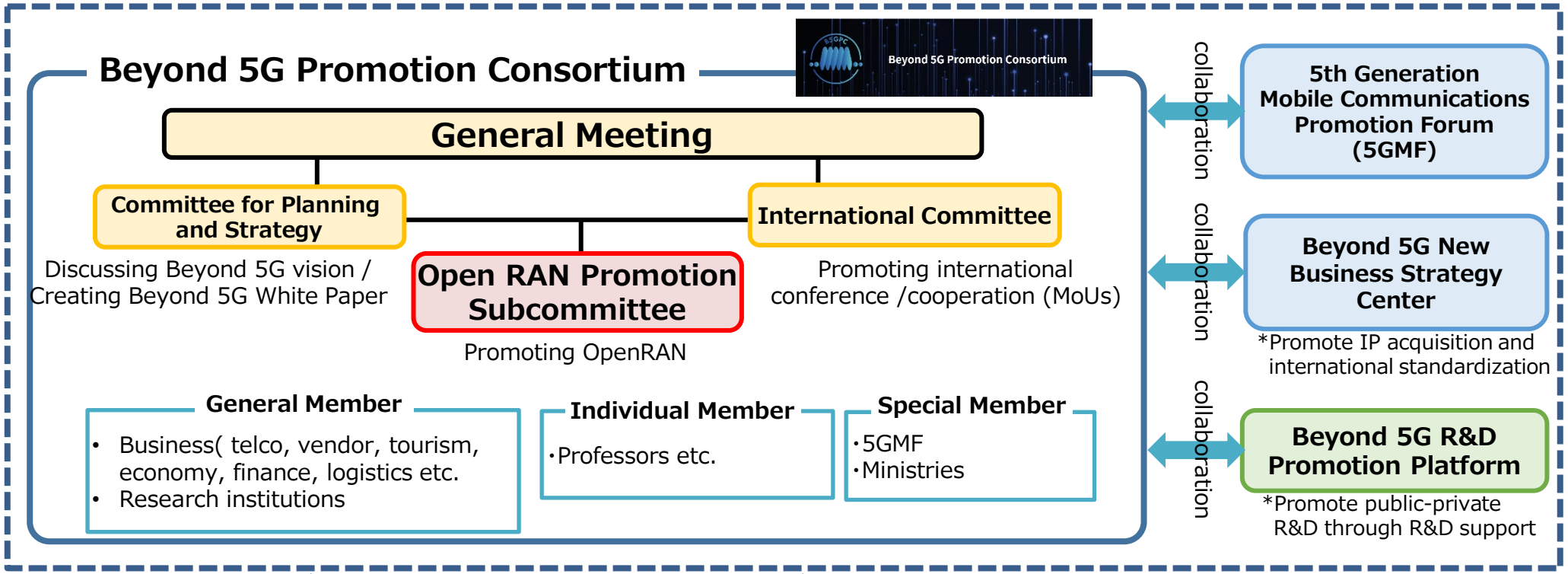
Beyond 5G White Paper (ver.1.0)
～Message to the 2030s～
【Overview】

White Paper Subcommittee, B5GPC

Mar. 18, 2022

Beyond 5G Promotion Consortium

- Established “Beyond 5G Promotion Consortium” to promote Beyond 5G Promotion Strategy through industry-academia-government collaboration.
  - International conference for international cooperation
  - Vision for Beyond 5G, White Paper etc.
  - Open RAN Promotion



***Free membership fee**
***Companies, organizations and individuals who wish to join can apply through website:**
https://b5g.jp/en/

Structure of White Paper Subcommittee

Committee for Planning and Strategy

White Paper Subcommittee

Chair : Nakamura (NTT DOCOMO)

- Forecast strong and lively society expected in the 2030's and clarify use cases and requirements of Beyond 5G
- Take international leadership by developing concept of Beyond 5G early on and reflecting it to international standardizations including ITU
- Contribute to strengthen international competitiveness by capturing and reflecting views from various industries and developing meaningful concept of Beyond 5G for all industries

Vision Working Group

Leader : KONISHI (KDDI), Sub leader: NAGATA(NTT DOCOMO)

- Develop the vision part of the white paper with forecasting our society around 2030 and studying use cases and requirements of Beyond 5G

Technology Working Group

Leader : NAKAMURA (FUJITSU), Sub-leader: SHIMONISHI(NEC)

- Develop the technology parts of the white paper with studying technology trends of Beyond 5G and clarifying roles and expectations of functions and values for users and markets

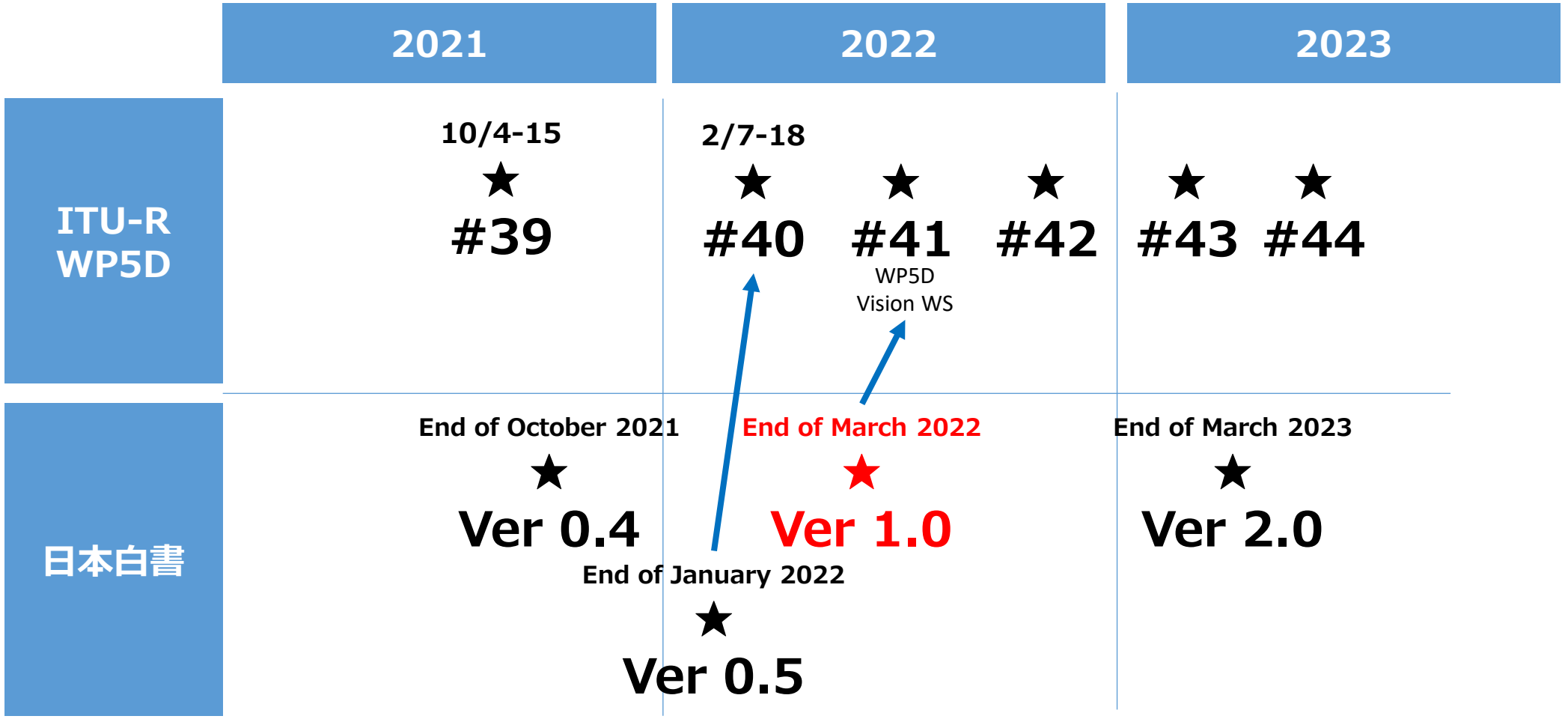
WP5D Ad Hoc

Leader : SUGATA (KDDI), Sub-leader: TAKETSUGU (NEC)

- Action planning and contribution to ITU-R WP5D based on studies in the subcommittee

Work schedule

Version 1.0 published on 18 March 2022



Structure of white paper

Chapter 1. Introduction

Chapter 2. Traffic trends

- This chapter describes the trends in traffic from mobile applications and use cases of Beyond 5G that are predicted to arrive around the year 2030.

Chapter 3. Market trends in the telecommunications industry

- This chapter discusses market trends in the mobile communications sector, particularly changes in the share structure for smartphones, base stations, and other communication infrastructure equipment, and technical trends in components related to smartphones.

Chapter 4. Trends from other industries

- This chapter identifies the current challenges in all existing industries, provides suggestions for problem solving, and summarizes the visions and dreams that industries should aspire for, as well as the performance and capabilities that are expected of Beyond 5G.

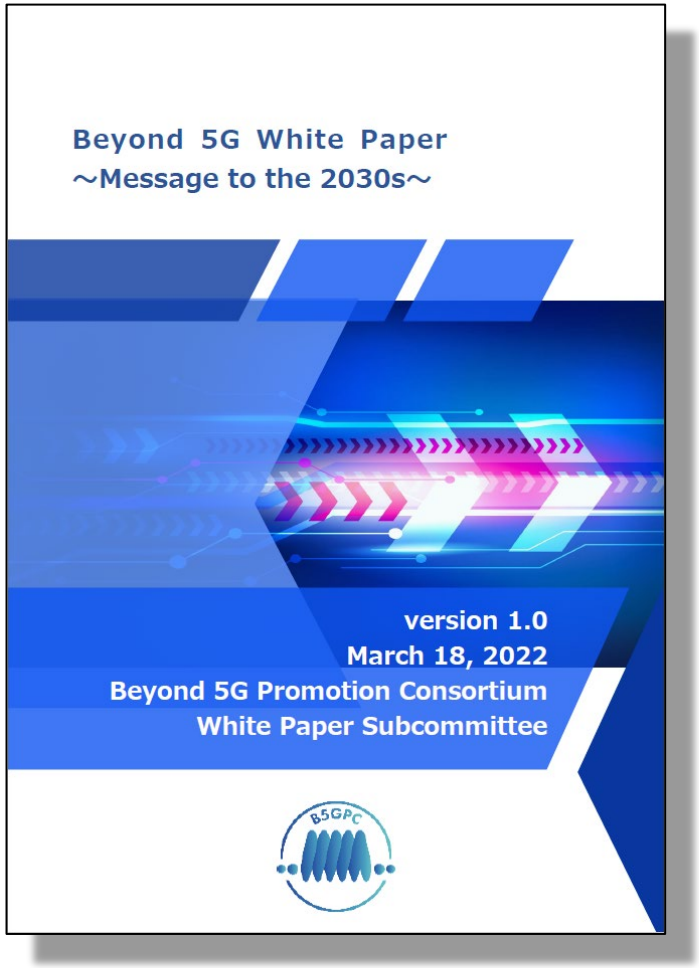
Chapter 5. Capabilities and KPIs required in Beyond 5G

- This chapter identifies the unique use cases in the various industries discussed in Chapter 4 and summarizes the performance of Beyond 5G required for each use case.

Chapter 6. Technology trends

- This chapter examines the trends in technologies required for Beyond 5G and clarifies the functions and values it will provide, as well as the roles it will play and the expectations of the users and markets.

Chapter 7. Conclusion



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Next steps and invitation toward collaboration

- This white pater contains useful information which promote to study on new future business and solutions for social issues among all industries not limited to communication industry. It is expected that the white paper helps shape better future society and promote global activities.
- This study continues and the white pater will be updated based on study. Any comments from readers are welcomed.
- This group is contributing to spectrum study and standardization activities in ITU/3GPP and conducting collaborations among industry, academia, government based on the white paper.
- Any related organizations are invited to give us an opportunity to exchange views on this white paper.

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～Message to the 2030s～
【Beyond 5G use case and requirement】

Vision Working Group,
White Paper Subcommittee, B5GPC

Mar. 18, 2022

Establishment of “Workshop on Society in 2030s”

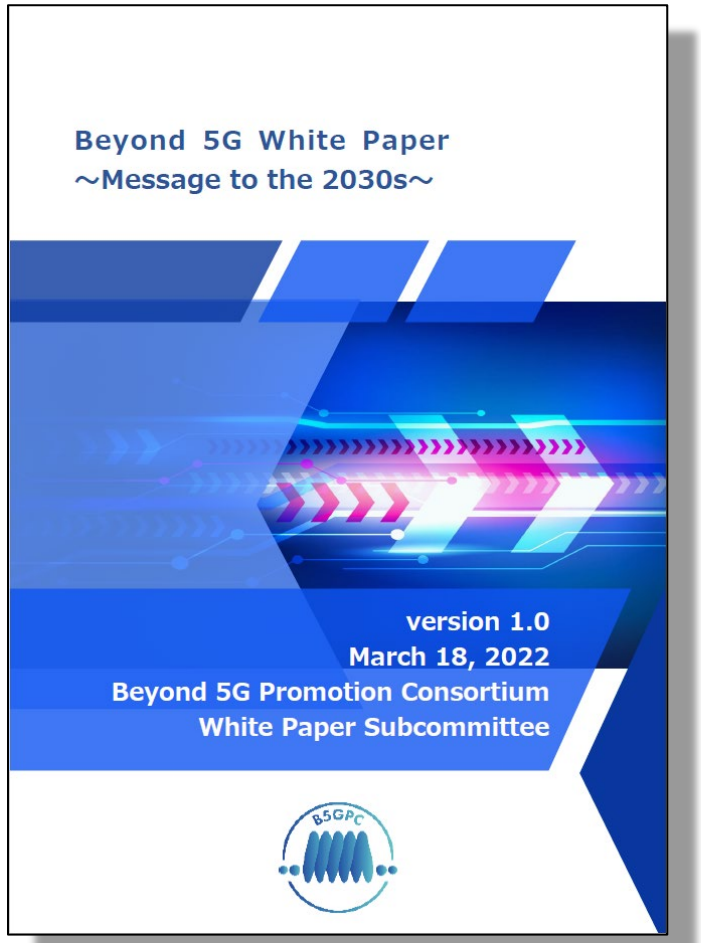
- **Started from June and held monthly.**
- **Speakers from various industries and discussions in Vision working group for vision and use cases in 2030s.**

List of 22 presenters in total at the workshop

June 15, 2021 1st Meeting	Telecom Services Association
	National Institute of Advanced Industrial Science and Technology
July 20, 2021 2nd Meeting	Social Welfare Corporation, Zenkoukai
	East Japan Railway Company
	CFA Society Japan
	Fuji Television Network
	Medical futurist Dr. Oku
Aug. 3, 2021 3rd Meeting	National Institute of Science and Technology Policy
	PREVENT Inc.
	Telexistence Inc.
	Arch Inc.
	Asratec Corp.

Sep. 14, 2021 4th Meeting	Toshiba Corporation
	Quora Inc.
	Japan Aerospace Exploration Agency
	Japan Science and Technology Agency
	Mach Corporation Co., Ltd.
Oct. 12, 2021 5th Meeting	Yamato Transport Co., Ltd.
	Shiftall Inc.
	Toyota Motor Corporation

Chapters in White Paper written by Vision Working Group



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Expectations from various industries for Beyond 5G

~ Examples from Section 4.x in the White Paper ~

4.3.1 Warehousing/Logistics

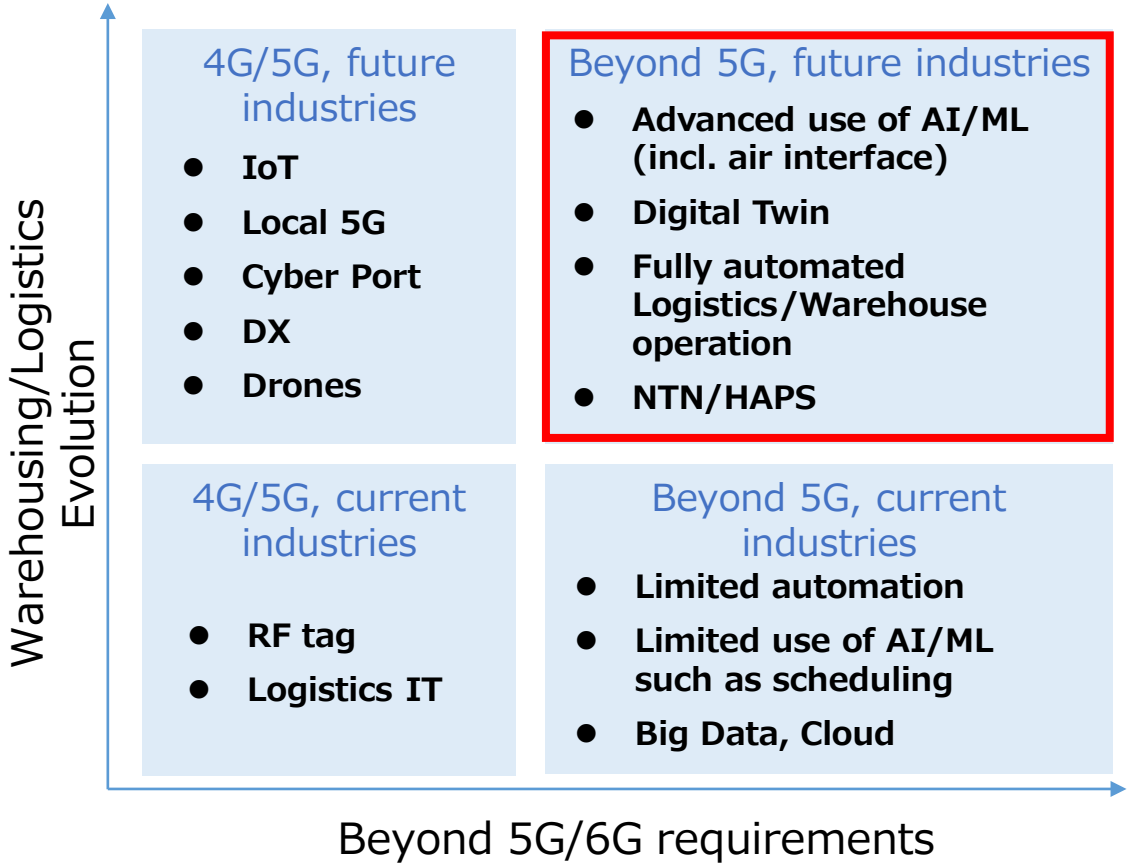
Current Situation

1. Demographic Trends and Labor Shortage
2. Safety and security against increasing natural disasters
3. Strengthening digitalization and innovation for Society5.0
4. Ensuring the sustainability of the global environment the SDGs
5. Response to pandemics

Expected Future of the industry

1. Fully optimized supply chain through Logistics DX and standardization (Simple and smooth logistics)
2. Logistics structural reforms against Labor shortage (Labor friendly Logistics)
3. Robust and sustainable Logistics Network (realizing strong and flexible logistics)

Expectation for Beyond 5G



Latency requirement is on **the order of milliseconds** in the local network, and time synchronization is required to **support PTP (microseconds)** as the accuracy of the internal clock including the radio section.

