Global coverage through non-terrestrial networks

Enabling cellular network services everywhere

White paper

Non-terrestrial networks (NTN) are comprised of satellites — geostationary equatorial orbit (GEO), medium-Earth orbit (MEO) and low-Earth orbit (LEO) — as well as high-altitude platform systems (HAPS), which include unmanned airships or airplanes above 20 km, and unmanned aerial systems (UAS) or drones. Commercial applications of NTN will initially target very low data rate text, MMS, messaging apps and the areas not served by terrestrial networks. They can later expand to broader regions to provide services, such as mobile broadband, internet of things (IoT) connectivity, terrestrial network backhauling, public safety, disaster relief, and communications for the maritime and transportation industries.

The traditional satellite industry is being disrupted by accelerated LEO deployments from companies like SpaceX (Starlink), Oneweb and Globalstar. These deployments have the potential to shape the future of critical networks. They have an opportunity to address emerging growth opportunities and take a larger share of the overall network value chain. In this white paper, we describe the challenges and the solutions of the NTN system and the importance of standards-based NTN solutions (Release 17 through future Releases 18 and 19), especially for LEO-based 5G NR and 4G NB-IoT/eMTC.

Contents

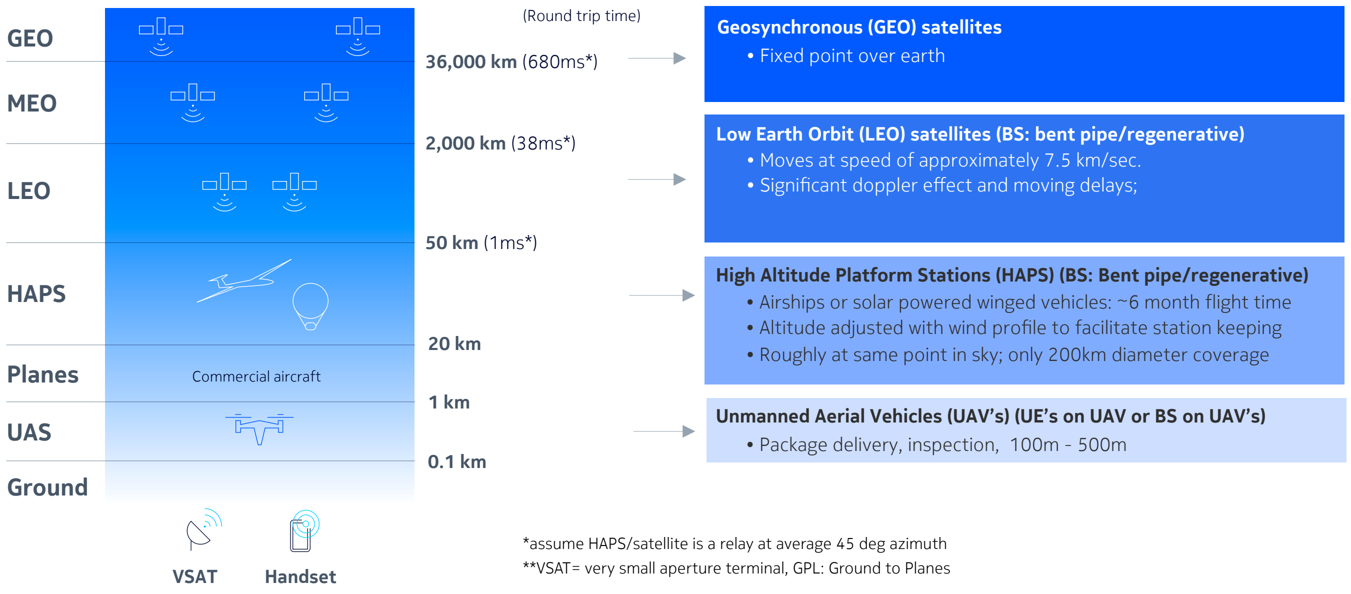
Non-terrestrial networks introduction

Over the last 10 years the cost of producing and launching a satellite in space has dropped significantly. This can be attributed to smaller-sized satellites designed for low-Earth orbit deployment (LEO), larger quantities of satellites per launch vehicle and the re-use of launch vehicles. Lower costs have enabled, in turn, the creation of non-terrestrial networks (NTN), which solve the issue of holes in terrestrial coverage, to provide truly global coverage. At the same time, NTNs can provide resilience to failure of parts of the terrestrial network in case of natural disasters like tsunamis and earthquakes, such as Starlink's intervention in Tonga in early 2022, or during wartime and other man-made disasters, as seen with Starlink's activity in the Ukraine since March 2022.

SpaceX/Starlink has already launched more than 3,000 satellites of their planned constellation as of the second half of 2022, and the FCC has granted them permission for 12,000 satellites [1]. They are offering fixed wireless access (FWA) in approximately 30 countries and deployments show throughputs well above 100 Mbps in the downlink and typically between 10-20 Mbps in the uplink [2]. Amazon is planning a system, called Kuiper, which will also have more than 3,000 satellites [3] to provide broadband connectivity to households and companies, while OneWeb has plans for around 650 satellites [5] in orbit to connect small business and companies. All these systems are using proprietary radio interfaces and require dedicated receivers with very small aperture terminal (VSAT) antennas or antenna arrays.

Alternatively, companies like AST and Lynk, and recently Starlink, intend to provide connectivity to existing 3GPP mobile devices, i.e., without requiring modifications to the phone. In August 2022, SpaceX/Starlink announced expansion of its offering with direct-to-3GPP phones, e.g., 5G-based Release 15 connectivity (pre-standard NTN) in partnership with T-Mobile US. AST will build a constellation of LEO satellites to provide connectivity in large parts of the world, and they have just launched a first test satellite in September 2022 [4]. Recently Apple announced that the iPhone14 will support emergency messages through the LEO satellites of GlobalStar when there is no terrestrial coverage.

