GSMA

Employing Non-Terrestrial Networks for IoT Connectivity

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Executive summary

1.0

Connectivity technologies are rapidly evolving beyond terrestrial boundaries. Non-terrestrial networks (NTNs) have emerged as a focus area in the 3GPP standards, with ramifications for the entire ecosystem from chipset makers, equipment manufacturers, satellite operators, network providers and mobile operators. As they support both terrestrial and satellite access capabilities under a converged standard, IoT technologies are opening up an unprecedented opportunity to provide a cost-effective way of connecting places that have lacked coverage to date. The introduction of NTN capability into the 3GPP standards-based cellular IoT ecosystem is set to extend connectivity to areas not covered by terrestrial mobile networks, including some of the most remote regions of our planet, oceans and flight paths.

However, adoption and implementation of any new connectivity technology faces obstacles from lack of awareness to end customer requirements, use cases and finally monetisation.

Experience from existing cellular IoT technologies, such as NB-IoT and LTE-M, suggests that there is a risk that operators and vendors take divergent paths and do not collaborate to build an ecosystem that can ensure a simple, consistent and seamless user experience. There is also a need to understand the evolution to 5G IoT NTN and what that could mean for the ecosystem as NTNs mature.

The focus of this whitepaper is on NTNs for IoT. It aims to increase understanding of the IoT NTN space and bring some consistent approaches to implementing IoT NTNs, thereby helping increase adoption. The GSMA plans to maintain and update this guide on a regular basis, particularly with respect to the adoption of new and emerging features that may become part of the minimum baseline recommendations.

2.0

Introduction

Introduction

2.0

NTNs are supported by a large ecosystem comprising satellite operators, network and service providers, chipset, module and device providers who all need to develop a cohesive set of approaches to accelerate rollouts. This ecosystem is keen to explore the potential of NTNs as an alternative means of connectivity for Mobile IoT (MIoT) use cases and services. But in the relatively nascent NTN market, some adoption myths need to be debunked to increase the deployment velocity.

The main standards for NTN connectivity are being defined by 3GPP, the organisation responsible for defining 5G and other wireless communication standards. 3GPP Rel. 17 has added two main specifications: NB-IoT NTN and eMTC/LTE-M NTN for IoT use cases, and NR NTN for data and voice-oriented applications. Additional enhancements will come in subsequent Rel-18 and Rel-19 specifications.

The growth of NTN-based services and the upcoming satellite/cellular convergence (3GPP Rel. 17+) are opening up new technological opportunities. As with any emerging technology, the ecosystem needs to carefully evaluate the gamut of possibilities, use cases and deployment considerations.
On terrestrial networks, 5G has emerged as the technology of choice for better application performance and improved latency. However, there is still very limited public awareness of the use cases that can be supported by NTNs and how that support can evolve in the context of 5G IoT NTN (or 5G NR NTN).

Experience from existing terrestrial NB-IoT and LTE-M suggest that there is a risk that operators and vendors take divergent paths and do not collaborate enough to build the ecosystem required to ensure a simple, consistent and seamless user experience.

The purpose of this paper is to debunk myths and help establish guidelines and recommendations in a few areas of IoT NTN, drive consistencies that help operationalise IoT NTN and potentially accelerate its adoption. It outlines the NTN and IoT concepts, the roles they play in the current technological landscape, and how IoT NTNs are set to revolutionise IoT connectivity across various industries.

The paper also addresses use cases, challenges, potential mitigations and key requirements from the perspectives of mobile operators and NTN providers.

Target audience and scope

Targeted at the wider ecosystem, this document considers different barriers to IoT NTN implementation and adoption to help drive a common understanding of the operational challenges and potential mitigations, where applicable. The document focuses on the Rel-17 NB-IoT NTN as a baseline IoT technology for NTN, while also presenting important considerations for the evolution to 5G NTN.

The structure of the document is driven by the following objectives:

- Mobile operators: To encourage take-up of Rel. 17+
- Satellite operators: To encourage commitment to Rel. 17+ NTN standards
- Chipset and module vendors: To encourage take-up and compliance to Rel. 17+ features and thereby further NTN deployments per expected timelines
- Enterprises: To raise awareness of how to leverage NTN for connectivity and services

Detailed descriptions of features and architecture are out of scope of the document.