4.5 Media (1)

- **In 2030, people can enjoy more immersive media experiences utilizing virtual space and holographic communication, e.g., “the metaverse”.**

Current Situation

- ✓ Various multi-media contents including TV/radio, publishing and advertise business, SNS, etc.
- ✓ Due to pandemic, the digitalization has been accelerated, e.g., online live events.

Expected Future of the industry

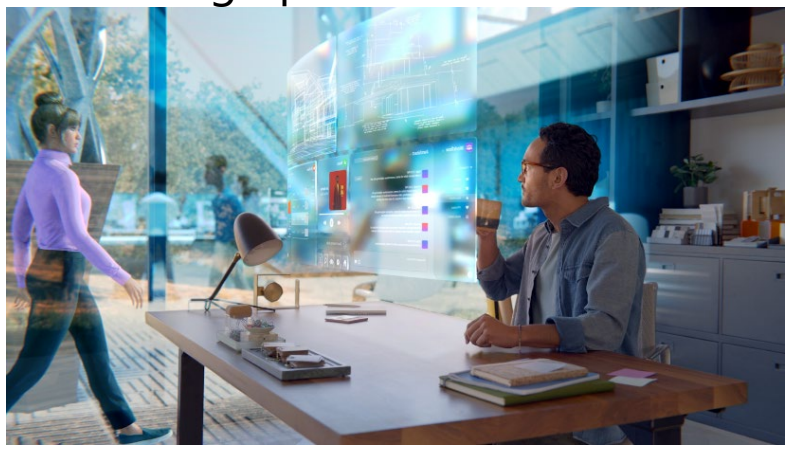
- ✓ All the contents can be accessed online via internet. Likewise, richer user-created contents can be delivered more easily regardless of time, place and device type.
- ✓ Utilization of virtual space and Holographic communication.
- ✓ Personalization/customization for more efficient contents delivery.

Online live event

Source: https://lineblog.me/livepress/archives/13261786.html

Entertainment in virtual space

Holographic communication

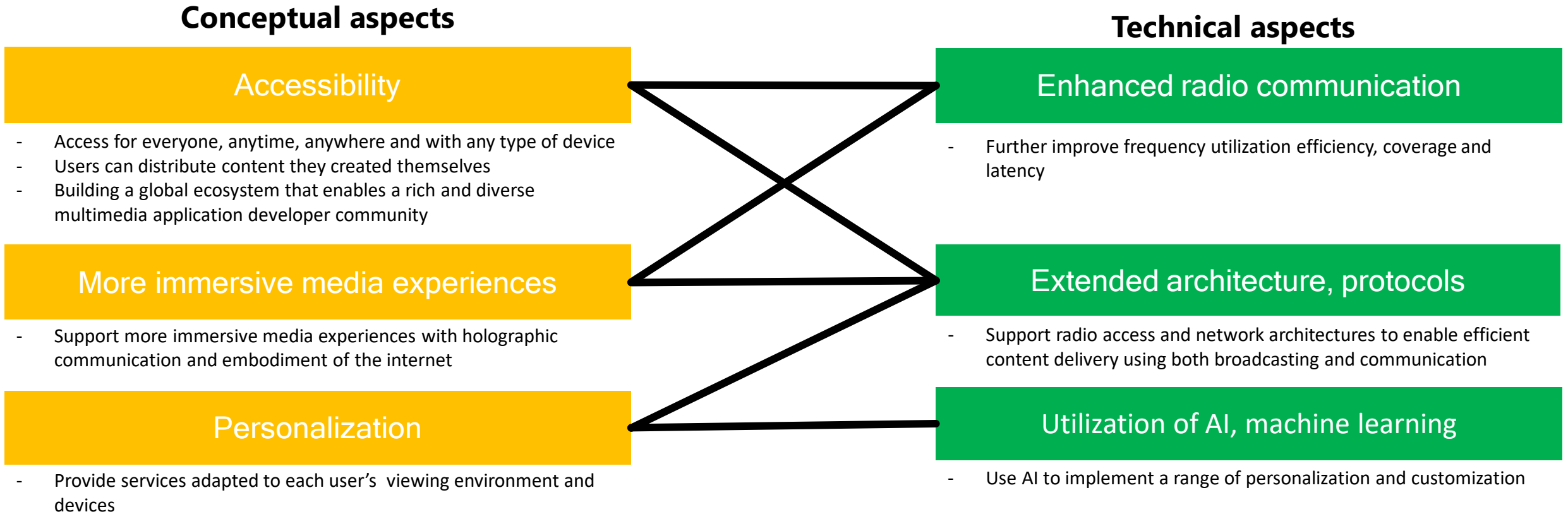


Source: https://about.fb.com/news/2021/10/facebook-company-is-now-meta/

4.5 Media (2)

- **The figure below summarizes the high-level requirements (Conceptual / Technical aspect) for beyond 5G.**
- **A few tens ~ hundreds Gbps of peak throughput can be expected for Holographic communication, as an example of performance for Beyond 5G.**

The black lines between the boxes represent what technical aspects will be relevant to the conceptual aspects



4.7 Automotive (1)

The aging society restricts people's mobility in rural areas, and population concentration in urban areas causes traffic congestion. A future society is envisioned in which all people can be ensured with unconstrained and efficient mobility irrespective of their living areas.

Issues Analysis

- Lack of drivers negatively affects the sustainability of public transportation in rural areas, while population concentration in urban areas causes traffic jam. Both adversely affect the quality of people's lives.
- Increased awareness of societal crisis on energy and environmental issues, and problems of traffic-accident caused by the aging society.

Key Tasks

- Realize a mobility-inclusive society that provides unconstrained and efficient mobility for all people
- Build a robust infrastructure for automated driving and safety driving assistance, and a low carbon-emission society

Future Vision

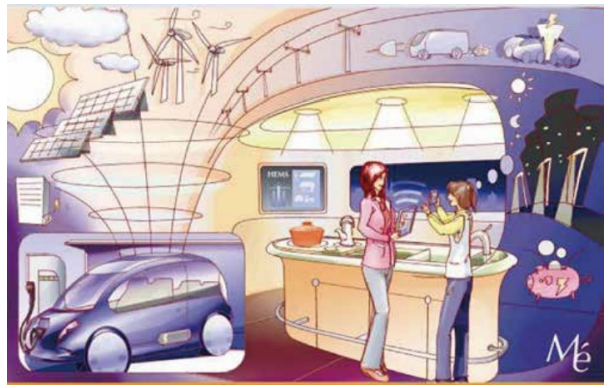
1. A society all people can move freely and efficiently

Source: ITS Japan

2. MaaS Platform allowing the Multi-modal mobility of people

Source: ITS Japan

3. Collaboration between vehicles with Smart Cities



Source: ITS Japan

4. Enabling digital society to realize Mobility-inclusive

Source: The Government of Japan, ITS Roadmap

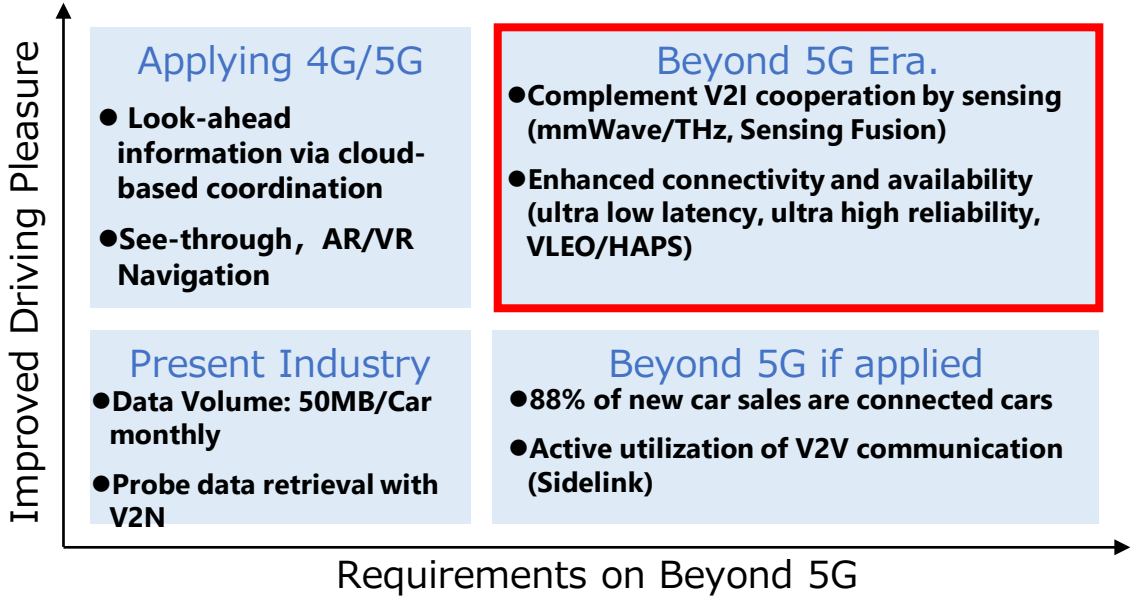
4.7 Automotive (2)

Towards Automotive Society in 2030 Era, Beyond 5G shall require the integration of highly accurate sensing and communication, distributed AI learning & inference, and ultra reliability

What are Required for Beyond 5G

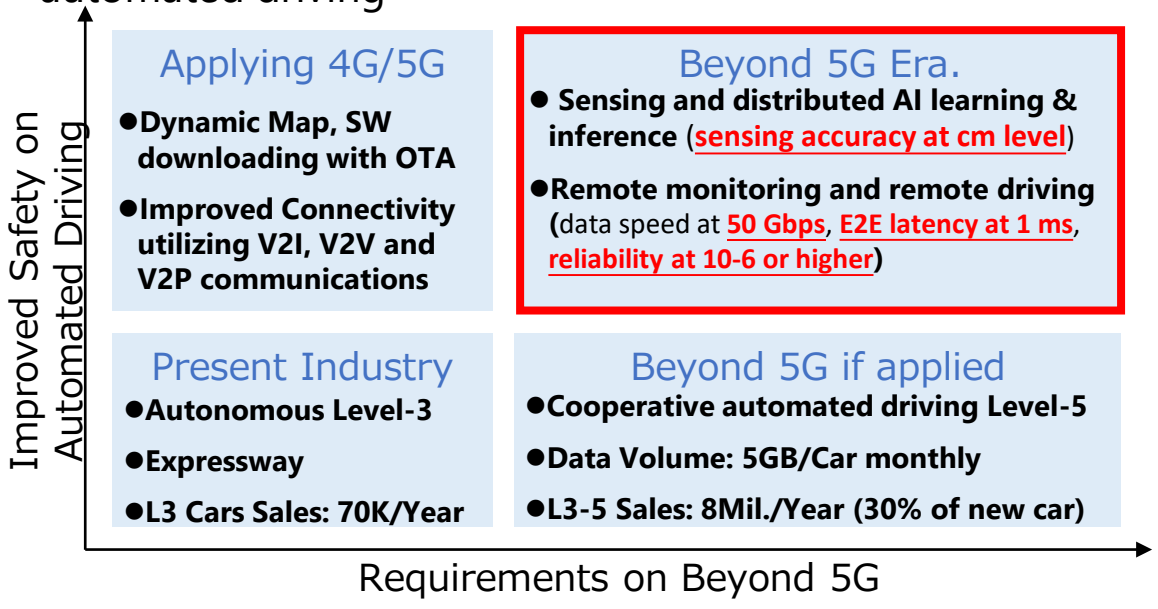
Safety Driving Assistance

Beyond 5G sensing and enhanced connectivity are required so as to support Safety Driving under extreme conditions, e.g., driving at intersections without a signal, under bad weather or in the event of a disaster.



Automated Driving

Integrated sensing and communication, distributed AI learning & inference, and quantum-cryptography-based security are required to accelerate the implementation of automated driving



4.12.1 Medical (1)

Current issues through analysis

1. Coexistence of various people in super-aging society
   - achieving harmony with a super-aging society, and to fulfill the role of presenting the world with solutions
2. New solutions to unknown diseases
   - putting systems and measures in place to respond and resolve them promptly when they occur.
3. Further development of medicine and medical device
   - achieving the world's highest medical technology standards and take the lead in the industry

Expectation of future life

1. Support and reproduction of physical functions and abilities

Source: Ministry of Health, Labor and Welfare (Home page)

2. Immediate response to unknown infectious diseases

Source: Cabinet Secretariat (COVID-19 Information and Resources)

3. Development of medical technologies

Source: Japan Agency for Medical Research and Development (Achievements)

4. Support for super-aging society

Source: Ministry of Health, Labor and Welfare (Home page)

5. Extension of healthy lifespan

Source: Ministry of Health, Labor and Welfare

4.12.1 Medical (2)

What is required for Beyond 5G

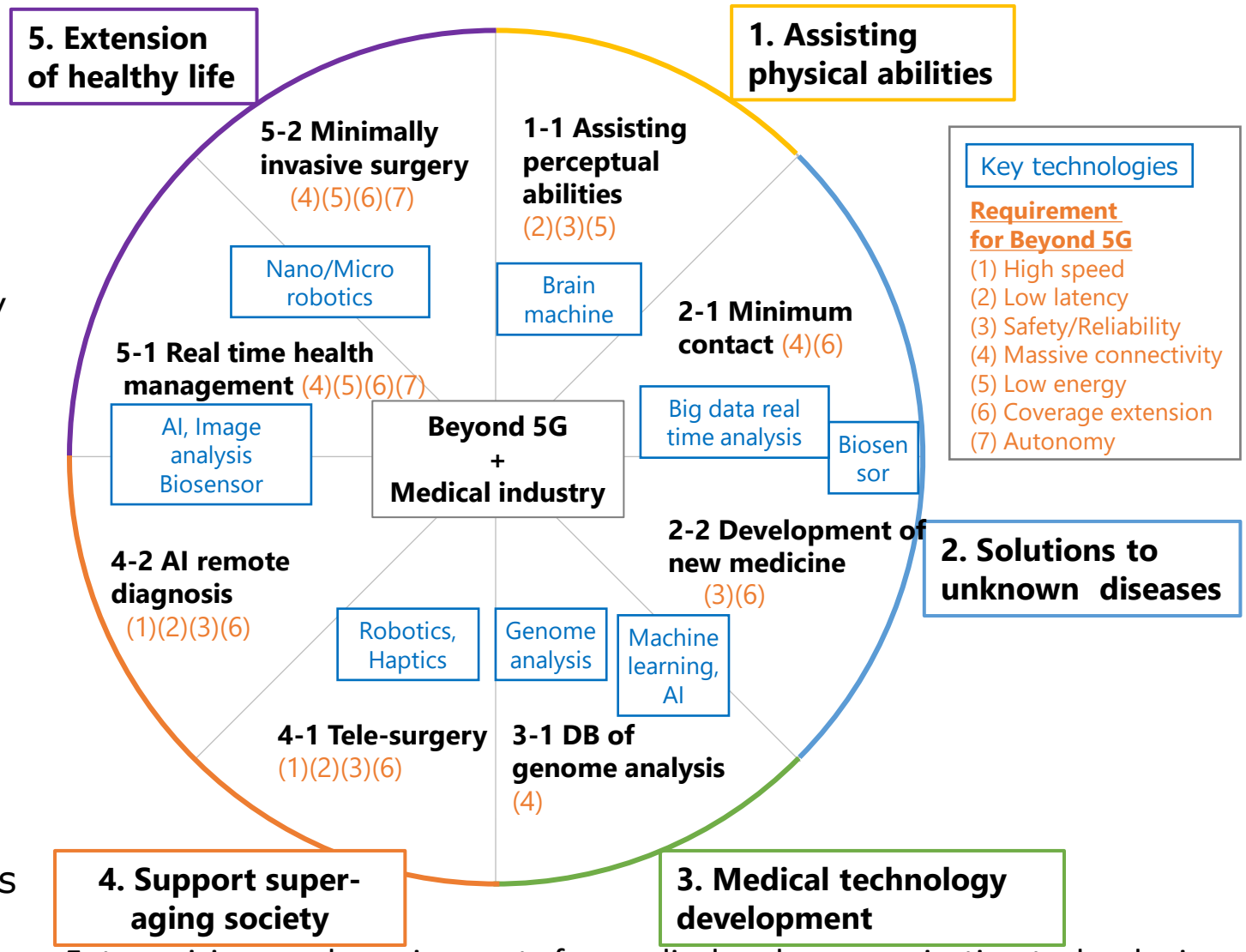
Use cases with Beyond 5G

1-1 Assisting perceptual abilities
Augmented human, Brain machine
2-1 Minimum contact, monitoring infections
Positioning, Centralized management of health status
3-1 DB of genome analysis
Personalized medicine, AI-based drug discovery
4-1 Tele-surgery
Robotics, AI based surgery
5-2 Minimally invasive surgery
Nano/Micro robotics, Energy harvesting

Beyond 5G requirements

Tele-surgery
- **Tens of Gbps** throughput
- **10^{-7}** reliability

Minimally invasive surgery
- **up to tens of millions/km²** connectivity
- Autonomous communication control of devices



Future visions and requirements for medical and communication technologies

4.15.1 Space (1)

To protect the people's lives on earth, it is required to contribute to solving social issues by space utilization. By developing of space utilization technology, efforts to expand the living area and activity area to space are required.