Figure 1. NTN is comprised of satellites (GEO, MEO and LEO) and HAPS along with unmanned aerial systems (UASs)



Geosynchronous (GEO) satellites
- Fixed point over earth

Low Earth Orbit (LEO) satellites (BS: bent pipe/regenerative)
- Moves at speed of approximately 7.5 km/sec.
- Significant doppler effect and moving delays;

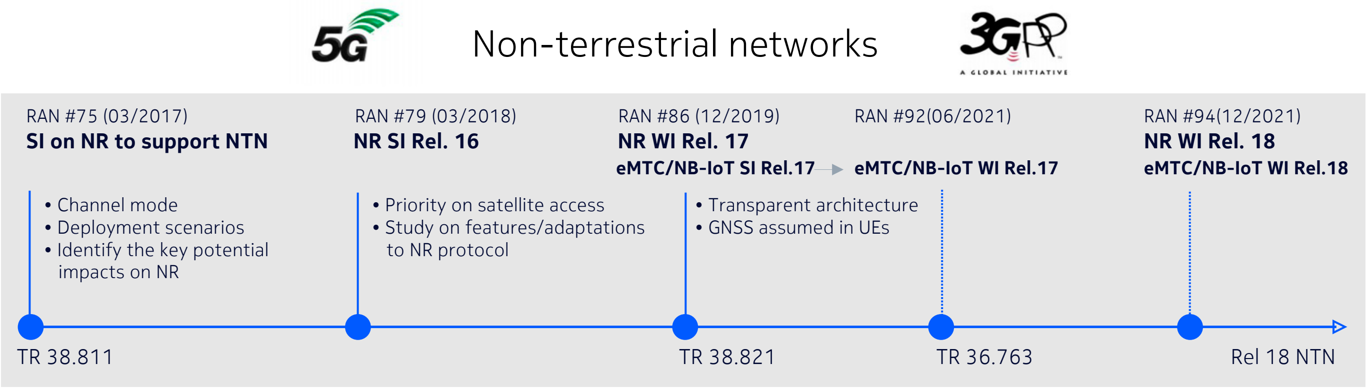
High Altitude Platform Stations (HAPS) (BS: Bent pipe/regenerative)
- Airships or solar powered winged vehicles: ~6 month flight time
- Altitude adjusted with wind profile to facilitate station keeping
- Roughly at same point in sky; only 200km diameter coverage

Unmanned Aerial Vehicles (UAV's) (UE's on UAV or BS on UAV's)
- Package delivery, inspection, 100m - 500m

*assume HAPS/satellite is a relay at average 45 deg azimuth
**VSAT= very small aperture terminal, GPL: Ground to Planes

3GPP started to work on enabling New Radio (NR) and IoT services through satellites in 2017, as shown in Figure 2, with study items on non-terrestrial networks (NTN) in Releases 15 and 16. In Release 17 both 5G NR over NTN and 4G IoT over NTN have been enabled. These Release 17 specifications cover both geostationary (GEO) and LEO transparent satellites and include high altitude platform systems (HAPS) as well with the goal of leveraging the 3GPP UE ecosystem.

Figure 2. Timeline of the NTN related study and work items in 3GPP



SI: Study item
WI: Work item

CT Rel. 17 aspects of 5GC architecture for satellite networks
SA Rel. 17 architecture aspectsfor using satellite access in 5G

The NR over NTN work item has enabled NR access over NTN for both regular 5G phones and VSAT terminals, while the NB-IoT/eMTC over NTN work has focussed on 4G mobile IoT devices. Furthermore, NTN Release 18, which started in May 2022, includes two WIs on further enhancements for NR and NB-IoT/eMTC over NTN, respectively.

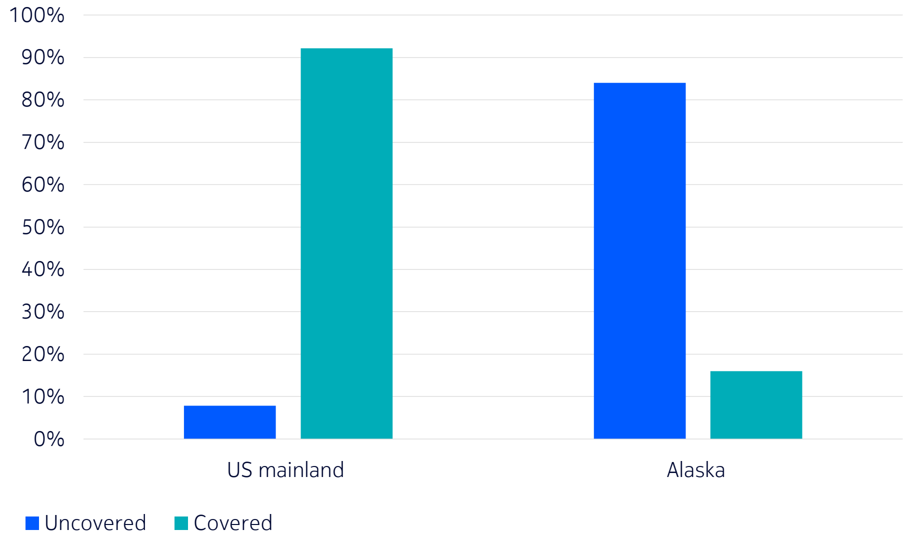
In this white paper, we provide a comprehensive view on the whole NTN space with special focus on NTN LEO Release 17 and the outlook for NTN LEO Releases 18 and 19.

