IoT Guide:
Hybrid Cellular/Non-Terrestrial Network (NTN)

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Introduction

Introduction

The use of satellites to connect IoT devices is nothing new, albeit typically for a limited set of use cases in IoT, specifically the monitoring of high value and highly remote assets. That satellite IoT market is set for a shot-in-the-arm in the coming decade because of two recent developments: the deployment of constellations of LEO satellites and the arrival of cellular connectivity using 'Non-Terrestrial Networks'.

Companies are lining up to launch fleets of Low Earth Orbit (LEO) satellites. The most eye-catching – and biggest – of these is SpaceX's Starlink which has plans for over 40,000 satellites by 2027. But it is not alone. There are also smaller fleets focused on IoT, typically involving a few dozen satellites deployed by other newcomers. With around 6,000 active satellites currently in orbit, these massive deployments promise a vast increase in satellite capacity.

In some cases, these LEO deployments are making use of standards-based cellular technology developed as part of the recent 3GPP Release 17. So too are some geostationary (GEO) satellites. The arrival of this Non-Terrestrial Network (NTN) capability allows devices using some cellular technologies to connect directly to satellites without incorporating any other technology. They are also increasingly being integrated into combined offerings of terrestrial and non-terrestrial cellular offerings.

This creates an opportunity for Mobile Network Operators (MNOs) and IoT MVNOs to further stitch satellite into their proposition. Many already do, through multi-mode cellular/satellite devices. The new technology developments, with a common set of hardware and comparatively simple switch-over between terrestrial and non-terrestrial networks, allow for a simpler and cheaper proposition. This comes at a time when MNOs are looking for differentiators for their IoT offerings, and additional value-added services to layer onto cellular connectivity. Satellite offers an opportunity to do that. Specifically in the form of hybrid cellular/satellite propositions.

In this report we examine the opportunities associated with specifically hybrid cellular/satellite offerings using 3GPP NTN. The report was compiled based on Transforma Insights' extensive research on the commercial and technical landscape for IoT satellite connectivity, as well as drawing on its comprehensive IoT market forecasts to identify what the opportunity might look like for hybrid cellular/satellite.

Matt Hatton - Founding Partner, Transforma Insights

02

Technology background on satellites

Technology background on satellites

In this section we provide a summary of some of the key concepts in satellite connectivity, which are more extensively covered in the Transforma Insights report '**A technology overview of Satellite IoT**' (January, 2022). This provides context of how it fits into a hybrid cellular/satellite offering, including types of satellites, architectures, frequency bands and protocols.

2.1

Types of satellite orbits: GEOs, MEOs and LEOs

There are essentially three main types of communications satellites define by their types of orbits: GEOs, MEOs and LEOs. The details of these three are explained in the Figure below.

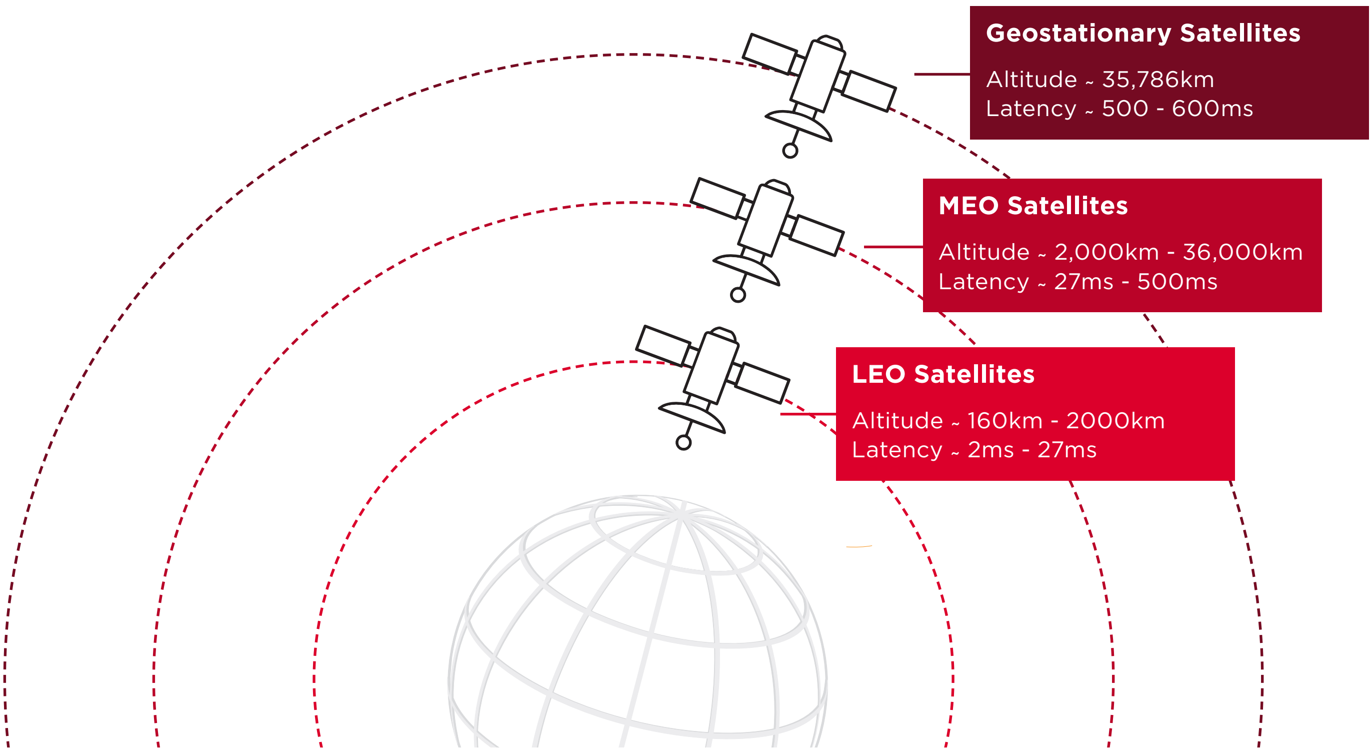

Figure 1

Categories of satellites [Source: GSMA]