Current Situation Analysis

- ✓ Space utilization is mainly preceded by national government, specific industries, R&D and satellite broadcasting
- ✓ New efforts are required by utilizing space and space development technology to solve social issues.

Social Issues

1. Japan's aging society and population decline
2. Global warming, intensification of natural disasters
3. Shift to clean energy, energy competition
4. Increased pandemic risk and realization of "New normal"
5. Realization of a society that affirms diverse ways of life

Expected Future Image

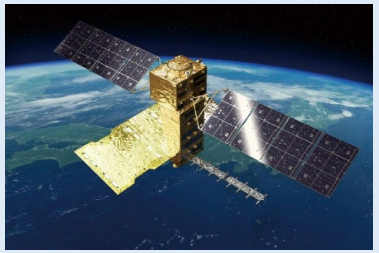
1. Communication to protect life

Smart communication infrastructure using space

Source: Smart City Public-Private Partnership Platform HP

2. Protect life by space data

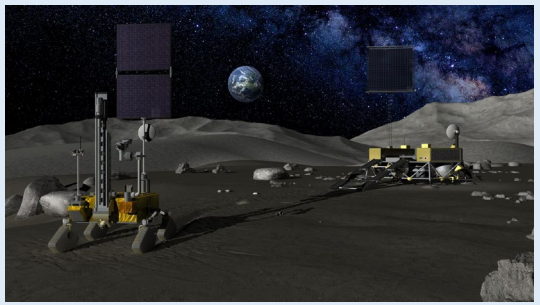
Space-generated data from a secure and resilient environment



Source: JAXA observation satellite HP

3. Utilization of space environment

Expanding the area of human activity to space



Source: JAXA

4. Adapt space to lifestyle

Realizing each diverse lifestyle using space

Source:JAXA/Adobe.stock.com

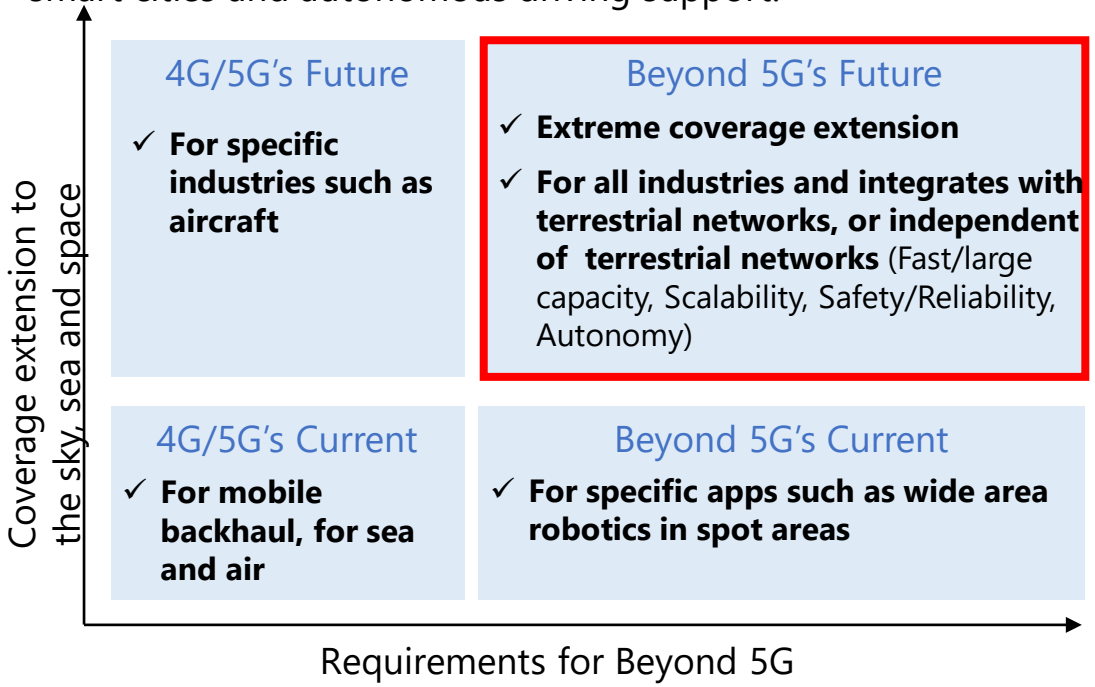
4.15.1 Space (2)

Fast/large capacity, scalability, safety, reliability, autonomy and low latency are required as requirements for 5G and beyond toward expected future image to protect the people's lives on earth.

The requirements of 5G and beyond

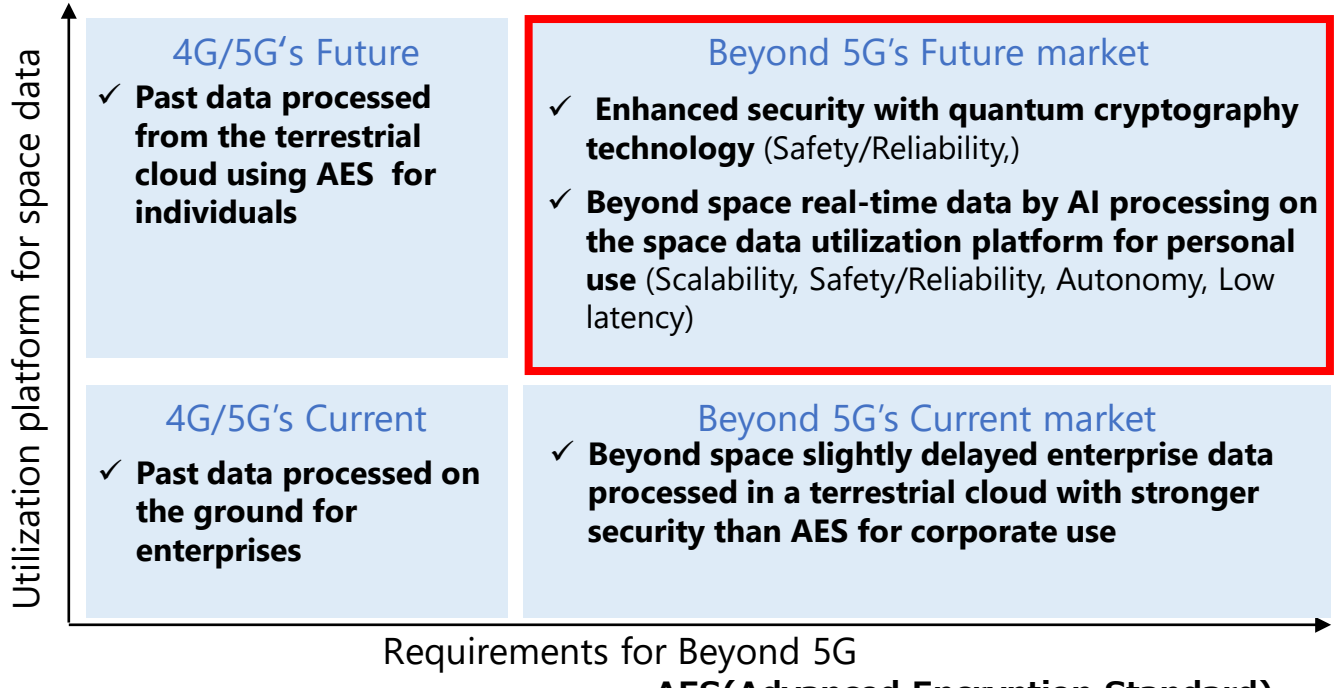
Coverage extension to the sky, sea and space

Fast/large capacity(approximately **several dozens of Gbps** by low/medium earth orbit satellite), scalability, safety/reliability and autonomy as Beyond 5G's performance are required for smart cities and autonomous driving support.



Utilization platform for space data

Scalability, safety/reliability, autonomy and low latency as Beyond 5G's performance are required for utilization platform for data observed and generated in space.



AES(Advanced Encryption Standard)

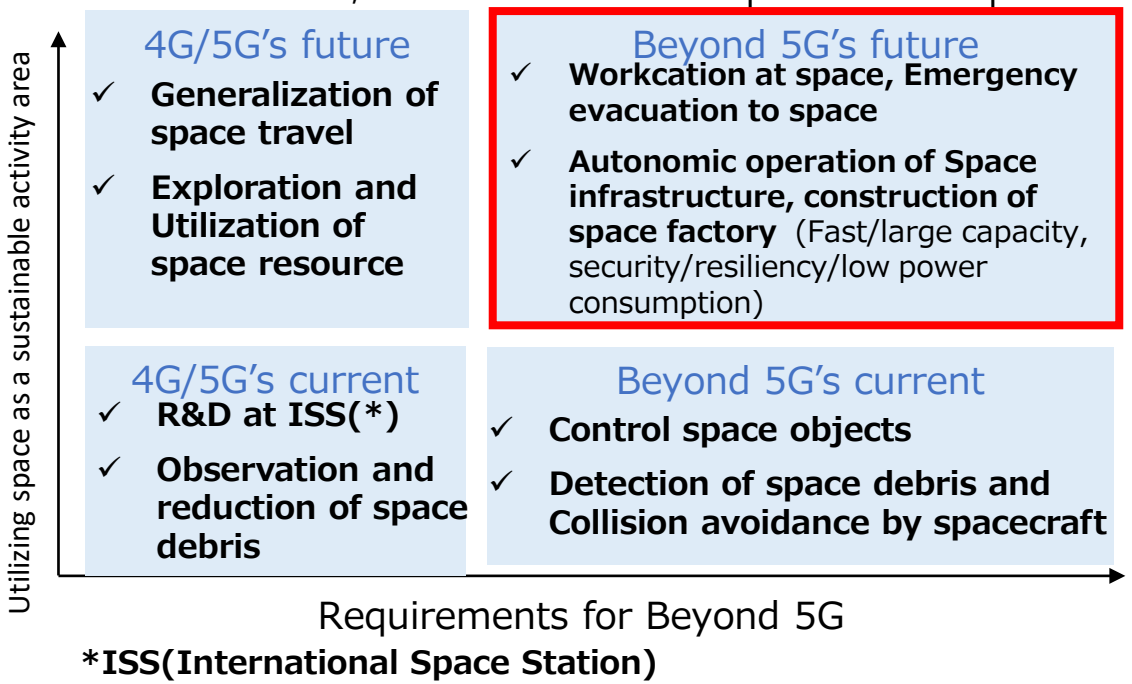
4.15.1 Space (3)

Fast/large capacity, security/resiliency, low latency, scalability and low power consumption are required as requirements for 5G and beyond toward expanding the area of human activity to space and realizing each various lifestyle using space.

The requirements of 5G and beyond

Utilizing space as a sustainable activity area

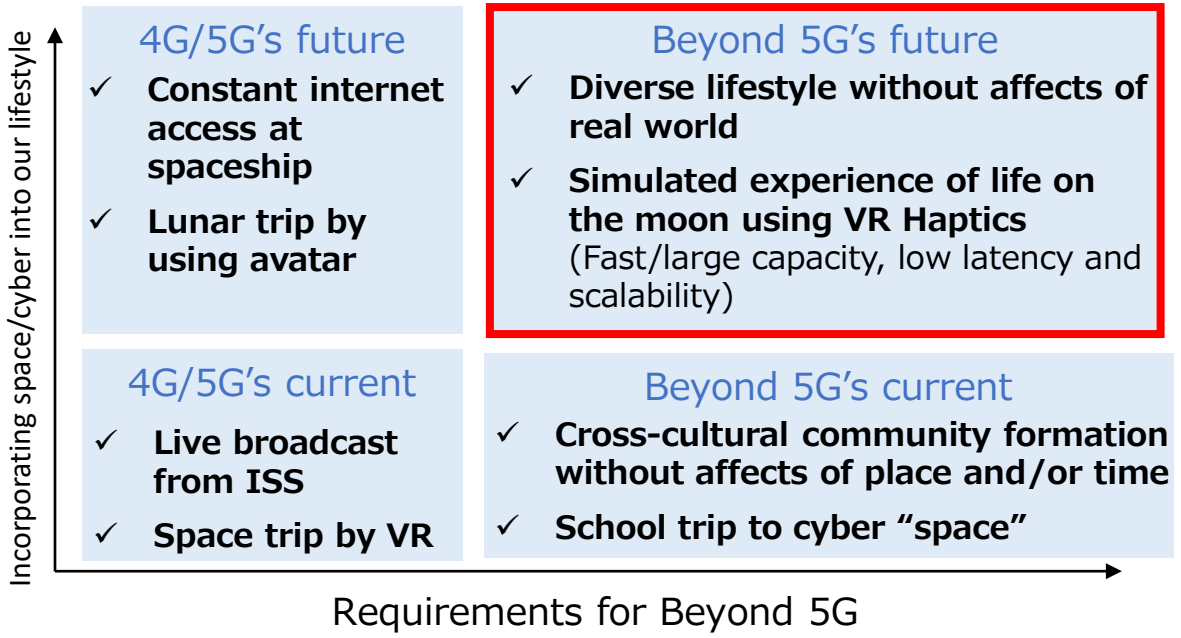
Fast/Large capacity and security/resiliency as Beyond 5G's performance are required for utilization space as a human activity area (moon and/or planets) sustainably. In addition, since the installed resources are limited, it is vital to realize low power consumption.



*ISS(International Space Station)

Incorporating space/cyber into our lifestyle

Fast/Large capacity, low latency and scalability as Beyond 5G's performance are required for cross-cultural communication by using space/cyber which has no border.



Capabilities required in Beyond 5G

~ Section 5.1 in the White Paper ~

Summary in Sec. 5.1 “Capabilities required to Beyond 5G” (1)

Category	Requirements	Capabilities required by each industry
Quantitative requirements	Ultra-fast and large capacity	• **10 to 100 Gbps** (Uncompressed transmission for holographic communications (Media)) • **50 Gbps** (Remote monitoring and remote control (Automotive)) • **10 to 100 Gbps** (Smart logistics (Retail and wholesale distribution)) • **Several tens of Gbps** (Remote surgery (Healthcare)) • **48 to 200 Gbps** (Volumetric video) • **Several tens of Gbps** (Low to medium orbit (Space)) • **10 Mbps** (Natural disaster prevention measures (Society))
	Ultra-low latency	• **Order of milliseconds*** (within the local network (Fully automatic operation of logistics facilities (Warehousing and logistics)) • **Several milliseconds*** (Emergency stops for super-high-speed trains (Railway)) • 100 ms* (Immersive remote-control system (Energy resources)) • **1 ms** (Remote monitoring and remote control (Automotive)) • **100 micro sec*** for local communications (Motion control (Machinery)) • 1 ms* (Robot remote control (Semiconductor)) • Motion-to-photon (MTP) 10 ms*, time-to-present (TTP) 70 ms* (Volumetric video) * Including processing delay at application layers
	Time synchronization accuracy	Time synchronization compatible with Precision Time Protocol (PTP) for the accuracy of internal clocks, including radio segments, (in microseconds) (Fully automatic operation of logistics facilities (Warehouse and logistics))

Summary in Sec. 5.1 “Capabilities required to Beyond 5G” (2)

Category	Requirements	Capabilities required by each industry
Quantitative requirements	Ultra-security and resiliency	• **10^{-6}** (Remote monitoring and remote control (Automotive)) • **10^{-7}** (Remote surgery (Healthcare)) (unit: block error rate)
	Positioning and sensing	• Positioning accuracy of 1 to 2 cm (Civil engineering (Construction and real estate)) • Centimeter-level sensing accuracy (Vehicles traveling singly in rural areas or at night (Automobile))
	Ultra-numerous connectivity	• **Several millions to tens of millions of devices/ km^2** (In-vivo devices (Healthcare))
	Coverage	• Supersonic passenger aircraft flying at higher altitudes than current passenger aircraft, which is **around 10 km**, and coverage area at an altitude of **more than 100 km** in outer space (Aircraft) • **100% land coverage** (Telecommunications and IT) • **Coverage area in outer space and the moon** (Space) • One HAPS aircraft covers tens to hundreds of kilometers in radius and a few kilometers above the ground (HAPS)

Summary in Sec. 5.1 “Capabilities required to Beyond 5G” (3)

Category	Requirements	Capabilities required by each industry
Qualitative requirements	Autonomy	• Autonomous optimization and future prediction functions that enable the provision of the necessary goods and services to the people who need them, when and where they need them (Telecommunications and IT industries) • Enhanced autonomy of different devices and universal compatibility for connection and operation (Electronics and precision electronics) • Automatic device connection with zero touch (In-vivo devices, camera collaboration (Healthcare))
	Ultra-low power consumption	• Use of lunar and planetary exploration probes with extremely limited on-board resources (Space)
	Others	• Distributed learning and inference functions (Processing using multiple vehicles and Beyond 5G base stations (Automobile)) • Inter-device interfaces, open APIs and open interfaces between non-communication systems, and common platforms for data analysis/ processing and content handling (Device collaboration (Electronics and precision electronics)) • Evacuation instructions can be received even when traveling at a speed of **1,000 km/h** (Natural disaster prevention measures (Society)) • NTN nodes can automatically connect to other NTN nodes and local sensor networks (Space) • Mesh networks that do not go through on-ground systems can be built through single NTN nodes or in combination with other NTN nodes (Space)

Summary

Common expectations from several industries

Common themes related to several industries	Expectations and dreams in industries	Expectations to Beyond 5G
(a) Decreasing birthrate and aging population	• Utilization of robots • Remote control • Autonomous driving	Ultra-fast and large capacity (up to 50Gbps) Ultra low latency (100 micro sec to 1 ms), Ultra-resiliency (10^{-7})
(b) Safe and secure	Prediction of natural disasters, life saving, and early recovery	100% coverage area with at least 10 Mbps
(c) Further wonderful life	• Flying cars • Immersive experience	Ultra-fast and large capacity (up to few 100 Gbps), Ultra low latency (1 ms), and Coverage area in outer space
(d) Exciting future	Activity supports in outer space and the moon	Communication infrastructure in outer space

