6G Position Paper

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Introduction

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With the advancement of next-generation mobile networks, 6G is expected to drive new innovations and bring about transformations in society, industry, and individual lives.

This position paper aims to organize the key technical issues that need to be addressed with 6G, considering the direction of Japan's future development and anticipated societal challenges. It seeks to deepen mutual understanding among industry, academia, and government, and to broadly communicate Japan's 6G concept both domestically and internationally.

Through this effort, the goal is to promote sustainable growth and innovation, and to accelerate discussions and initiatives toward the realization of next-generation mobile networks.

The direction of Japan's future development

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Here are the items considered important regarding the direction of Japan's future development, to which mobile networks can particularly contribute, and the direction of the evolution of mobile networks, along with the customer value they realize.

Direction of future development and evolution	Customer values
Advanced mobility	MaaS (Mobility as a Service), Automation of transportation infrastructure (automobiles, railways), Improvement of user communication experience while on the move
Promotion of the content industry	Advancement on the consumer side, such as AR/XR, Advancement on the production side (e.g., wireless production studios, remote editing)
Advancement of primary industries	Smart agriculture, smart fisheries, smart forestry, etc.
Development based on AI	Platforms for utilizing AI, AI-native networks, etc.

Societal challenges

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On the other hand, there are also numerous societal challenges. Below are the priority areas where mobile networks are expected to contribute to their resolution, along with the customer value to be realized in addressing these challenges.

Societal challenges	Examples of customer value for problem solving
Population Decline Labor Shortage Low Productivity	Manpower saving, Remote Monitoring, Remote Control Automation, Industrial Digital Transformation
Environmental Impact of Industry, Sustainability	Industrial Optimization (e.g., through data collection and analysis) Smart Logistics, Utilization of IoT and AI
Disaster Resilience	Disaster Prevention, Disaster Mitigation （e.g., Emergency Alerts, Damage Prediction, Evacuation Information） Recovery, Resilient Infrastructure
Maintenance of Infrastructure in Depopulated Areas	Mobility and Logistics Optimization (e.g., Autonomous and Remote-Controlled Buses) Infrastructure Monitoring
Maintaining Urban Functionality in Densely Populated Cities	Enhancement of Urban Functions Sufficient Communication Capacity Traffic Congestion Mitigation Efficiency in Infrastructure Development and Maintenance
Shortage of Medical Resources, Healthcare Access Disparities	Remote Medical Consultation, Telesurgery
Aging Population (Healthy Life Expectancy)	Preventive Medicine, Health Management

Enabling 6G through emerging technologies

Enabling 6G through Emerging Technologies

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This section summarizes how the technologies being studied in each of the 6G-related projects under XGMF—namely, the *6G Wireless Technology Project*, *6G Network Architecture Project*, *NTN Promotion Project*, *Terahertz Wireless Technology Project*, and *Space-Time Synchronization Project*—are expected to contribute to Japan’s future developments and address societal challenges.

The value enabled by wireless technologies (6G Radio Access Technology Project)

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Customer Value	Value Proposition	Specific technologies	Differences from the present
Remote Monitoring, Remote Operation and Control, Mobility Optimization (Autonomous and Remote-Controlled Buses)	The ability to expand high-speed, high-capacity communication coverage at low cost	Wireless Repeaters and Passive Reflectors	Maximizing the Effectiveness of 6G RAN
	The ability to provide consistently high communication quality throughout the target area, while maintaining a high level of service even during mobility.	Cell-Free MIMO	Advanced inter-TRP coordination (e.g., CJT, MU-MIMO, increased number of layers)
	The ability to understand the surrounding environment at low cost	Wireless Sensing	The sensing functionality itself is newly added
Automation, Industrial DX, Industrial Optimization	The ability to provide highly reliable communication anywhere within the service area.	Cell-Free MIMO	Advanced inter-TRP coordination (CJT/MU-MIMO etc.)
	Maximizing performance by operating the wireless system in accordance with the service area and specific use cases.	Improving effective performance through AI.	The technology has matured
	Understanding the surrounding environment with low latency and low cost.	Wireless Sensing	The sensing functionality itself is newly added
Advancement of AR/XR on the Consumer Side	Providing high-speed, high-capacity coverage areas to support rich content delivery.	Advancement of Massive MIMO technology	Increased number of layers
		Improving effective performance through AI.	The technology has matured
Remote Medical Consultation, Telesurgery, Preventive Medicine, Health Management Advancement of AR/XR on the Production Side	Providing stable high-speed, high-capacity communication at specific locations.	Utilization of high-frequency bands /Wireless Repeaters and Passive Reflectors	Maximizing the Effectiveness of 6G RAN
	Providing highly reliable communication throughout the entire service area.	Cell-Free MIMO	Advanced inter-TRP coordination (CJT/MU-MIMO etc.)