Definitions

Term	Description
IoT	Internet of Things, a generic term for the network of physical objects that contain embedded technology to communicate and sense or interact with the external environment. IoT offers functions and services that go beyond the scope of M2M. 4th Generation (of mobile technology)
M2M	Machine-to-machine, a general term referring to any network technology allowing devices to communicate with each other. For example, two industrial robots connected to each other via Ethernet in a factory are a part of M2M, but not part of the IoT.
MIoT	Mobile Internet of Things, a GSMA term that refers to the 3GPP-standardised low power wide area (LPWA) technologies using licenced spectrum bands (aka LTE-M, NB-IoT and EC-GSM-IoT). From 3GPP Release 13 and the following releases, user equipment that supports power consumption optimization, extended coverage and lower complexity are part of the MIoT (CAT M1, CAT NB1 from Release 13 and CAT M2, CAT NB2 from Release 14). MIoT is a subset of the far bigger IoT concept. For example a bunch of sensors connected together via Wi-Fi or Bluetooth are a part of IoT, but not MIoT.
NTN	Non-terrestrial networks referring to satellite-based network connectivity only.
LTE-M	LTE-M is the simplified industry term for the LTE-MTC technology standard published by 3GPP in the Release 13 specification. It specifically refers to LTE Cat M, which is suitable for the IoT. LTE-M is a LPWA technology that supports IoT through lower device complexity and provides extended coverage, while allowing the reuse of the LTE installed base.

Abbreviations

Term	Description
3GPP	3rd Generation Partnership Project
ARPU	Average revenue per user
EC-GSM	Extended coverage GSM
eMTC	Enhanced machine type communications
GSM	Global system for mobile communications
GSMA	GSM Association
IoT	Internet of Things
ITU	International Telecommunications Union
LPWA	Low power wide area
LTE	Long-Term Evolution
LTE-M	Long-Term Evolution machine type communications
M2M	Machine-to-machine
MIoT	Mobile Internet of Things
MNO	Mobile network operator
MTC	Machine type communications
MVNO	Mobile virtual network operator
NB-IoT	Narrowband IoT
NR	New Radio
NTN	Non-terrestrial network
ODM	Original device manufacturer
OEM	Original equipment manufacturer
RF	Radio frequency
TN	Terrestrial network
UE	User equipment

References

Ref	Doc Number	Title
	IOTTF07_DOC004	MIoT Roaming Whitepaper Draft. GSMA NG working group
	3GPP TS 21.917	Average revenue per user

3.0

Employing NTNs for the IoT

Employing NTNs for the IoT

3.0

Contextualising NTNs and IoT

3.1 Exploring a new frontier: how non-terrestrial networks can transform the IoT

In a world teeming with interconnected devices, efficient and reliable connectivity has become the cornerstone of our tech-driven society. The Internet of Things (IoT) refers to the billions of physical devices worldwide that are connected to the Internet, each of them collecting and sharing data. From your smartphone to your smartwatch, to the device on your dog's collar, if it's connected to the Internet, it's part of the IoT. These devices comprise an interconnected network of devices that can communicate and exchange data, enabling new ways of interacting with the world and automating processes.

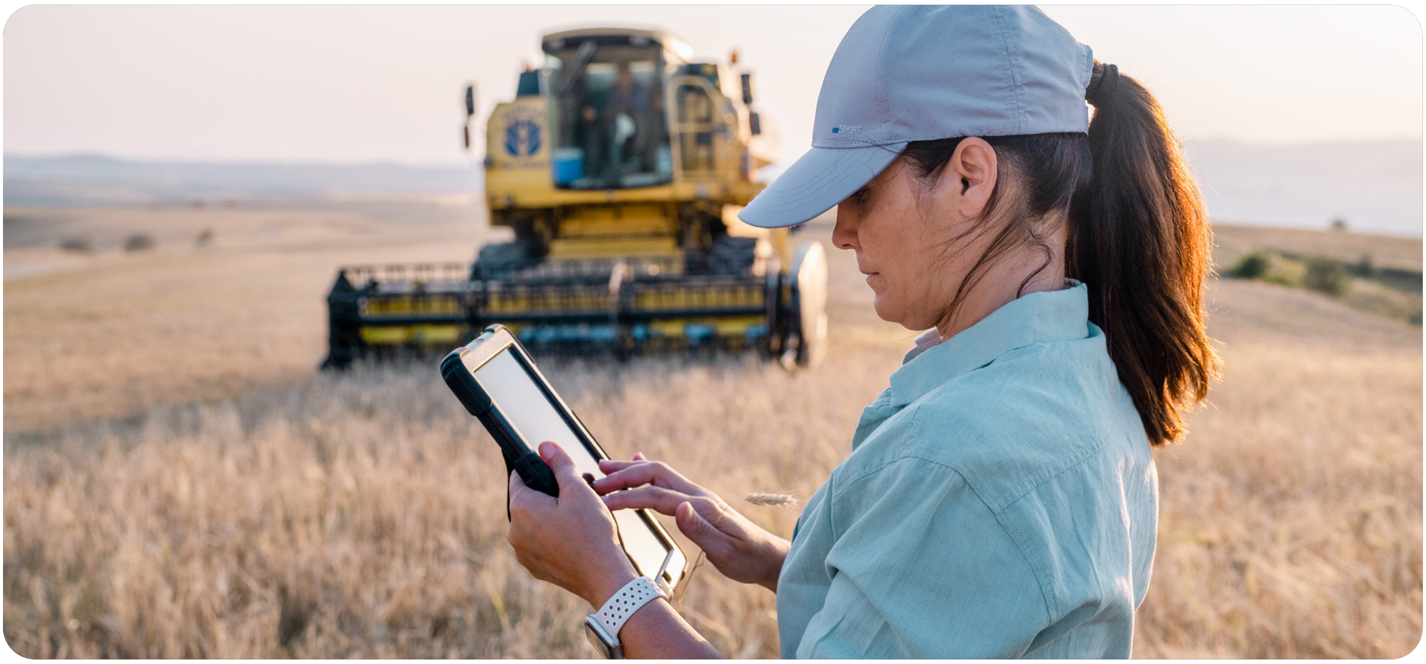
As the IoT becomes more deeply ingrained in our daily lives, there is a push for communication networks that can keep up with the demands of this new frontier. IoT non-terrestrial networks (NTNs), which promise a transformative shift in how IoT devices connect and communicate, can step in here. A NTN leverages non ground-based infrastructure, such as satellites, to provide Internet connectivity.