Summary of presentation and future works

- New trials for developing Vision part in White Paper (ver.1.0) and its originality are as follows:
  - Valuable information from various industries were collected through "**Workshop on Society in 2030s**," which was newly established by Vision WG
  - In addition to information from the workshop, investigations and studies were conducted by Vision WG, then WG defined capabilities required to Beyond 5G
  - Noteworthy points can be picked up as follows:
    - ✓ In order to be widely used as a new infrastructure for future social platforms, not only broadband and low latency capabilities, **coverage area in the sky** and **ultra-high reliability in Beyond 5G system are required**
    - ✓ Capabilities for **3D video transmissions are required** in both real and virtual spaces to feel immersive images like holography for future media services
    - ✓ Furthermore, **coverage area for outer space including the moon** will also be required in Beyond 5G

- Future works ~ toward ver.2.0, which will be issued in March 2023 ~
  - To collect options and comments from various industries while introducing the White Paper
  - To update the White Paper, especially contents of industries, for which we need further analysis and studies
  - To clarify issues in telco industry toward Beyond 5G

Appendix

Outline of Chapter 2 to 4 in the White Paper

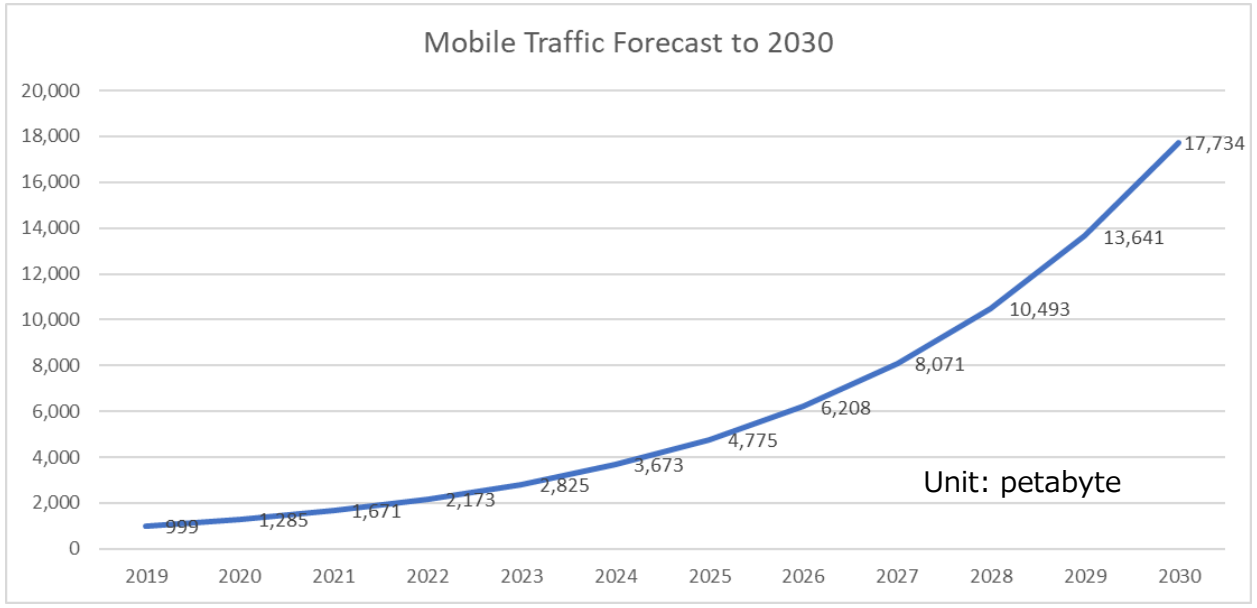
2. Traffic trends

Current status analysis and issues

1. Stay-at-home demand with Covid-19
   - Mobile traffic increased due to mobile apps, video distribution services, online games, etc. in Covid-19.
2. 5G's trendy services unknown
   - 5G has already appeared, but 5G's trendy applications and services are unclear.

Quote : ASCII.jp VR conference / collaboration tool

Expected future image/What is required of Beyond 5G



1. Expectation for new videophones and online meetings
   - Expect the arrival of videophones using new devices and online conferences using avatars.
2. Expectation for the Metaverse market
   - Expect killer apps that avatars come and go between physical space and cyberspace by the arrival of VR / AR / MR services.
3. Expansion of mobile phone usage coverage to sea, mountains and space
   - Mobile phone will improve the convenience of connecting anywhere.

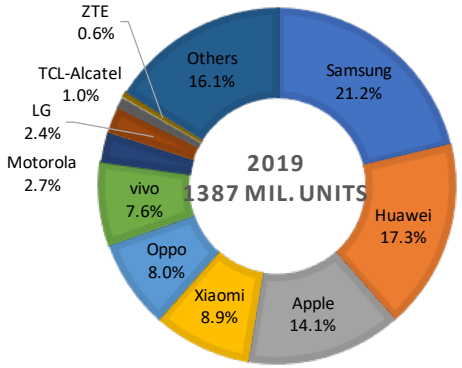
3. Market Trend of Communication Industry (1)

The market for small cell base stations and electronic components is expected to expand with the utilization of the millimeter-wave band and terahertz band, which are expected to be used in Beyond 5G.

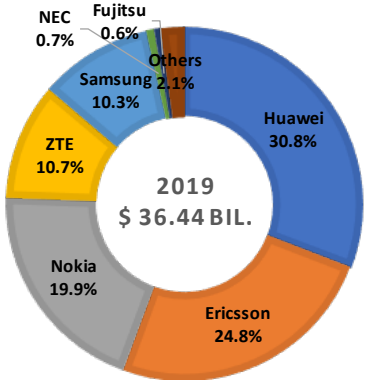
Share structure in the world market

Smartphone & Macro cell base station

While the companies that make up the market share of smartphones have changed significantly in the past 10 years, the market share of macro cell base stations has changed, but the lineup of companies has not changed significantly.



Smartphone (based on the number of units)



Macro cell base station (based on shipping value)

Beyond 5G is expected to expand the market for small cell base stations as the higher frequency bands are utilized.

Electronic components

It is expected that the number of important electronic components will increase by utilizing the high frequency band. If we can obtain a high market share, we may be able to reduce costs through mass production.

Smartphone related parts	Outline	Global market share (based on shipment quantity)		
		1	2	3
Multilayer ceramic chip capacitor (MLCC)	A component that controls voltage in an electric circuit	Murata Manufacturing Around 40%	Samsung EM (KR) Around 20%	Taiyo Yuden 10~15%
Surface acoustic wave (SAW) filter	A filter that extracts only the required frequency from the wireless signal	Murata Manufacturing Over 50%	Qualcomm (US) 30~35%	
Ceramic oscillator	Used as a clock signal source for digital circuits, etc.	Murata Manufacturing 75%		
Wireless LAN module	Wireless LAN module attached to mobile terminals, etc.	Murata Manufacturing 50~60%	USI (CN)	TDK
Bluetooth module	Module attached to mobile terminals, etc.	Murata Manufacturing 50%	Alps Alpine	
Inductor	Used in all high frequency circuits	TDK 25~30%	Murata Manufacturing	Taiyo Yuden
Camera actuator	Used for camera autofocus and camera shake correction	Alps Alpine 70~80%	MinebeaMitsumi	TDK
CMOS image sensor	Used with smartphone cameras, etc.	Sony 50%	Samsung (KR) 24%	OmniVision (US) 14%
Lithium ion polymer battery	Thin battery	TDK 40~50%	Samsung SDI (KR) 30%	LG Chem (KR) 10~20%

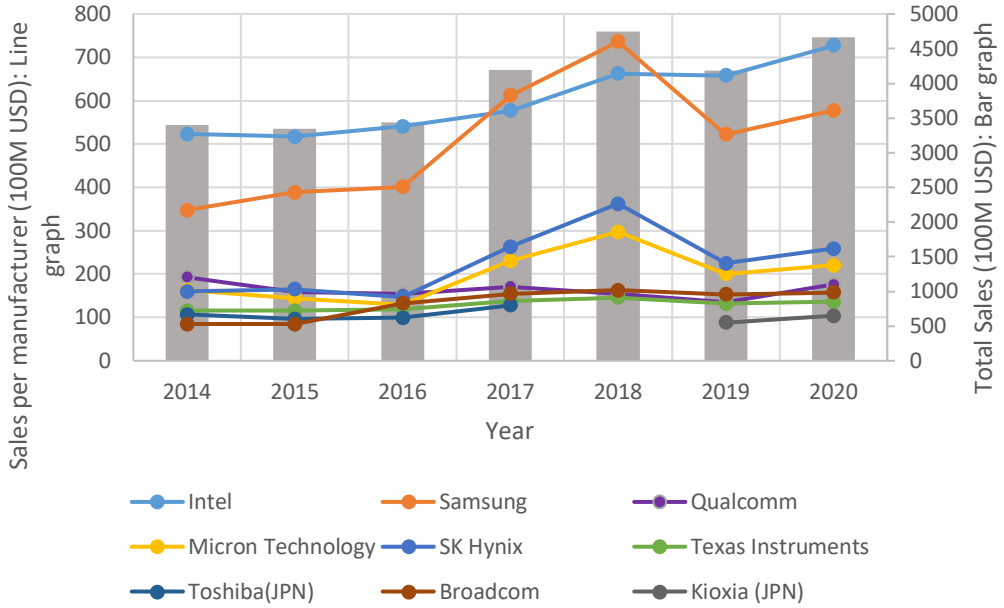
3. Market Trend of Communication Industry (2)

The semiconductor market is expected to continue expanding in the future, and power consumption tends to increase accordingly.
For Beyond 5G, it is important to develop technologies to reduce power

Trends related to the telecommunications industry

Semiconductor

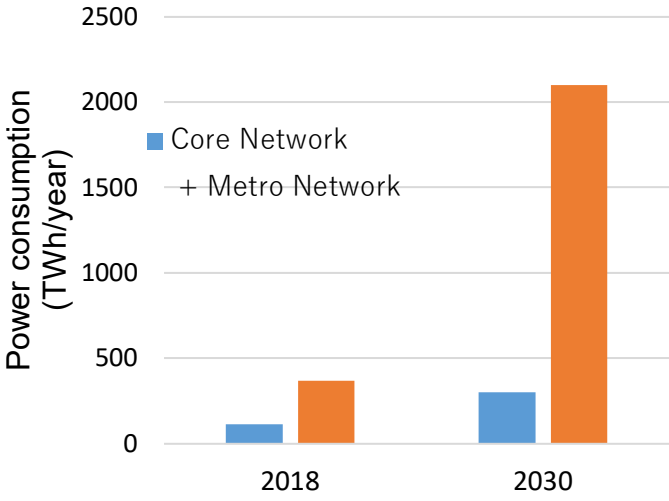
Although the semiconductor market is in a boom and bust, it is generally on a growth trend, with US and Korean companies gaining a high market share.



Semiconductor manufacturer share

Power consumption

Network-related power consumption is expected to increase about four to five times in 2030 compared to 2018. If the power consumption per base station increases, the power consumption will increase further.



Global network-related power consumption

4.1 Finance

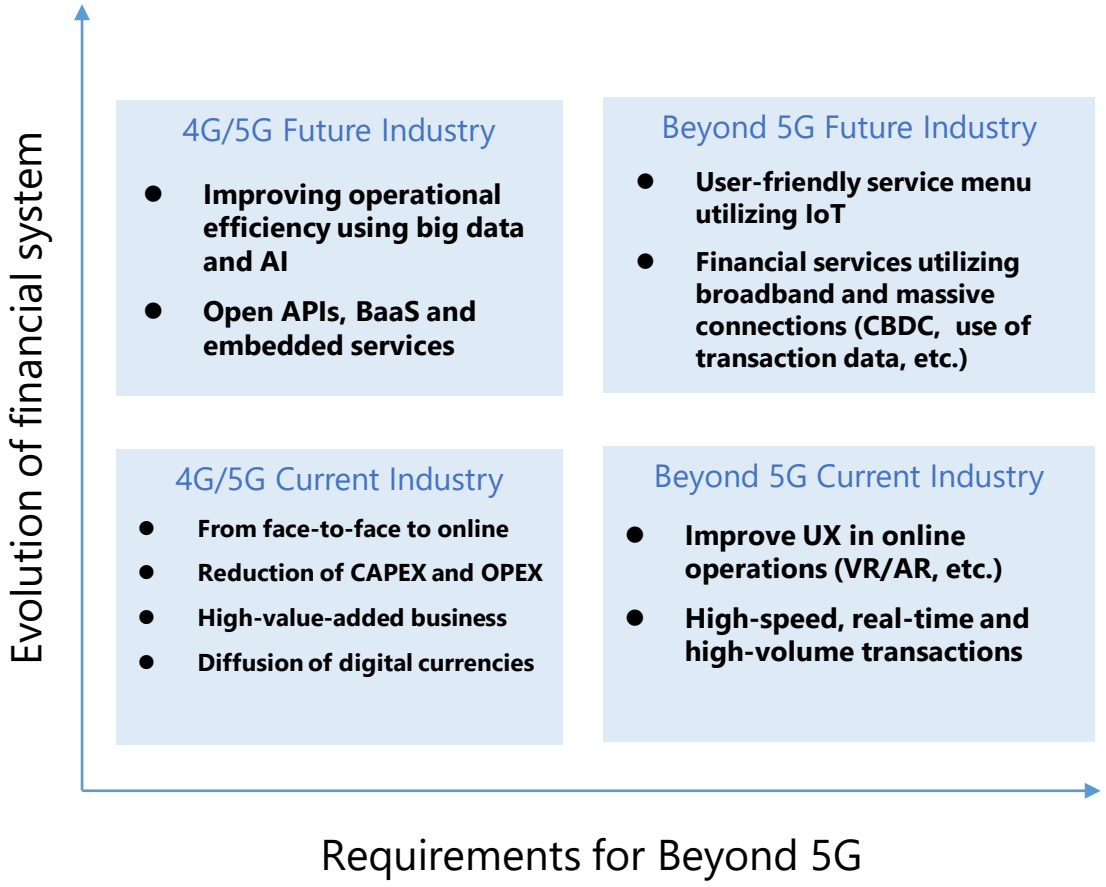
Current State Analysis and Challenges

1. Shift from face-to-face business to online business
2. Reduction of CAPEX and OPEX (Store consolidation, scale reduction, ATM reduction)
3. Shift to high-value-added business (Alternative investments, advisory services, etc.)
4. Diffusion of digital currencies

Future Vision

1. Upgrading existing services
   - ✓ Improving operational efficiency using big data and AI
   - ✓ Service menu suitable for users
2. Integrated services with other industries
   - ✓ Open APIs, BaaS
   - ✓ Embedded finance
3. New financial services
   - ✓ Central Bank Digital Currency (CBDC)
   - ✓ Secondary use of transaction data, etc.

What is required for Beyond 5G



CBDC: Central Bank Digital Currency

4.2 Construction / Real estate (1)

Current State Analysis and Challenges

Construction

- Building a sustainable industry
- Reduced number of employees, and aging
- Workstyle reforms by improving wage levels and expanding holidays, and improved productivity through use of ICT.
- "i-Construction" aiming at drastic productivity improvement

Real estate

- Aging workforce and shortage of successors
- Idle and/or deteriorated real estate
- Support for the diversified lifestyles
- Safe and secure real estate transaction and realization of sustainable society

Future Vision

Construction

- Innovative technologies in construction/infrastructure areas
- Business efficiency and sophistication due to CIM / BIM

BIM/CIM: Building/ Construction Information Modeling, Management

i-Construction

Real estate

Utilization of new technologies such as AI, IoT and robots, improved efficiency and convenience

4.2 Construction / Real estate (2)

What is required for Beyond 5G

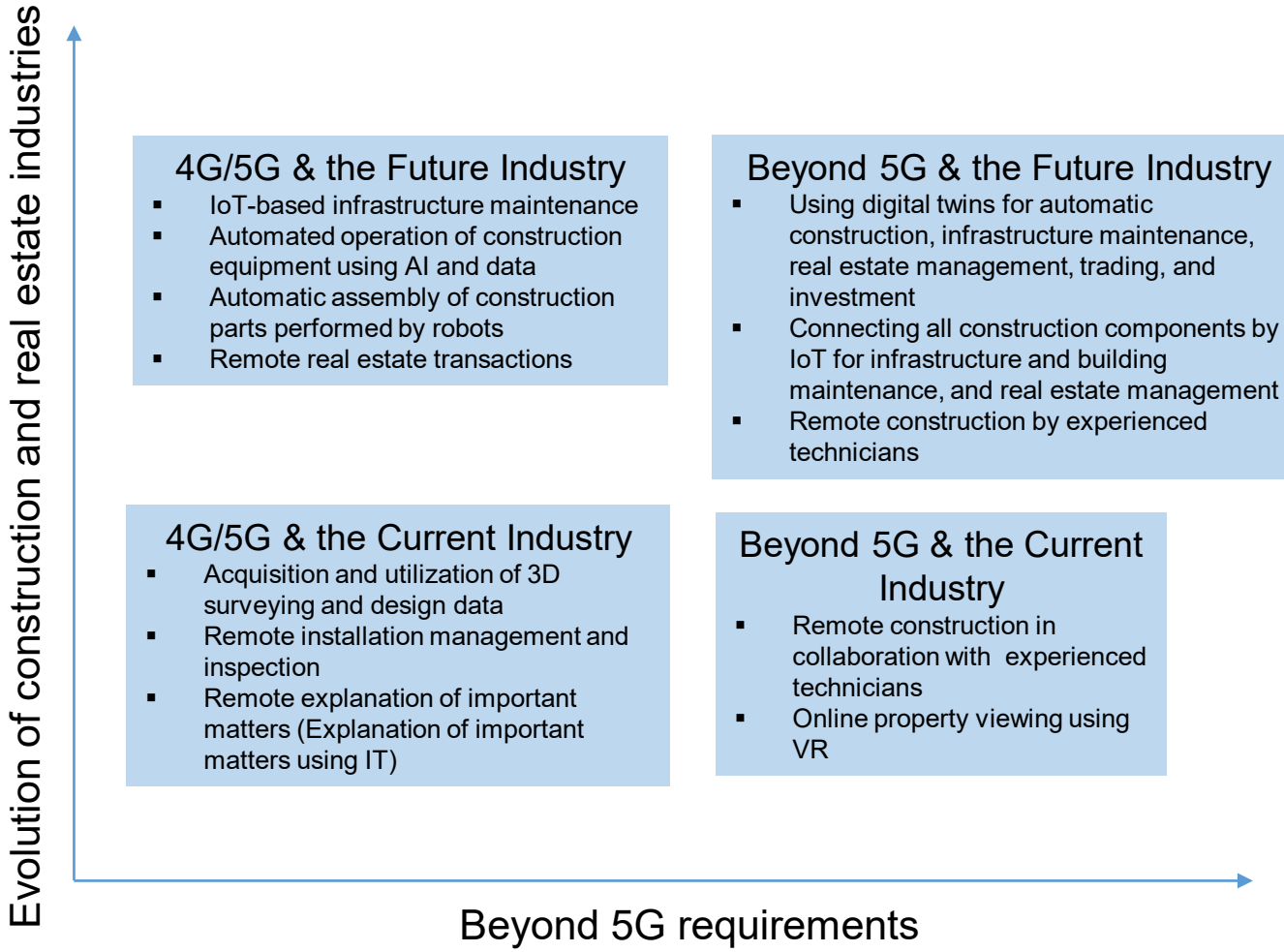
Expected Use Cases

Construction

- Remote construction by experienced technicians
  - Collaborate with experienced technicians with VR technology
  - Remote control of construction machinery or robots with haptics and/or VR technology
- Maintenance and management of buildings or infrastructure by IoT
- Design and construction in physical and cyber space
- Fully automated construction by automated construction machines and robots

Real estate

- maintenance and management of Real estate by IoT
- Real estate management, transaction and investment by digital twin
- Online property viewing using VR



Requirements for Beyond 5G

- For automatic construction using digital twins, **1 to 2 cm location accuracy** is required in civil engineering work.

