Non-Terrestrial Networking: Extending the Internet to Space

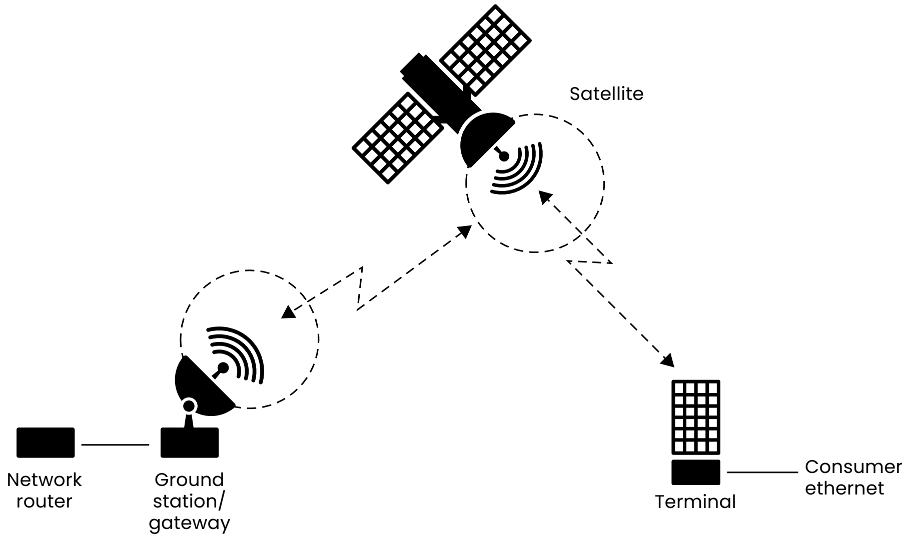
One of the hottest topics at Mobile World Congress in Barcelona, Spain, 2024, Non Terrestrial Network (NTN) is a market where NXP products are well-positioned, with continued focus on power efficiency and reliable compute.

So, what is this NTN-thing all about? Rest assured, it has nothing to do with talking to aliens (just yet). Instead, NTN augments the existing (terrestrial) wireless telecommunication network (the one operated by the likes of Verizon, Vodafone and China Mobile) with a satellite-based system. The primary purpose is to extend the reach of wireless communications to truly span the Earth.

This concept is not a new one. Motorola famously innovated the Iridium satellite constellation that has provided mobile phone access from a satellite network since the early 2000s. The end-user benefits stem from the global scope of satellite connectivity — no more limitations from country borders and local operators. However, Iridium was a bit ahead of its time. Driven by technology limitations at the time, it ended up as a bulky and expensive niche application.

The Impact of Market Changes

So why are things different now and could NTN become more successful? There are a few factors coming together. First, the cost of satellite deployments is coming down dramatically as new, reusable satellites come to market. SpaceX is a very visible company in this space with reusable technology that helps drive down cost. Once the barrier-to-entry is low enough, the market opens for non-governmental players to enter. A second factor is the standardization of the air interface. One of the differentiating factors of 5G is that the waveform is designed to be flexible, including support for non-terrestrial deployment. This enables reuse of mass volume (terrestrial) technology for NTN use cases, including reuse of 5G ecosystem components, interfaces and software stacks. This reduces complexity and timeline, and thus cost and risk. A third factor is market demand. The unserved half of the world's population accounts for both a huge market opportunity and a way to achieve government funding.



Non-terrestrial network (NTN) systems are enabled by NXP. Explore the [Layerscape processors] to see how NXP is extending the internet to space.

LA12xx

LA9310

LA1043

LS1046

LX2160

i.MX 8MP

Typical NTN system with ground station, satellite and terminal units

NTN Target Applications

NTN is far from being uniform in functionality, architecture and implementation. This is driven by the wide range of target applications:

- Broadband wireless - This is the "Internet to the (mobile) home" application that consumers are most familiar with. Obvious applications include rural areas where traditional (wireline) Internet is hard to get. According to the United Nations, approximately half of the world's population has no access to Internet.
- Internet of Things (IoT) - a market of many "things" that are connected to each other, to the Internet, or both — and without wires. The scale of the "things" in IoT can be from the very small, such as agricultural sensors that transmit bits per day, to large items such as cars that produce many gigabits per second.
- Positioning, Navigation and Timing (PNT) - The market for Global Navigation Satellite Systems (GNSS) is hundreds of billions of dollars and is expected to expand with the advent of self-driving cars, drones and other mobile solutions that depend on accurate positioning. However, current GNSS solutions (GPS, Galileo and others) have been shown to have limitations, including indoor coverage (link budget challenges), accuracy (not reaching centimeter level yet) and security (subject to spoofing).