NTNs can connect areas where terrestrial coverage does not exist, such as remote locations, areas with diverse terrain, or locations whose terrestrial networks have collapsed during natural disasters. It also extends the promise of global and high-speed connections — features synonymous with 5G connectivity — to every corner of the globe.

3.2 NTN meets IoT: A revolution in connectivity

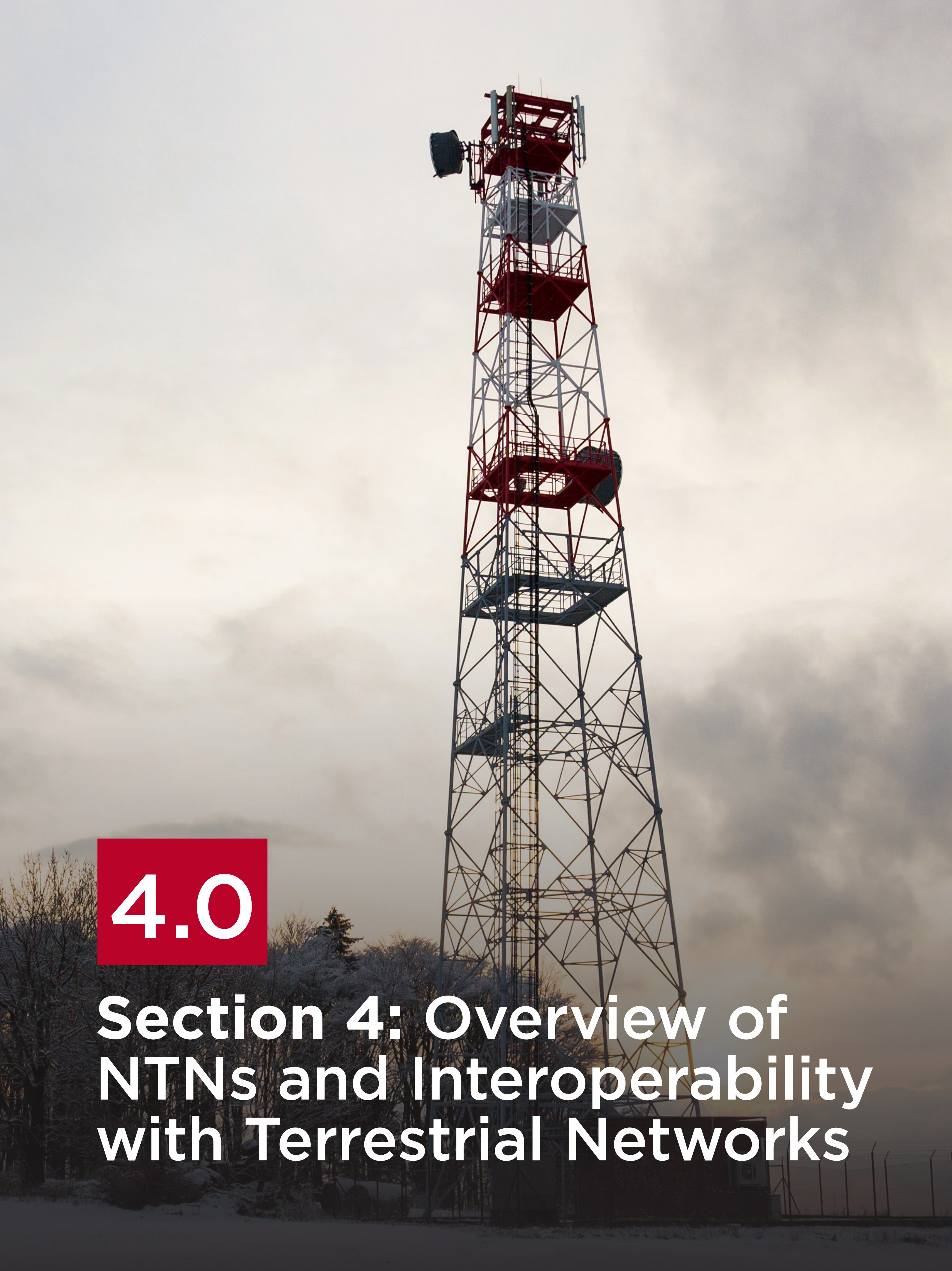
The marriage between IoT and NTNs holds significant potential in reshaping the way we interact with technology. By lifting the geographical limitations on connectivity, NTNs are enabling a paradigm shift in the ability of IoT devices to connect and communicate. Here are a few examples of the wide-reaching applications of an IoT NTN:

- Asset tracking and maritime applications - IoT devices connected to containers, for example, can keep track of the position, detect shocks, and monitor the temperature and humidity of goods in a vessel in the middle of the sea and on roads without terrestrial coverage. Tracking these containers can help to manage the end-to-end supply chain, optimise delivery times and reduce greenhouse gas emissions.
- Agriculture and livestock - Monitoring cattle can help farmers reduce the cost of health control, improve the quality of the end product, improve reproduction and prevent virus outbreaks. In the case of extensive livestock farming, NTNs can be used to augment terrestrial coverage. Farmers could also deploy NTN IoT devices in fields to monitor soil moisture, crop health, and weather conditions. These devices, connected via a NTN, would function regardless of how remote the farmland is, allowing for farming techniques that could boost yield and remote sustainable farming practices.



- Energy - Pipelines crossing deserts or other sparsely populated areas can be monitored using NTNs where terrestrial network coverage is scarce or non-existent. The connectivity can support the digitalisation of operations, enhancing automation, safety, security and personnel welfare. Proactive monitoring for fuel theft can also help avoid accidents and economic losses. NTN IoT devices could also monitor the performance of wind turbines or solar panels situated in remote locations. With terrestrial coverage often limited in remote areas, NTN could provide complementary connectivity. The data collected could provide insights into maintenance needs, efficacy improvements and power generation. These data streams may contribute to more reliable and efficient energy grids.
- Environment and utilities - Efficient water management is a social responsibility in the many countries where this resource has been affected by climate change. Satellites can be used to connect weather data, flow monitoring or water distribution systems, for example.
- Scientific research - Devices stationed in remote locations, such as meteorological buoys anchored out in the open ocean or equipment in polar research facilities, could transmit critical data in real-time thanks to IoT NTN connectivity. This could significantly accelerate the progress of research and offer new insights into challenging questions.
- Emergency response - A first responder in a disaster-stricken area where the terrestrial cellular network is unavailable needs an alternative source of reliable connectivity. An IoT NTN-connected wearable device could transmit real-time information critical to the success of the first responder's relief mission. The satellites employed in the IoT NTN could send back information from the first responder to the rest of their team, enabling a better coordinated response.

Each of these examples represents just a snapshot of the potential applications of NTN in the world of IoT.



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Section 4: Overview of NTNs and Interoperability with Terrestrial Networks

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4.1 Ubiquitous connectivity

To take full advantage of ubiquitous connectivity, a device needs to seamlessly switch between terrestrial and non-terrestrial networks with the same user experience making it seamless to the end user. This would require network switching in the device and backend roaming integration for the network switch over.

4.2 Switching between IoT NTNs and IoT terrestrial networks (TNs)

Ideally, the UE would facilitate seamless switching between satellite and terrestrial networks, contingent upon home network configuration capabilities and user preference. The following points should be taken into consideration for switching (as recommended guidelines):

- **Network availability:** Network conditions can be tracked by the device as a foundation for network switching, which can occur based on user/network/standard predefined scenarios.
- **Prioritisation:** Intelligent decision-making in network selection requires prioritisation. Non-terrestrial networks may, for example, be engaged for data communication only when a preferred terrestrial network is unavailable for a predetermined minimum duration threshold, maintaining a hierarchy in the preference list.
- **Reconnection quality:** While switching between NTNs and terrestrial networks, the reconnection process should be swift and reliable, preventing any loss of critical data.
- **Preferences:** A modem may provide options to configure switching preferences and switching control parameters and thresholds by the application, including minimum RF conditions and scanning frequency to switch from one network to another.
- **Battery life:** Device applications can balance the need for network switching with battery life considerations.

4.3 Characteristics of an IoT NTN

The IoT NTN ecosystem aims to provide a seamless NTN/TN hybrid experience for devices, ensuring they meet stringent connectivity, power and user experience criteria. However, to achieve this, the network must confront the challenges associated with NTNs and reassess the behavioural similarities of terrestrial networks. The following characteristics play a pivotal role in this endeavour:

- **Global coverage:** An advantage of NTNs is their ability to offer global coverage, as satellites can cover vast areas, making it possible to establish communication links over challenging terrains.
- **Network latency:** Propagation delay due to satellite distance, orbital dynamics, and signal transmission delays will impact latency, requiring the IoT NTN network to provide connectivity steering through the network interfaces.
- **Network interconnect:** Providing roaming interfaces between NTNs and TNs makes it straightforward to provide seamless connectivity for UE and devices in the field.
- **Regulatory compliance:** The network must be compliant with national and international regulations, including licensing, frequencies and adherence to lawful and responsible operation.
- **Standards compliance:** NTN network infrastructure compliance with industry standards enables the partner ecosystem to seamlessly advance technology and onboard well-known established processes.