Emerging use cases for NTN

Non-terrestrial network (NTN) use cases are quite diverse:

- Global user services supplementing cellular coverage in geographical areas without terrestrial cellular service. Terrestrial services typically cover high population density areas, whereas areas with low population density are not economical for mobile network operators. Figure 3 illustrates the percentages of covered vs. uncovered areas, for example, between the US mainland and Alaska (based on [8]).
- Global IoT coverage allows the tracking of goods anywhere in real time. For example, a container leaving a harbor in Asia, sailing to Brazil and moving into the Amazon can be tracked and information abouts its status monitored until it reaches its destination.
- Automotive connectivity to support vehicle-to-everything (V2X) use cases. For instance, over 200 million vehicles are equipped with applications sharing hazard and traffic warnings on the road [9], yet they require ubiquitous connectivity, which can be a challenge, particularly in rural or remote areas. NTNs will enable hybrid connectivity solutions for the car of the future.
- Backhauling remote cellular radios where terrestrial solutions are more expensive.
- Communication service resilience in case of a failure of the terrestrial network due to natural accidents, like earthquakes, NTNs provide coverage and service to normal phones, available to existing subscribers of the terrestrial network.

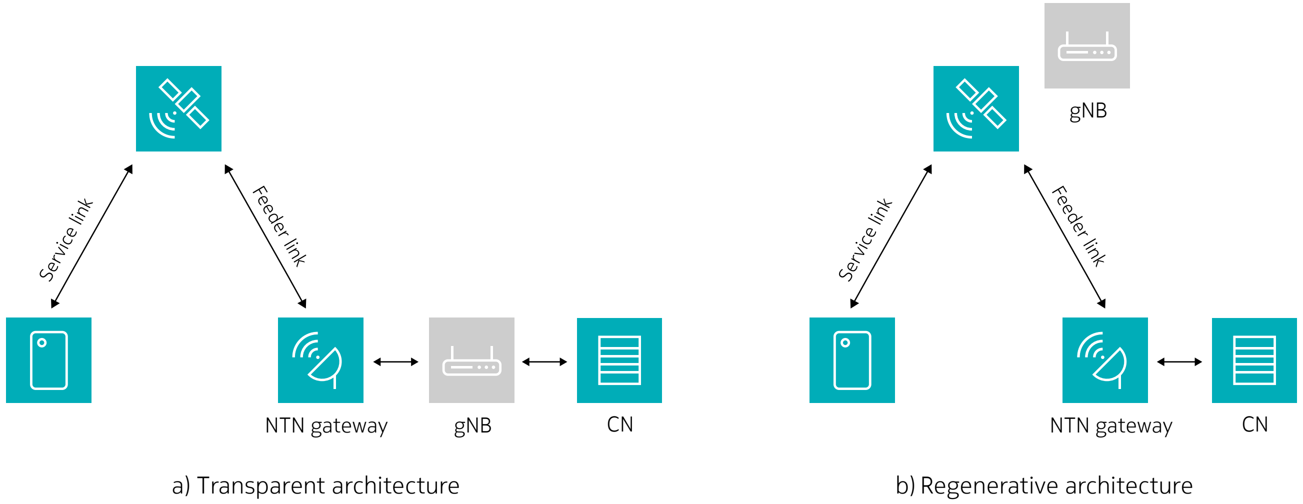
Figure 3. Percentage of uncovered and covered areas in US mainland and Alaska



NTN Architecture

The two main architectures for NTN are the transparent payload architecture and regenerative payload architecture, as shown in Figure 4. In the transparent architecture the satellite or HAPS acts as a repeater. It receives the downlink signals from the gNB through the terrestrial satellite gateway, and the satellite/HAPS translates the frequency and transmits the signals using a beamformer. The biggest advantage of this architecture is its simplicity. Being deployed on Earth, the gNB is as simple to maintain as in terrestrial networks.

Figure 4. Transparent and regenerative architectures for NTN



a) Transparent architecture

b) Regenerative architecture

In the regenerative architecture, the satellite carries either the full gNB or a part of the gNB on board. If only a part of the gNB is on board, this is typically the gNB-DU, while the gNB-CU is on the ground. The advantage of the regenerative architecture is that the delays between the gNB and the user equipment (UE) is shortened compared to the transparent architecture (at least at the lower communication layers). This can lead to better system and network performance by avoiding hybrid automatic repeat request (HARQ) stalling and shorter delays for channel quality feedback.

Another advantage of the regenerative architecture is that it can increase efficiency on the feeder link. In the transparent architecture, the full downlink or uplink of a cell needs to be transported regardless of how much traffic there is in the cell. The regenerative architecture can process and pack the traffic more efficiently over the feeder link. One disadvantage of the regenerative architecture is that the gNB requires space hardening.

In the remainder of this paper, we will focus on the transparent architecture, as this is the architecture 3GPP is defining for Releases 17 and 18.

NTN LEO challenges

There are several challenges to make NR and IoT work over NTN LEO satellites. First, there is the large distance between the UE and gNB. The signal must travel via the service link to the satellite payload (in space) and via the feeder link to the satellite gateway (on Earth). This leads to a poor link budget and impacts the throughputs (to be addressed below) and causes large round-trip times (see Table 1). The large round-trip time (RTT) is problematic for some of the control loops in a 3GPP network. For instance, it can lead to stalling since the HARQ acknowledgements are not received within a specified window. Furthermore, channel feedback from the UE will be stale before it reaches the gNB.

Table 1. Distances and minimum and maximum RTT for different satellite orbit and elevation angles

Case	Distance at 30˚ (LEO) or 60˚ (GEO)	Distance at 90˚	Minimum RTT	Maximum RTT
LEO 600 km	1,200 km	600 km	8 ms	16 ms
LEO 1500 km	3,000 km	1,500 km	20 ms	40 ms
GEO 36000 km	42,600 km	36,000 km	480 ms	568 ms

For non-geostationary (NGSO) satellites there is a further complication since the satellites move very fast relative to Earth. A LEO satellite at 600 km height, for instance, moves at approximately 7.5 km/s. This extreme high-speed movement leads to two major issues:

1. **Time drift:** as a satellite moves towards or away from the UE, the reference time between the UE and gNB moves faster or slower. A signal moving straight to the UE from a LEO at 600 km height at an elevation angle of 30 degrees drifts around 21 ns per second. This is challenging for time synchronization and for the initial time advance. Also, neighbor measurements become more difficult as the serving cell and neighbor cell timing may move in opposite directions when the cells are on different satellites.
2. **Doppler shifts:** like time drift, the fast movement of the satellites leads to a frequency shift. Studies in 3GPP show these can be as large as 21 and 24 ppm for 1,200 and 600 km height, respectively.

