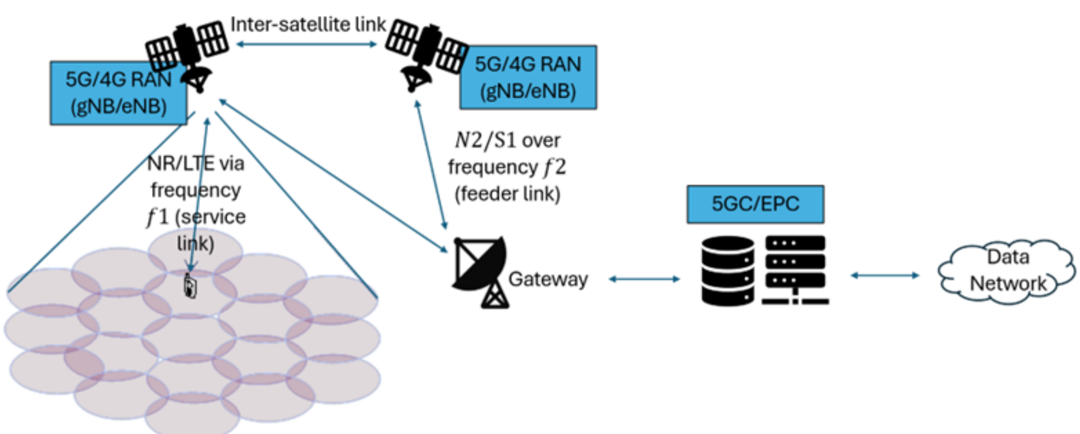
The move into supplement services comes with it large enhancements to coverage and growing pains. Several MNO may use different PLMN ID to help identify these coverage areas and their initial limitations. MNO may charge differently for access to these different regions. Some regulators may apply different licensing to support the supplement services, ideally any regulatory cost should be cost recovery for space assets filings, MNO have likely already paid for any licensing of the spectrum through normal processes.

3. Non-terrestrial network architecture

3.1 Opportunities for common interfaces across Direct-to-Satellite networks

A satellite-based 5G network system will rely on advanced technologies to switch between the satellite and terrestrial components to provide network service connectivity to end-users. Figure 3 illustrates common interfaces across a direct-to-satellite network with a base station onboard the satellite. A satellite radio interface is implemented on the service link between the satellite and the UE. A regenerative satellite payload processes the satellite radio interface protocol between the service link and the feeder link, potentially using the inter-satellite links. The gNB (eNB in case of 4G) knows when it can start serving a certain AMF/MME (part of 5GC/EPC) based on its ephemeris information, including the orbital trajectory and coordinates. Existing N2/S1 procedures are used for setup requests and responses between the RAN and the core. Regenerative-based satellite access paved the way for store and forward (S&F) satellite operations facilitating the storing and forwarding of UE information in periods of time and/or geographical areas in which the serving satellite is not simultaneously connected to the ground network via feeder link or inter-satellite link[10].

Figure 3. Common interfaces across Direct-to-Satellite network architecture [Adapted from 3GPP TR 38.811]



Depending on the space partner there may be several interfaces used to support D2C and/or SCS that may vary from the 3GPP envisioned NTN. These include S8 roaming architecture that can provide MSS-ATC service or FSS ESIM broadband service. Alternatively, space partners may provide an IaaS model where the space interface appears as eNB or in the future gNB. In the S8 mode, depending on the location of the earth stations, the MNO and space partner may need a business interface to support regulatory requirements. (e.g., WEA, roamer notifications, and EIR requirements). This interface may have more services if the earth station is in a different country. The business interface may also deal with and collect information required for local regulation such as wireless priority alerting and access, domestic roaming, access to PSAP, and other call centers. (Coastal waterways may require new access to the coastguard.)