GEO (Geostationary Orbit)	These operate at altitudes of 35,786km in a circular orbit above the equator. They remain in fixed positions, with speeds that match the earth's rotation. Because of their distance from Earth it is possible to cover most of the surface with just three satellites. Geostationary satellite systems also benefit from not needing more expensive tracking antennas because they never move relative to the antenna. However, they are often inconveniently located for devices at higher or lower latitudes due to the required angle to reach the equator. The other main drawback is the distance from the surface, which increases the latency (in the order of 100-300ms) which means that two-way communications, including some protocols such as TCP/IP that require 'handshakes', are not optimal (although there are work-arounds). Major GEO constellations include AsiaSat, Eutelsat, Intelsat and SES.
MEO (Medium Earth Orbit)	Less frequently deployed, these operate between 2,000km and 35,786km. Historically an altitude used by positioning satellites (e.g. for GNSS). Being further away makes for simpler tracking of satellites by ground-based devices. The distance also means fewer satellites required for constant global coverage. However, the additional distance makes for higher latency.
LEO (Low Earth Orbit)	Typically operate between 160km and 2,000km. These satellites are not geo-stationary, with an orbit period (i.e. the time to circle the earth) of 84-127 minutes. The lower orbit means hundreds are required to cover the surface of the earth with constant coverage. However, the fact that they are not geostationary means that a small number of satellites can cover large amounts of the earth during a 24-hour period for non-real-time communications. Being close to the earth makes for lower latency communications (~20ms) assuming that there is a satellite overhead when data communications are required and the large number of satellites increases the capacity relative to small numbers of GEO satellites.

LEO satellites are typically significantly smaller and cheaper than GEO satellites; of the order of 100kg-400kg[1] versus 1,500kg-7,000kg for GEOs. The cost for a LEO satellite is typically around USD500,000, compared to USD500 million for a GEO satellite. Launch costs are also comparably higher for GEO.

To balance that slightly, LEO constellations need a lot more satellites to provide coverage, are more complex to run, may require more ground stations (albeit smaller and cheaper), and the user equipment is sometimes more complex – requiring electronically steerable antennas – and expensive. It should be noted that many companies do not see it as an either/or decision. For instance, Eutelsat is deploying a LEO constellation to complement its GEO offering.

[1] And potentially much lower with Micro- (10-100kg), Nano- (1-10kg) and Pico- (100g-1kg) satellites. CubeSats, for instance, have dimensions of 10cm x 10cm x 10cm and a maximum weight of 1.33kg.

2.2

Frequency bands

Satellites and the services they provide are also defined by the frequency bands that they use, as illustrated in the Figure below.

Figure 2
Frequency bands used in satellite communications [Source: Transforma Insights]

BAND	FREQUENCIES	USE FOR SATELLITE
VHF	30 - 300 MHz	Limited use today, for low data rate uplink and downlink, amateur satellite activity, some military and aviation uses, and CubeSats utilising amateur radio frequencies.
UHF	300 MHz - 1 GHz	Limited use today. Used by some communication and meteorological/ environmental satellites and amateur.
L-band	1-2 GHz	Used for low bandwidth communications (e.g. satellite phones, LEOs, IoT) and navigation systems (GPS, GLONASS, Galileo and Beidou). Lower frequency means less atmospheric interference.
S-band	2 - 4 GHz	Communications satellites and weather radar. VSAT terminals. Good under adverse weather conditions. Higher power. So-called MSS (mobile satellite service) operations are run in the S-band, both using LEO (e.g. Globalstar, Iridium) and GEO.
C-band	4 - 8 GHz	Used typically for satellite communications and TV feeds, and for maritime.
X-band	7.25 GHz - 7.75 GHz and 7.9 - 8.4 GHz	Largely for military use, including 7.25 GHz - 7.75 GHz (for space to earth uplinks) and 7.9 GHz - 8.4 GHz (for earth to space downlinks).
Ku-band	12 - 18 GHz	Used largely for satellite communications and satellite broadcasting. This is the other major maritime band.
K-band	18 - 27 GHz	High levels of attenuation due to water vapor absorption at this frequency make it largely unusable for satellite communications.
Ka-band	27 - 40 GHz	Communications satellites, typically uplink. Large frequency range at high frequency makes for better support of higher bandwidth services, but more susceptible to atmospheric attenuations (e.g. rain fade). Also typically uses more targeted beams, necessitating higher pointing accuracy of devices. Generally, this is the preferred band (along with Ku-band) for LEOs.
V-band	40 - 75 GHz	Large amounts of this spectrum have been identified for use with satellites. A number of operators have already filed to use the V-band including O3b Networks, OneWeb and SpaceX.