Furthermore, as NTN coverage can be rather large, with beams up to 1,000 km in diameter, a cell may cover multiple countries at a time. Additionally, mobility is an inherent challenge for NTNs, as non-geostationary satellites cause frequent handovers (HOs) even for stationary UEs.

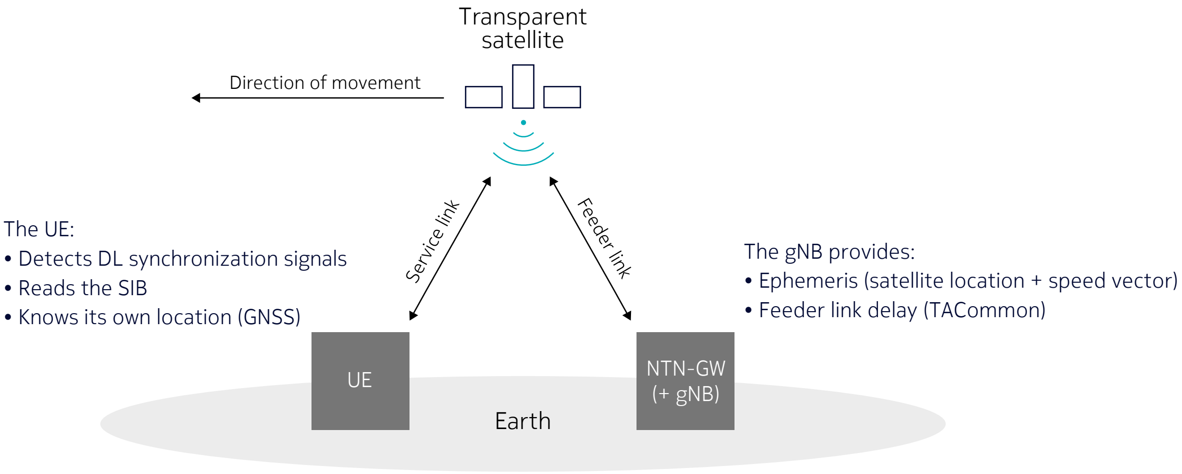
Solutions to these challenges are detailed in the following sections.

Synchronization and initial access

To overcome the first two challenges of time and frequency drift, pre-compensation by the UE is specified. The procedure for the time part is shown in Figure 5 and works as follows:

- The UE detects the DL reference signals and reads the SIB from the network. The NTN-specific SIBs contain the ephemeris of the satellite (satellite location and direction of travel) and additional information about the feeder link delay.
- The UE knows its own location from GNSS, as required by the specifications.
- The UE can calculate, based on the information in the SIB and its own location, the delay between itself and the gNB on the ground (considering the propagation via the transparent satellite). Thus, it can pre-compensate the delay when accessing the system.

Figure 5. Pre-compensation by the UE in NTN



The UE:
- Detects DL synchronization signals
- Reads the SIB
- Knows its own location (GNSS)

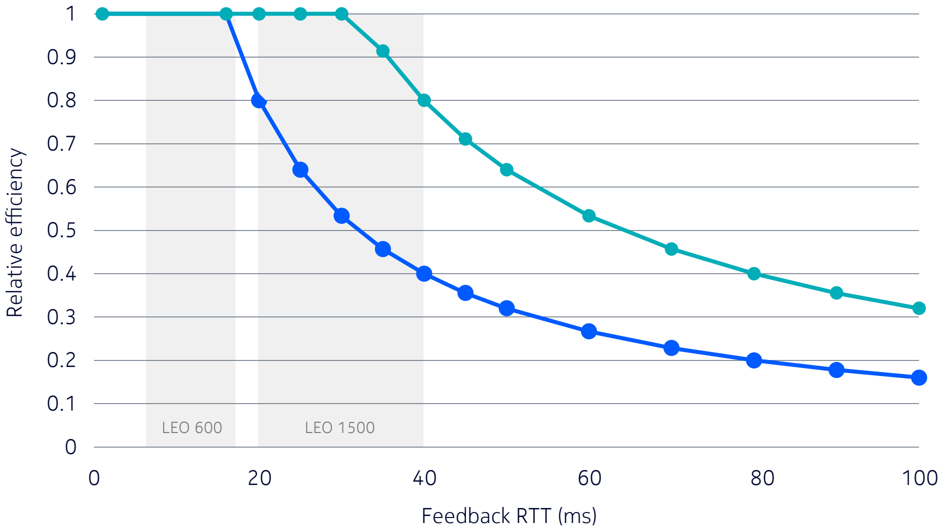
The gNB provides:
- Ephemeris (satellite location + speed vector)
- Feeder link delay (TACommon)

Similarly in the uplink, a UE compensates for the Doppler shifts, whereas the network does not compensate for the downlink Doppler shifts.

Impact of longer delays

As reflected in Table 1, the RTT in NTN can be long. This means that there may be a loss in link efficiency due to communication stalling. Stalling happens if the system cannot send new data for a HARQ process because the system is still waiting for the acknowledgement of the previous send data. The loss depends on the number of processes, the scheduling frequency, and the RTT in relation to the frame duration. Figure 6 shows the relative efficiency vs. RTT for the case of 16 and 32 HARQ processes and a subframe duration of 1 ms. With 16 HARQ processes there is no risk of stalling for a connection when a user is constantly scheduled, as long as the RTT is below 16 ms. This shows that for LEO satellite at 600km, 16 HARQ channels work, whereas for a LEO satellite at 1,500 km, stalling will happen if a user is constantly scheduled with 16 HARQ processes. For geostationary satellites, this problem will be present in a much larger degree due to the very long RTT.