3.2 Review of IMT 2020 S proposal

IMT 2020-S is a reference to work in International Telecommunication Union (ITU) where requirements have been established for NTN, and new bands are being investigated These are expected to have an MSS allocation, it is unclear if they will have an ATC support but that may be a regional regulatory ruling. The spectrum allocation are expected to be finalized at the end or WRC 27 AI 1.12

The ITU has been entrusted with facilitating the resource allocation, regulation, and safeguarding of the satellite component of the International Mobile Telecommunications-2020 (IMT-2020) systems. This work is guided by ITU-R Study Group 4 (Satellite Services) and Resolution ITU-R 65 to facilitate the development of proposals for the satellite component of the radio interface(s) for IMT-2020 and their subsequent evaluation. As the terrestrial component of IMT-2020 is already well-defined and established, the satellite component is expected to consider the capabilities, system architecture, and radio interface(s) of the terrestrial component to adopt a common architecture framework. The report ITU-R M.2514[iv] defines the vision for the satellite component of IMT-2020 for an efficient IMT service delivery with respect to application scenarios, services, system, radio, and network interface aspects. Further developments and recommendations on the satellite component of the integrated/hybrid satellite-terrestrial network systems are in progress.

3.3 MOCN/ORAN and work in 3GPP

3GPP started the study on NTN for NR from Release 15 of its specification series by defining use cases and investigating the basic characteristics of NTN such as channel model and potential impacts on NR. The study phase continued in Release 16 from both system and RAN perspective. Finally, in Release 17, NTN requirements were added to the 3GPP specifications. In addition to NR NTN, this Release also supports NTN for cellular IoT (CIoT) such as NB-IoT. A brief overview of evolution of NTN in Release 17 and 18 is provided in the previous white papers from 5GAmericas.

In Release 19 the following item are under development:

- Downlink coverage enhancement for GSO and NGSO constellations: employing link level or system level optimizations to improve the downlink coverage considering the limited power of satellite and power sharing among beams.
- Uplink capacity optimization: Due to large footprint of an NTN cell, a large number of UEs are in the coverage area of the cell, competing for the resources. Therefore, the limited spectrum resource needs to be efficiently managed (e.g., by means of multiplexing multiple UEs using orthogonal cover codes).
- Enhanced Multicast-Broadcast Services (MBS): MBS may be intended for a sub-region of the entire cell coverage. The existing mechanisms need to be updated to indicate which region is the target of MBS.
- Support of NTN architecture with regenerative payload: This support is necessary to enable UE-Satellite-UE and Network-UE communications. In addition, mechanism for intra and inter-gNB mobility needs to investigated for any necessary enhancements.
- Introduction of RedCap and eRedCap NTN on FR1: RedCap devices can outperform 4G IoT technology (i.e., NB-IoT) while keeping the complexity level low. In R19, the essential changes required to support NTN RedCap/eRedCap is under study.
- Inter-RAT mobility from E-UTRA TN to NR NTN: Mobility inside NR from TN to NTN and vice-versa is defined in Release 17 and 18. Release 19 is focusing on idle-mode mobility based on cell reselection from E-UTRA TN to NR NTN.

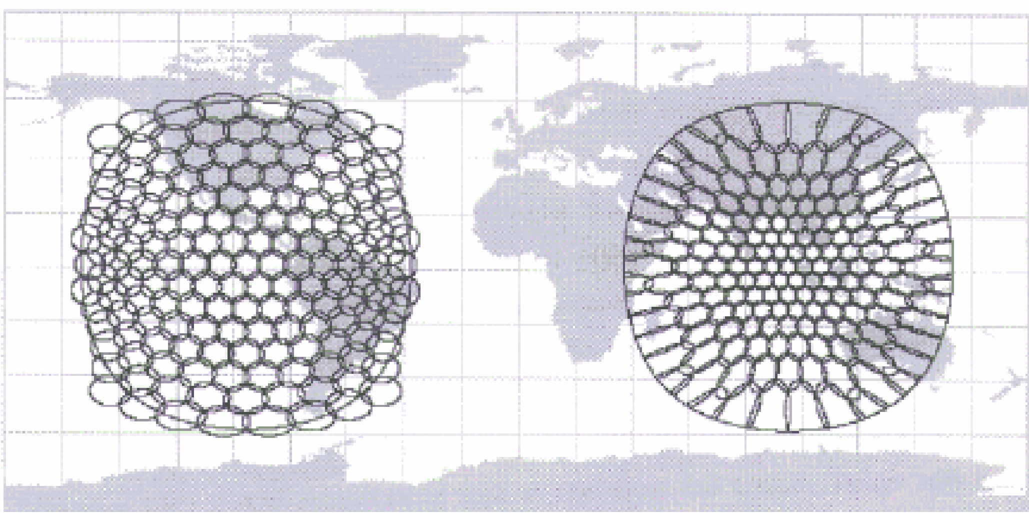
Some of these items are also studied for IoT NTN, such as store and forward, which supports cost-effective and delay-tolerant IoT applications. In addition, due to a massive number and diverse types of NB-IoT devices in the coverage area, the uplink capacity enhancement for IoT system is being studied.

