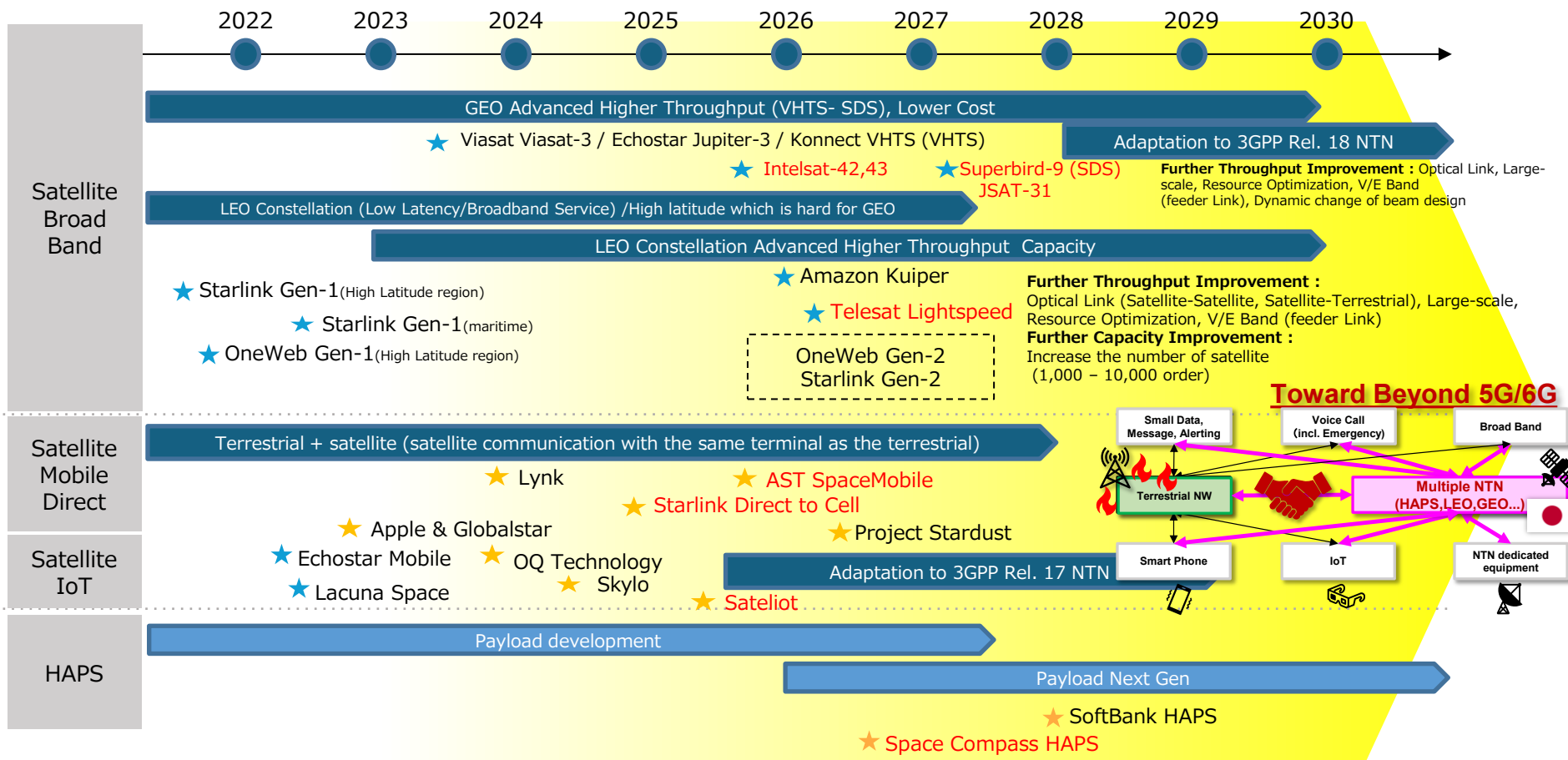


NTN Technology Roadmap (2024 version)

**NTN Promotion Project
XG Mobile Promotion Forum
Revised in July, 2025**

NTN Technology Roadmap



Summary of NTN Roadmap Updates for FY2024



Satellite Broadband

- Fixed the timing of SDS (Software Defined Satellite) (Intelsat-42 and 43 will be launched in 2026, Superbird-9 will be launched in 2027), and JSAT-31 will be added (launched in 2027).
- Telesat Lightspeed timeline fixed (launch starts in 2026)

Satellite Mobile Direct

- Starlink Direct to Cell launch date revised to December 2024 (launch in New Zealand)
- AST Space Mobile launch date corrected to late 2025
-

Satellite IoT

- Sateliot start date revised to 2025

HAPS

- SoftBank to update based on input information from Space Compass

Toward Ideal All Japan NTN in 10 years

Current Situation

Although there are some exceptions, conventional NTN systems are basically independent systems from terrestrial NWs, and each has evolved and developed independently.

Toward Beyond 5G/6, IMT-2030

1) There are areas where it is difficult to provide TN by various NW services (Autonomous driving, forestry, shipping, DX etc.) current and in future due to several factors. Covering these areas with NTN is expected to improve the continuity of seamless communication network services.

→ Deepening and developing Japanese-style hospitality services across TN and NTN

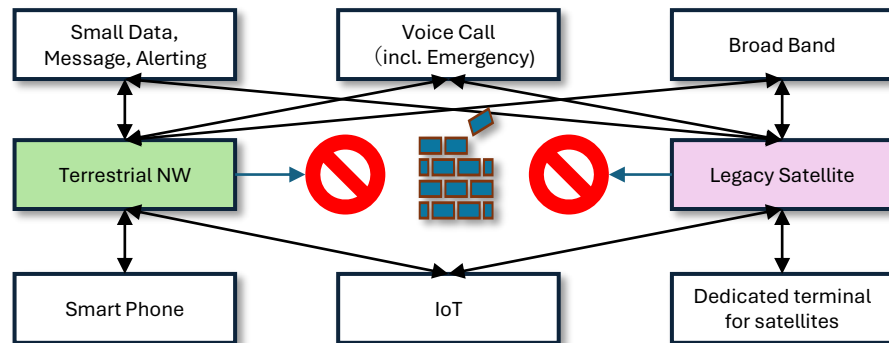
2) Even in emergency situations on the ground, such as large-scale NW failure, congestion, etc. due to disasters, providing the minimum level of services through NTN as a backup for the terrestrial NW is expected to support on recovery and reconstruction.

→ Establish All Japan NTN that provide cooperation across the ground/satellites during emergencies based on experience and knowledge.

