NTN Technology Roadmap (2023 version)

NTN Promotion Project
XG Mobile Promotion Forum
Revised in October, 2024

Landscape Map: NTN Technology Roadmap

2022 2023 2024 2025 2026 2027 2028 2029 2030

Satellite Broad Band

GEO Advanced Higher Throughput (VHTS- SDS), Lower Cost

★ Viasat Viasat-3 / Echostar Jupiter-3 / Konnect VHTS (VHTS) ★ Intelsat-42,43 / Superbird-9 (SDS)

Adaptation to 3GPP Rel. 18 NTN

Further Throughput Improvement : Optical Link, Large-scale, Resource Optimization, V/E Band (feeder Link), Dynamic change of beam design

LEO Constellation (Low Latency/Broadband Service) /High latitude which is hard for GEO

LEO Constellation Advanced Higher Throughput Capacity

★ Starlink Gen-1 (High Latitude region)

★ Starlink Gen-1 (maritime)

★ OneWeb Gen-1 (High Latitude region)

★ Amazon Kuiper

★ Telesat Lightspeed

OneWeb Gen-2
Starlink Gen-2

Further Throughput Improvement :
Optical Link (Satellite-Satellite, Satellite-Terrestrial), Large-scale, Resource Optimization, V/E Band (feeder Link)
Further Capacity Improvement :
Increase the number of satellite (1,000 – 10,000 order)

Toward Beyond 5G/6G

Satellite Mobile Direct

Terrestrial + satellite (satellite communication with the same terminal as the terrestrial)

★ Lynk

★ AST SpaceMobile

★ Starlink Direct to Cell

★ Apple & Globalstar

★ Project Stardust

Satellite IoT

★ EchoStar Mobile

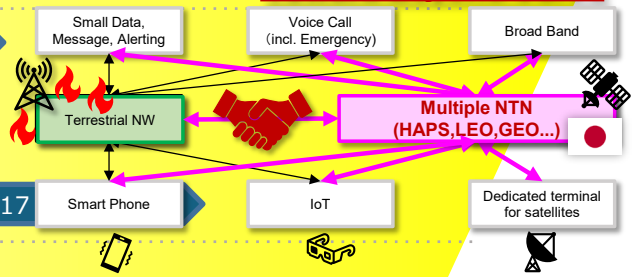
★ OQ Technology

★ Lacuna Space

★ Skylo

★ Sateliot

Adaptation to 3GPP Rel. 17



HAPS

Solar Panel Lightweight/High Efficiency

Next Gen Solar Pane

Battery high density/high cycling

Next Gen. 400 ~ 500 Wh/kg

Gen after Next Gen 600 ~ 1000 Wh/kg

Payload multi-cell/high capacity

★ SoftBank HAPS

★ Space Compass HAPS

Toward Ideal All Japan NTN in 10 years

Current Situation
Although there are some exception, conventional NTNs are basically independent systems from terrestrial NWs, and each has evolved and developed independently.