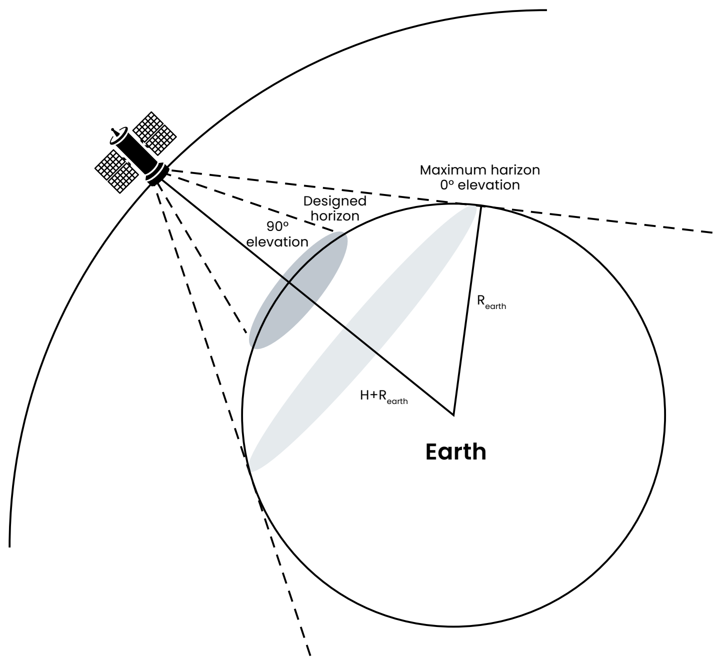
Constellation Types Explained

Satellite networks are defined by the constellation type—which defines the configuration of the network with regards to the distance between ground and satellite station. The choice of constellation type to be deployed involves striking a balance between the required number of deployed satellites, cost per satellite, latency/throughput considerations and other factors. Constellation types are defined by the distance between satellite and Earth, in GEO, MEO and LEO (and lesser-known HAPS and HEO) options:

- GEO – Geostationary Earth Orbit. These satellites operate at 36000km. At this height, satellites track the orbit of the Earth, which means they remain at the same point above the ground. This makes GEO systems suitable for "localized" (geographically bound) services such as North American TV broadcasts or similar. GEO coverage is large (at continent level), given the distance of the satellite to the Earth. It is also expensive and suffers from high latency (~550ms round-trip) which makes real-time communication a challenge.
- MEO – Medium Earth Orbit. These satellites operate at 5000-20000km and are (together with LEO) Non-GeoStationary Orbital (NGSO). Probably the most popular example of a MEO satellite system is the Global Positioning System (GPS). GPS is unique because it is in what is called a semi-synchronous orbit at an altitude of ~20200km. This gives it an orbital period of 12 hours and passes over the same two spots on the equator every day.

- LEO – Low Earth Orbit. These satellites operate at 500-1200km. At this altitude, the cost of deploying a unit is much lower than for the other two systems. As such, there are thousands of operational satellites in this orbit, used for scientific, communication, imaging and many other needs. LEO satellites have the smallest geographical coverage which means many satellites are needed (10s to 100s) to achieve coverage and a fast orbit around the Earth (<2 hours/orbit). LEO satellites are affected by atmospheric drag, which gradually degrades the orbit and limits the satellite lifespan to 7-10 years.

Note how LEO is an outlier here with regards to the combination of limited lifetime, good (real-time) performance and the need for a large amount of satellites. This makes LEO systems particularly attractive for innovation, including "batch" deployments using low-cost commercial space companies that have been coming online in the last few years.