The specifics of which parts of each band are available to use will depend on the applicable licensing regime. Some parts of the bands are allocated globally for satellite, while others are license exempt and may be usable only in certain strict circumstances. The International Telecommunications Union (ITU) is responsible for assigning radio frequencies, including for satellite. Satellite operators register with their local regulatory authority, e.g. the FCC in the US and the European Commission in Europe. The most used bands for IoT are, in declining order: L-band, S-band, C-band and X-band. The higher frequency high bandwidth capabilities are generally unnecessary for IoT use cases, and the power requirements are also comparably increased in higher frequency bands.

2.3

Protocol choices and standards

At the Data Link layer there are numerous (and expanding) options for the protocols used for connectivity. There are some satellite-specific technologies. However, much of the discussion around communications satellites recently has revolved around using traditionally terrestrial cellular technologies for the Data Link, most notably the cellular technologies (NB-IoT, LTE-M and 5G NR), and two low power wide area (LPWA) technologies developed originally for use in license-exempt bands, LoRaWAN and Sigfox.

In 2017, the 3rd generation partnership project (3GPP) – a body which combines the world's major standards development organisations for the purposes of defining a common standard for global cellular communications – started to examine the potential for integrating satellites into 5G. Release 17 of the 3GPP standards, unveiled in 2022, includes two relevant elements: 'NR over Non Terrestrial Networks (NTN)' (i.e. regular 5G 'New Radio' for communications and broadband access via satellite), and 'IoT over Non Terrestrial Networks (NTN)', which is focused on the low power wide area (LPWA) technologies, NB-IoT and LTE-M. NTN-NR focuses on just LEO constellations, whereas NTN-IoT is for both LEO and GEO. The main focus of NTN overall is satellite but also includes the likes of ground-to-air connectivity for in-flight connectivity on planes, as well as high-altitude platforms based on balloons.

There has been extensive work ongoing to refine 5G NR to be more appropriate for the satellite medium. One development that helps to support satellite connectivity is the ability to split a 5G base station (or 'gNB') between a central unit (CU) and a distributed unit (DU), to allow the switching functionality to be located on the satellite. This approach is referred to as a 'regenerative' architecture, in contrast to the more well-established 'bent pipe' or 'transparent' architecture where the satellite simply acts as a repeater. Furthermore, developments in the MAC layers, the network layer and other elements have been explored to cope particularly with the relatively high latency implicit in satellites. Release 17 is working on all of these elements.

The 3GPP development has also sought to define the most appropriate bands (user terminals would use S-band, while more capable VSAT devices and others with phased array antennas could use either S-band or Ka-band). This applies to both LEO and GEO. Furthermore, in Release 18, there will be further enhancements on NTN including new frequency bands, and efforts to optimise for satellite access. Release 17 focused on L-band and S-band, so frequencies in the 1-4GHz, which covers most the frequencies used by NB-IoT, although there are several sub-GHz bands used. Overall the bands specified for NTN are as follows:

- n255: 1,626.5 - 1,660.5 MHz (uplink) and 1,525 - 1,559 MHz (downlink)
- n256: 1,980 - 2,010 MHz (uplink) and 2,170 - 2,200 MHz (downlink)
- Release 18 will add a couple of further bands In Rel-18, another MSS FDD band will be added:
- 1,610 - 1,626.5 MHz (uplink) and 2,483.5 - 2,500 MHz (downlink)
- Release 18 is also expected to specify three bands in 17.7 - 20.2 GHz (downlink) and 27.5 - 30 GHz (uplink), with a focus on VSAT terminals and other devices with high-gain antennas.

Of particular importance to this report are the 3GPP items on IoT networks. In 2021, NB-IoT-related capabilities were approved in Release 17. Prior to this, some satellite operators already offered NB-IoT services via satellite but without the optimisation in Release 17, for instance in coping with base station power limits, high latency and Doppler effects for non-geostationary satellites. In particular, the challenges of Doppler effect and high latency cause problems for the 'Random Access' (RA) mechanism for scheduling transmission. Some of these challenges can be offset by the use of GNSS capability, i.e. understanding where the device is located and therefore the angle of elevation for the communication allows for compensation on uplink and downlink channels. Alternatively, the calculation can be done by the satellite for the expected delay based on a device at the centre of the beam and compensation for variation.

The first NB-IoT service was launched over satellite in June 2021 by Skylo in collaboration with Inmarsat (which was subsequently acquired by Viasat in 2023).

The first NB-IoT service was launched over satellite in June 2021 by Skylo in collaboration with Inmarsat (which was subsequently acquired by Viasat in 2023). Several have also deployed 5G over satellite, including Omnispace, OQ Technology and Sateliot. More details of strategies of the various satellite operators offering NTN are provided in the vendor landscape section.

2.4

Gateway vs end device

Another variable for satellite IoT deployments is whether the satellite is connecting to the end terminal, or to a gateway. In the latter case a satellite link is being used for backhaul. Many LoRaWAN-over-satellite solutions, for instance, will consist of nothing more than a VSAT terminal with a parabolic antenna connected to a LoRaWAN gateway. There are many instances where a gateway might be sensibly used, supported by satellite backhaul, for instance to connect agriculture applications, or oil & gas, in remote areas. Many of the GEO offerings for unlicensed LPWA connectivity will in fact be focused on backhauling LPWA. The advantage of this approach is that, unlike direct-to-device LoRaWAN or Sigfox, it allows for two-way communication, because the satellite uplink is using licensed spectrum.

What is more interesting and game-changing is Direct-to-Device (DTD) connectivity, whereby the device is connected to the satellite using a technology supported natively on that device itself. That is the main radical departure in NTN and similar approaches with, for instance, LoRaWAN: the device is connecting directly to the satellite using the same communications technology as it uses to connect directly to the terrestrial base station.