4.3.1 Warehousing/Logistics

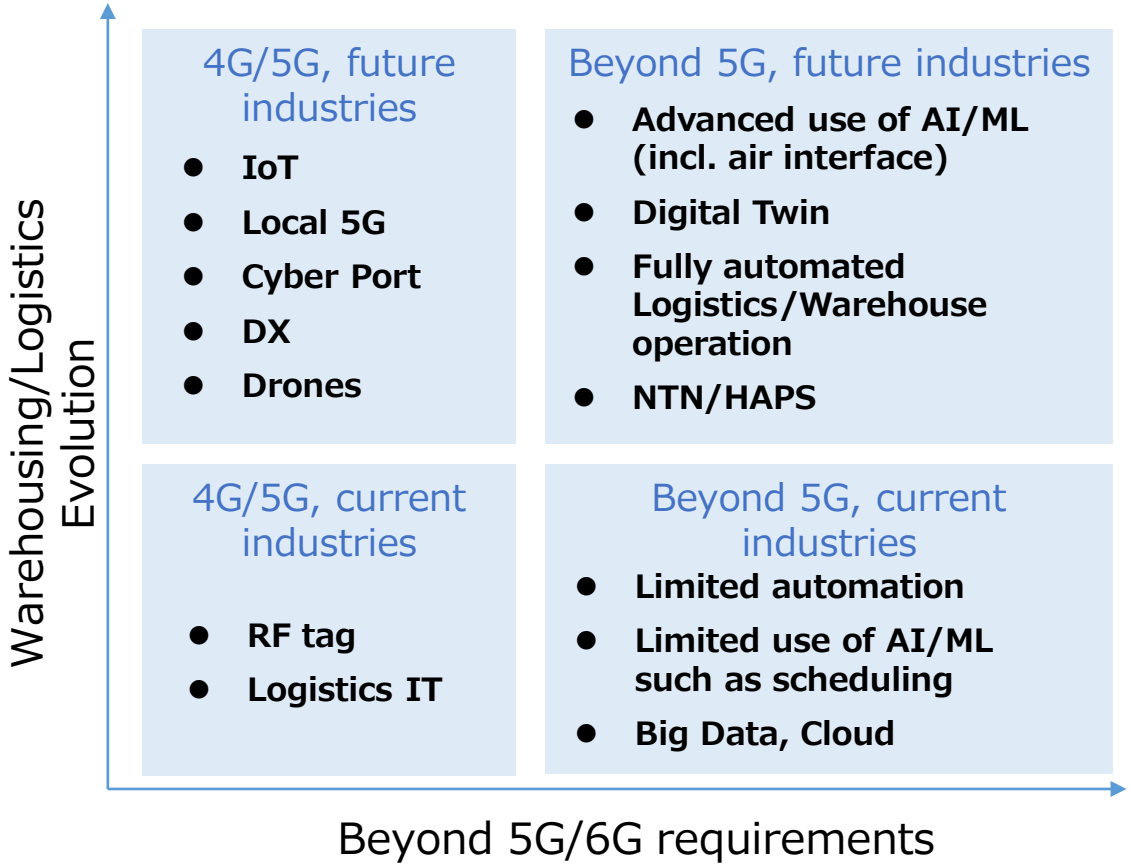
Current Situation

1. Demographic Trends and Labor Shortage
2. Safety and security against increasing natural disasters
3. Strengthening digitalization and innovation for Society5.0
4. Ensuring the sustainability of the global environment the SDGs
5. Response to pandemics

Expected Future of the industry

1. Fully optimized supply chain through Logistics DX and standardization (Simple and smooth logistics)
2. Logistics structural reforms against Labor shortage (Labor friendly Logistics)
3. Robust and sustainable Logistics Network (realizing strong and flexible logistics)

Expectation for Beyond 5G



Latency requirement is on **the order of milliseconds** in the local network, and time synchronization is required to **support PTP (microseconds)** as the accuracy of the internal clock including the radio section.

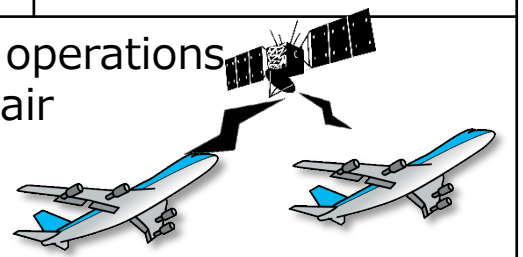
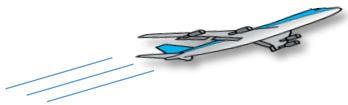
4.3.2 Aviation (1)

The number of air travelers is on an increasing trend, reflecting growth of the global economy. Safe, secure and highly efficient operation, meet diverse needs, climate and environment-friendliness are demanded

Current situation and issues

- ✓ The number of air travelers is on an increasing trend, reflecting growth of the global economy.
- ✓ The services required of the aviation industry are becoming more diverse. Services at airports and aircraft must be improved to suit diverse passenger needs.
- ✓ Realizing a decarbonized society entails the use of fuel-efficient aircraft and equipment and further weight reduction are considered.
- ✓ Advanced air traffic management systems are currently being developed, e.g. through the CARATS roadmap by the Ministry of Land, Infrastructure, Transport and Tourism in Japan
- ✓ Safe and secure operation with increasing the rigor of security inspections while reducing the burden

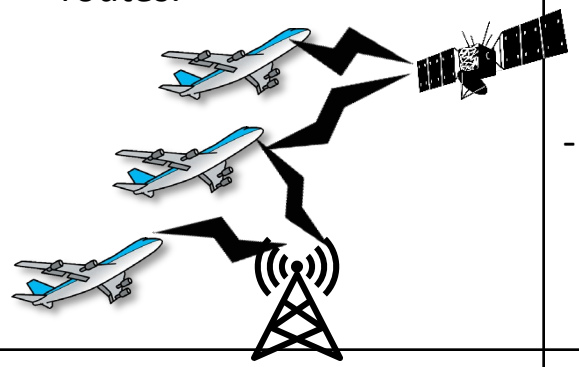
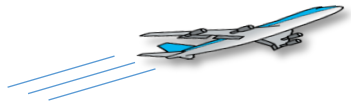
Expected future image

Passenger service	Safe and stress-free transportation, including at the airport	Comfortable in-flight service 
Technical evolution of the aircraft	Improved fuel efficiency and achieve decarbonization	Piloting assistance and unmanned operations
Air traffic control	Increase density of operations through advanced air traffic control 	
New flight service	Safe and comfortable operation of drones and flying cars 	Supersonic aircraft 

4.3.2 Aviation (2)

Beyond 5G features such as expanded coverage to the sky, high-speed, high-capacity comm., URLLC and high-precision positioning contribute to the aviation industry

Services that can be achieved with Beyond 5G

	Comfortable in-flight service	Improved fuel efficiency and decarbonization	Increase density of operations through advanced air traffic control	Drones and flying cars	Supersonic aircraft
	- VR / AR utilization - Provide more comfortable space and time by providing personalized environment	Wireless avionics intra-communication (WAIC).	- Zero waiting time for takeoffs and landings - Operation on fuel-efficient routes. 	- Drones for logistics, measurement, monitoring, disaster response, and infrastructure inspection. - Flaying taxi, emergency vehicles. 	- The comeback of supersonic aircraft - High-speed point-to-point suborbital transport 
Beyond 5Gs's contributions	• High-speed, high-capacity communications in flight.	• URLLC • Low power consumption sensor device	• High-precision positioning / environmental sensing • Seamless terrestrial and non terrestrial communication.	• URLLC at low altitude. • Ultra-high-speed, large-capacity communication to high-speed mobiles .	• Coverage areas of **high-altitude above 10km** and outer spaces (**altitudes above 100 km**)

4.3.3 Railway Industry (1)

Mobility needs have declined due to population decrease and changes working styles. Ambidexterity is required to “Exploitation” and “Exploration”.

Current Situation Analysis

- ✓ Mobility needs declined due to population decline and changes working styles.
- ✓ Ambidexterity is required to deepen the existing railway business and search for new profitable businesses.

Task

1. Zero accidents and early restoration
2. Aging and population decline
3. Aging infrastructure and systems
4. Distributed society

Expected Future Image

1. Safe and Secure

Utilization of IoT and robots

Source: Tokyo Metro, Demonstration experiment of robot

2. Automation

Self-driving and early restoration of timetable

Source: JR East, Automatic Train Operation

3. Improving Service

MaaS cooperation and all-in-one payment

Source: MLIT, Promotion of Japanese version of MaaS

4. Town Planning

Living in a new city that transcends space

Source: 4th meeting of Vision Working Group, JR East’s presentation

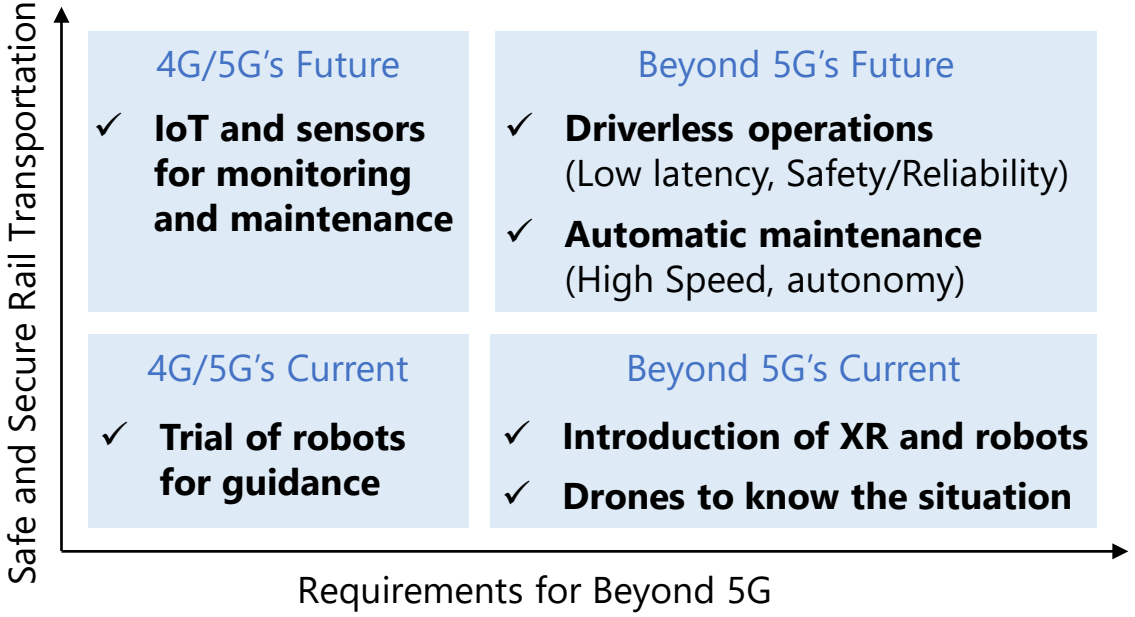
4.3.3 Railway Industry (2)

Low latency, safety/reliability, and autonomy are required as requirements unique to Beyond 5G toward expected future image.

What is Required for Beyond 5G

Expected use cases

Driverless operations and automatic maintenance are expected as use cases for Beyond 5G.



Requirements for Beyond 5G

Driverless operations use cases require highly reliable real-time wireless communication.

Low Latency	In an emergency stop of an ultra-high-speed railway, **an end-to-end delay time of about several milliseconds** is required.
Safety/Reliability	In CBTC (Communications-Based Train Control) systems, **highly reliable real-time wireless communication** is required to prevent train collisions and overspeeds.

4.4 Communication and IT (1)

Necessity of creating a mechanism by which smart solutions can be found through smartification via a digital transformation and by promoting the concept of data free flow with trust. Such a mechanism could be one that finds solutions by utilizing big data in real time, and thereby projecting what is happening in physical space to cyberspace.

Current Situation Analysis & Task

- ✓ Development of an advanced communications infrastructure : Safely and reliably realize extremely high-level data synchronization across both physical and cyber space everywhere.
- ✓ The construction of platforms that operate autonomously : Establishing technologies and rules for all machines to work autonomously with sensors
- ✓ Strengthen security and disaster resistance : Ensuring cyber security and a stable network that prevent communication interruptions even in times of disaster

Expected Future Image

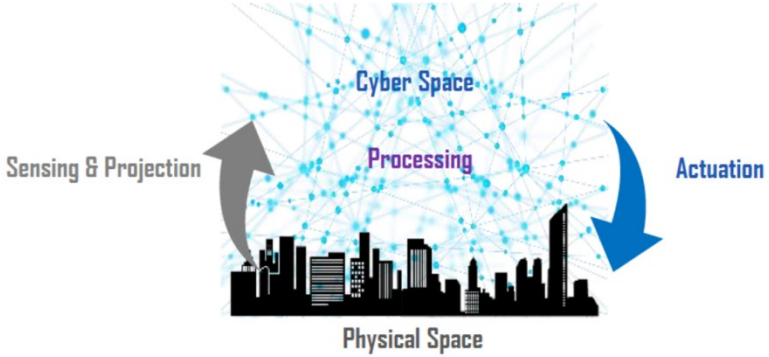
① An Inclusive Society

A society in which everyone can play an active role by the removal of differences such as age, disabilities, geographical barriers, and other differences through the expansion of physical and cognitive abilities through wearable devices and realistic experiences anywhere via robots.

Source : NICT（Beyond 5G/6G White Paper : Telepresence）

② A Sustainable Society

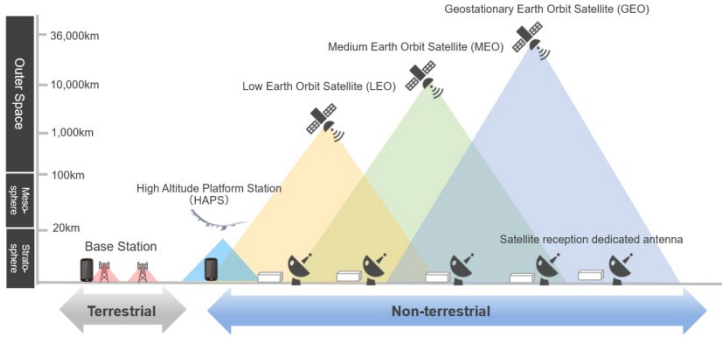
A society can achieve sustainable growth and be convenient, without any social loss, through optimization in cyberspace with real-world reproduction that can be fed back to the real world.



Source : NICT（Beyond 5G/6G White Paper : Cyber-physical system）

③ A Dependable Society

A society which will prevent communication interruptions even in times of disaster by flexibly and autonomously changing network configuration, thus everyone will be able to work with peace of mind.