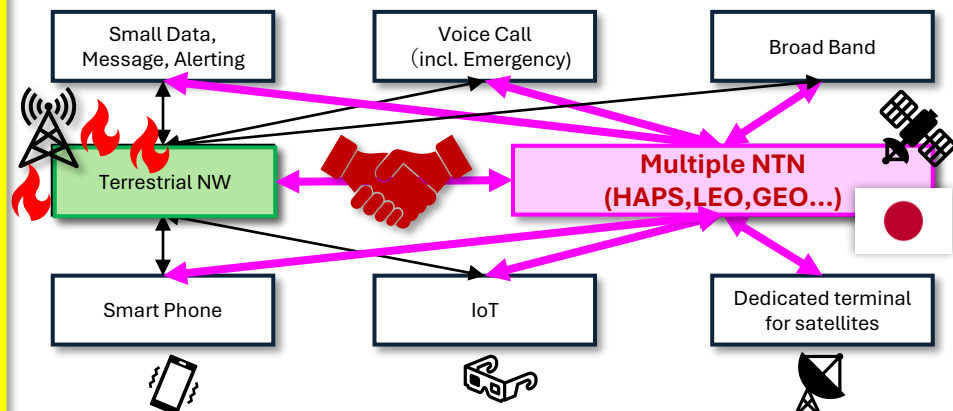
3) In order to ensure reliability even under disadvantageous conditions compared to ground areas (latency, radio wave quality and reliability), ensuring redundancy and cooperation within the NTN group without depending on a specific network system, constellation, or operator is required.

→ Ensure Made in Japan service quality by introducing domestically produced satellites & communication equipment while cooperating with the private sector & overseas satellite services on the premise of cooperation between multiple operators and satellite systems.

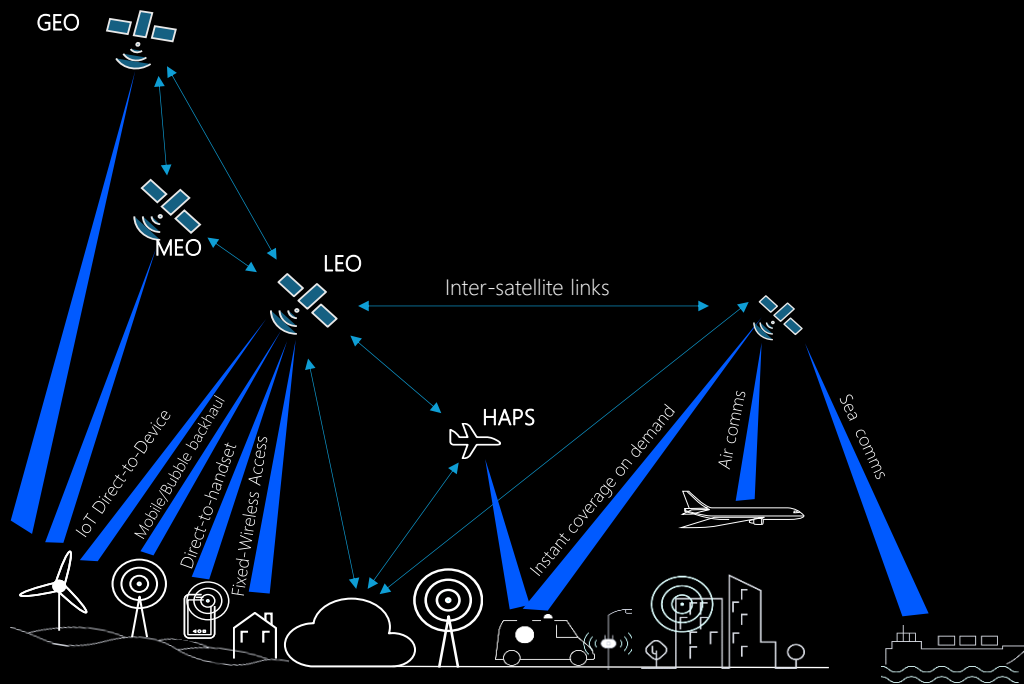
Current Situation



NTN Toward Beyond5G/6G



Non-Terrestrial Networks (NTN)

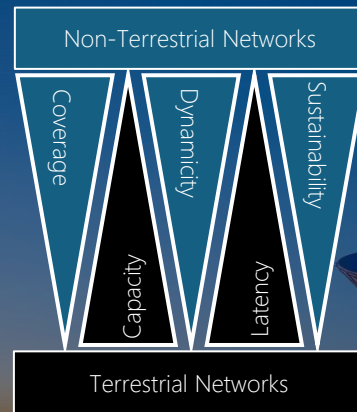


Integrated TN-NTN Ground Infrastructure

LEO/MEO/GEO = Low/Medium/Geostationary Earth Orbit
HAPS = Low/High Altitude Platform Systems

NTN is a wireless communication network that utilizes satellites, HAPS, drones, or other aeronautical platforms.

Complement each other with their respective strengths



NTN Technology Roadmap



Satellite Broadband

The use of Starlink continues to grow, with more than 4.6 million subscribers worldwide as of January 2025. Smaller and lighter terminals have also been released, improving convenience. In addition to services for ships, the company will also offer services for aircraft in September 2024. In addition, OneWeb has also launched a service, and a service by Project Kuiper is scheduled to be launched in the future, and competition with the LEO constellation is expected to intensify further.

In addition, efforts are being made to comply with the 3GPP standard for VSAT systems and to support multi-orbit satellites in terminals using flat-type antennas, and it is expected that the integration of terrestrial mobile communication networks and satellite communication networks and support for multi-orbit will progress in the future.

Satellite Mobile Direct

Direct communication between satellites and smartphones is already available for both iPhone and Android in some models and areas, and services available on existing smartphones are also being made available by Starlink D2C. AST SpaceMobile has also begun launching commercial satellites and is expected to launch beta services soon. At present, it often takes time to send and receive texts, but it is expected that performance and communication opportunities will be improved by increasing the satellite constellation in the future. In addition, 3GPP Rel-17 NTN-compliant terminals are also appearing, and their use is expected to expand in the future.

Satellite IoT

HAPS

Continuing from last year, we are still in the development and testing stage. It is expected to expand mobile network coverage, including not only in the event of a disaster, but also on remote islands, mountainous areas, at sea and in the air. In terms of the system, the revised RR will come into effect on January 1, 2025, and the 1.7 GHz and 2.6 GHz bands will be specified worldwide, and the 700-900 MHz band will be specified worldwide, except for some countries in Asia. As the trial development phase progresses, it is expected that domestic institutionalization measures will proceed at the same time.