The value enabled by network architecture (6G Network Architecture Project)

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Customer Value	Value Proposition	Specific technologies	Differences from the present
Remote Monitoring, Remote Operation and Control, Mobility Optimization (Autonomous and Remote-Controlled Buses)	E2E wavelength routing contributes to low latency and low jitter, and the increased controllable distance enables a reduction in the number of remote operation sites.	APN AI/Compute/Network Convergence（e.g. DCI）	Reducing latency and jitter in the wired segments
Contents : Advancement of AR/XR on the Consumer Side	Low latency and low jitter achieved by end-to-end wavelength routing, along with optimized routing for device-to-device communication, contribute to improved user experience. Offloading terminal functions reduces device costs, extends operational time, and enables more advanced services.	APN AI/Compute/Network Convergence（e.g. In-Network Computing） SRv6	Offloading of terminal functions Advancement of device-to-device communication
Environmental Impact and Sustainability of Industry (Watts and Bits)	E2E wavelength routing contributes to low latency and low jitter, reducing constraints on physical equipment placement and enabling deployment in locations with more favorable power conditions. Dynamic scaling and relocation of Network Functions (NFs) based on demand can further reduce power consumption	APN AI/Compute/Network Convergence （e.g. DCI） NFV/Cloudification	Reducing latency and jitter in the wired segments
Recovery and Infrastructure Resilience	E2E wavelength routing enables low latency and low jitter, increasing flexibility in the placement of physical infrastructure and network functions (NFs). Dynamic scaling and relocation of NFs also contribute to faster recovery in the event of failures.	APN (Wavelength Path Switching) AI/Compute/Network Convergence （e.g. DCI） NFV/Cloudification	Cloud-Native Transformation of Network Functions (NFs)

*1 :APN All Photonics Network
A network that minimizes electrical processing during intermediate stages and establishes end-to-end connections using optical technology

*2 : DCI data centric infrastructure
・Providing Infrastructure as a Service on an open, distributed communication and computing platform.

The value enabled by NTN (Non-Terrestrial Networks Promotion Project)

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Customer Value	Value Proposition	Specific technologies	Differences from the present
Disaster Prevention and Mitigation (e.g. Emergency Alerts, Damage Forecasts, Evacuation Information, Environmental Information Collection), Recovery, Infrastructure Resilience	**Provision of resilient communications networks from the sky (NTN in general):** Contributing to the early restoration of communications in disaster-stricken areas and monitoring of natural disasters **High penetration, high capacity, low latency, and high mobility (HAPS):** Contributes to the use of communication even indoors or obstacles during search operations in the event of a disaster, and to the handling of a certain level of image data during remote rescue operations. In addition, it can be quickly deployed after a disaster occurs.	**HAPS** (High Penetration, High Capacity, Low Latency, High Mobility) **LEO and GEO** (Ultra-Wide Area Coverage)	**The advent of NTN native:** With the maturation of elemental technologies and the lowering of procurement costs through the construction of a global ecosystem, social implementation is progressing, and use cases that were limited in the current (5G) NTN will expand to primary industries (agriculture, fisheries, forestry), telemedicine, autonomous driving, etc., and will be used everywhere as a matter of course **NTN contributes to the SDGs that are friendly to people and the environment:** By using NTN in 6G, we will expand the scope of application to environmental measures that have not been reached so far and contribute to the realization of a more human-friendly and environmentally friendly future, such as global traffic optimization, environmental monitoring, and energy reduction associated with the movement of people and goods through remote access.
Maintenance of infrastructure and improvement of mobility and logistics efficiency in depopulated areas (e.g. Automated and remotely driven buses), infrastructure monitoring	**Provision of ubiquitous communications networks from the sky (NTN in general):** Covering areas in underdeveloped areas, replacing ground base stations in unprofitable areas, and improving the efficiency of mobility and logistics in depopulated areas **High Capacity, Low Latency (HAPS):** Contributing to the provision of advanced content including Internet and video services, as well as the provision of services using drones and autonomous driving that utilize low latency	**HAPS** (High Capacity, Low Latency) **LEO and GEO** (Ultra-Wide Area Coverage)	
Smartening the primary industries (agriculture, fisheries, forestry, etc.)	**Provision of ubiquitous communication networks from the sky (NTN in general):** Contributing to the avoidance of dangers and ensuring the safety of workers in areas where it is difficult to install ground infrastructure (mountainous areas, maritime areas, etc.), as well as improving welfare and operational efficiency. Contributing to the monitoring of agricultural crops and marine products using IoT sensors, as well as automated work in agriculture and fisheries. **High penetration, high capacity, low latency (HAPS):** Contributes to advanced data linkage, including video data in monitoring, and automation of tasks that requires high accuracy.	**HAPS** (High Penetration, High Capacity, Low Latency) **LEO GEO** (Ultra-Wide Area Coverage)	
Telemedicine and Telesurgery	**Provision of ubiquitous communication networks from the sky (NTN in general):** Contributing to the provision of stable medical services in areas where it is difficult to install ground infrastructure, such as islands and villages in mountainous areas. **High Capacity, Low Latency (HAPS):** Contributes to the provision of advanced communications, including video data, for remote diagnosis and telemedicine	**HAPS** (High Capacity, Low Latency) **LEO** (Ultra-Wide Area Coverage)	
MaaS, automation of transportation infrastructure (automobiles, railways), improvement of communication environment	**Provision of ubiquitous communications networks from the sky (NTN in general):** Contributing to the provision of stable communications services even in areas where it is difficult to install ground infrastructure **High Capacity, Low Latency (HAPS):** Contributes to supporting safe and efficient operation of autonomous driving by realizing advanced data linkage, including video data	**HAPS** (High Capacity, Low Latency)**LEO** (Ultra-Wide Area Coverage)	