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03

Commercial trends for NTN

Commercial trends for NTN

In this section we consider some of the emerging approaches being taken the commercial models for the use of NTN.

3.1

NTN as 'just another network'

One of the most notable evolutions of satellite connectivity that comes from the NTN activities is that NTN is being positioned now as just another network onto which cellular devices can roam, with all the simplicity that implies. The nature of the agreements between NTN providers and Mobile Network Operators and MVNOs is as with existing roaming deals. We have even seen examples where the satellite providers are engaging third party roaming providers such as Comfone to handle negotiating roaming with multiple MNOs/MVNOs. Most of the NTN providers identified in the vendor landscape section of this report do not sell direct, but act as a wholesale carrier for the various MNOs/MVNOs.

3.2

NTN/cellular hybrid offerings'

The main driving force behind the availability of NTN is to provide the same technology or technologies that are available on terrestrial networks but globally outside of terrestrial coverage areas. There has naturally followed a set of propositions that combine cellular and NTN capabilities in a 'hybrid' product, making use of terrestrial networks where available and switching to non-terrestrial where they are not, including management via the same connectivity management platforms.

The trend has been particularly stimulated by the availability of a common set of hardware, rather than needing a multi-mode device with separate satellite connectivity module. Cost implications of including satellite connectivity as an option are near to zero, at least for GEO connections. Plus, of course, the new devices can make use of the ecosystem of terrestrial device hardware makers and terrestrial network operators.

There has been a small flurry of announcements of hybrid offerings, including NTT with Skylo and Telefonica with Sateliot. Probably the most prominent hybrid offering to date is that announced by Deutsche Telekom. Hybrid offerings are discussed in the vendor landscape section, profiling NTN providers.

3.3

NTN as an alternative to cellular

One additional opportunity that has been proposed to Transforma Insights is that satellite-based NTN may be able to act as an alternative to cellular network roaming in a small number of markets, and in relevant use cases, where relying on very expensive roaming might not be appropriate.
It should be noted that this is probably an option of last resort. The price points for satellite connectivity will likely be an order of magnitude greater than even the costliest roaming agreement. Furthermore, while NTN satellite coverage might be positioned as universal, it is still going to face challenges connected devices that are located indoors, or even in forested areas.

3.4

NB-NTN as a driver for NB-IoT

Thus far the focus of this report has been on how NB-IoT can be extended by the use of NTN. We can also take that one step further and consider how the availability of global ubiquitous coverage – but with fallback to a terrestrial network where available – might drive the overall appeal of NB-IoT as a technology, and likewise any other 5G technologies that will subsequently be supported. In the use cases and market growth section we consider the various use cases that might benefit from the use of hybrid satellite/cellular connectivity. In addition to that we should also consider that the availability of NB-IoT over NTN might provide a shot in the arm for NB-IoT as a technology by virtue of having that additional functionality versus other technologies. This is less a question of growing the overall market for IoT and more one of improving the prospects of those technologies that support both terrestrial and non-terrestrial connectivity. As a side note, one potential non-IoT example might be the inclusion of NB-NTN support in smartphones for resilient messaging globally.

3.5

NTN challenges

In addition to all the positive implications of NTN noted above, there will continue to be some challenges with the technology:

- **In-building coverage** – By virtue of being supported by satellites there will always be a limitation on availability, for instance in building or in heavily wooded areas. It is for this reason that the hybrid cellular/satellite offering, particularly taking advantage of terrestrial NB-IoT's good in-building penetration, has a substantial advantage over pure satellite connectivity.
- **Data rates** – Satellite connectivity can only support IoT connections generating very small amounts of data. The typical charges of satellite connectivity, in the region of USD1 per KB, means that this is really a fall-back, or for use in deployments with very low data rates or very high value assets.
- **Control logic to manage multimode** – The relative cost of satellite connectivity means that any IoT deployment will need to adapt the control logic

of the application to reflect whether it is connecting via satellite or terrestrial networks. The pricing disparity is stark. For instance, for NB-IoT the pricing is typically somewhere in the region of USD1-2 per year for multi-MB plans, in contrast with the USD1/KB charge typical for satellite. The application will need to be connectivity-aware in order to adapt frequency and volume of communication depending on which network is being used.

- **Latency** – Satellite connectivity, due to the distances involved, is always high latency. For GEO satellites round-trip time can be over 500ms, and for LEO it can be tens of milliseconds. In the latter case, however, the true latency will depend on how many LEOs are deployed (and therefore how long the device needs to wait to send the message to the satellite) and where the ground stations are (and therefore how long for the satellite to deliver the payload).

- **Ongoing financial viability of LEO constellations** – There has been a flurry of announcements in recent years of launches of LEO satellite constellations. In many cases the subsequent pace of launch has lagged the company's ambition, and included many companies that have opted not to deploy at all, or significantly curtailed their ambitions. There is also quite a fundamental issue with the lifespan of LEO satellites, which runs at only 5-10 years. If companies deploying such satellites cannot acquire business at a fast enough rate they may struggle to keep up with replacing satellites as they expire, not to mention expanding the constellation.

- **Device cost** – The principle behind NTN is to support IoT devices using a common piece of hardware that will connect to both terrestrial and non-terrestrial networks. However, there is a degree of complexity, with LEO-connected devices requiring steerable antennas to cope with moving satellites.