Source : SoftBank Corp.（The Power of Technology “Gijutsu no Chikara” Beyond 5G／6G）

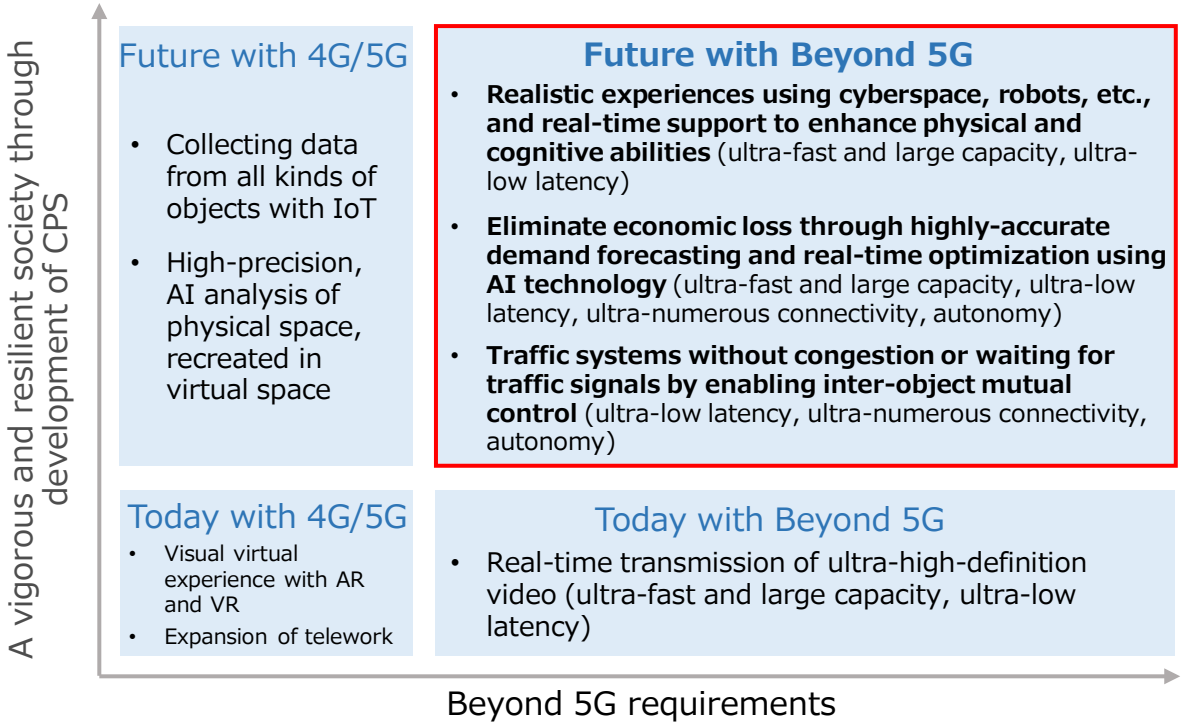
4.4 Communication and IT (2)

Achieving the desired future vision will require further enhancement of 5G features and new, “Beyond 5G” features

Requirements for Beyond 5G

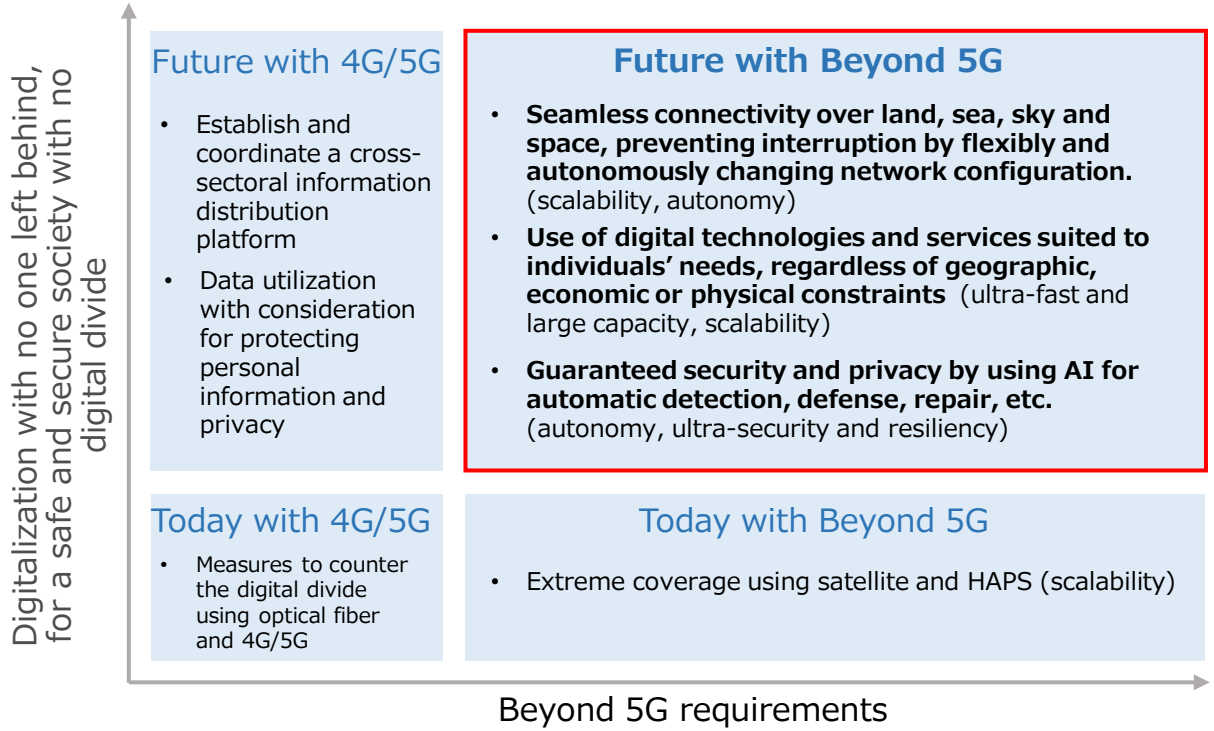
A vigorous and resilient society through development of CPS

Autonomous optimization and future forecasting functions are required to provide the necessary goods and services to the people that need them, when they need them and only what they need



Digitalization with no one left behind, for a safe and secure society with no digital divide

The requirement for **100% land coverage** by terrestrial and non-terrestrial networks will ensure that all people can benefit from digitalization and work with peace of mind



4.5 Media (1)

- **In 2030, people can enjoy more immersive media experiences utilizing virtual space and holographic communication, e.g., “the metaverse”.**

Current Situation

- ✓ Various multi-media contents including TV/radio, publishing and advertise business, SNS, etc.
- ✓ Due to pandemic, the digitalization has been accelerated, e.g., online live events.

Expected Future of the industry

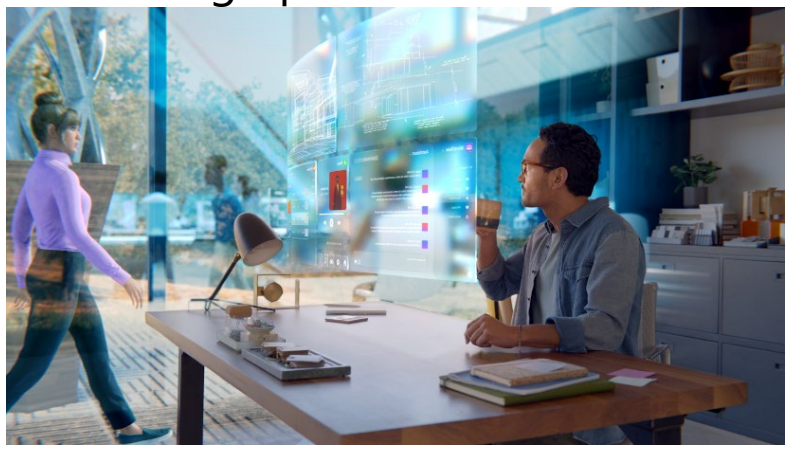
- ✓ All the contents can be accessed online via internet. Likewise, richer user-created contents can be delivered more easily regardless of time, place and device type.
- ✓ Utilization of virtual space and Holographic communication.
- ✓ Personalization/customization for more efficient contents delivery.

Online live event

Source: https://lineblog.me/livepress/archives/13261786.html

Entertainment in virtual space

Holographic communication

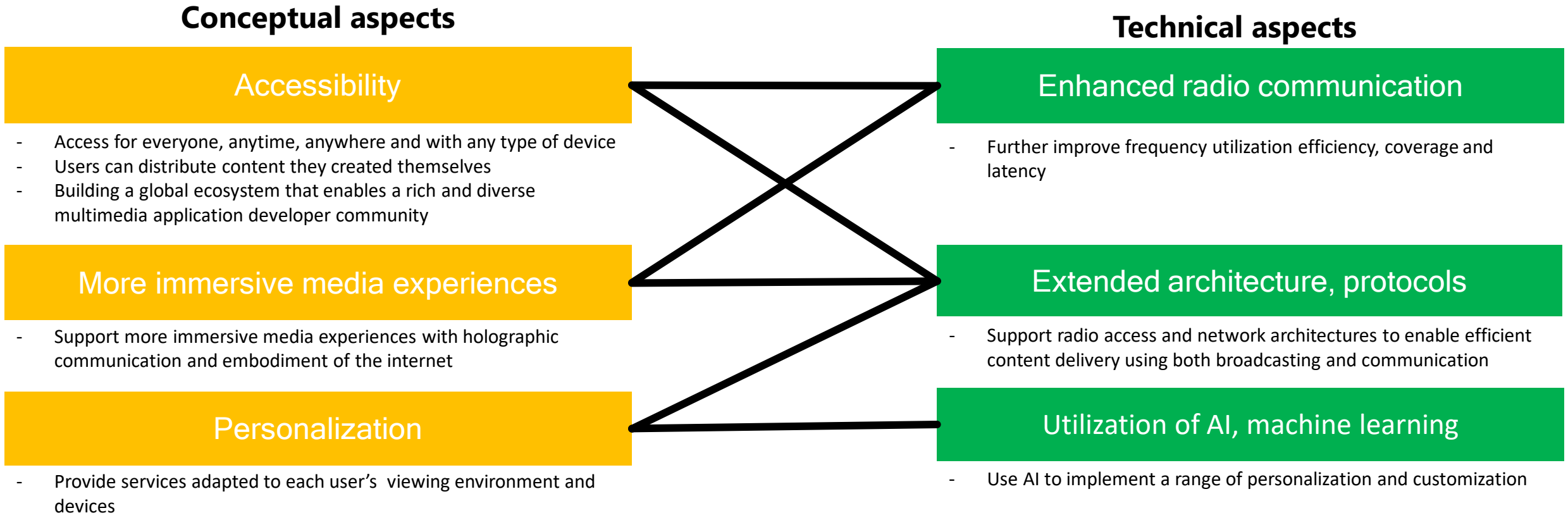


Source: https://about.fb.com/news/2021/10/facebook-company-is-now-meta/

4.5 Media (2)

- **The figure below summarizes the high-level requirements (Conceptual / Technical aspect) for beyond 5G.**
- **A few tens ~ hundreds Gbps of peak throughput can be expected for Holographic communication, as an example of performance for Beyond 5G.**

The black lines between the boxes represent what technical aspects will be relevant to the conceptual aspects



4.6 Energy, Resource, Material (1)

Introduce new technologies such as IoT and automation, improve the working environment in mines and plantations, the efficiency of equipment and the movement to the "venous industry“ to secure stable resources and decarbonize for a sustainable society

Current situation analysis

1. Toward a sustainable society, Mineral resources industry is focusing on recycling and marine resource development and Paper industry is focusing on new businesses related decarbonization
2. Promote the study and introduction of new technologies to improve efficiency and the work environment in mines and forest plantations
3. Companies in both industries, which are large-scale equipment industries, are promoting efforts for energy saving and decarbonization

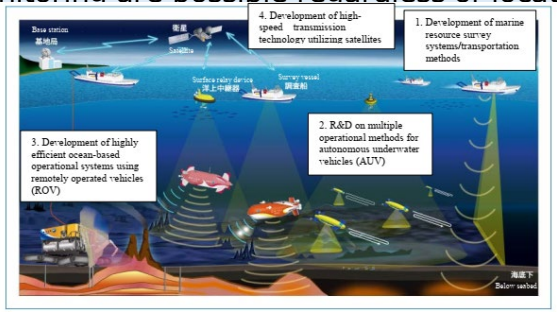
Tasks

1. Promote the introduction of automated machinery and remote operation / remote monitoring regardless of location
2. Promote equipment efficiency improvement and introduction of energy saving / decarbonization technology utilizing IoT / big data
3. Promote "veinous industry" through IoT as a broad infrastructure base

Expected future of the industry

Efficient, safe and secure working environment

Robot utilization and remote control / monitoring are possible regardless of location



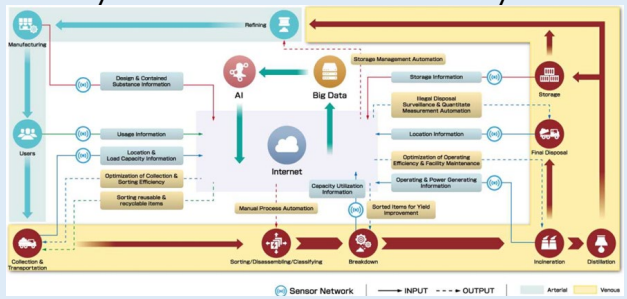
Source: “Recommendations for Developing a New Basic Plan on Ocean Policy -Ocean Policy for Society 5.0-” Keidanren (Japan Business Federation) *prepared by the Keidanren Secretariat based on website of the Cabinet Office Council for Science, Technology and Innovation “Next-generation technology for ocean resources exploration(Zipangu in the Ocean)” SIP

Automation of logging | Automatic cable-yarding system | Autonomous driving Forwarder

Source: Excerpt from “Forestry Innovation Field Implementation Promotion Program” , Forestry Agency

Recycling as a common infrastructure

“venous industry" with a extreme-massive connectivity that is not restricted to any location



Source: “The IoT Council of Waste Management and Recycling HP”

Optimal operation of energy-saving and low-carbon equipment

Manufacturing DX/Value chain utilizing IoT and big data

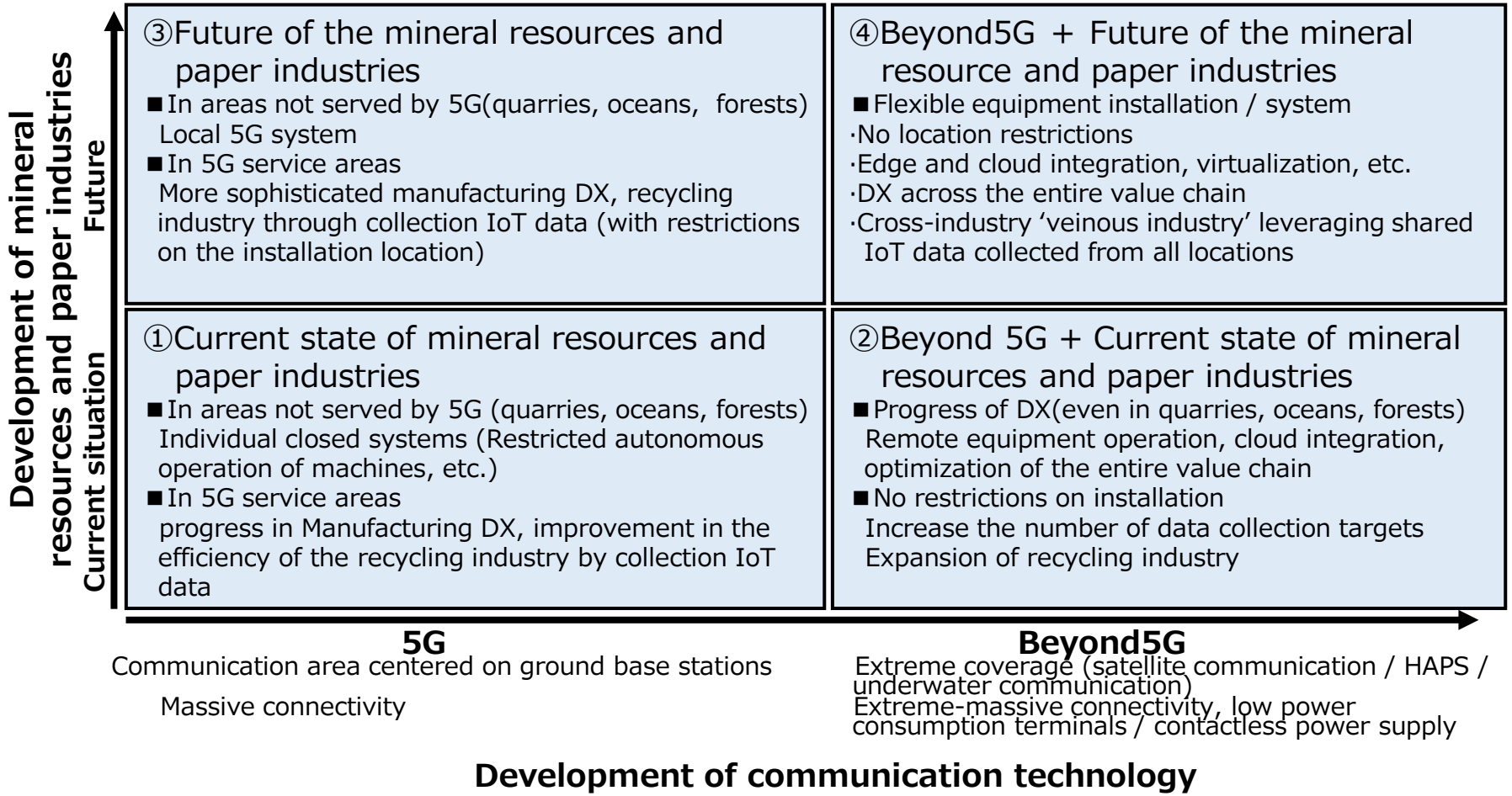
4.6 Energy, Resource, Material (2)

Requirements unique to Beyond 5G to realize the expected future are extreme coverage extension, extreme-low latency, extreme-massive connectivity, extreme-low power consumption terminals, and contactless power supply

What are required for Beyond 5G

Requirements

- **Extreme coverage extension**
  High-speed communication in mountains and at sea
- **Extreme-low latency**
  45 ms or less for an immersive remote control system aimed at improving the working environment (example)
- **Extreme-massive connectivity**
  Realization of CPS by collecting environmental data and mobile data of all things and places
- **Extreme-low power consumption terminal / contactless power supply**
  IoT terminals that are easy to install and operate anywhere (no power supply required, etc.)



4.7 Automotive (1)

The aging society restricts people's mobility in rural areas, and population concentration in urban areas causes traffic congestion. A future society is envisioned in which all people can be ensured with unconstrained and efficient mobility irrespective of their living areas.

Issues Analysis

- Lack of drivers negatively affects the sustainability of public transportation in rural areas, while population concentration in urban areas causes traffic jam. Both adversely affect the quality of people's lives.
- Increased awareness of societal crisis on energy and environmental issues, and problems of traffic-accident caused by the aging society.