: Items to which NTN's contribution is expected particularly large

The value enabled by high-frequency utilization (Terahertz Wireless Project)

Customer Value	Value Proposition	Specific technologies	Differences from the present
Improvement of urban functions, sufficient communication capacity, Alleviation of traffic congestion and congestion, Improving the efficiency of infrastructure development and maintenance	**Reduction of infrastructure development costs and communication load** • As a complement to APN, it enables connections in places where it is difficult to deploy optical fibers, reducing the cost of 6G infrastructure development. • Simplify the installation of base stations to respond to sudden increases in traffic at event venues, etc., and alleviate traffic congestion.	**Millimeter-wave and sub-terahertz device technology** • Small size, low cost, power saving, and easy installation • Semiconductors, Packages, Low Loss and Low Dielectric Constant Materials **Shielding measures and area expansion** • Narrow beamforming, control • RIS, Reflector Utilization **Modulation, Demodulation and NW technology** • MIMO multiplexing, 100Gbps-class modem technology • Multi-link	• Standard implementation of millimeter-wave bands in terminals, full-scale dissemination of millimeter-wave bands • In addition to millimeter waves, the use of sub-terahertz waves (backhaul, FWA, etc.) achieves a transmission speed of 100 Gbps as an APN complement.
Disaster Prevention and Mitigation (e.g. Emergency Bulletin, Damage Forecast, Evacuation Information, Environmental Information Collection), Recovery, Infrastructure resilience	**Backup redundancy of optical fiber networks, early recovery from disasters** • Can be easily installed as a replacement for damaged optical fibers, contributing to rapid infrastructure recovery after a disaster		• Efficient recovery by linking with NTN and other wide-area networks
Manpower Saving, Remote Monitoring, Remote Control Automation, Industrial Digital Transformation	**Shortening of wiring construction period and simplification of maintenance** • Real-time sharing of high-definition sensing data that takes advantage of the features of ultra-high speed and ultra-low latency contributes to automatic and remote control of industrial equipment, robots, etc. • Contributing to flexible equipment placement in data centers, video production studios, etc., by introducing some wireless wires with complex wiring connections.		• Mobility support through integration of communication and sensing • Evolution of out of coverage area measures using repeaters, etc. • Improved connectivity with Sub-6 and unlicensed bands by multi-link

The value enabled by space-time synchronization (Space-Time Synchronization Project)