NTN Technology Roadmap

2023

2024

2025

2026

2027

2028

2029

2030

Aviation field	Broadband communication (In-flight Wi-Fi etc.)	<p>GEO advanced/ high-speed (VHTS・SDS), lower cost</p> <p>LEO constellation advanced/ high-speed/ large capacity</p> <p>In the field of aviation, the use of in-flight Wi-Fi services (IFC) with geostationary satellites as backhaul is expanding. Starlink is also starting to provide in-flight Wi-Fi, and the service is becoming faster and cheaper.</p>
	Mobile direct IoT	<p>Although there is a possibility that there will be a demand for the use of in-flight Wi-Fi in the future, such as improving communication speed and stability, and expanding the range of use, there are many countries where LTE and 5G communication are not allowed on board for aviation safety reasons, and it is expected that the use of satellite mobile direct in the aviation field will not progress for the time being.</p>
Maritime field	Broadband communication (In-flight Wi-Fi etc.)	<p>GEO advanced/ high-speed (VHTS・SDS), lower cost</p> <p>LEO constellation advanced/ high-speed/ large capacity</p> <p>Internet access for crew and passengers is becoming mandatory on ships, and the use of Starlink's LEO satellites is also advancing. On the other hand, there are issues related to congestion and charges when access is concentrated. In the future, it is expected that the capacity and sophistication will increase due to the expansion of the LEO constellation, and the price will decrease due to increased competition among users and operators. In addition, user terminals are becoming smaller and easier to install, and it is expected that the use of these devices on small vessels will increase in the future.</p>
	Mobile direct IoT VDES	<p>Transfer from dedicated satellite communication system to 3GPP Rel. 17 NTN compliant service & integration with terrestrial mobile services</p> <p>Advanced maritime operation by transfer from AIS to VDES</p> <p>It is expected that the use of direct communication between satellites and HAPS and smartphones will be used in small vessels and boats where it is difficult to use the above-mentioned satellite broadband. In addition, a demonstration experiment of VDES, which enables two-way communication at a high transmission rate in Japan, is planned until FY2024~2027, after which a global demonstration is planned.</p>

NTN Technology Roadmap accompanying materials : NTN Technology Issues

Technology issues to be solved for utilization of NTN

Category	NTN Technology Issues	Source
Communication	① Digital coherent optical communication technology, adaptive optics technology, site diversity technology ② Satellite constellation, Base station backhaul line using HAPS ③ Optical data relay technology transmit sensing information via GEO satellite ④ Development of new frequency sources (Q band/V band)	R&D Theme (*)
Environmental measures	⑤ HAPS base station that realizes decarbonization	
Area construction/design	⑥ Radio wave propagation model ⑦ Technology development ("Cylinder antenna" and "rotating connector" etc.) for stabilized communication area and network construction	
Operation	⑧ Management for integrated network including satellite, HAPS networks, orchestration technology, autonomous operation technology using AI & machine learning (Zero-touch automation) ⑨ Space / NTN open architecture technology	
Payload	⑩ HAPS payload during the disaster ⑪ Automatic tracking technology compatible with multiband-NTN antenna and moving NTN nodes (HAPS and LEO) ⑫ Regenerative relay payload with gNB and MEC function ⑬ Next generation battery ⑭ Next generation control technologies for encryption and encryption keys applicable to satellites	
Terminal	⑮ Multi access terminal capable of simultaneous connection of NTN and ground networks	
Platform	⑯ Cloud platform linking ground and space (Data center)	
Connection protocol	⑰ Optimized protocol and multiple access methods for integrated NTN networks	
Intersatellite link control	⑱ Advanced routing and interconnection schemes between satellite constellations	Use cases

*Source : Information and communication technology strategy for Beyond 5G >Industry, academia and government collaboration on Beyond 5G R&D Theme > 【Theme 6】 NTN (HAPS・Space Network) Technology, <https://www.soumu.go.jp/menu_news/s-news/01tsushin03_02000352.html>

NTN Technology Roadmap Comparison: Satellite broadband



		VHTS・SDS (Geostationary satellite)	OneWeb	Starlink	Amazon Kuiper	Telesat Lightspeed
Satellite		GEO	LEO	LEO	LEO	LEO
Service link frequency		Ku-band, Ka-band	Ku-band	Ku-band, Ka-band (from GEN-2)	Ka-band	Ka-band
Terminal		Dedicated device (VSAT etc.) 60cm~1.2m diameter parabolic antenna	Dedicated device ~1.2mdiameter parabolic antenna 50x45cm Flat antenna	Dedicated device 50x30cm Flat antenna 57x51cm Flat antenna	Dedicated device (Flat antenna) 17.8cm x 17.8cm 38cm x 38cm 48cm x 76cm	Parabolic antenna Flat antenna
Throughput		~150Mbps (Downstream)	~195Mbps (Downstream)	~350Mbps (Downstream)	~1Gbps (Downstream)	~7.5Gbps
Latency		~600ms (Altitude 35,000km)	~70ms (Altitude 1,200km)	20~40 ms (Altitude 500km)	~50 ms? (Altitude 600km)	~70ms? (Altitude 1,015km, 1,325km)
Coverage		Depends on the satellite position. Covering polar regions is difficult.	Global	Global	Global	Global
Characteristics		Can use existing ground systems for geostationary satellites. Reduce costs by increasing capacity and optimize coverage with flexible beams.	Intersatellite optical link (Not included in early constellations)	Intersatellite optical link (Not included in early constellations)		Regenerative relay system Intersatellite optical link
Related systems	Radio Regulations	Can be used with existing FSS allocation frequencies (Ku/Ka/Q/V Band etc.)	Can be used with existing FSS allocation frequencies (Ku/Ka Band)	Can be used with existing FSS allocation frequencies (Ku/Ka Band)	Can be used with existing FSS allocation frequencies (Ka Band)	Can be used with existing FSS allocation frequencies (Ka Band)
	Introduction to Japan	Can be used within the allocated FSS frequency system	Gen-1 has been institutionalized	Gen-1 has been institutionalized	System development is required when introducing it to Japan.	System development is required when introducing it to Japan.
	Standards	DVB-S2X(ETSI) etc.	European standards ・ECC Report 271 ・ECC Decision (18)05 ・ETSI EN 303 980	European standards ・ECC Report 271 ・ECC Decision (18)05 ・ETSI EN 303 981	—	—
Use cases		Rural areas, Broadband for ships and aircraft, mobile backhaul, backup lines for disasters	The basic use case is similar to services provided by geostationary satellites (VHTS/SDS). Although it is considered advantageous in terms of latency, throughput, cost, and ease of terminal installation, there will be many cases where it is difficult to use it because of the stricter line-of-sight conditions than those of GEO satellites. With the case for ships & aircraft, they will be actively used in the future as line-of-sight conditions are not an issue.			