Key Tasks

- Realize a mobility-inclusive society that provides unconstrained and efficient mobility for all people
- Build a robust infrastructure for automated driving and safety driving assistance, and a low carbon-emission society

Future Vision

1. A society all people can move freely and efficiently

Source: ITS Japan

2. MaaS Platform allowing the Multi-modal mobility of people

Source: ITS Japan

3. Collaboration between vehicles with Smart Cities

Source: ITS Japan

4. Enabling digital society to realize Mobility-inclusive

Source: The Government of Japan, ITS Roadmap

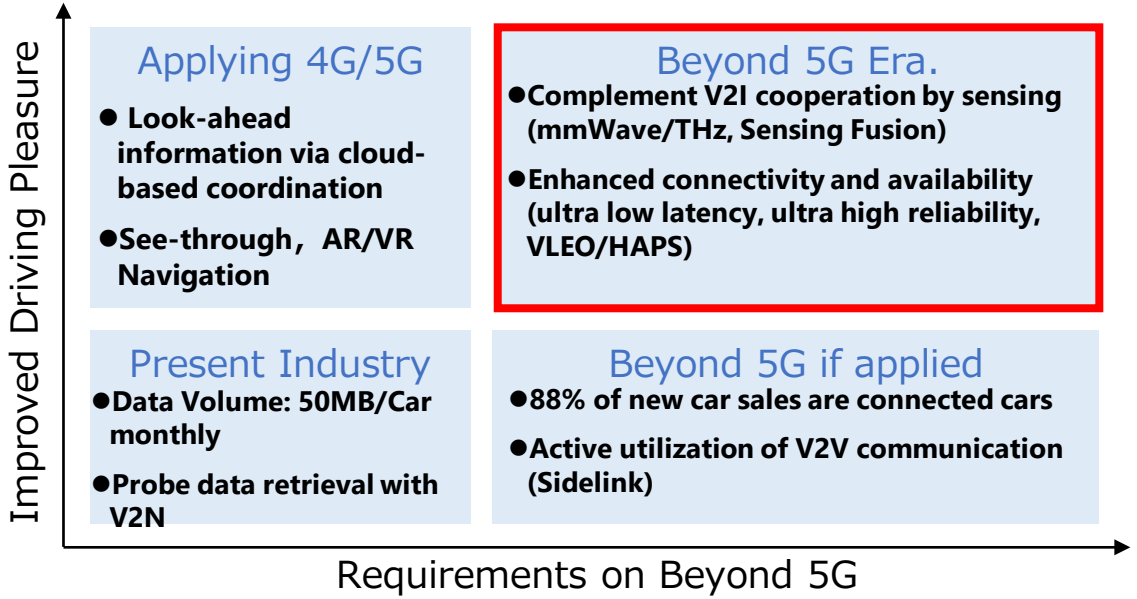
4.7 Automotive (2)

Towards Automotive Society in 2030 Era, Beyond 5G shall require the integration of highly accurate sensing and communication, distributed AI learning & inference, and ultra reliability

What are Required for Beyond 5G

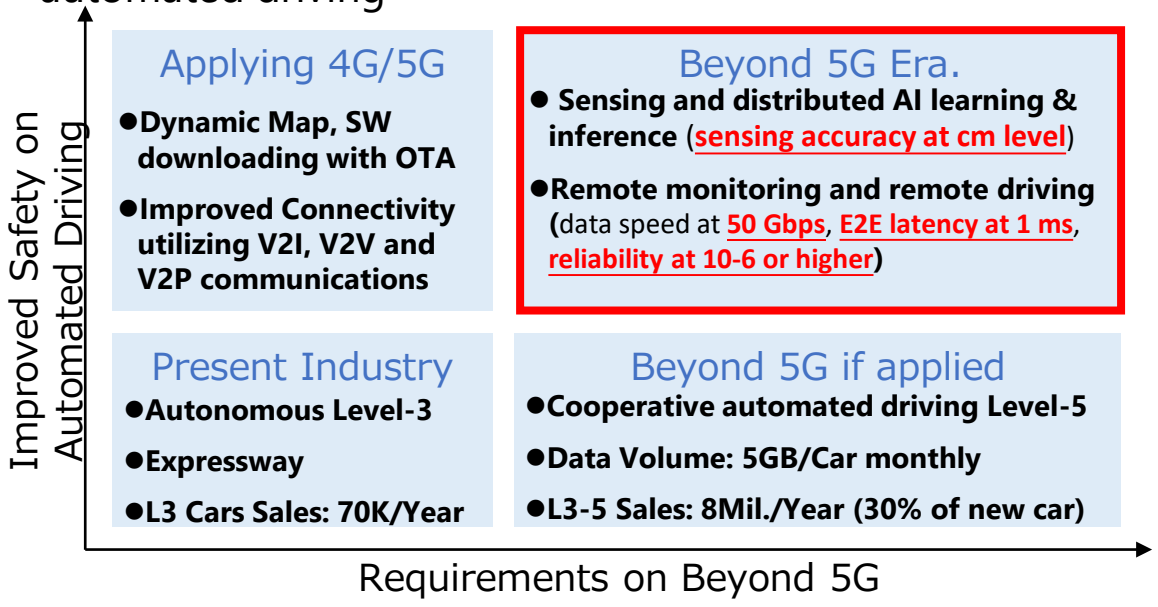
Safety Driving Assistance

Beyond 5G sensing and enhanced connectivity are required so as to support Safety Driving under extreme conditions，e.g., driving at intersections without a signal, under bad weather or in the event of a disaster.



Automated Driving

Integrated sensing and communication, distributed AI learning & inference, and quantum-cryptography-based security are required to accelerate the implementation of automated driving



4.8 Machines (1)

Machines are the foundation of all aspects such as daily life, production / distribution, social infrastructure, and energy use. Improving performance, efficiency, and reliability through various improvements, sensor evolution and system optimization by utilizing ICT are progressing.

Current Situation Analysis

1. Decline in the working population (SDG 8,9)
   - Automation/Labor saving, Collaborative work with humans
2. Global environment protection (SDG 13)
   - Reducing the environmental burden at every stage
3. Production / energy efficiency (SDG 7,12)
   - Optimization of design / manufacturing / logistics / operation
   - Utilization of ICT
4. Resolving inequality (SDG 10)
   - Gender / Disability / Age
   - Country / Region / Race

Expected Future Image

Item	Expected progress
Design	● Improved design efficiency through remote collaboration and digital twins ● Design employing contactless power supply and wireless communication ● Optimal design of fuel efficiency, mechanical efficiency, and control efficiency by AI / HPC
Manufacturing	● Digital twin and optimized production by connected cyber factories ● Efficient logistics, distributed production and local production for local consumption
Autonomous control	● AI-based maneuvering, labor saving, unmanned and autonomous operation of machines ● Autonomous driving with accurate and dense sensing, positioning, and optimal control
Expanding the coverage area	● Coverage expanding to sky, stratosphere, space, pelagic, underwater, underground
Machine intelligence and cooperation with human	● AI-based autonomous robot with improved accuracy and speed ● Enhanced human with expanded organs, perception, multi-sensory and remote operation capability of plural machines ● Robots serving as communication partners and alternatives to home appliances
Monitoring and maintenance	● Acquisition of operating data with enhanced types, sampling density and number of objects in operation ● Analysis and feedback through computing resources distributed optimally among devices/edges/clouds

4.8 Machines (2)

What is Required for Beyond 5G

Expected Use Cases

1 Intelligent / automated work / manufacturing process

Automatic process generation / improvement, ultra-low latency motion control*, direct teaching, real-time CPS

2 Remote operation / control / diagnosis

Application of robot technology to construction machinery and agricultural machinery, application of autonomous driving technology to aircraft and ships, intuitive HMI, product / breeding management

3 Flexible construction / processing / production / operation management

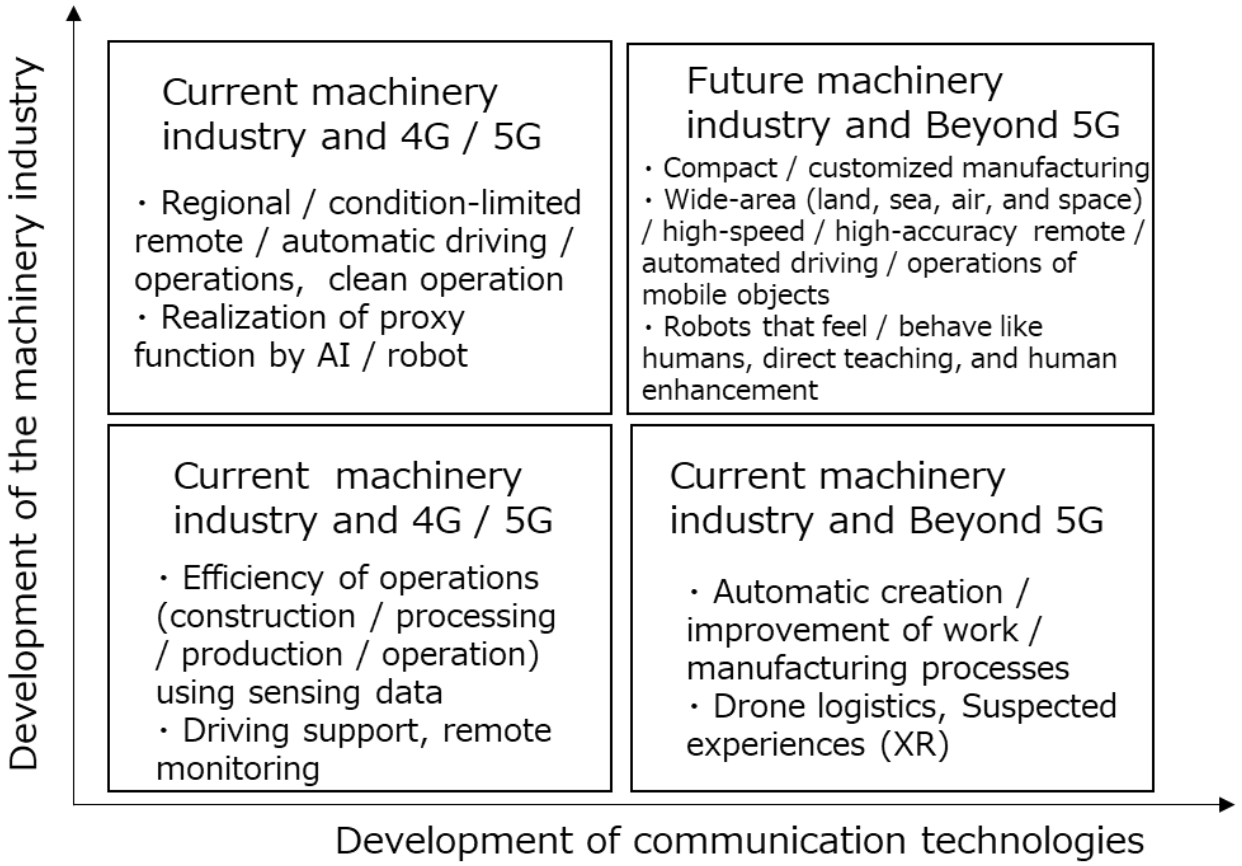
Smart maintenance by AI and/or robot / equipment sharing / reflection of production / working environment conditions

4 High-speed mobility / energy saving / comfort

High-precision positioning and control of wide-area, high-speed moving objects, navigation plan management by utilizing data, automation and sophistication of security inspections, traceability , seamless transportation

5 New mobility service

Flying taxi, simulated experience



Mechanical and communication technology requirements that support the expected future image

*: **100 micro second in E2E** local area communication

4.9.1 Electronics and Precision electronics

Widely adopted Beyond 5G connected equipment into daily work and life.
Required to transform platform industries for support social essential infrastructure.

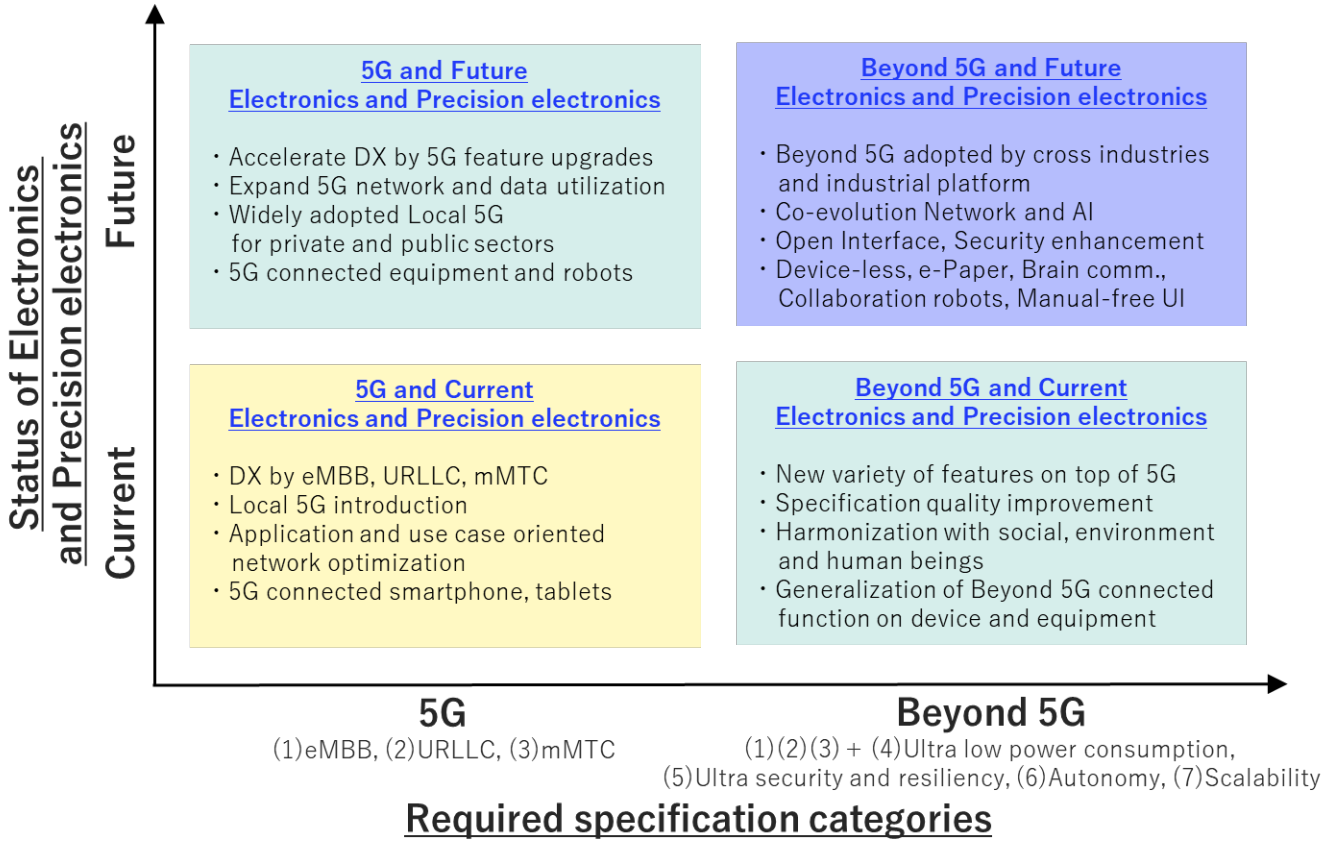
Current issued through analysis

- ✓ Electronics and precision electronics equipment to be important parts of social platform with accelerating DX and 5G deployments.
- ✓ AI active use leads to Co-evolution between Network and AI

Expectation of future

1. Socially total optimization of equipment / system sharing, energy efficiency & consumption
2. Cross industries collaboration
3. Shift to future-oriented and user-centric design

What is Required for Beyond 5G



4.9.2 Semiconductor

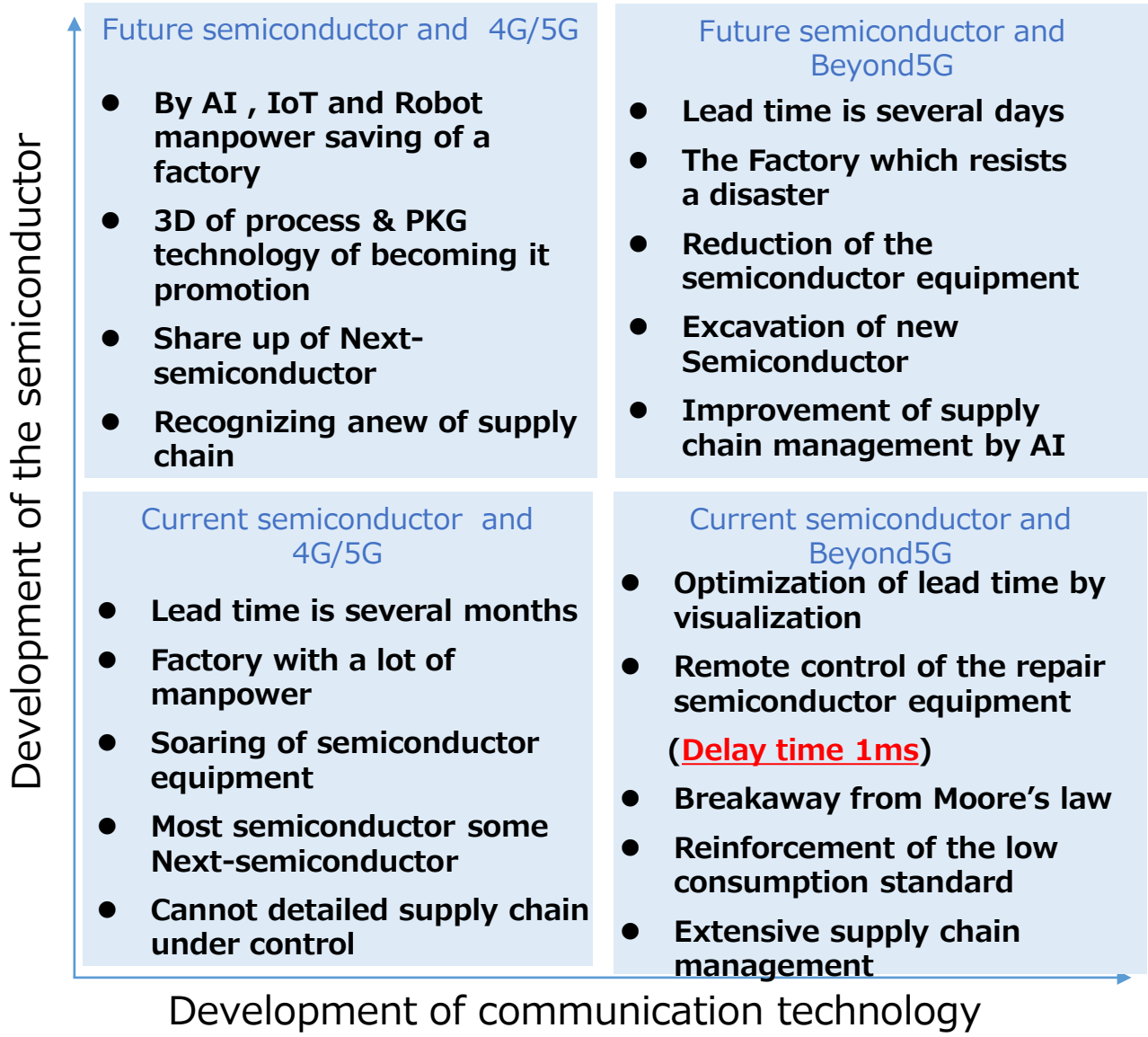
The present analysis and problem

1. Semiconductor understock
2. Anti-stress reinforcement to a disaster
3. Soaring of semiconductor equipment
4. Reduction in power consumption
5. Lack of understanding supply chain