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04

Vendor landscape

Vendor landscape

In this section we identify some of the key players involved in deploying NTN, and particularly hybrid cellular/satellite offerings, as well as relevant players with similar competing offerings. Transforma Insights' report 'Low Earth Orbit (LEO) satellite IoT connectivity vendor landscape' (February, 2022) provides a more comprehensive guide to the providers of LEO and GEO satellites, and the report 'The opportunity in hybrid cellular/satellite 3GPP Non-Terrestrial Networks (NTN)' (March, 2024) gives a deeper dive on the relevant hybrid cellular/satellite offerings.

There are several companies going through the process of launching NB-NTN (i.e. NB-IoT over non-terrestrial networks) services. In some cases these are intended to support customers directly, while in others the approach is to build a wholesale offering that other connectivity providers can stitch into their offerings.

Skylo has been the most active NTN provider for hybrid cellular/satellite offerings. It is focused on supporting Release 17 NTN, specifically NB-NTN for messaging services. It is headquartered in Mountain View, California. It does not own its own satellites but acts as an aggregator of connectivity from partners Ligado Networks, Viasat, Strigo/TerreStar and EchoStar. Its first operator agreement, with Deutsche Telekom, was announced in February 2023. It subsequently struck agreements with several MNO/MVNOs, including with BICS, emnify, floLIVE, Monogoto, O2 Telefonica (Germany), Particle, Soracom, Transatel, and Truphone.
In February Blues Wireless launches the Starnote version of its Notecard offering, which includes satellite connectivity from Skylo, bundling 18KB of data in the USD49 product.

The other NTN provider with which MNOs have been striking deals is Sateliot. This Barcelona-headquartered company uses its own network of LEO satellites. Currently has just two LEO satellites in orbit, with plans for a further four commercial satellites in 2024. Partners today include Deutsche Telekom IoT, Telefonica, Transatel and Turkcell. With Telefonica it has successfully demonstrated roaming-style handover between satellite and cellular networks.

Other significant players with NTN offerings available or in the process of deployment include EchoStar, which already provides a pan-European LoRaWAN network via satellite, Globalstar, Omnispace, which has an agreement with STC and MTN, and OQ Technology which has two public MNO deals, with O2 Deutschland and Deutsche Telekom.

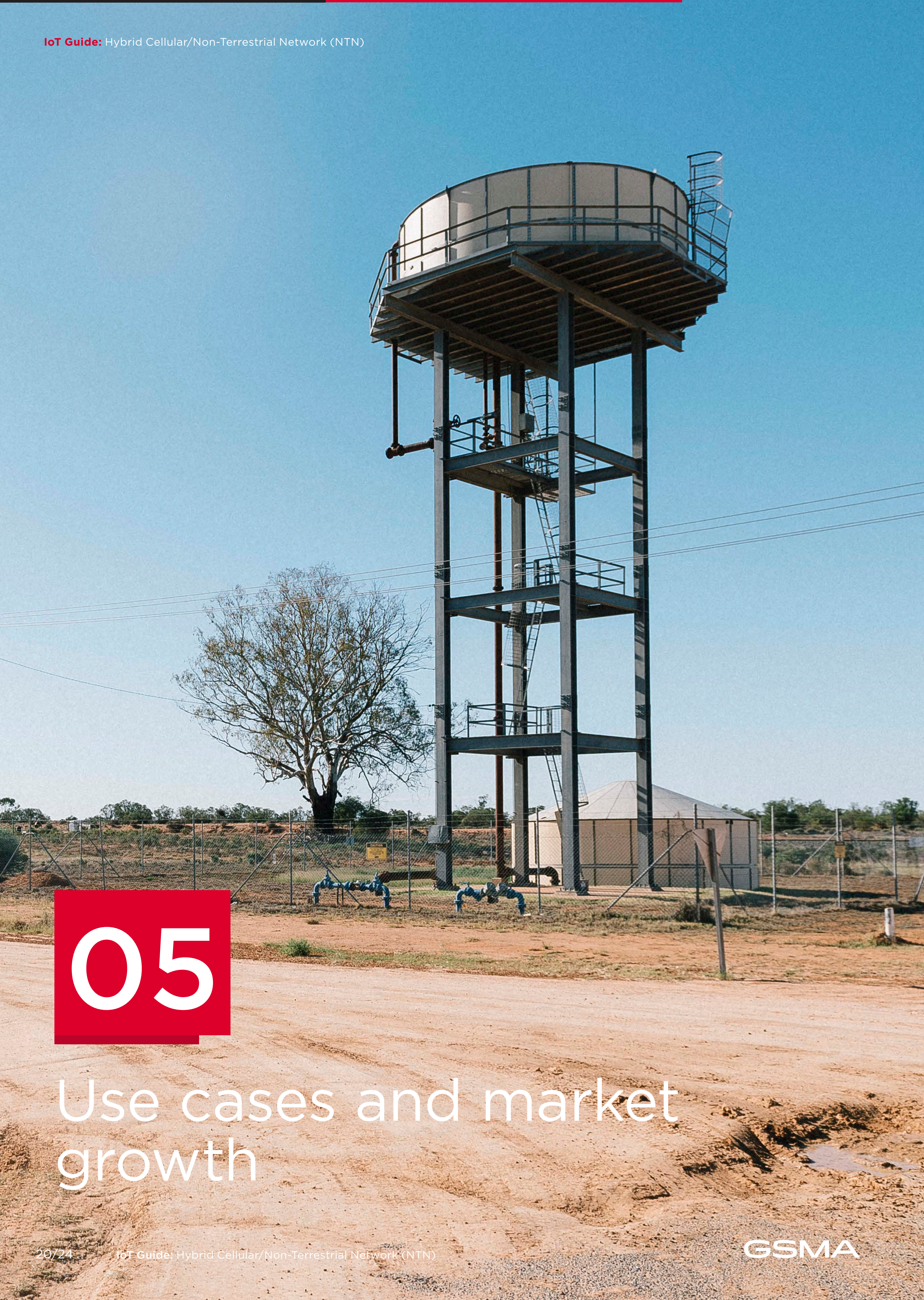
Today, the most fully realised hybrid satellite/cellular IoT offering is that from Deutsche Telekom. Working with Intelsat and Skylo, it has two offerings. The first is an extension to its NB-IoT offering, whereby the NTN capability is charged at a premium of EUR0.90 per KB (charged per byte) in addition to the standard annual fee of EUR2.70 per device for terrestrial NB-IoT connectivity. As such it is positioned as an overage-style additional charge which applies when the NB-IoT devices needs to connect using satellite. That offering is based on Skylo, with Sateliot and OQ Technology lined up as future roaming partners. The other satellite connectivity product is Satellite Connect, which is a combination of 4G/5G terrestrial connectivity plus non-NTN satellite connectivity. It is aimed at higher data rate applications, charged at EUR211.50 per month for 5GB of cellular and 1GB of satellite data. That offering uses Intelsat's network and devices, with Viasat integrated as a second partner. Other MNOs/MVNOs with hybrid cellular/satellite NTN offerings today include Blues, emnify and Telit Cinterion.