Figure 6. Relative efficiency loss due to stalling for 16 and 32 HARQ processes vs. the RTT



To solve this problem 3GPP has introduced three mechanisms with Release 17:

- Turn off HARQ, meaning no L1 retransmissions are performed. This can be done per HARQ process.
- The number of HARQ processes is increased from 16 to 32. As shown in Figure 6, this decreases the problem for LEO at 1,500 km, although for GEO it will still be present.
- Slot aggregation to create longer HARQ process duration.

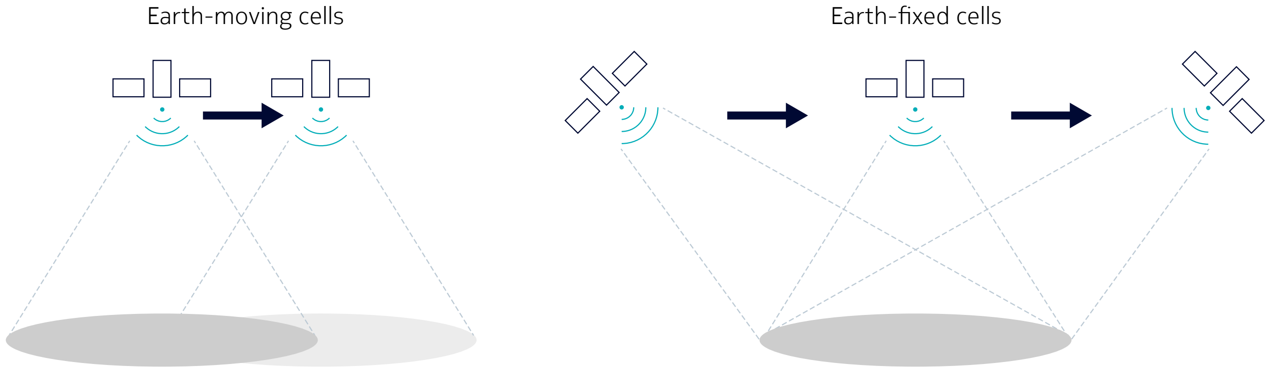
Impact of large cells

To overcome the challenges introduced by large cells, multiple tracking areas are supported by a cell in NTN, meaning that when an NTN cell's coverage spans a geographical area covered by multiple tracking areas, the NTN cell supports these multiple tracking areas. The UE selects one of these tracking areas, and the network can take this selection together with movement of the satellites into account to reach (page) a UE when needed. Additionally, a cell may broadcast multiple PLMN codes as a cell may cover multiple countries. If the UE selects a PLMN it is not allowed to use based on its location, the PLMN can reject the UE's registration request indicating that the PLMN is not allowed to operate at the UE's current location.

Impact on mobility

As already described in the challenges section, with non-geostationary satellites even stationary UEs experience frequent handovers. Therefore, mobility solutions are important. There are two possible deployments, Earth-moving cells (EMC) and Earth-fixed cells (EFC), as shown in Figure 7.[1] Depending on the deployment of EMC or EFC and the cell size, the HO frequency can range from an order of seconds to a few minutes. With Earth-moving cells, the satellite beam's orientation is fixed, therefore the radio coverage on Earth's surface moves following the satellite movement. Even for stationary UEs, this leads to frequent HOs of UEs between satellite cells. With Earth-fixed cells, the satellite beams are steerable to remain in a specific location while the satellite is moving. Therefore, the radio coverage is (quasi) stationary on Earth, even if the satellite is moving. While this requires a more complex implementation on the satellite, it simplifies management on Earth, for example, definitions and management of tracking areas. HOs occur in bursts when the coverage is handed over between satellites, but the frequency of HOs can be significantly reduced compared with Earth-moving cells.