※ Future Consideration Items

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Customer Value	Value Proposition	Specific technologies	Differences from 5G
Manpower saving, Remote Monitoring Remote Operation and Control Mobility and Logistics Optimization (e.g., Autonomous and Remote-Controlled Buses) Infrastructure Monitoring Environmental Data Collection Smart Agriculture	**Improved positioning performance** • Quickly get time and positions • Quickly obtain positional information of other individuals, suppress the occurrence of spatial interference, and achieve a high degree of cooperative operation **High-density multiplexing** • Improved time and frequency accuracy improve the density of time and frequency multiplexing	Miniature Atomic Clock Wi-Wi Cluster Time System Distributed MIMO	Each device has a high-precision, high-stability, and local time. Ensuring autonomy and reducing design redundancy Reduction of guard band and guard time
Enhancing infrastructure resilience	**Reduce over-dependency on GNSS** • By autonomously generating a time that is less likely to shift by an atomic clock, the hold time of the time is extended, and the operating time is expanded even after the GNSS signal is lost	APN Miniature Atomic Clock Cluster Time System Optical lattice clock High-precision local time generation and sharing technology	Long-term operation even in the event of a loss of synchronization with GNSS/GMC
Contents : Wireless production studio, remote editing	**Enables a large number of synchronous real-time connections/edits** • Wireless clock synchronization is possible, improving the mobility of cameras and other devices • Highly time-segmented transfer of multiple videos and consistent organization based on chronological order • Even if the wireless connection is temporarily interrupted, the local clock continues to operate to maintain synchronization for a certain period of time.	Wi-Wi High-stability local time generation/sharing technology Engraving Generation/Sharing Technology	Since not only the time but also the phase of the clock is synchronized, no need to resynchronize the clock even if communication is disrupted.

Wi-Wi: Wireless two-way interferometry

Future directions/Societal challenges, Values, and Technologies

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Future directions

- Advanced mobility
- Promotion of the content industry
- Advancement of primary industries
- Development based on AI

Societal challenges

- Population decline, labor shortage, low productivity
- Environmental impact of industry, sustainability
- Disasters, resilience
- Infrastructure maintenance in depopulated areas
- Maintaining functionality in overcrowded cities
- Shortage of medical resources and disparity in access
- Aging population (healthy life expectancy)

Technology Values

- High speed and large capacity
- Low latency and low jitter
- Massive connectivity
- High reliability
- Mobility
- Low power consumption
- Coverage area improvement
- Resilience

Technologies

- Advanced/Distributed M-MIMO
- Air interface enhancement by AI
- Sensing
- cmW/mmW
- SubTHz
- All Photonic Network
- AI/Compute/Network Fusion
- NFV/Cloudification/SRv6
- GEO/LEO
- HAPS

Challenges in the Telecommunications Industry
(To Be Further Explored in the Future)

Challenges in the Telecommunications Industry

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Profitability and New Business

- No monetizing option anything other than the amount of data
- ARPU cannot rise sufficiently even when commodity prices are rising
- Insufficient formation of the enterprise ecosystem
- The next device beyond smartphones

Infrastructure Maintenance

- Data traffic continues to increase
- Operation and maintenance of ubiquitous and resilient networks

Generations of infrastructure

- Efficient operation of multiple generations
- Difference between Vertical and telecommunications infrastructure lifecycle

Challenges of 5G

- Dissemination of SA, mmWave and local 5G
- Further use of 5G

Challenges of 6G

- Differentiation and value of 6G over 5G
- Services and devices that require 6G
- Compatibility with existing systems and smooth migration
- Global harmonization of 6G frequencies (bandwidth, width)
- Spectrum sharing technology

Challenges in the Telecommunications Industry
（Domestic Focus）

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Challenges of 5G

- It is essential to build the world's No. 1 network as the foundation for growth scenarios that create innovation and improve productivity dramatically.

- Differentiation from 4G as a user experience (problem due to coverage priority)

Challenges of 6G

- It is essential to align Japan's Beyond 5G (6G) strategy with the global 6G direction

- It is essential to be incorporated into the global 6G ecosystem, and on top of that, it is necessary to find technologies that Japan will focus on

- Feasibility of introducing SubTHz radios

Infrastructure Maintenance

- Area coverage rate (for each MNO, for all MNOs)

Generations of infrastructure

- Maintenance of the old system and the regulatory system (e.g., voice)

Japan's influence

- Japan influence on Global Standardization

Summary

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6G aims to deliver faster and more reliable communications, while integrating with a wide range of technologies such as AI, IoT, and XR to drive new value creation.
This position paper outlines the key technical challenges that should be prioritized at this stage, based on Japan's future development and pressing societal challenges. It also summarizes the technologies expected to address these challenges through 6G.

Looking ahead, it is essential for industry, academia, and government to collaborate in promoting standardization and R&D, to realize a global 6G ecosystem—not only through individual technologies, but as a comprehensive system. Through this paper, we hope to foster a shared understanding and encourage concrete actions toward the realization of 6G.

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