VHTS (Very High Throughput Satellite)

Satellite overview		A satellite that places multiple spot beams to reuse frequencies is called an HTS that has a capacity several dozen times more than a conventional geostationary satellite. VHTS is the next generation satellites with even greater capacity than HTS. In 2023, Konnect VHTS (500Gbps) by SES and Jupiter 3 (>500Gbps) by Hughes was launched. These satellites use Ka band for their service links.
Technology		High-power (20kW) supporting thousands beams. Bandwidth can be flexibly reassigned from area with low demand to high demand after launch.
Terminal		VSAT, ESIM (Can use existing terminal used for geostationary satellites.) Throughput: > 100Mbps
Use case		Rural areas, Broadband for ships and aircraft, mobile backhaul, backup lines for disasters. Available more widely and at lower cost than before.
Related systems	Radio Regulations	Can be used with existing FSS allocation frequencies (Ku/Ka/Q/V Band etc.)
	Introduction to Japan	Can be used within the allocated FSS frequency system.
	Standards	DVB-S2X (ETSI) etc.
Others		

SDS (Software Defined Satellite)

Satellite overview		The beam design can be changed after the launch of satellite, unlike conventional satellites. Beam placement, size, bandwidth and power can be changed dynamically. SKY Perfect JSAT's Superbird-9, IS-42, IS-43, IS-41, IS-44 by Intelsat, GX7, 8, 9 of Inmarsat etc. are planned. Service link uses Ku band and Ka band. GX7, 8, 9 can place thousands of beams simultaneously.
Technology		Thousands of beams can be dynamically repositioned by latest digital processing and phased array antenna.
Terminal		VSAT, ESV, ESIM (Can use existing terminal used for geostationary satellites). Throughput: > 100Mbps
Use case		Rural areas, Broadband for ships and aircraft, mobile backhaul, backup lines for disasters. Available more widely and at lower cost than before.
Related systems	Radio Regulations	Can be used with existing FSS allocation frequencies (Ku/Ka/Q/V Band etc.)
	Introduction to Japan	Can be used within the allocated FSS frequency system.
	Standards	DVB-S2X(ETSI) etc.
Others		

OneWeb

Satellite overview		<ul style="list-style-type: none"> • Constellation consists of 588 satellites at the orbit altitude of 1,200km (Gen-1) • Global coverage (including maritime coverage).
Technology	Optical communication	• Not implemented in Gen-1. Planning to implementation of inter-satellite optical link in Gen-2.
	Frequency	<ul style="list-style-type: none"> • Service link : Ku band • Feeder link : Ka band ※V/E band (Considering implementation in Gen-2)
	Ground station	• To be installed 40-50 stations worldwide
Use case		<ul style="list-style-type: none"> • BCP/Remote area/Broadband communications for land mobile • Broadband communications for ships/aircraft
Related systems	Radio Regulations	Can be used with existing FSS allocation frequencies (Ku/Ka band).
	Introduction to Japan	Gen-1 has been institutionalized.
	Standards	European Standards <ul style="list-style-type: none"> • ECC Report 271 • ECC Decision (18)05 • ETSI EN 303 980
Possibility of international collaboration		<ul style="list-style-type: none"> • Solar panel technology • Debris removal technology

Starlink

Satellite overview		<p>Satellite constellation by SpaceX (Altitude approx. 550km) More than 5,000 units have been launched. The FCC's permission allows the launch of 12,000 units. Maximum download throughput 220Mbps. Service link uses Ku band (Gen-2 and later is planning to use of Ka band and V band). Gen-2 constellation plans to launch 30,000 units (approximately 330km to 610km altitude).</p>
Technology		<p>Adopts the latest digital processing and phased array antenna. Provides communication services even at locations far from the gateway by Inter Satellite Laser link (ISL).</p>
Terminal		Dedicated Starlink terminal manufactured by SpaceX. Phased array antenna.
Use case		Rural areas, Broadband for ships and aircraft, mobile backhaul, backup lines for disasters.
Related systems	Radio Regulations	Can be used with existing FSS allocation frequencies (Ku/Ka band)
	Introduction to Japan	Gen-1 has been institutionalized.
	Standards	<p>European standards</p> <ul style="list-style-type: none"> •ECC Report 271 •ECC Decision (18)05 •ETSI EN 303 981
Possibility of international collaboration		

NTN Technology Roadmap Comparison: Satellite Mobile Direct

13

		SpaceMobile	Lynk	Starlink Direct to Cell	Apple & Globalstar
Satellite		LEO	LEO	LEO	LEO
Service link frequency		3GPP frequency (Mid-band, Low-band) Use frequencies of partner MNO	3GPP frequency (Low-band) Use frequencies of partner MNO	3GPP frequency (Mid-band) Use frequencies of partner MNO	Use frequency of Globalstar (L-band/S-band)
Terminal		Existing mobile phone (3GPP)	Existing mobile phone (3GPP)	Existing mobile phone (3GPP)	iPhone14, iPhone 15 series
Service		Text, voice, broadband	Text (voice and data in future)	Text (voice and data in future)	Emergency call, roadside service (USA only)
Coverage		Global. However, in the range where partner MNO frequencies can be used.	Global. However, in the range where partner MNO frequencies can be used.	Global. However, in the range where partner MNO frequencies can be used.	16 countries (as of Jan. 2024) (possibly can be used within the range of Globalstar coverage in future).
Characteristics		Large phased array antenna. Bent-pipe method. Doppler and delay correction on the ground.	1m-1.5m phased array antenna. Mount eNodeB & EPC on satellite. Provides text messaging services even at locations far from the gateway by Store & Forward communication.	2.7m x 2.3m phased array antenna. Mount eNodeB on satellite. Doppler correction.	Use satellite communication function of Globalstar.
Related systems	Radio Regulations	•Additional MSS allocation is required for the frequency used •Article 4.4 applies due to use of unallocated frequencies for mobile satellite service	•Additional MSS allocation is required for the frequency used •Article 4.4 applies due to use of unallocated frequencies for mobile satellite service	•Additional MSS allocation is required for the frequency used •Article 4.4 applies due to use of unallocated frequencies for mobile satellite service	【No issues】 Can be used with existing MSS allocated frequency (L/S band)
	Introduction to Japan	System development is required after solve the institutional issues (type of radio station, license, etc.) due to the direct communication of mobile phone and satellite.	System development is required after solve the institutional issues (type of radio station, license, etc.) due to the direct communication of mobile phone and satellite.	System development is required after solve the institutional issues (type of radio station, license, etc.) due to the direct communication of mobile phone and satellite.	【Issue unknown】 Institutionalized as an MSS system.
	Standards	2G, 4G, 5G	2G, 4G, 5G	3GPP Rel-8 and later (LTE)	Unknown
Use case		Significant expansion of mobile network coverage. Mobile network restoration in the event of a large-scale disaster etc.	Messaging service outside of mobile coverage, emergency call.	Messaging service outside of mobile coverage, emergency call.	Emergency call outside of mobile coverage. Roadside service.

SpaceMobile

Satellite overview		95 satellites constellation by AST SpaceMobile (Altitude approx. 730km). Provides direct communication service to the existing mobile phones (Text, voice, broadband) Uses frequency of MNO partner (3GPP frequency Low-band & Mid-band) Launched test satellite, BlueWalker3 in Sep. 2022. Achieved voice call and downlink throughput of 14Mbps in a demonstration experiment in 2023.
Technology		Large phased array antenna. Bent-pipe method (eNB is placed on the ground). Doppler and delay correction.
Terminal		Existing mobile phone (3GPP terminal)
Use case		Significant expansion of mobile network coverage. Mobile network restoration in the event of a large-scale disaster etc.
Related systems	Radio Regulations	<ul style="list-style-type: none"> • Additional MSS allocation is required for the frequency used • Article 4.4 applies due to use of unallocated frequencies for mobile satellite service
	Introduction to Japan	System development is required after solve the institutional issues (type of radio station, license, etc.) due to the direct communication of mobile phone and satellite.
	Standards	2G, 4G, 5G
Others		Rakuten Symphony is developing eNodeB for SpaceMobile.