A key challenge of NTN systemes coverage — how large of the earth cross section can be covered by a satellite

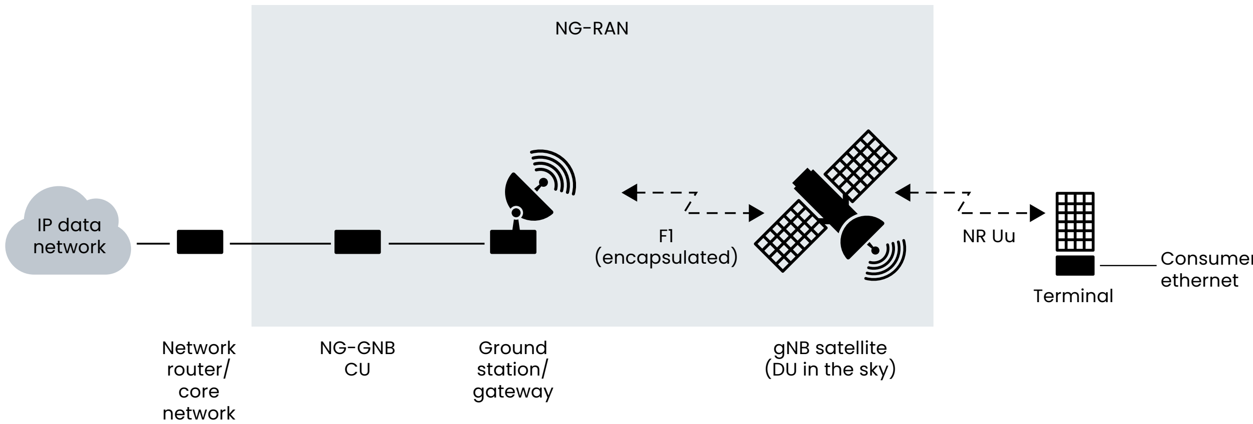
NTN and Standardization

With regards to standardization, NTN is gradually being standardized in the 3GPP consortium over time, with 3GPP Study Items in Releases 15 and 16. 3GPP Release 17 started normative work, focused on adapting the 3GPP stack to support both broadband and IoT applications. Several aspects of the 3GPP stack are subjected to optimization to tackle the unique aspects of space deployment, including physical layer aspects like doppler shift and propagation delay, high Round Trip Time (RTT), which impacts retransmission algorithms and control plane signaling that needs to be enhanced to include satellite information and support handovers for non-mobile UEs.

Components and the Stress Factor

As an interesting point to NXP as a semiconductor component provider, space is unique in how it stresses electrical components differently compared to Earth. This stress comes in various shapes: thermal (extreme temperature changes), vibration, radiation and more. Higher-orbit systems require what is called "radiation hardened" (rad-hard) components because they are outside of the Van Allen belts and exposed to a higher level of radiation. This comes together with the expected lifespan. The satellite lifespan increases with the distance of the satellite from the Earth – GEO satellites have a typical lifespan of 15 years or more, while LEO satellites are expected to remain useful for only half of this time. A device that has a higher lifespan will obviously be exposed to a higher level of radiation over this lifespan.

Driven by the various component stress factors, combined with required component lifetime (these systems typically operate over 10 years or more), the pool of "allowed" components for satellite systems is dramatically reduced compared to what is used for consumer products on Earth. There are vendors specialized in these types of components and/or subsystems that are "space-qualified".



Satellite system architecture that re-uses standardized (O-RAN) 5G components.

Complexity Drives Design

As you can see, these NTN systems present a unique set of challenges to the system designed — system design complexities (dealing with doppler, reliability, mesh network options, and so on), relatively low volumes (thousands and not millions), limited component availability (need for hardened components) and large capacity (up to 100s Gbps) all drive engineering complexity. This engineering complexity intuitively drives a modular design in which smaller subsystems can be instantiated multiple times, because this allows engineering energy to be focused on optimization of such a subsystem. And it's exactly this modularity that allows an ecosystem of smaller industry players to come online, where each company optimizes a small aspect of the larger NTN system.

Possibilities As Vast As Space Itself

So why does NXP care about all of this? The NTN market shows good commercial potential and allows for innovation not only in the satellite itself, but also in the consumer terminals on Earth. The programmable, flexible and open nature of many NXP products can help our customers solve the unique problems that NTN exposes. Where do you think the future of NTN will lead?

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