4. NTN in coastal areas

4.1 Challenges and opportunities

Each satellite partner has access to various architectures and this includes how it will deploy it is spaces assets. Depending on the deployment of these assets coverage and cell geometry may differ

Figure 4. Satellite Beam Patterns at different elevation angles[11]



In this example for a GEO plan, one can see the stretching of cell, we expect this as well in LEO plans where space providers may not have a large array of satellites. in order to equitably allow competing coverages from multiple satellite providers, some that will have relative few satellites to those that will have very a large arrays, there will coverage geometries that will manifest it self over the international waters. This also manifests its self on lack of coverage on costal areas if restricted to land masses, as these system with few satellites may not be able to provide competing coverage.

The FCC has a current inquirer out on this matter, driven by the use of mobile service on various gas and oil platforms. Providing coverage out to the Exclusive Economic Zone (EEZ)[12]would allow mobile operator and their partners to participate in this zone meeting the ideals of GATT and the WTO to open up markets to competition. However safety of life is paramount, and these users may not have access to marine based safety of life radios, and access to D2C will be beneficial.

4.2 Regulations and amendments

In an NOI released in May 2022, the FCC seeks input on whether changes in rules and policies are needed to support offshore commercial and private networks. The NOI aims to gather information on various offshore spectrum use cases, the demand for offshore spectrum, and potential spectrum rights models. It also explores different assignment mechanisms for initial licensing, such as geographic area licensing and unlicensed use, and seeks comments on which spectrum bands could best support offshore operations. The goal is to develop a comprehensive record to inform future FCC actions and policies related to offshore spectrum management. The use of supplemental services in these costal waterways need to be included in the discussion[13].

Conclusion

Summary of key points

The deployment of supplement services from space or NTN systems will provide enhanced coverage for terrestrial mobile operators. However there will be growing pains, as there will be various implementation and interworking between space systems and terrestrial systems to be worked out. Initial capacity of these systems will be limited either due to the number of satellites supporting coverage, and contiguous coverage area, the orbits of these space systems and their cell geometries provided. To avoid impacts to existing terrestrial services, some spectrum planning is required limited the amount of spectrum available to the space segment and it associated coverage and capacity. It will not be broadband service delivered to thousand of users as experienced today. Over time capacity will increase, requiring additional satellites, and earth stations, and may also require the aggregation of additional bands offered over the space systems. The use of the additional spectrum may bring additional regulatory hurdles and or business solutions between MNO and or space segment partners where the additional spectrum is controlled by other MNO in the areas targeted for capacity increases.

It is hoped regulators will embrace the opportunity to remove the digital divide in rural and remote area, but also appreciate the challenges when integrating supplementary services.

Future outlook

For NR NTN to become a reality in the coming years the entire ecosystem will need to be in place to support the adoption of this technology. This is largely dependent on suitable spectrum that has the regulatory authority to be broadcast from satellites. New 5G devices will be needed to support both the 3GPP technology and the NTN bands. Networks on the ground also need to be in place to provide both the infrastructure and service to customers.

Appendix

Appendix A

Table A: Broadband and satellite providers 2024

Operator	Satellite system (deployed)	Spectrum	Technology	Operational	Services
SpaceX (Starlink)	12000+ (6219) LEO	Ka, Ku-band	Proprietary	Yes	Broadband
Eutelsat OneWeb	35 GEO, 648 (634) LEO	Ka, Ku, C -band	Proprietary	TBD	Broadband
Kuiper	3236 (2*) LEO	Ka band	Proprietary	Estimated 2024	Broadband
Galaxy Space	1000 (8) LEO	Q/V spectrum	Proprietary	TBD	Broadband
Viasat + Inmarsat	18 GEO (18) +planned LEO	L, Ka, Ku-band	Proprietary	TBD	Broadband to IoT, Broadband
Telesat	198 (3) LEO	C, Ku, Ka bands	Proprietary	TBD	Broadband
Echostar	10 GEO (10)	Ku, Ka, S bands	Proprietary	Yes	Broadband
HughesNet	3 GEO (3)	Ka band	Proprietary	Yes	Broadband
SES Intelsat	100 GEO + 26 MEO	KA, Ku, C and L-band			Broadband