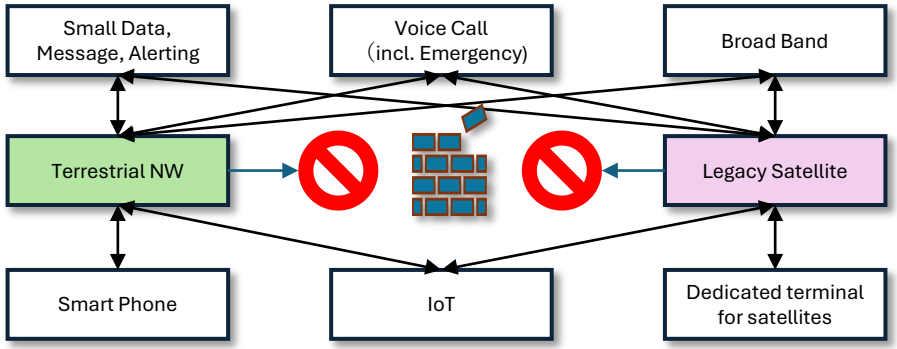
Toward Beyond 5G/6, IMT-2030

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

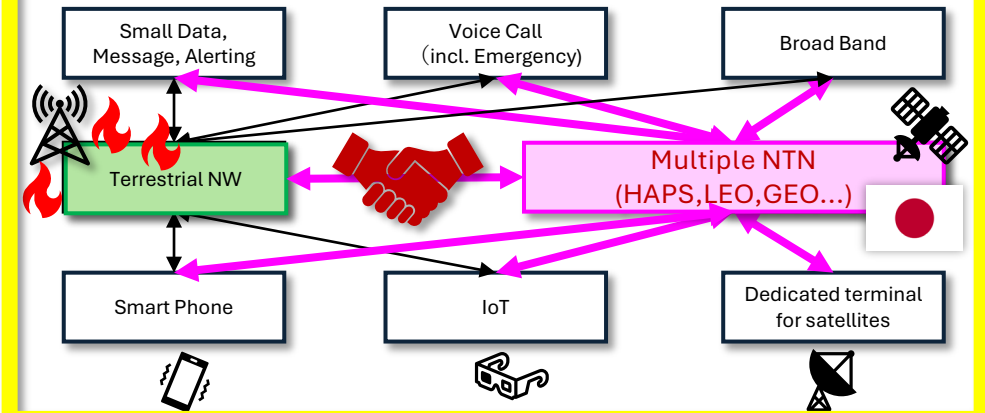
2) Even in emergency situations on the ground, such as large-scale NW failure, congestion, etc. due to disasters, providing the minimum level of services through NTN as a backup for the terrestrial NW is expected to support on recovery and reconstruction.
➔ Establish All Japan NTN that provide cooperation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



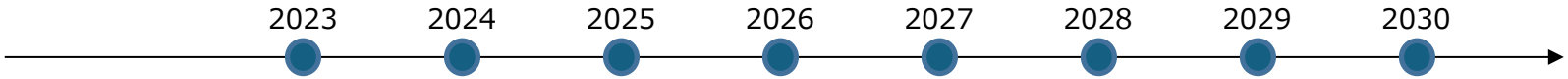
NTN Toward Beyond5G/6G



NTN Technology Roadmap

Satellite Broadband	Starlink subscriptions are growing rapidly, with the number exceeding 2.3 million worldwide as of December 2023. The services for vessels have been started, and service expansion to aircraft is also planned in 2024. Competition among LEO constellations is expected to intensify with the launch and expansion of OneWeb and Project Kuiper services. With geostationary satellites, Low-cost, high-speed services have been launched based on VHTS such as Konnect VHTS and JUIPITER 3. Services based on SDS (Software Defined Satellite) are also planned and expected to develop services with low-latency and high-speed. Currently, frequency of service link mainly uses Ku band, usage of Ka band is also increasing. With feeder links, the use of higher frequency bands such as Q/V bands has also begun.
Satellite Mobile Direct Satellite IoT	Direct satellite communication services with smartphone have been started by Lynk and Bullitt, and AST SpaceMobile and Starlink are also planning the launch of services in future. Services can communicate with directly IoT terminals (3GPP Rel 17 NTN compatible terminals and Lora terminals) are about to start, and it enables significantly increased coverage as both terrestrial and satellite networks can be used on the same device. The dissemination of the services is expected with the expansion of the service area and improvement of performance.
HAPS	Research and development is in progress. The usage method of mobile direct communication and CPE is planned. The expected HAPS usage is for a hyper-expanding mobile coverage and backup communications in the event of disasters. Although HAPS has narrower coverage than satellites due to its lower altitude, it can provide high-speed communication services with low latency compared with those of satellites.

NTN Technology Roadmap



Aviation field	Broadband communication (In-flight Wi-Fi etc.)	GEO advanced/ high-speed (VHTS・SDS), lower cost LEO constellation advanced/ high-speed/ large capacity The use of In-flight Wi-Fi (IFC) using geostationary satellites as backhaul is growing in aviation field. The use of LEO constellations is expected to expand in the future, leading to lower costs and higher speeds. However, high institutional hurdles such as aviation laws might take time for propagation.
	Mobile direct IoT	The use in the aviation field is unlikely in progress as many countries do not allow LTE and 5G communications on board for aviation safety, and the Wi-Fi service is sufficient for users.
Maritime field	Broadband communication (In-flight Wi-Fi etc.)	GEO advanced/ high-speed (VHTS・SDS), lower cost LEO constellation advanced/ high-speed/ large capacity Demand for satellite broadband as Wi-fi backhaul line is high as the internet connection on board is becoming necessity. LEO constellations are expected to see increased use on small vessels because they use terminals that are relatively compact and easy to configure compared to GEO.
	Mobile direct IoT VDES	Transfer from dedicated satellite communication system to 3GPP Rel. 17 NTN compliant service & integration with terrestrial mobile services Advanced maritime operation by transfer from AIS to VDES Smaller vessels that are difficult to use broadband communications are expected to use direct communication between satellites and HAPS & smartphones. International efforts are in progress to utilize satellites to coordinate and improve global maritime operations. The efforts in Japan and other countries include implementation of VDES that extends the current AIS and allows bidirectional communication at higher transmission rates.

NTN Technology Roadmap accompanying materials : NTN Technology Issues

Technology issues to be solved for utilization of NTN

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

*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.			