Figure 7. Earth-moving and Earth-fixed cells

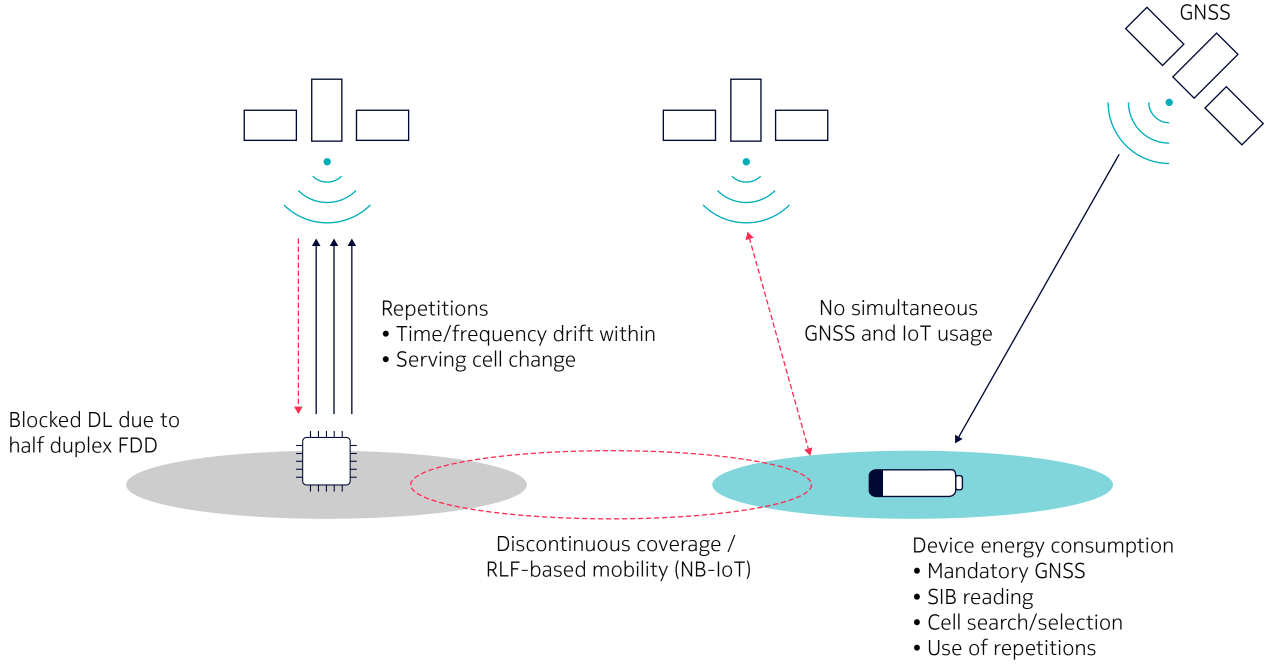


To assist UE HO procedures, the predictability of the satellite moving on well-defined/planned orbits can be utilized. The conditional handover (CHO) was introduced in 3GPP Release 16 for pre-configuration of the UE with upcoming cell information. For NTN purposes, additional timing and location-based triggers have been added in the CHO procedures. Whereas the conventional handover algorithm leads to frequent radio link failures and handover failures [10], with the use of the conditional handover and these new settings, the handover performance resembles that of terrestrial networks [11].

Internet of things (IoT)

One of the practical ways to support global IoT coverage is to leverage NTN. In parallel with developing the specification for NR support over NTN, 3GPP also specified NB-IoT/eMTC support over NTN, which reuses many of the NR solutions. Some critical challenges specific to IoT are summarized in Figure 8.

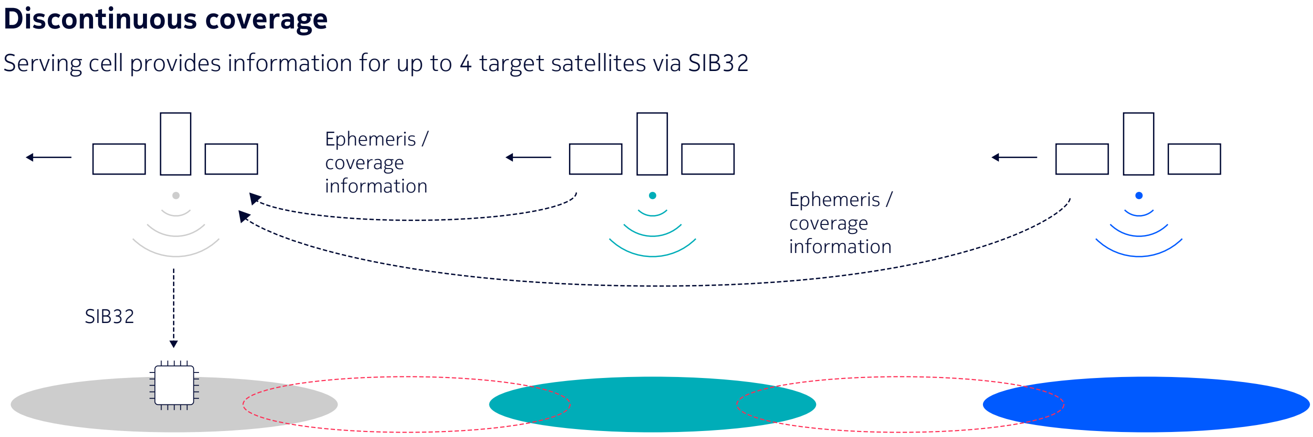
Figure 8. IoT specific challenges for support of NTN



Discontinuous coverage

Discontinuous coverage is caused by the (expected) use of a sparse constellation. It means the satellites don’t provide continuous coverage leading to periods where a UE cannot detect any satellite. This may cause a UE to fruitlessly search for a cell, leading to the waste of UE energy. For this reason, 3GPP introduced the dedicated SIB32 for discontinuous coverage, which provides ephemeris/coverage information on up to four target satellites, as shown in Figure 9. The UE can use this information to estimate the next coverage opportunities and save energy between the availability of satellites.

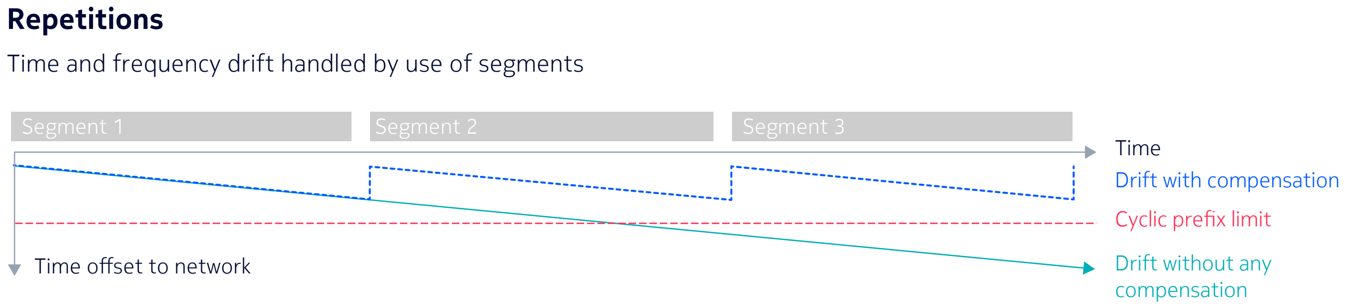
Figure 9. Discontinuous coverage solution for NB-IoT/eMTC over NTN



Repetitions

In NTN LEO, the service and feeder link distances are continuously changing due to the motion of the LEO satellite. IoT devices in NTN scenarios are expected to use many repetitions for uplink transmission to overcome the large path loss. The transmission may last multiple seconds and thus the total timing shift during the transmission period may exceed the cyclic prefix or the maximum timing-error tolerance of the receiver. Therefore, Release 17 introduces segmented uplink transmission for IoT NTN, which enables a repetition period to be split into segments. The time and frequency can then be adjusted at the beginning of every segment, as shown in Figure 10.