Lynk

Satellite overview		Satellites constellation by Lynk (Altitude approx. 500km). Provides direct communication service to the existing mobile phones (Text). Uses frequency of MNO partner (3GPP frequency Low-band). 3 commercial satellites have been launched. Commercial service started in June 2023.
Technology		1m-1.5m phased array antenna. Mount eNB & EPC on satellite. Provides text messaging services even at locations far from the gateway by Store & Forward communication. Doppler and delay correction.
Terminal		Existing mobile phone (3GPP terminal)
Use case		Communication in the dead zone. Emergency communications during large-scale disasters etc.
Related systems	Radio Regulations	<ul style="list-style-type: none"> • Additional MSS allocation is required for the frequency used • Article 4.4 applies due to use of unallocated frequencies for mobile satellite service
	Introduction to Japan	System development is required after solve the institutional issues (type of radio station, license, etc.) due to the direct communication of mobile phone and satellite.
	Standards	2G, 4G, 5G
Others		

Starlink Direct to Cell

Satellite overview		Starlink Satellites constellation for communication with mobile phones (Altitude approx. 550km). Provides direct communication service to the existing mobile phones (Text. Voice and data communication will be available in future). Uses frequency of MNO partner (3GPP frequency Mid-band). 6 satellites were launched in January 2024 and succeeded in sending & receiving text. The service is to start within 2024.
Technology		2.7m x 2.3m phased array antenna. Mount eNodeB on satellite. Connects existing Starlink constellation with Laser backhaul (No dedicated gateway is required). Doppler and delay correction.
Terminal		Existing mobile phone (3GPP terminal)
Use case		Communication in the dead zone. Emergency communications during large-scale disasters etc.
Related systems	Radio Regulations	<ul style="list-style-type: none"> • Additional MSS allocation is required for the frequency used • Article 4.4 applies due to use of unallocated frequencies for mobile satellite service
	Introduction to Japan	System development is required after solve the institutional issues (type of radio station, license, etc.) due to the direct communication of mobile phone and satellite.
	Standards	4G
Others		

NTN Technology Roadmap Comparison: Satellite IoT

17

		Skylo	OmniSpace	EchoStar Mobile	Lacuna Space	OQ Technology	Sateliot
Satellite		GEO	LEO	GEO	LEO	LEO	LEO
Service link frequency		L-band (n255) S-band (n256)	L-band (n255) S-band (n256)	S-band Licensed frequency	S-band Licensed frequency	S-band Licensed frequency	L band & S band?
Terminal		5G IoT terminal (3GPP Rel17)	5G IoT terminal (3GPP Rel17)	Lora terminal for LR-FHSS	Lora terminal for LR-FHSS + dedicated antenna	5G IoT terminal	5G IoT terminal (3GPP Rel17)
Service		Communicate with satellite directly from 5G IoT terminal	Communicate with satellite directly from 5G IoT terminal	Communicate with satellite directly from Lora terminal	Communicate with satellite directly from Lora terminal	Communicate with satellite directly from 5G IoT terminal	Communicate with satellite directly from 5G IoT terminal
Coverage		Global except polar regions	Global. LEO constellation service.	Europe only. Service by EchoStar XXI (geostationary satellite : 10.25°E)	Global. LEO constellation service (Approx. 500km)	Global. LEO constellation service.	Global. LEO constellation service.
Characteristics		Integrate with terrestrial networks to expand 5G IoT coverage	Integrate with terrestrial networks to expand 5G IoT coverage	Integrate with terrestrial networks to expand LoRa coverage	Integrate with terrestrial networks to expand LoRa coverage	Integrate with terrestrial networks to expand 5G IoT coverage	Integrate with terrestrial networks to expand 5G IoT coverage
Related systems	Radio Regulations	Can be used with existing MSS allocated frequency	Can be used with existing MSS allocated frequency (S band)	Can be used with existing MSS allocated frequency (S band)	Can be used with existing MSS allocated frequency (S band)	Can be used with existing MSS allocated frequency (S band)	–
	Introduction to Japan	System development is required as regulations are to be set for each system in principle.	System development is required as regulations are to be set for each system in principle.	System development is required as regulations are to be set for each system in principle.	System development is required as regulations are to be set for each system in principle.	System development is required as regulations are to be set for each system in principle.	System development is required as regulations are to be set for each system in principle.
	Standards	3GPP Rel 17 NTN	3GPP Rel 17 NTN	LR-FHSS	LR-FHSS	–	3GPP Rel 17 NTN
Use case							

OmniSpace

Satellite overview		Satellite constellation by OmniSpace. Provides direct communication service to 5G terminal. Uses frequency 3GPP band n256 (S band) Launched test satellites Spark-1, Spark-2 in April & May 2022. The satellites are for NB-IoT.
Technology		Details are not disclosed.
Terminal		3GPP Rel.17 compatible terminal for band n256.
Use case		IoT use case in general (asset tracking etc.)
Related systems	Radio Regulations	【No issues】 Can be used with existing MSS allocated frequency (S band)
	Introduction to Japan	【Issues】 System development is required as regulations are to be set for each system in principle.
	Standards	3GPP Rel-17 NTN(NB-IoT)
その他		

EchoStar Mobile

Satellite overview		Uses EchoStar XXI (geostationary satellite : 10.25°E). Uses licensed S band frequency. Direct communication service to LoRa terminal has started in Europe since July 2022.
Technology		Can be used by integrating LoRa network on the ground.
Terminal		LR-FHSS compatible Lora terminal
Use case		IoT use case in general (asset tracking etc.) Lora IoT service coverage expansion
Related systems	Radio Regulations	Can be used with existing MSS allocated frequency (S band)
	Introduction to Japan	System development is required as regulations are to be set for each system in principle.
	Standards	LR-FHSS
その他		

Lacuna Space

Satellite overview		Cubesat satellite constellation by Lacuna Space (Approx. 500km). Provides direct communication service to LoRa terminal. S band frequency (2GHz band) Launching commercial satellites (7 satellites have been launched. Plan to launch total 32 satellites).
Technology		Store & forward communication. Can be used by integrating LoRa network on the ground.
Terminal		LoRa module for LR-FHSS + dedicated antenna
Use case		IoT use case in general (asset tracking etc.) LoRa IoT service coverage expansion
Related systems	Radio Regulations	Can be used with existing MSS allocated frequency (S band)
	Introduction to Japan	System development is required as regulations are to be set for each system in principle.
	Standards	LR-FHSS
Others		Announced collaboration with OminiSpace (in March 2021), service uses S band frequencies of OminiSpace.