*prototype

These systems use proprietary technology and typically operate in the higher (Ku/Ka) frequency bands.

Appendix B

The technical requirements for the satellite component cannot be identical to those of the terrestrial component due to the spacecraft and link budget constraints. Nevertheless, for the purpose of alignment and uniformity with the terrestrial component, similar technical performance parameters are adopted for the satellite component, to the extent possible. The key minimum technical performance requirements of the satellite component of IMT-2020 are listed in Table 1. The requirements were derived using an assignable channel bandwidth of up to 30 MHz over one satellite beam.

Table B: Minimum requirements of the satellite component of IMT-2020 [iv]

Parameter	Explanation	Satellite Requirement
Downlink peak data rate	Maximum achievable channel data rate under ideal conditions	70 Mbit/s
Uplink peak data rate		2 Mbit/s
Downlink user experienced data rate	Data rate maintained for 9 % of the time	1 Mbit/s
Uplink user experienced data rate		100 kbit/s
Downlink peak spectral efficiency	Number of bits of data per Hz in a band	3 bit/s/Hz
Uplink peak spectral efficiency		1.5 bit/s/Hz
Downlink average spectral efficiency	Average channel spectral efficiency	0.5 bit/s/Hz
Uplink average spectral efficiency		0.1 bit/s/Hz
Downlink 5th percentile user spectral efficiency	5% point of the cumulative distribution function (CDF) of the number of correctly received bits, divided by the channel bandwidth	0.03 bit/s/Hz
Uplink 5th percentile user spectral efficiency		0.003 bit/s/Hz
User plane latency	The time required for a packet to traverse the network from a source to a destination	10 ms
Control plane latency	Transition time from idle state to active state	40 ms
Mobility	Maximum moving speed allowed to maintain service transmission and QoS requirements	250 km/h
Connection density	Total amount of connected machine type devices (MTD) per unit area	500/km^2
Area traffic capacity	Overall traffic in a coverage area	8 kbit/s/km^2 (DL)
		1.5 kbit/s/km^2 (UL)
Reliability	Capability of transmitting traffic with high success probability	1-10^{-3}

Figure A: Coverage of Terrestrial Mobile Wireless Systems.[14]