Figure 10. Repetitions for NB-IoT/eMTC over NTN using segmented transmission



GNSS limitation and half duplex

NB-IoT and eMTC devices rely on half-duplex communication, meaning a UE can either receive or transmit in a subframe. The UE will consider the subframe before and after an uplink transmission as blocked, i.e., the UE does not receive potential downlink signaling in these two subframes. In terrestrial networks this is easy to handle as the network knows the timing of the (stationary) UE. However, due to the aforementioned satellite movement, the NTN UEs pre-compensate the uplink transmissions based on their own location. This creates a challenge for the network because it needs to be aware of when a UE will transmit in order to avoid the downlink blocking of the affected subframes. For this reason, in IoT NTN, the UE reports its timing advance value to the network, allowing the network to deduce the correct timings for uplink and downlink transmissions.

Furthermore, similar to NR over NTN, every UE is assumed to have GNSS and be aware of its location. However, in NB-IoT and eMTC, it is assumed that GNSS cannot be used simultaneously with data transmission or reception. Therefore, in Release 17, it is assumed that data transmission and reception is short and in case the UE has outdated GNSS location information, which is indicated through a so-called GNSS validity duration timer, the UE will move to RRC Idle mode. At the beginning of the connection setup, the UE reports the GNSS validity duration timer to the network so that the network is aware of how long the UE is potentially available.

GEO satellites

The previous sections looked primarily at LEO, but 3GPP also has considered geostationary equatorial orbit (GEO) satellites in Releases 17 and 18. GEO satellites hover at an altitude of 35,786 Km with an orbital period of 24 hours. In the case of GEO satellites, there is no significant Doppler shift and time drift since they follow the rotation of the earth. A small Doppler and time drift may be introduced due to the actual orbit of the GEO satellite. However, this effect is several magnitudes smaller than for LEO satellites and supported by the same solution.

There are two key phenomena, namely long propagation delay and poor link budget, both caused by the long distance between the satellite and Earth, which provides difficult challenges for GEO satellites. The long delays have an impact on the feedback from the UE and on HARQ. For the latter the same solutions are available as described above for LEO, but simply increasing the number of processes from 16 to 32 will not be enough.

The poor link budget means that reaching a GEO satellite from a handheld device will require repetitions, where the number of repetitions depends on the actual conditions and deployment scenario and high antenna gains. Voice calls are not feasible due to the long delay, however, IoT devices may still be able to upload small amounts of data. A solution to the poor link budget is to use a VSAT antenna or antenna array, which typically uses higher frequencies, like the Ka band. Lower frequencies, like the L and S band, are also used today for GEO.

Performance in NTN Release 17

One of the most interesting questions is the expected performance of NTN. In 3GPP, two kinds of user equipment (UE) types are considered: VSAT and handhelds. VSAT is a small dish antenna (or antenna array), typically using higher frequencies. Due to the good antenna gains, throughputs of 200 Mbps in DL and 100 Mbps in UL can be achieved with 400 MHz of bandwidth taking the assumptions from [12].

The throughputs achievable with normal handsets are significantly lower as can be seen in Table 2, where the 5% worst, median and 5% best throughputs are shown for the case where a normal handset is connected to a LEO satellite at 600 km height at 2 GHz with a 30 MHz bandwidth. Whereas the downlink throughputs are high enough to enable different services in the downlink, the uplink throughput is very limited. The reason for this is the maximum output power of the terminal (23 dBm) in combination with the large distance to the satellite and the omnidirectional antenna of the UE. The table shows performance for frequency reuse 1 and 3, as satellite networks suffer from intercell interference, so dividing the spectrum in three parts to mitigate interference between the cells is a common practice. Especially in the uplink, this is helpful, where the benefits in the downlink are absorbed by the fact that only one third of the spectrum is available.

Table 2. Performance range for a handset connected to a LEO satellite at 600 km height with 30 MHz bandwidth

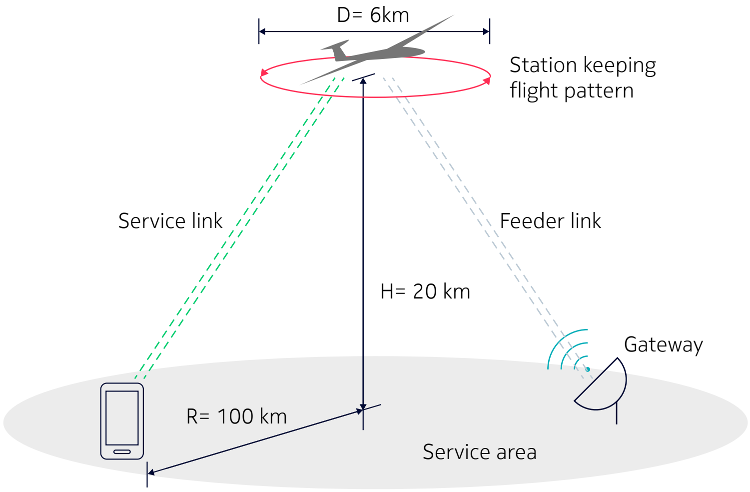
	5% worst throughput	**median throughput**	**5% best throughput**
Downlink reuse 1	15 Mbps	21 Mbps	25 Mbps
Downlink reuse 3	17 Mbps	19 Mbps	20 Mbps
Uplink reuse 1	100 kbps	200 kbps	300 kbps
Uplink reuse 3	400 kbps	500 kbps	600 kbps

Brief overview of HAPS

High-altitude platform stations (HAPS) are also part of NTN. Where it differs from satellites is that HAPS doesn't require changes in the handset and network. The HAPS may be a series of balloons or solar/hydrogen-powered airplanes, which can stay aloft in the stratosphere for several weeks or months as base station platforms. At a typical altitude of 20–50 km, HAPS systems are radio stations in the sky that cover a large service area with a higher throughput and lower latency than satellite links. They are ideal for bringing high-speed broadband to remote and unserved areas, supplementing existing networks, global IoT coverage, and serving as instant infrastructure for emergency communications and disaster relief. Google Loon was a radical approach to bridging the digital divide using balloons but was discontinued due to lack of commercial viability [13].