OQ TECHNOLOGY

Satellite overview		<p>Satellite constellation by OQ TECHNOLOGY (plan to launch 72 satellites). Provides direct communication service to 5G IoT terminal. S band frequency (2GHz band) 8 satellites have been launched. Commercial service started in June 2023.</p>
Technology		<p>Details are not disclosed. Obtained US patent for “wake-up” technology that enables efficient power use only when terminal is communicating with satellites.</p>
Terminal		3GPP R17 IoT-NTN compatible
Use case		IoT use case in general (asset tracking etc.)
Related systems	Radio Regulations	Can be used with existing MSS allocated frequency (S band)
	Introduction to Japan	System development is required as regulations are to be set for each system in principle.
	Standards	3GPP Rel-17 NTN(NB-IoT)
Others		

Sateliot

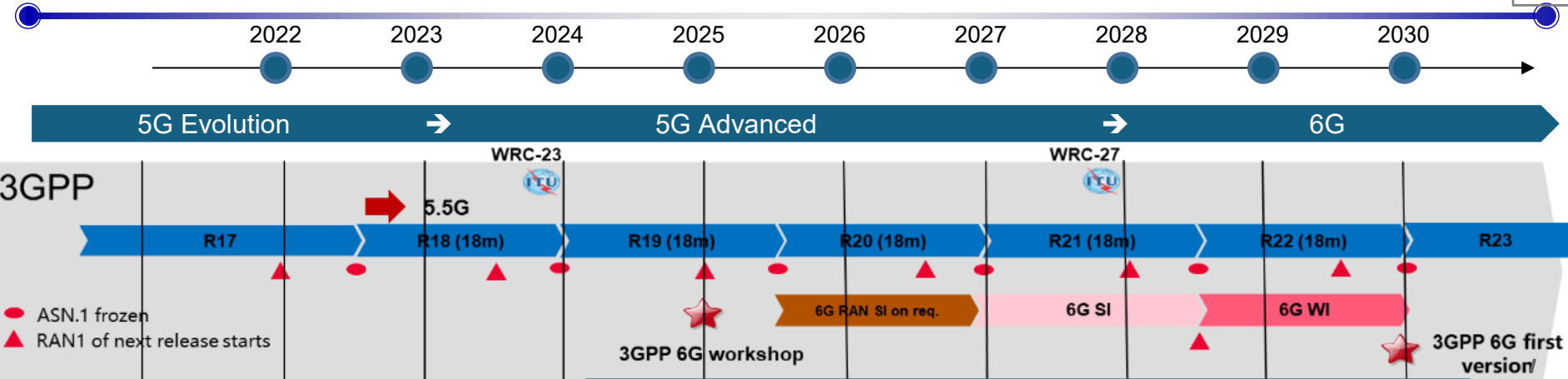
Satellite overview		Satellite constellation by Sateliot (plan to launch 250 satellites). The 1 st satellite for the constellation was launched in April 2023. Provides direct communication service to 5G NB-IoT terminal Commercial service launch is planned in 2024.
Technology		Details are not disclosed.
Terminal		3GPP R17 IoT-NTN compatible.
Use case		IoT use case in general (asset tracking etc.)
Related systems	Radio Regulations	—
	Introduction to Japan	System development is required as regulations are to be set for each system in principle.
	Standards	3GPP Rel-17 NTN(NB-IoT)
Others		

		HAPS
Satellite		HAPS
Service link frequency		3GPP frequency Use frequencies of partner MNO
Terminal		Existing mobile phone (3GPP) _LTE/5G
Service		Text, voice, Broadband
Coverage		200km diameter area
Characteristics		Footprint fixation technology
Related systems	Radio Regulations	2GHz band has been specified as used frequency worldwide. Also 1.7GHz band & 2.6GHz (worldwide) , 700-900MHz band (worldwide except certain Asian areas) are specified as the result of WRC-23 Agenda 1.4 (Effective from Jan. 1, 2025, when the revised RR comes into effect).
	Introduction to Japan	System development is required as the different radio station from existing mobile phone base stations
	Standards	3GPP (HAPS BS Standard)
Use case		<ul style="list-style-type: none"> •Significant expansion of mobile network coverage. •Mobile network restoration in the event of a large-scale disaster etc. •Migration support to next-generation communications •Realization of low-latency communication

HAPS

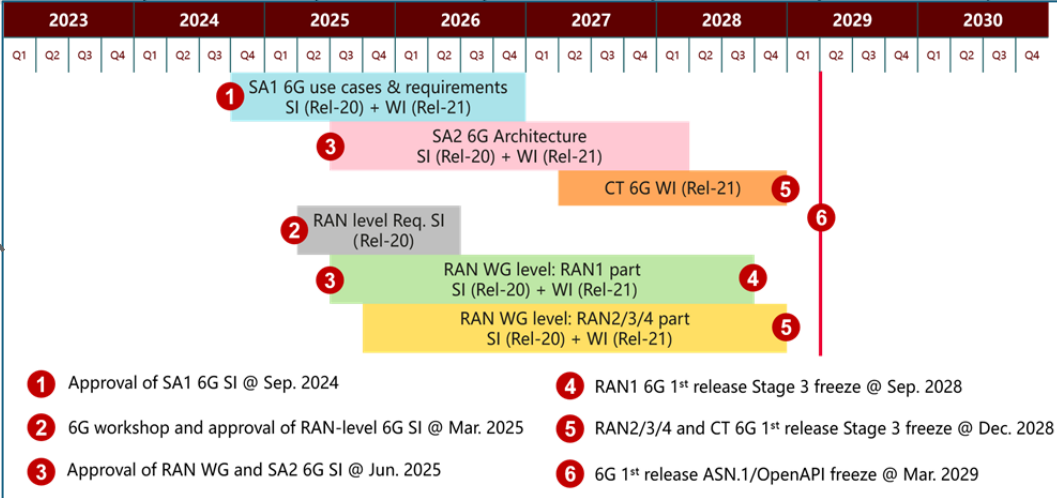
Overview		<ul style="list-style-type: none"> • Uses unmanned aircraft (UAV) that flows in the stratosphere as communication base station to provide communication service over wide area. • Provides communication network (LTE, 5G) by emitting radio waves towards the ground from the onboard radio equipment.
Tec hno logy	Payload	<ul style="list-style-type: none"> • Develops optical radio of FeederLink (Establishment/improvement of technology for fine/coarse tracking). • Develops radio management technology assuming ground station interference/prohibited area (fixed footprint, radio wave propagation model/simulation). • Establishes Inter-HAPS technology (Stratosphere mesh configuration construction/operation rate improvement) • Multiple cells/increased capacity
	Battery	<ul style="list-style-type: none"> • High-density/lighter weight (Solid state battery) • Improved battery life/Improved number of cycles (Next-generation resin foil) • Improved safety in stratospheric environments
	Solar panel	<ul style="list-style-type: none"> • Development of module for Stratospheric environmental application • Lighter weight/higher efficiency
Use case		<ul style="list-style-type: none"> • Rural areas/remote island areas/3D coverage/disaster communication/IoT/sensing services (camera etc.)
Rel ate d sys tems	Radio Regulations	2GHz band has been specified as used frequency worldwide. Also 1.7GHz band & 2.6GHz (worldwide), 700-900MHz band (worldwide except certain Asian areas) are specified as the result of WRC-23 Agenda 1.4 (Effective from Jan. 1, 2025, when the revised RR comes into effect).
	Introduction to Japan	System development is required as the different radio station from existing mobile phone base stations.
	Standards	3GPP (HAPS BS Standard)
Possibility of international collaboration		<ul style="list-style-type: none"> • Promotes coordination with other systems (ICAO,FAA,EASA,CASA) 、 International frequencies (ITU、3GPP)