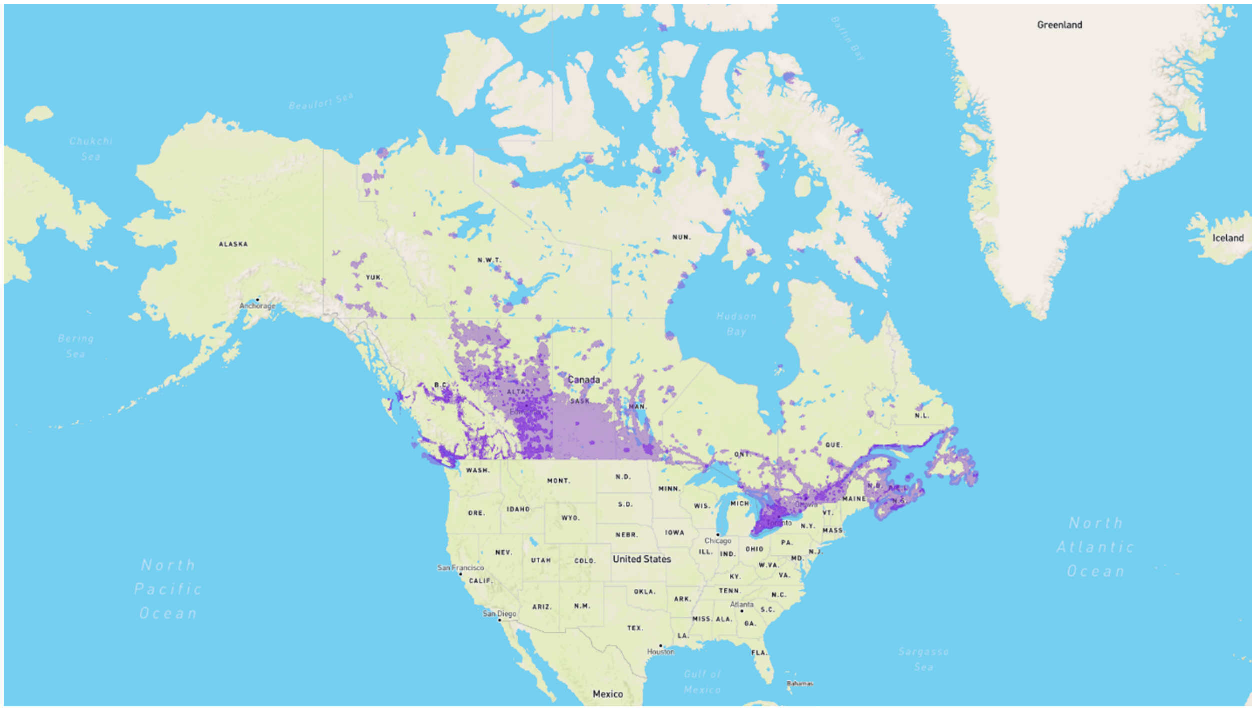
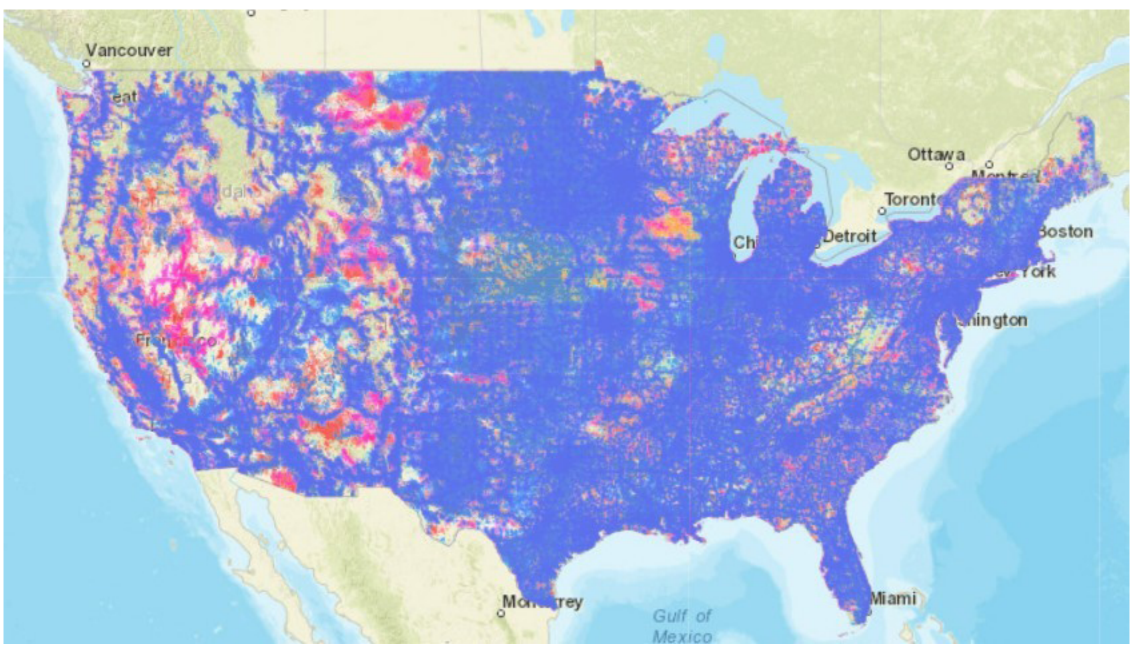


Figure B: United States Coverage Map[15]



In the USA, there are challenging areas where coverage is lacking as seen in Figure B.