4.4 Operational requirements

The demand for continuous network connectivity has increased as IoT, consumer and other critical use cases have emerged. Various scenarios, such as a hiker needing network access during an emergency, enabling an oil pipeline to report damage, or the need to trace a container crossing oceans, have significant social impacts. Inevitably, every device in the future will support hybrid connectivity, ensuring seamless connection regardless of its geographical location. However, accessing the network, whether terrestrial or non-terrestrial, needs to be made reliable and simpler to achieve these goals.

Seamless switching between terrestrial and non-terrestrial networks requires a network infrastructure that complies with a set of standards while considering the unique attributes of each network, such as latency, bandwidth and coverage. Similarly, the chipset or device ecosystem must possess the necessary capabilities to enable seamless navigation across these networks.

Creating a reliable network infrastructure is just the first step. To ensure optimal results, we need to focus on operational aspects that are crucial in maintaining the efficiency, reliability, and effectiveness of the switching process. These operational aspects include:

- Network monitoring,
- Redundancy that provides uninterrupted service,
- Capacity planning to anticipate network demands,
- Parameterising the network configuration for efficient data routing in critical use cases,

- Implementing strict policies with predefined rules and standards for security and regulatory guidelines,
- Providing training for network operators to handle the complexities of seamless switching and scaling to accommodate the growing number of use cases.

Switching between terrestrial and non-terrestrial networks requires a comprehensive understanding of the technical nuances of each network, the development of capabilities that enable seamless switching between networks, and the creation of a network infrastructure that can accommodate the demands of terrestrial and non-terrestrial networks. An NTN modem, together with the device application, needs to incorporate the required technical nuances to provide a much simpler user interface and a seamless user experience.

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Section 5: Enterprise Requirements

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5.1 Enterprise use cases and motivation for NTN

Multinational companies who deploy IoT solutions based on cellular connectivity need true global service coverage and high reliability, which can have a major impact on the efficiency and operating experience of their business. In some cases, this can be financially critical and may even be a matter of life or death.

Adding satellite connectivity to cellular connectivity may be the solution for many current enterprise IoT challenges. Having the possibility to utilise and manage both satellite and cellular connectivity for their IoT devices can solve four fundamental problems:

1. **Limited cellular coverage in each country:** Enterprises want to ensure all their devices are reliably connected. In remote areas it can be challenging to connect devices to the mobile network or to ensure seamless data streams from moving objects.
   -> Combined cellular/satellite connectivity may enable full availability at agreed data rates, allowing critical infrastructure use cases to be implemented.
2. **No global coverage:** Some enterprises need to connect all their assets around the globe – onshore and offshore. Terrestrial networks have their limits: deserts or oceans cover 70% of the earth's surface. Furthermore, IoT networks, such as NB-IoT or LTE-M, have not yet been deployed in many countries. But even where they are in place, roaming is not always possible. In this case connecting assets in different countries sometimes requires multiple and complex contracts.
   -> Combined cellular/satellite connectivity can, at least technically, provide coverage in any given spot of the Earth's surface.
3. **Multiple connectivity contracts and fragmented management systems:** Different use cases have different communication requirements for data volume, data rate, latency and criticality. In the past, these requirements can only be fulfilled by utilising different cellular and satellite providers with (proprietary) technologies and separate connectivity management systems. Having to manage different contracts and integrating different systems is costly and adds operational complexity.
   -> Combined cellular/satellite connectivity allows enterprises to handle all their connectivity needs with a minimum number of contracts and platforms.
4. **Multiple devices for the same use case:** Many use cases, especially mobile ones, require combining satellite and cellular connectivity in one single device. Today's satellite connectivity requires specific, proprietary terminals. If a use case also needs a cellular connection, two separate devices consume space and increase costs.
   -> Going forward, integrated 5G IoT radio modules (3GPP Rel. 17+) can seamlessly switch between terrestrial and non-terrestrial networks. Initially, these will only be serving narrowband use cases (NB-IoT NTN), but in subsequent years, higher data rates may be possible with converged devices (NR-NTN).

Most of today's outdoor IoT use cases would benefit from converged cellular and satellite connectivity. Three main categories of use cases are most relevant:

1. Mobile objects mainly use cellular connectivity, but occasionally require satellite connections whilst being in coverage voids (e.g. remote areas or oceans). Examples include transport and logistics, agricultural and construction vehicles, or (in the longer term) passenger cars.
2. Critical infrastructure, requiring a redundant data connection for guaranteed availability, or service level agreements (SLAs) for guaranteed data rates. Examples include wind parks, solar parks, pipelines or mining sites.
3. Seamless sensors: Massive IoT devices - typically low-cost, battery-powered and (frequently) stationary sensors - are being deployed at a large scale and hence require zero-touch installation procedures without the need for an individual connection check at each site. Most devices will be connected by cellular networks, but some will require satellite connectivity. Examples include soil or crop sensors, environmental monitoring or infra structure monitoring.