NTN Technology Roadmap: 3GPP/Standardization trend



Note: this is an initial possible thoughts based on a plan from NTN proponents in RWS-210074. ITU-R schedule referred from WP5D#39 Temp/526. The indicated schedule does not show any official nfo nor view of Scalability-WG contributors.

Details of 3GPP Rel 20 mile stones, so far planned.



- 3GPP started to discuss NTN: Non-Terrestrial NW from Release 15, stipulated the first specification (Phase 1) at Release 17 and functional enhancement (Phase 2) at Release 18. Discussions on expanding NTN are in progress for Release19 and later.
- The transparent relay NTN architecture supports the following use cases at Release 17/18. Expected architecture expansion in future as a regenerative repeater architecture in which some or all of the base station functions are mounted on a satellite is discussed at Release 19 and later.
 - Handset terminal based on 5G NR
 - IoT terminals based on NB-IoT/eMTC
- Regarding frequency support targeting NR base, n256/n255 were stipulated at Release17, and n254 was added at Release 18. Expected to further expanding.

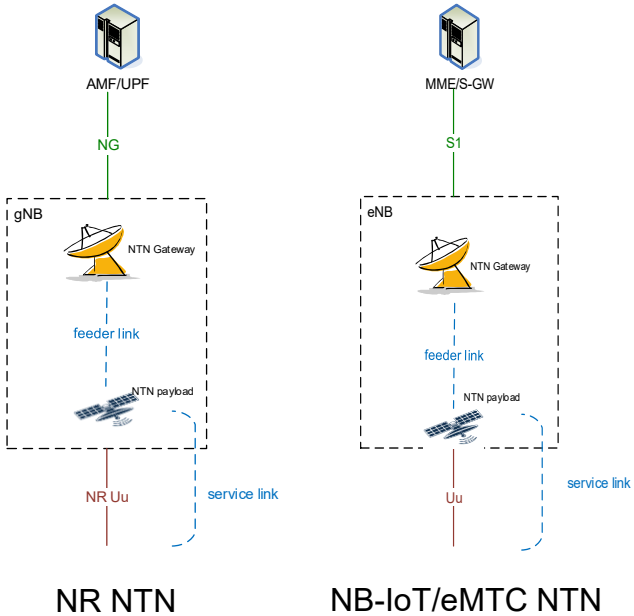
Types of NTN platforms(TR 38.821)

Platforms	Altitude range	Orbit	Typical beam footprint size
Low-Earth Orbit (LEO) satellite	300 – 1500 km	Circular around the earth	100 – 1000 km
Medium-Earth Orbit (MEO) satellite	7000 – 25000 km		100 – 1000 km
Geostationary Earth Orbit (GEO) satellite	35 786 km	notional station keeping position fixed in terms of elevation/azimuth with respect to a given earth point	200 – 3500 km
UAS platform (including HAPS)	8 – 50 km (20 km for HAPS)		5 - 200 km
High Elliptical Orbit (HEO) satellite	400 – 50000 km	Elliptical around the earth	200 – 3500 km

Satellite operating bands in FR1(TS38,108)

Satellite operating band	Uplink (UL) operating band SAN receive / UE transmit $F_{UL,low} - F_{UL,high}$	Downlink (DL) operating band SAN transmit / UE receive $F_{DL,low} - F_{DL,high}$	Duplex mode
n256	1980 MHz – 2010 MHz	2170 MHz – 2200 MHz	FDD
n255	1626.5 MHz – 1660.5 MHz	1525 MHz – 1559 MHz	FDD
n254	1610 MHz – 1626.5 MHz	2483.5 MHz – 2500 MHz	FDD

NOTE: Satellite bands are numbered in descending order from n256.



NTN Technology Roadmap Comparison : 3GPP 27

		3GPP NTN (Rel-17) incompatible Rel16 and earlier	3GPP NR NTN (Rel-17/18)	3GPP NB-IoT/eMTC NTN(Rel-17/18)	After Rel-19 Beyond 5G/6G
Satellite		N/A	HAPS/LEO/GEO/MEO	HAPS/LEO/GEO/MEO	To be decided (HAPS/LEO/GEO/MEO)
Service link frequency		3GPP frequency. Use frequencies of partner MNO.			
Terminal		Existing mobile phone (3GPP)	5G NR terminal (3GPP Rel17)	5G IoT terminal (3GPP Rel17)	To be decided
Service		Text, voice, broadband	Text, voice, broadband	Text, voice, broadband	To be decided
Coverage		Global. However, in the range where partner MNO frequencies can be used			
Characteristics					
Related systems	Radio Regulations	<ul style="list-style-type: none"> Additional MSS allocation is required for the frequency used Article 4.4 applies due to use of unallocated frequencies for mobile satellite service 	Can be used with existing MSS allocated frequency (S Band)	Can be used with existing MSS allocated frequency (S Band)	—
	Introduc tion to Japan	System development is required after solve the institutional issues (type of radio station, license, etc.) due to the direct communication of mobile phone and satellite.	System development is required as regulations are to be set for each system in principle.	System development is required as regulations are to be set for each system in principle.	—
	Standards	3GPP Rel-8 and later (LTE)	3GPP Rel 17 NTN	3GPP Rel 17 NTN	— (3GPP Rel 19 and later)
Use case		Significant expansion of mobile network coverage. Mobile network restoration in the event of a large-scale disaster etc.	Significant expansion of mobile network coverage. Mobile network restoration in the event of a large-scale disaster etc.	Significant expansion of mobile network coverage. Mobile network restoration in the event of a large-scale disaster etc.	To be decided