Detailed Technology Info: Satellite Broadband

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		

Detailed Technology Info: Satellite Broadband

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		

Detailed Technology Info: Satellite Broadband

OneWeb

Satellite overview		・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	・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		・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 ・ECC Report 271 ・ECC Decision (18)05 ・ETSI EN 303 980
Possibility of international collaboration		・Solar panel technology ・Debris removal technology

Detailed Technology Info: Satellite Broadband

Starlink

Satellite overview		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).
Technology		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).
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	European standards ・ECC Report 271 ・ECC Decision (18)05 ・ETSI EN 303 981
Possibility of international collaboration		

NTN Technology Roadmap Comparison: Satellite Mobile Direct

		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.

Detailed Technology Info : Satellite mobile direct

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**	・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.

Detailed Technology Info : Satellite mobile direct

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**	・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		

Detailed Technology Info : Satellite mobile direct

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	・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

		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							

Detailed Technology Info ：Satellite IoT (Mobile direct)

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		

Detailed Technology Info : Satellite IoT

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		

Detailed Technology Info : Satellite IoT

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.

Detailed Technology Info : Satellite IoT

OQ TECHNOLOGY

Satellite overview		Satellite constellation by OQ TECHNOLOGY (plan to launch 72 satellites). Provides direct communication service to 5GIoT terminal. S band frequency (2GHz band) 8 satellites have been launched. Commercial service started in June 2023.
Technology		Details are not disclosed. Obtained US patent for “wake-up” technology that enables efficient power use only when terminal is communicating with satellites.
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		

Detailed Technology Info : Satellite IoT

Sateliot

Satellite overview		Satellite constellation by Sateliot (plan to launch 250 satellites). The 1st 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		

NTN Technology Roadmap Comparison: HAPS

		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		・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

Detailed Technology Info: HAPS

HAPS

Overview		・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.
Technology	Payload	・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	・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	・Development of module for Stratospheric environmental application ・Lighter weight/higher efficiency
Use case		・Rural areas/remote island areas/3D coverage/disaster communication/IoT/sensing services (camera etc.)
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)
Possibility of international collaboration		・Promotes coordination with other systems（ICAO,FAA,EASA,CASA）、International frequencies（ITU、3GPP)