5.2 Adapting NTN to enterprise security requirements

Enterprises employ multiple layers of security between application, network infrastructure and device to ensure an end-to-end secure network. As such, a NTN, beyond the satellite beam to the earth station connectivity, operates as a terrestrial network for all practical purposes. The security requirements for IoT devices, cloud security for networks hosted in the cloud and application security all apply to NTNs.

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Section 6: Integrating IoT NTNs into Mobile Networks

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6.0

6.1 General perspective of mobile operators

In an era defined by ubiquitous connectivity, mobile network operators (MNOs) aim to orchestrate global and reliable connections for diverse IoT customers, such as enterprises (for direct use) and solution providers (for indirect use).

As the IoT ecosystem expands, MNOs are building scalable IoT networks that can accommodate the growing number of connected devices and higher data rates. In doing this, efficient operations built on streamlined processes are crucial to remain competitive in this dynamic IoT landscape. Likewise, a strong focus on user-facing simplicity is essential to optimise the customer experience and hence growth and retention.

To pave the way for an interconnected future, MNOs are therefore relying on and promoting 3GPP industry standards, contributing to the advancement and harmonisation of the wider IoT industry.

6.2 Motivation for IoT NTN

As MNOs integrate roaming partners to complement their own cellular network footprint, they can work with satellite networks to extend their coverage to offer full global IoT connectivity coverage as a one-stop shop.

Fortunately, the costs for NTN solutions have fallen considerably in recent years, making it increasingly viable for enterprises to connect their devices via converged TN/NTN connectivity.

Moreover, the deployment and operation of such solutions is gradually becoming much easier and more cost-effective due to the upcoming availability of converged off-the-shelf devices based on global 3GPP standards (Rel. 17+).

6.3 Mobile Operator use cases

Non-terrestrial networks can be integrated via regular roaming by leveraging existing and proven standard interfaces and contracts. It is advisable to start with NB-IoT connectivity, as the first NTN-ready modules and chipsets will already be available in 2024. With Release 19 of the 3GPP standards, devices with higher data rates (NR-NTN) will also support converged connectivity, although they are likely to take several more years to become commercially available.

6.4 Specific interests from R17 feature set

As outlined in the introduction, 3GPP's efforts in Release 17 aim to enhance connectivity beyond terrestrial networks, extend IoT reach, and explore innovative solutions for NTN-based communication through various work items. These goals are support-ed by a diverse range of stakeholders from vendors (terminal, chipset, network) to service providers from both the mobile and space industries, and vertical user groups. Let's delve into some specific aspects related to NTN IoT networks:

1. **NB-IoT- and eMTC-based satellite access:**
   a. The 3GPP Rel-17 specification extends support to NB-IoT and eMTC (enhanced Machine Type Communication) based satellite access.
   b. This adaptation addresses massive Internet of Things (IoT) use cases across various domains, including agriculture, transport, logistics, tracking, monitoring, public safety (SOS) and more.
2. **NB-IoT satellite access for handheld devices:**
   a. Besides NR-based access, the Rel-17 specifications support NB-IoT-based satellite access deployed in Frequency Range 1 bands (sub 6 GHz spectrum). This enables global seamless low data service continuity for handheld devices augmenting cellular networks for emergency connectivity and other use cases.
   b. The goal is to enhance connectivity and coverage, especially in remote or challenging environments where cellular coverage is not economically feasible.
3. **Feasibility studies and solutions:**
   a. Researchers are exploring efficient transceiver designs to integrate NB-IoT into NTN via low earth orbit (LEO), medium earth orbit (MEO) and geosynchronous (GSO/GEO) satellites.
   b. Challenges related to architecture and technical aspects are being addressed, paving the way for future advances in this space.

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Section 7: Challenges and Evolution to 5G IoT NTN

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7.1 Satellite operators' perspective on IoT NTN and current challenges

To achieve the ful digitisation of society and industry, global coverage of IoT networks is a must and satellite solutions are well positioned to solve the dead zone of terrestrial networks. But this is not enough.

In the past, satellite operators have deployed IoT solutions from space, but the implementation costs and operational costs prevented mass adoption. Now the integration of 3GPP terrestrial networks and non-terrestrial networks under the same standard has dramatically reduced the cost of the user equipment and, at the same time, facilitates the seamless integration and operation between both networks. Satellite operators recognise in 3GPP Rel 17, and beyond, a big opportunity to extend NB-IoT coverage for networks compliant with GSMA roaming interfaces and 3GPP protocols.

To achieve this goal, one of the most important challenges is to speed-up the UE certification process and avoid proprietary solutions that can monopolise the market and result in customer and technology lock-in. MNOs, MVNOs and IoT service providers all need to support the process.