NTN System 3GPP Rel-15

Approach for 5G		Introduction of the NTN subject. Service requirements for 5G via satellite. Satellite propagation model definition & Issues for 5G support NTN.
NTN related standardization activities		<ul style="list-style-type: none"> • Deployment Scenarios and Related System Parameters (Satellites and HAPS) • 5G service requirements for 5G via satellite • Satellite propagation model definition & Issues for 5G support NTN
Tech.	RAN	<ul style="list-style-type: none"> • Study item (SI) on NTN scenarios and channel models: TR 38.811
	SA	<ul style="list-style-type: none"> • KPIs for a 5G system with satellite access: TS 22.261
Use case for satellite access		NR NTN IoT NTN
Possibility of international collaboration		Yes, at 3GPP

NTN System 3GPP Rel-16

Approach for 5G		Assessment of the issues. Study satellite features for 5G system and RAN.
NTN related standardization activities		<ul style="list-style-type: none"> • Study satellite features for 5G system and RAN* • Satellite architecture and key issues • Management and orchestration aspects <p>*HAPS could be considered as a special case of non-terrestrial access with lower delay/Doppler value and variation rate</p>
Tech.	RAN	<ul style="list-style-type: none"> • Study on solutions for NR to support non-terrestrial networks (NTN): <u>TR 38.821</u>
	SA	<ul style="list-style-type: none"> • Integration of Satellite Access in 5G : WID in SP-180326 ; TR 22.822 • Study on architecture aspects for using satellite access in 5G : WID in SP-181253 ; TR 23.737 • Study on management and orchestration aspects with integrated satellite components in a 5G network : WID in SP-190138; TR 28.808
Use case for satellite access		NR NTN IoT NTN
Possibility of international collaboration		Yes, at 3GPP

NTN System 3GPP Rel-17

Approach for 5G		Definition of Market enabling features. Define satellite features for 5G system and RAN.
NTN related standardization activities		<ul style="list-style-type: none">• Specify basic NTN features for 5G system and RAN• Specify basic satellite features for LTE NB IoT/eMTC• Specify NTN components in the 5G architecture• Specify RF requirements based on the result of co-existence study
Tech.	RAN	<ul style="list-style-type: none">• TS 38 series referred in § 5.1.2 in TR21.917 (NR NTN)• TS 36 and 38 series referred in § 5.2 in TR21.917 (NB-IoT/eMTC for NTN)
	SA	<ul style="list-style-type: none">• TS 23, 24, 29 and 31 series referred in § 5.1.2 and 5.2 in TR21.917
Use case for satellite access		NR NTN IoT NTN
Possibility of international collaboration		Yes, at 3GPP

NTN System 3GPP Rel-18

Approach for 5G		Definition of enhancements optimizing performance and enabling new capabilities. Define enhanced satellite features for 5G system and RAN.
NTN related standardization activities		<ul style="list-style-type: none"> • Coverage enhancement for direct smart phone connection • UE location verification for PLMN selection • Support for non-continuous coverage with sparse constellation • Support of Satellite Backhauling
Tech.	RAN	<ul style="list-style-type: none"> • NR NTN (Non-Terrestrial Networks) enhancements : WID in RP-223534 • Introduction of the satellite L/S-band for NR: WID in RP-223485 • IoT (Internet of Things) NTN (non-terrestrial network) enhancements: WID in RP-223519 • NB-IoT/eMTC core & performance requirements for Non-Terrestrial Networks (NTN): WID in RP-223437
	SA	<ul style="list-style-type: none"> • Enhancement to the 5GC LoCation Services : SID in SP-211637 • Study on Support of Satellite Backhauling in 5GS : SID in SP-211317 • Study on satellite access Phase 2 : SID in SP-211651
Use case for satellite access		NR NTN IoT NTN
Possibility of international collaboration		Yes, at 3GPP

NTN System 3GPP Rel-19 (preliminary forecast)

Approach for 5G		<ul style="list-style-type: none">• Definition of 2nd set of enhancement optimizing performance and enabling new capabilities
NTN related standardization activities		<ul style="list-style-type: none">• Define 2nd enhanced satellite features for 5G system and RAN• RAN and AS enhancement for global seamless coverage supported by satellite constellation
Tech.	RAN	<ul style="list-style-type: none">• Some continuations from Rel-18 (e.g. further performance enhancements, regenerative architecture) ;• TN-NTN, NTN-NTN with regenerative architecture• Enhanced mobility management• Carrier Aggregation
	SA	<ul style="list-style-type: none">• Seamless coverage with satellite constellation; UPF on board; E2E
Use case for satellite access		Enhanced direct to cell services Support Redcap Supporting terminals without GNSS
Possibility of international collaboration		Yes, at 3GPP

<https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2030/Pages/default.aspx>

6 Usage scenarios

Extension from IMT-2020 (5G)

- eMBB → Immersive Communication
- mMTC → Massive Communication
- URLLC → HURLLC (Hyper Reliable & Low-Latency Comm.)

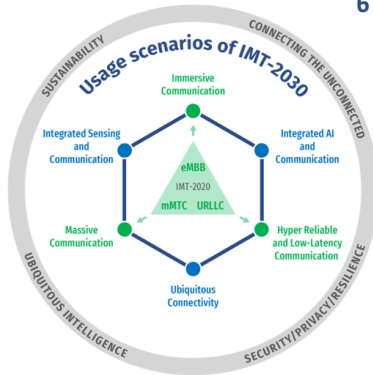
New

Ubiquitous Connectivity
Integrated AI and Communication
Integrated Sensing and Communication

4 Overarching aspects:

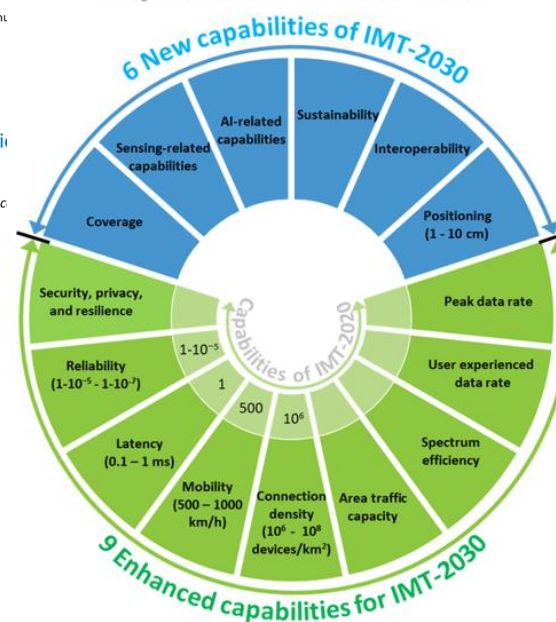
act as design principles commonly applicable to all usage scenarios

Sustainability, Connecting the unconnected,
Ubiquitous intelligence, Security/privacy/resilience



So called "Wheel diagram"

Capabilities of IMT-2030



So called "Palette diagram"

The range of values given for capabilities are estimated targets for research and investigation of IMT-2030.

All values in the range have equal priority in research and investigation.

For each usage scenario, a single or multiple values within the range would be developed in future in other ITU-R Recommendations/Reports.