There is a further interesting development which relates to Starlink. It currently has a constellation of around 5,500 LEO satellites as of March 2024,

> Today, the most fully realised hybrid satellite/cellular IoT offering is that from Deutsche Telekom

representing the vast majority of communications satellites deployed globally. By the end of 2023 SpaceX had deployed six satellites to provide 'Direct-to-Cell' LTE connectivity, which sees the satellite act as an LTE eNodeB. To date T-Mobile US, Rogers, KDDI, Optus and several other MNOs have signed up for the service. This capability, which is still in testing phase, currently provides SMS services to smartphones with plans to extend to other voice and data services in 2024 and IoT in 2025. This is not using Release 17 NTN, but nevertheless represents a potential hybrid cellular/satellite offering, particular due to the scale and dominance of Starlink in LEO deployments. It is as yet unclear how Starlink has dealt with some of the challenges of delivering cellular connectivity from space as identified in the technology background section, above.

> This capability, which is still in testing phase, currently provides SMS services to smartphones with plans to extend to other voice and data services in 2024 and IoT in 2025



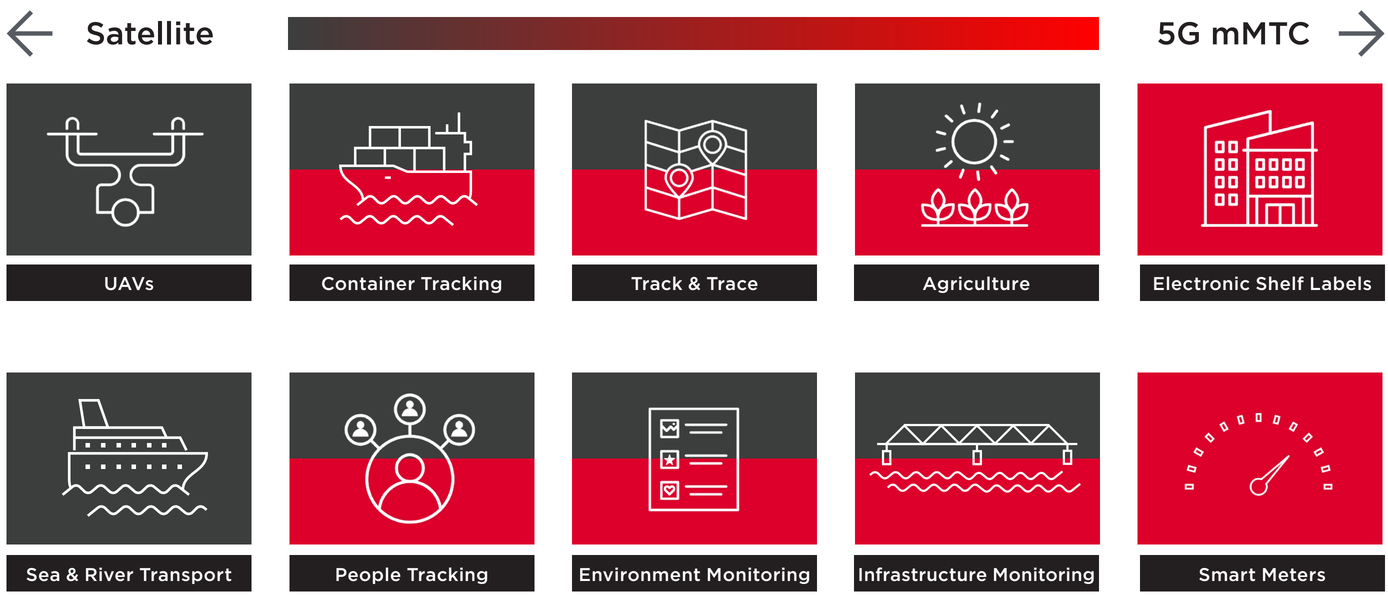
05

Use cases and market growth

Use cases and market growth

The question raised by this analysis of the NTN IoT landscape is: what are the use cases that will dominate and how big will the market be? In both cases we need to distinguish between two types of satellite connections. There are those for which the satellite connection will likely be the primary one, including sea transport, large unmanned aerial vehicles (UAVs), some forms of asset monitoring (for instance for well heads), and potentially for high value asset tracking. Other than these, there are applications where devices will be designed predominantly to use terrestrial networks – in this case 5G mMTC technologies, mostly NB-IoT – but which will benefit in some circumstances from being able to rely on a satellite network as an alternative, including as a fallback. And, to complete the picture we should recognise that there are applications that are substantial users of 5G mMTC but which will not make use of satellite, largely by virtue of being deployed heavily in buildings. A few of each of these categories are illustrated in the Figure below.