7.2 Motivation: spectrum, ecosystem readiness, challenges

With the adaptation of 5G to NTN solutions, the satellite industry has an opportunity to reshape some well-established elements of satellite and terrestrial connectivity. One of these elements is regulation.

Any satellite solution needs to take into consideration ITU regulations and national regulations to land a service in a specific region. Regulators need to be encouraged to allocate more spectrum for 5G IoT NTN applications and avoid customer captivity. This will also help chip manufacturers to increase their revenues by adding NTN to their current chip design and extending their RF capability to support mobile satellite service bands located adjacent to some existing NB-IoT terrestrial bands.

7.3 Evolution to 5G and satellite ecosystem challenges

Satellite implementations of 3GPP NTN are well positioned to fill the gap where it is not feasible to deploy terrestrial coverage, but this evolution requires the involvement of many actors:

- MNOs and MVNOs need to be aware of 3GPP IoT NTN and ask chipset vendors and/or module makers to include NTN features as soon as possible.
- Industrial verticals, MNOs and MVNOs need to participate in the 3GPP NTN process.
- Test equipment vendors and UE certification programs need to accelerate.
- All satellites providers need to embrace the 3GPP NTN technology to build economies of scale in user equipment.
- Public administrations need to support 3GPP NTN current and future evolutions.

7.4 Use cases and constellation evolution

Current IoT implementations use terrestrial coverage and often stationary user equipment, but the digitalisation of industrial processes also requires outdoor ubiquitous coverage with mobility. For example, asset tracking is one of the most important use cases that today can be limited by home operator coverage, because roaming is not cost effective for massive IoT deployments with low ARPU.

Satellite coverage can go beyond any frontier, reducing the number of roaming agreements for mobile IoT coverage everywhere. In this scenario, a constellation of satellites can offer global coverage - satellites can be coordinated in different orbits and capacity can be increased by adding more satellites and more ground gateways for IoT data to be routed to the home mobile operator. A specific quality of service can be achieved by satellites in different planes and gateways strategically located to reduce the end-to-end latency.

Satellite coverage can go beyond any frontier, reducing the number of roaming agreements for mobile IoT coverage everywhere.

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Section 8: Device Readiness (Modules/Chipsets/IoT devices)

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Satellite-based communication systems have been used for decades. But two major challenges have prevented their widespread adoption for IoT: high cost and high-power consumption chipsets.

Communication devices had either supported terrestrial networks or satellite communication and for cases where there was a need to support both TN and NTN, a costly two-chip solution was required. The need for a cost-optimised solution targeted for IoT prompted the introduction of a new standard in 3GPP Release 17, which leverages the advantages of LTE-M and NB-IoT technologies for satellite communication as well. Various chipset vendors were involved in this process and have developed support for 3GPP NTN standard features.

Some IoT devices are now able to operate on both the TNs and NTNs, and as needed, roam between the networks according to predefined scenarios. The TN-NTN implementation can be supported by a single SIM covering roaming agreements between TNs and NTNs, or a dual SIM option with an automatic or user-initiated switch between the networks.

8.1 Chipset features and dependencies

The functionalities of chipsets, designed to meet NTN requirements, assume a pivotal role in facilitating and enhancing the IoT device connectivity landscape. The enablement of chipsets and support over NTNs into the device ecosystem involves navigating through regulations, certifications, and use case adaptability. Numerous factors, including cost, size, power efficiency, and application capabilities, contribute to the overall IoT device connectivity experience.

Several critical functional requirements and dependencies come into play during the operational enablement of chipsets, including compatibility with 3GPP standards and alignment with NTN-specific requirements for smooth interaction and communication within the broader network infrastructure. Moreover, regulatory and certification processes have to be followed to ensure that the chipsets comply with the necessary lawful and regulatory standards. Adherence facilitates the seamless enablement of IoT devices and establishes trust among consumers, businesses, and regulatory bodies. By addressing these facets, the NTN ecosystem can expand robustly and support efficient IoT deployments

The TN-NTN implementation can be supported by a single SIM covering roaming agreements between TNs and NTNs, or a dual SIM option with an automatic or user-initiated switch between the networks.

8.2 Standards, certification and regulatory compliance

Standardisation bodies, including 3GPP, have made significant progress in supporting NTN IoT technology. Some of the key aspects regarding NTN IoT compliance are:

1. 3GPP compliance leads to global and widespread interoperability within optimally-utilised spectrum.
2. The inclusion of GCF certification criteria for interoperability and conformance,
3. Defining, maintaining and enforcing wireless regulatory standards to ensure that devices comply with established norms with respect to robustness, reliability, and high-quality, e.g. FCC, RED, and similar national regulatory bodies.
4. Device manufacturers, operators, and developers can innovate confidently, knowing their products will interoperate.
5. As they design devices based on established standards, manufacturers' compliance with 3GPP specs accelerates development and certification processes.
6. Compliance reduces testing efforts and avoids custom solutions leading to cost savings and lower time to market.