NTN Technology Roadmap: 3GPP/Standardization trend

2022 2023 2024 2025 2026 2027 2028 2029 2030

5G Evolution → 5G Advanced → 6G

3GPP

WRC-23 WRC-27

5.5G

R17 R18 (18m) R19 (18m) R20 (18m) R21 (18m) R22 (18m) R23

ASN.1 frozen

RAN1 of next release starts

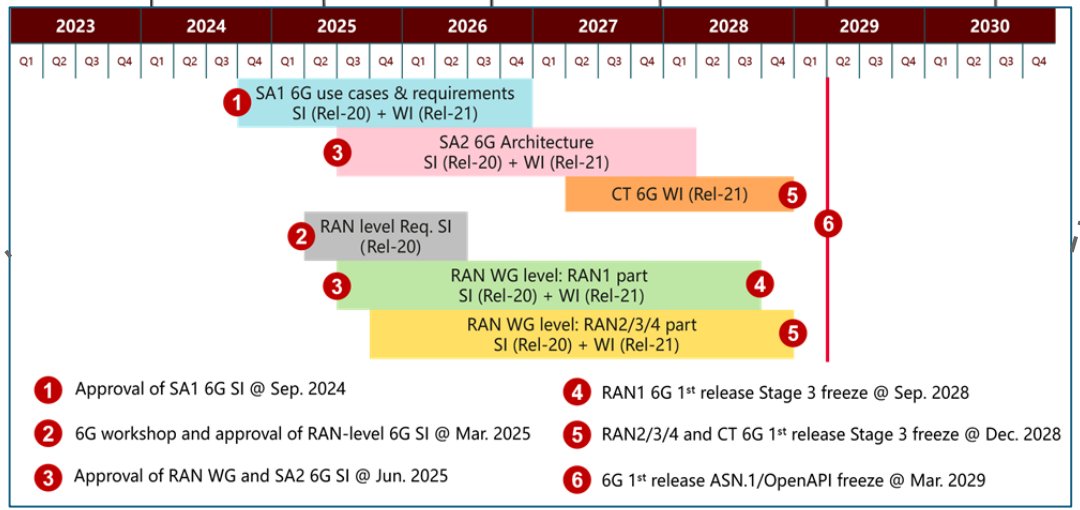
6G RAN SI on req. 6G SI 6G WI

3GPP 6G workshop

3GPP 6G first version

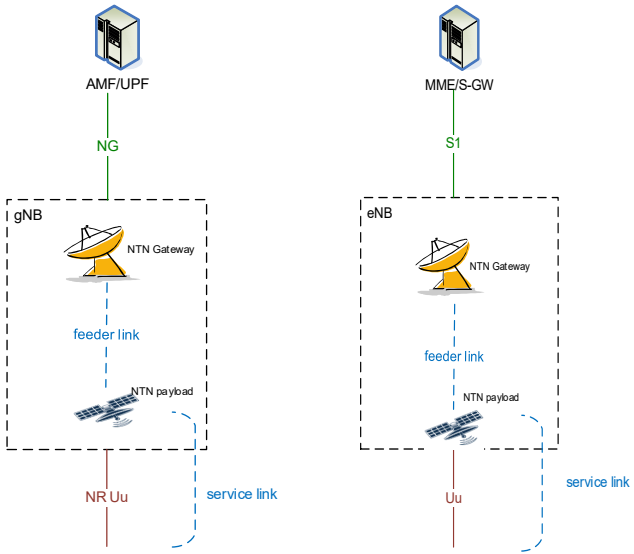
Note: this is an initial possible thoughts based on a plan from NTN proponents in RWS-210074.
ITU-R schedule referred from WP5D#39 Temp/526.
The indicated schedule does not show any official nfo nor view of Scalability-WG contributors.

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



NTN Technology Roadmap: 3GPP/Standardization trend

- 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.



NR NTN NB-IoT/eMTC NTN

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

		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	・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)	–
	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 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		• 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**	• Study item (SI) on NTN scenarios and channel models: TR 38.811
	SA	• 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

Landscape Map : Detailed Technology Info -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		• Study satellite features for 5G system and RAN* • Satellite architecture and key issues • Management and orchestration aspects *HAPS could be considered as a special case of non-terrestrial access with lower delay/Doppler value and variation rate
Tech.	**RAN**	• Study on solutions for NR to support non-terrestrial networks (NTN): TR 38.821
	SA	• 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

Landscape Map : Detailed Technology Info -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		• Specify basic NTNfeatures 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**	• 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	• TS 23, 24, 29 and 31 series refried 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**

Landscape Map : Detailed Technology Info -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		• 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**	• 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	• 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**

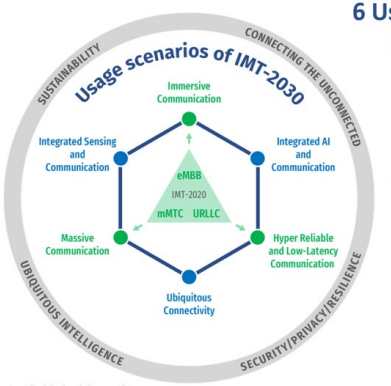
Landscape Map : Detailed Technology Info -3GPP-

NTN System 3GPP Rel-19 (preliminary forecast)

Approach for 5G		・Definition of 2nd set of enhancement optimizing performance and enabling new capabilities
NTN related standardization activities		• Define 2nd enhanced satellite features for 5G system and RAN • RAN and AS enhancement for global seamless coverage supported by satellite constellation
Tech.	**RAN**	• 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	• 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

NTN and MT-2030

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



So called "Wheel diagram"

6 Usage scenarios

Extension from IMT-2020 (5G)

- eMBB ➡ Immersive Communication
- mMTC ➡ Massive Communication
- URLLC ➡ HRLLC (Hyper Reliable & Low-Latency Commu

New

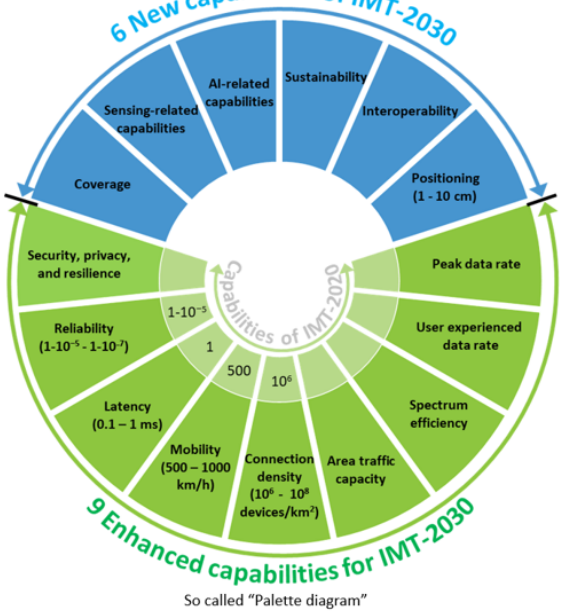
- Ubiquitous Connectivity
- Integrated AI and Communication
- Integrated Sensing and Communicati

4 Overarching aspects:

act as design principles commonly applicable to all usage sc

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

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.