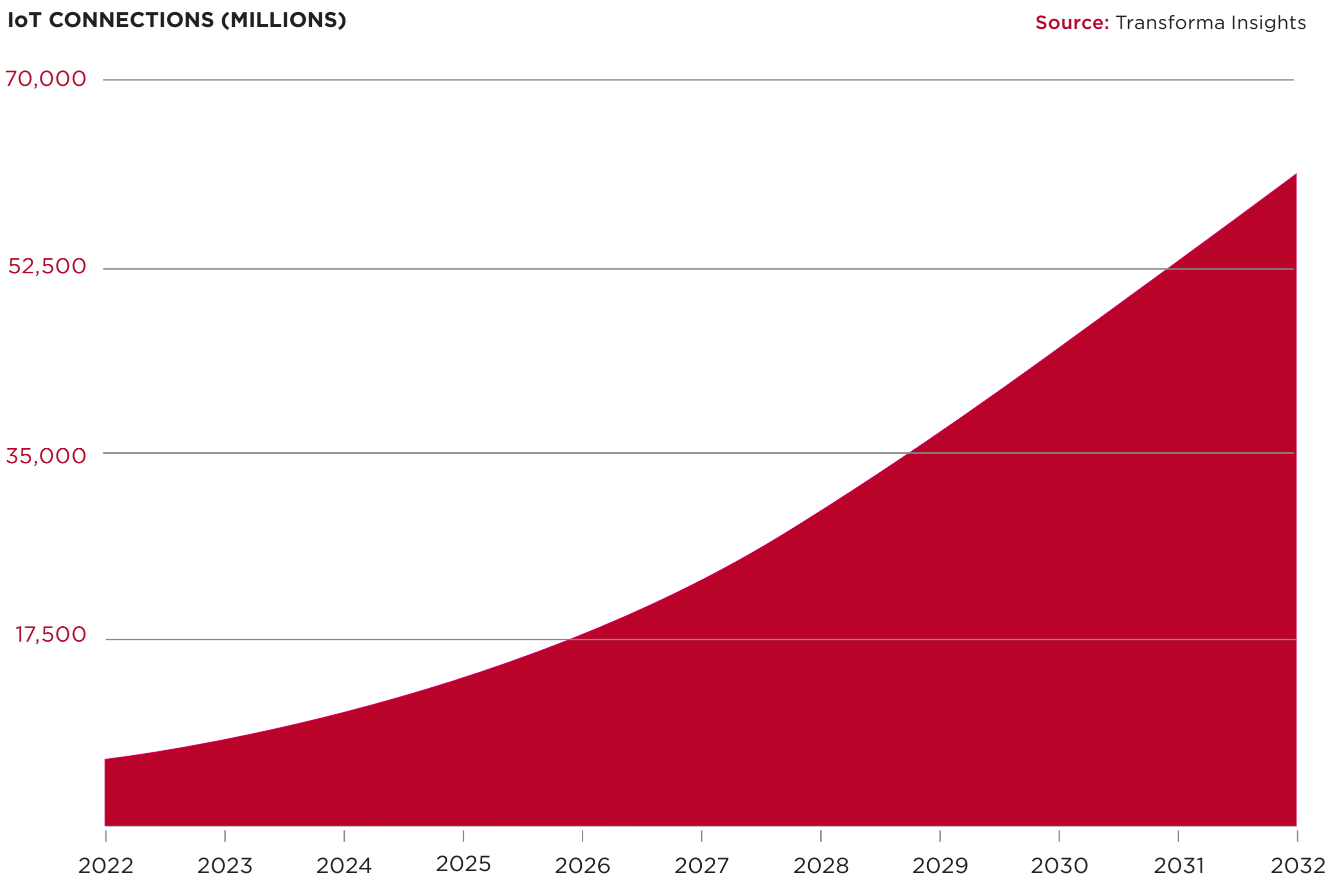
Figure 3
Satellite vs hybrid vs 5G mMTC major use cases [Source: Transforma Insights]



We should note here that we are referring exclusively here to the Direct-to-Device market. Devices that connect via a gateway that happens to be connected to a VSAT terminal are not considered. While this satellite backhaul certainly represents an opportunity for someone it does not have the same implications for market dynamics, particularly for hybrid cellular/NTN.

In terms of volumes, it is necessary therefore to distinguish between devices that use satellite as a primary connectivity technology and those for which it is a potential fall-back. In the next Figure we present Transforma Insights' view of the number of connections which use satellite as their primary connectivity technology, based on our ultra-granular IoT market forecasts. We should note that this is not a particularly new market, with satellite having been used for decades for tracking certain assets. The advent of Release 17 NTN and the proliferation of LEOs (supporting technologies of all types) has accelerated the adoption. According to those Transforma Insights forecasts, the number of connections will grow from 6.5 million connections at the end of 2022 to over 60 million in 2032. We should note that this spans all satellite network technologies including proprietary and non-cellular standards.