8.3 Standards, certification and regulatory compliance

When it comes to NTN NB-IoT device readiness, there are several challenges to consider beyond the well-established challenges associated with cellular NB-IoT devices. Let's explore these challenges in the context of NTN-based NB-IoT for reliable communication anywhere on earth and to contribute the growth of the NTN IoT ecosystem:

1. **Propagation loss and signal strength:**
   a. In NTNs, the signal may travel a long distance through space, leading to significant propagation loss, particularly in GSO/GEO satellites.
   b. Ensuring that the transmitter is powerful enough to maintain sufficient signal strength at the receiver is crucial, especially in a context of a typical NB-IoT device - the standard allows several power classes below 23dBm for terrestrial operation, but a minimum of 23dBm TX power for NTN is crucial
   c. Antenna gains can help compensate for some of the signal loss.
2. **Satellite movement and distance:**
   a. NTN involves communication with satellites, which move in orbit.
   b. Challenges arise due to the great distance between devices under test and the satellites.
   c. Doppler shift and high attenuation need to be addressed.

3. **Timing and synchronisation:**
   a. NTN devices rely on accurate timing synchronisation.
   b. Larger beam radii and longer link distances impact timing advance (TA) and uplink (UL) frequency compensation.
   c. Integrating the Global Navigation Satellite System (GNSS) helps mitigate these issues.
4. **Cost optimisation:**
   a. Balancing performance and cost are essential for widespread adoption.
   b. Optimising components, reducing bill of materials (BoM), and achieving economies of scale are key.
5. **Lifecycle management:**
   a. NTN NB-IoT devices have long lifecycles requiring power optimisation.
   b. Planning for long-term support, including software updates and maintenance, is necessary.

8.4 Device operational requirements from mobile operators

The chipset is a vital part of communication technology that enables efficient data transmission access to both IoT TN and IoT NTN networks. Comprising hardware, RF, modem software and supporting applications, this complex ecosystem should ensure maximum performance by implementing robust error correction capabilities, enhancing the frequency range and support bands beyond terrestrial networks while building the tracking capabilities for satellite coordinates and addressing the Doppler compensation.

The need to ensure device readiness presents several challenges requiring an innovative and constructive approach, which may vary depending on the environment, technology and use cases. These challenges include:

- The development and readiness of applications,
- Compliance with regulatory standards set by national and international authorities,
- Educating users and enabling them to grasp the intricacies of the IoT NTN network,
- Managing power consumption especially in cases where sensors have limited power sources
- Accounting for environmental factors such as topography and interference.

Collaboration between device manufacturers, standardisation bodies, and regulatory authorities is paramount to overcome these challenges. Continuous standardisation efforts and collaboration, through constructive dialogue and the exchange of ideas, can play a pivotal role in surmounting these challenges.

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Section 9: Conclusions & Next steps

Section 9: Conclusions & Next steps

9.0

9.1 Summary of key takeaways for the different ecosystem players

- We encourage MNOs to take note of the new 3GPP NTN Release 17+ evolutions for massive IoT and to bring this technology into their operations by working with satellite operators compliant with the 3GPP Release 17+ standard to avoid technology lock-in and protect their investment.
- We encourage all satellite operators to take advantage of the NTN initiative in the mobile sector to extend the coverage of MNOs and reach the massive IoT market using a common solution for terrestrial and non-terrestrial networks and improve the economies of scale for the whole ecosystem.
- Chip vendors are one of the most important players in the 3GPP NTN evolution. Now that Release 17+ is a reality, we encourage them to reach the next step: GCF/PTCRB certification in the lab and on the field to speed-up chip production during 2024 and the corresponding service commercialisation. Satellite operators and their customers are ready to start using this technology.
- Value added service providers, system integrators, IoT operators and end-users should ask their MNO provider to include NTN chipsets in their list of certified equipment and start testing the service with delay-tolerant and near real time applications.

9.2 What is needed to drive NTN deployments to scale

As this paper shows, NTNs have evolved leaps and bounds as a potential solution for ubiquitous connectivity. As with any new technology, implementation requires addressing all the impediments to deployment including velocity and scale. Device readiness is one of the key challenges: chipsets, modules and devices need to address the additional requirements.

Use cases are expected to evolve from emergency SOS to two-way messaging to perhaps low-definition streaming. From an IoT standpoint, the bandwidth available to support additional use cases is compelling enough to sustain NB IoT NTN. In a few years, business needs and the associated monetisation may drive newer use cases that may gradually shift the network upgrades to NR NTN. It is safe to conclude that IoT NTNs are here to stay and will evolve into new horizons.

Call to Action

- To consider advice and opinions in this whitepaper and evaluate adoption
- To socialise and encourage adoption of the guidelines within organisations
- To continuously evaluate the merit of the recommendations and to weigh in with any modifications to the guidelines, assuming there is a broad consensus.

GSMA

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