Appendix C: Regulatory, Security, and Lawful Intercept issues

911 Emergency services

Emergency services (both text and voice to 911) could benefit from SCS in MNO spectrum if SCS coverage is provided in areas with no existing terrestrial coverage. Both Apple and Google have indicated proprietary support for sending emergency texts to 911 using satellite coverage. However, if MNOs are to provide a similar text to 911 service (or even voice call to 911 service) using SCS in MNO spectrum, MNOs will need to ensure interference prevention management between terrestrial and SCS coverage (not specific to emergency services).

Wireless emergency alerts (WEA)

WEA may benefit from future SCS in MNO spectrum, especially in areas with low or no terrestrial cellular coverage. For example, there is great benefit to hikers in a remote wooded area being able to receive a WEA about a nearby fire when terrestrial coverage is non-existent. If SCS is used only to provide coverage in MNO spectrum where no terrestrial coverage exists, then there are limited challenges with managing interference between the satellite beam and the terrestrial coverage. If SCS is used to provide coverage in MNO spectrum in the same areas in which terrestrial coverage exists, then interference management (independent of WEA) will be a great challenge for operators. Another challenge that is WEA-specific will be how to manage serial numbers assigned by cell broadcast centers used in WEA messages to assist the mobile device in WEA duplication detection (i.e., suppression of presentation of the same alert due to WEA rebroadcasts). Coordination of cell broadcast center usage for terrestrial and satellite WEA broadcasts will need to be done to preserve today's existing WEA duplication detection mechanisms in the device.

Lawful intercept

Cellular communications for targets of interception are subject to lawful interception based on national regulations applicable in both home and visited networks. If such communications involve one or more satellite transmission links, lawful interception is still applicable and may be implemented in a variety of ways, including using points of interception on the ground as well as potentially on a satellite. 3GPP is currently discussing various architectures for satellite communications, and lawful intercept standards are expected to be developed in the future to support multiple architecture scenarios.

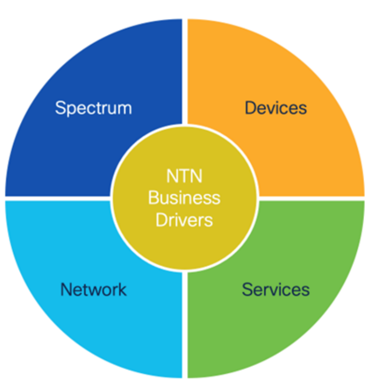
Priority services

Wireless Priority Service (WPS) and Next Generation Priority Services are expected to work seamlessly from a user perspective for both terrestrial cellular and SCS enhanced coverage. To support seamless operation of priority services with satellite involvement in the communication path, industry standards will need to be developed specifically to ensure that priority services work as expected.

EIR (stolen handset blocking issue)

If S8/N9 interface to space, then who is using the service from roamers is an issue.

Figure C: NTN Business Drivers



Appendix D: Acronyms

DL: Downlink

eMTC: Enhanced Machine-Type Communication

FDD: Frequency division duplex

GEO: Geostationary Earth Orbit

GNSS: Global navigation satellite system

HARQ: Hybrid Automatic Repeat Request

IoT: Internet of Things

LEO: Low Earth Orbit

MNO: Mobile Network Operators

NR/gNB: New Radio 5G

NGSO: Non-Geostationary

NTN: Non-terrestrial network

OIA: Office of International Affairs

RA: Random Access

RTT: Round Trip Time

SIB: System Information Broadcast

TAC: Tracking Area Code

UE: User Equipment

UL: Uplink

VSAT: Very small aperture terminal

Acknowledgments

5G Americas' Mission Statement: 5G Americas facilitates and advocates for the advancement of 5G and beyond toward 6G throughout the Americas.

5G Americas' Board of Governors members include Airspan Networks, Antel, AT&T, Ciena, Cisco, Crown Castle, Ericsson, Liberty Latin America, Mavenir, Nokia, Qualcomm Incorporated, Rogers Communications, Samsung, T-Mobile USA, Inc., and Telefónica.

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Endnotes

1 GSMA:Addressable telco revenues via wholesale satellite partnerships.

2 5G Americas Member Company

3 "ITU-R M.2514-0 Vision, requirements and evaluation guidelines for satellite radio interface(s) of IMT-2020," 09-2022.

4 5G Americas Member Company

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