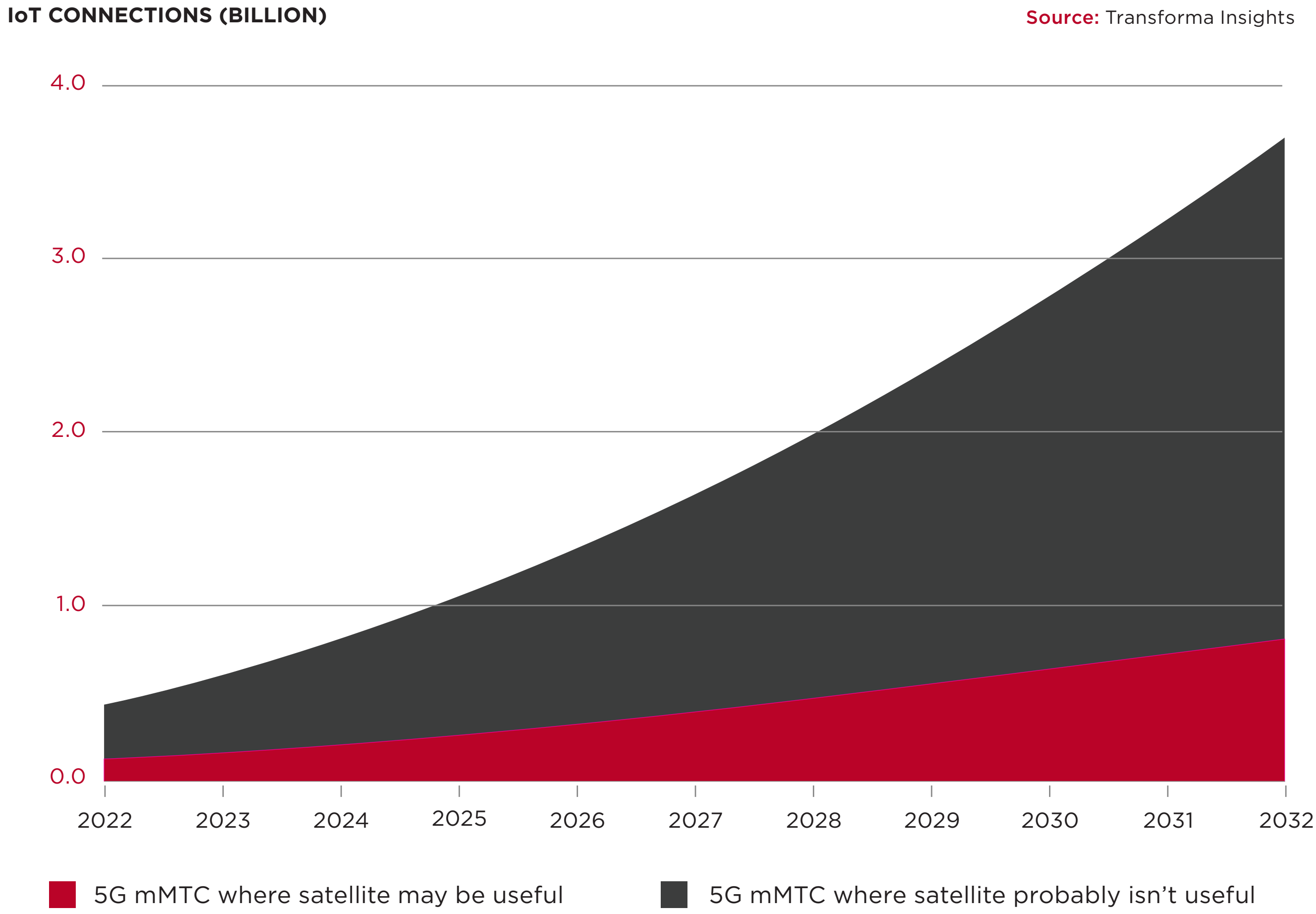
Figure 4
Satellite primary connections 2022-32



However, as noted above, this is only a fraction of the potential market. What is worth considering is what proportion of the 5G mMTC space would benefit from having access also to satellite networks. Not as the primary form of connectivity, but with the ability to fall back to NTN. According to Transforma Insight's assessment of hundreds of different applications using 5G mMTC, over 800 million out of a total of over 3.5 billion 5G mMTC connections may benefit from NTN by 2032, as illustrated in the next Figure.

Figure 5

5G mMTC devices and potential for hybrid NTN



There is also the question of revenue. However, this is less easy to identify in the context of hybrid devices. In many cases the satellite connectivity can be expected to be provided as a fallback or overage option, as discussed in Section 5. In that context, many of the potential 800 million devices would generate no NTN revenue at all. Whereas devices with satellite as the primary connection generate well over USD250/year in connectivity revenue, those for which it will be a back-up will generate a very small fraction of that; certainly less than USD1/year on average. As such, the fact that the volume of devices with satellite fall-back is more than 10x that of primary satellite devices still does not push the revenue for fall-back beyond 5% of all satellite connectivity for IoT, and most likely well below that.

We should note that in comparison to the revenue accruing from NB-IoT devices typically, which will be of the range of USD1-5 per year, the additional overage charges from satellite fall-back may be quite significant. All of this waits to be proven in the field. The value is in the availability of the satellite connectivity, rather than necessarily in its use. Making such NTN functionality available to customers will be a differentiator of the key product, typically NB-IoT connectivity, rather than necessarily a revenue generator in its own right.

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