Figure 11 shows the typical scenario where the HAPS is flying at an average altitude of 20 km at a speed of 80–120 km/h in a repetitive flight pattern known as station keeping. It maintains a 6 km diameter circle to provide consistent coverage on the ground. Data services are provided to UEs via the HAPS service link over the 4G/LTE or 5G NR air interface at sub-6 GHz carrier frequency. The HAPS is also connected to one or more ground gateway stations by the feeder link as the backhaul for the aggregated traffic of the service link.

Figure 11. Typical operating scenario of airplane-based HAPS



The performance of a HAPS system depends on a variety of factors including payload capacity and the power requirement of the HAPS platform, architecture type, antenna design, the number of cells it can support, and the bandwidth of the access and feeder links. The median throughput for a handset connected to a HAPS design with seven beams providing 100 km radius coverage at 20 km height with 20 MHz bandwidth is 28 Mpbs (DL) and 12 Mpbs (UL) (published in [14][15]).

Looking ahead

While Release 17 provides the basic functionality for 3GPP communication via satellite, more enhancements are still to be specified, as shown in Table 3.

Table 3. 3GPP Release 18 objectives for NR and IoT over NTN

Rel 18 NR over NTN	Rel 18 IoT over NTN
Enhancements for coverage	HARQ feedback disabling
Deployment above 10 GHz	GNSS position acquisition during a connection
Network verified UE location	Mobility enhancements
Mobility between NTN and TN	Further support of discontinuous coverage

Some more fundamental enhancements are left for future Releases 19 and beyond, such as enabling the regenerative architecture, which will enable links between satellites and more efficient feeder links, inter-satellite links, and store and forward architectures for IoT.

Spectrum

3GPP has focused on the L and S bands in Release 17, which are lower frequency bands suitable for handhelds. The TMO-Starlink announcement indicated that they will be using the TMO-US nationwide PCS spectrum at 2 GHz subject to regulatory approval and interference studies. In Release 18 frequency bands above 10 GHz will be looked at with the focus on VSAT receivers. The Ka band will be used as example. All considered bands are FDD.

HAPS in general can use terrestrial spectrum with additional spectrum to be specified in WRC-23, for which coexistence studies are ongoing with active Nokia participation. In addition to fixed service, FR2 spectrum can be used for inter-HAPS links and for feeder link in HAPS and LEO.

Expanding the number of NTN regulatory requirements will be important to protecting the different systems in space and on Earth. This will include cross-country spectrum arrangements.

Conclusion

By providing coverage in places without terrestrial coverage, non-terrestrial networks enable truly global coverage. The throughputs that can be achieved depend on the type of terminal being used. VSAT terminals used for fixed wireless access provide throughput of hundreds of Mbps, whereas the throughput of smartphones is much more limited.

Table 4. A summary comparison of NR over HAPS, LEO and GEO

	Pre Rel-17	**HAPS**	**LEO**	**GEO**
Height	500-1,400 km	20-50 km	600-1,500 km	36,000 km
Architectures	Transparent and regenerative	Regenerative and transparent	NR Rel-17 and 18: transparent	NR Rel-17 and 18: transparent
UE requirements	no extra requirements	no extra requirements	3GPP NTN requires at least Rel-17 implementation	3GPP NTN requires at least Rel-17 implementation
Spectrum	Can reuse terrestrial spectrum in agreement with operator.	Can reuse terrestrial spectrum in agreement with operator.	S, L band in Rel-17. Ka band in release 18.	S, L band in Rel-17. Ka band in Rel-18.
Typical Throughputs (median, normalized to 30 MHz)	Handheld: • Messaging only VSAT 100-200 Mbps (400 MHz).	Handheld: • 42 Mbps DL • 18 Mbps UL VSAT 100-200 Mbps (400 MHz).	Handheld: • 20 Mbps DL • 200-500 kbps VSAT 100-200 Mbps (400 MHz).	Handheld only low throughput IoT devices. VSAT 100-200 Mbps (400 MHz).

Currently, new satellite constellations are being built using both LEO and GEO, targeting fixed wireless access. Companies like Starlink, AST and Lynk are also aiming to provide service to pre-Release 17 3GPP smartphones. 3GPP introduces NTN support in Release 17 phones for NR and NB-IoT/eMTC services, and this is expected to provide higher throughputs and capacities than the pre-Release 17 NTN implementations. For handhelds, the throughputs are expected to be in the order of 20 Mbps in the downlink and 100–600 kbps in the uplink. The low uplink throughput still allows users to make phone calls and send messages in places where there would otherwise be no service at all.

Release 18 will continue the evolution of non-terrestrial networks for both NR and NB-IoT/eMTC with several new enhancements, like network verified positioning, coverage enhancements and mobility related improvements. This will not be the end of the story as it is expected that the evolution will continue in Releases 19 and 20 and, eventually, in 6G.

Abbreviations

CHO	Conditional handover
DL	Downlink
eMTC	Enhanced machine-type communications
FCC	Federal communications commission
GEO	Geostationary equatorial orbit
GNSS	Global navigation satellite system
HAPS	High altitude platform station/systems
HARQ	Hybrid automatic-repeat-request
HO	Handover
IoT	Internet of things
LEO	Low-Earth orbit
LTE	Long term evolution
MEO	Medium-Earth orbit
NB-IoT	Narrowband IoT
NGSO	Non-geostationary satellite orbit
NR	New radio
NTN	Non-terrestrial networks
PLMN	Public land mobile network
RRC	Radio resource control
RTT	Round-trip time
SIB	System information broadcast
UAS	Uncrewed aerial system
UE	User equipment
US	United States
VSAT	Very small aperture terminal

References

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