The future image to expect

1. Shortage lead time
2. Manpower saving of factory, unmanned
3. Reduction in equipment price
4. Power consumption is reduced in Next-Semiconductor
5. Improvement of the supply chain management power

What is required for Beyond 5G



4.10.1 Agriculture and Livestock

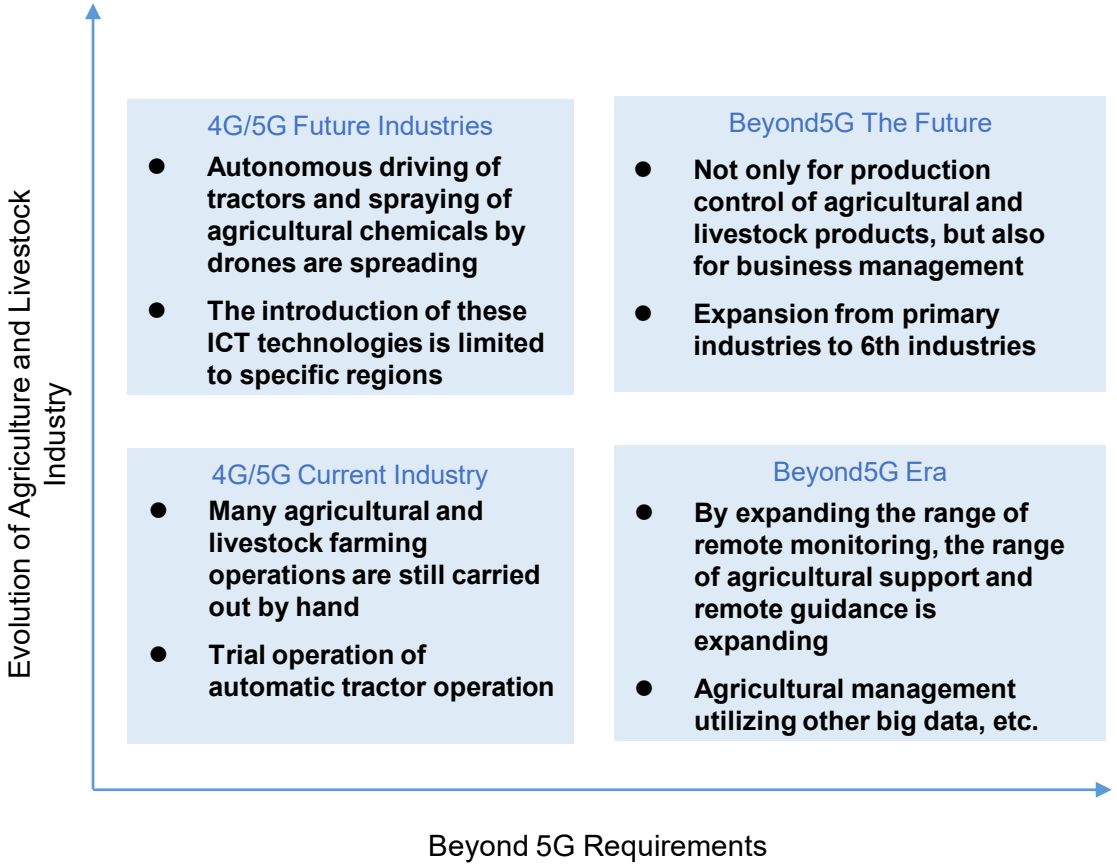
Current Situation Analysis and Issues

1. Labor shortages due to the declining birthrate and aging population will be a serious problem.
2. Reducing the burden of agricultural work and labor saving in agricultural work itself are also issues.
3. Strengthening the production base regardless of the size of the business or the conditions of rural areas.

Expected future vision

1. By combining cutting-edge technologies such as robots, AI and IoT with B5G, the sophistication of "smart agriculture" such as remote monitoring, automation of agricultural work and productivity improvement of agricultural crops will advance.
2. Remote control and automatic operation of tractors, tillers and rice planters from cyberspace.
3. Spraying agricultural chemicals using drones, monitoring animal damage using IoT technology, and agricultural support and remote guidance using XR technology.
4. Production and management of agricultural and livestock products.

What is required for Beyond 5G?



4.10.2 Food

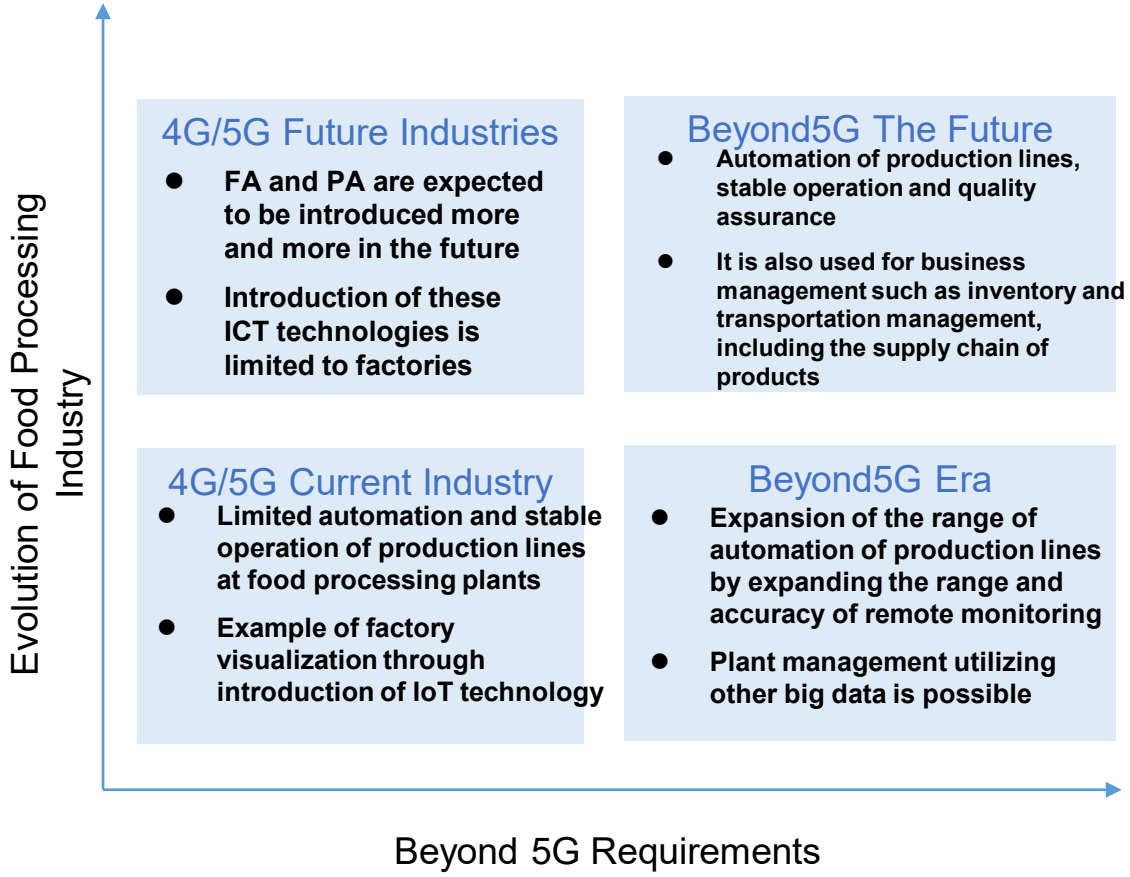
Current Situation Analysis and Issues

1. Shortage of working population due to low birthrate, aging population and declining population is a serious problem.
2. In the field of food production, issues include automation and stable operation of production lines, and ensuring product quality.
3. Stable supply of materials to food processing plants, inventory control of products and logistics control are also issues.

Expected future vision

1. The sophistication of "smart factories" advances through automation and stable operation of factories and ensuring product quality through robots, AI, IoT, etc.
2. The shift to B5G wireless technology at the plant is now on the rise, contributing to the stable operation of production lines and productivity improvements such as video monitoring.
3. Reduction of food loss by grasping the inventory status of food products at retailers as big data

What is required for Beyond 5G?



4.10.3 Household and Cultural Goods

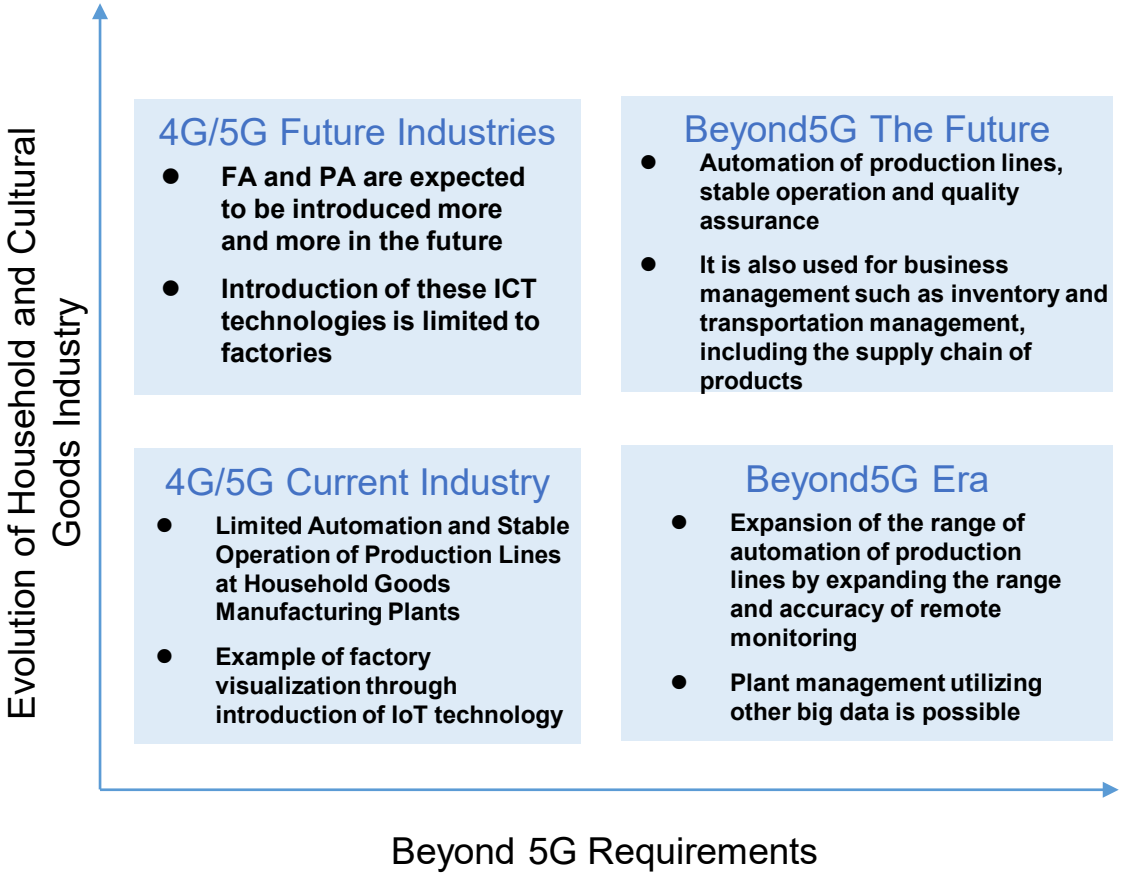
Current Situation Analysis and Issues

1. Shortage of working population due to low birthrate, aging population and declining population is a serious problem.
2. Issues at goods production sites include automation and stable operation of production lines and ensuring product quality.
3. Issues include stable supply of raw materials to product factories, inventory control of products, and logistics control.

Expected future vision

1. The sophistication of "smart factories" advances through automation and stable operation of factories and ensuring product quality through robots, AI, IoT, etc.
2. The shift to B5G wireless technology at the plant is now on the rise, contributing to the stable operation of production lines and productivity improvements such as video monitoring.
3. Grasping raw materials of products and inventory status at retail stores as big data and using it for business management

What is required for Beyond 5G?



4.11 Retail and wholesale distribution business

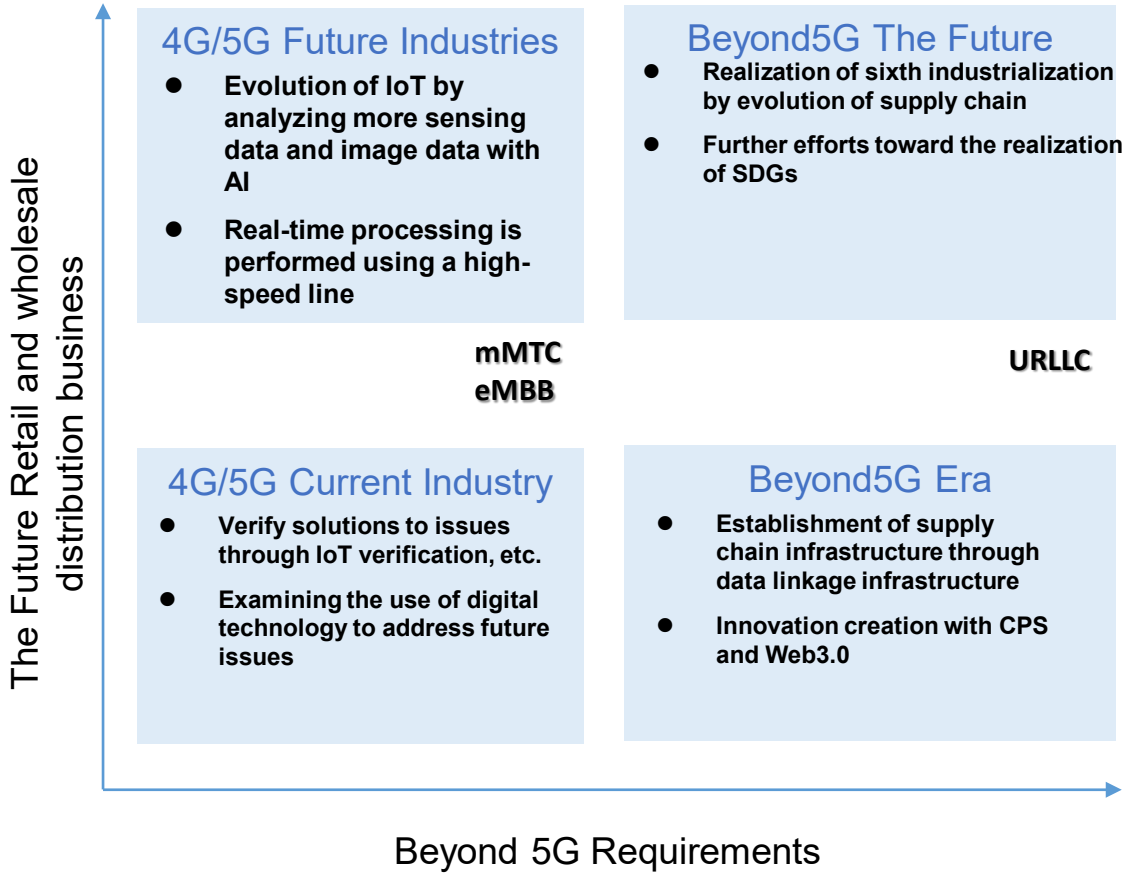
Current Situation Analysis and Issues

1. The shrinking domestic market due to a shrinking population, difficulties in securing human resources such as producers, ESG initiatives, sustainable supply in times of disaster, and many other issues are coexisting.
2. Labor shortage and aging of drivers in the logistics industry.
3. There are both positive and negative effects of changes in purchasing behavior due to the COVID-19.

Expected future vision

1. Creation of innovation in industries using advanced technologies such as robotics, AI artificial intelligence, and IoT.
2. Comprehensive and integrated promotion of agriculture, forestry, fisheries (primary), manufacturing (secondary), retail (tertiary), and other industries to create new added value through sixth-tier industrialization.
3. Promote the Logistics DX "Outline of Comprehensive Logistics Policies".

What is required for Beyond 5G?



4.12.1 Medical (1)

Current issues through analysis

1. Coexistence of various people in super-aging society
   - achieving harmony with a super-aging society, and to fulfill the role of presenting the world with solutions
2. New solutions to unknown diseases
   - putting systems and measures in place to respond and resolve them promptly when they occur.
3. Further development of medicine and medical device
   - achieving the world's highest medical technology standards and take the lead in the industry

Expectation of future life

1. Support and reproduction of physical functions and abilities

Source: Ministry of Health, Labor and Welfare (Home page)

2. Immediate response to unknown infectious diseases

Source: Cabinet Secretariat (COVID-19 Information and Resources)

3. Development of medical technologies

Source: Japan Agency for Medical Research and Development (Achievements)

4. Support for super-aging society

Source: Ministry of Health, Labor and Welfare (Home page)

5. Extension of healthy lifespan

Source: Ministry of Health, Labor and Welfare

4.12.1 Medical (2)

What is required for Beyond 5G

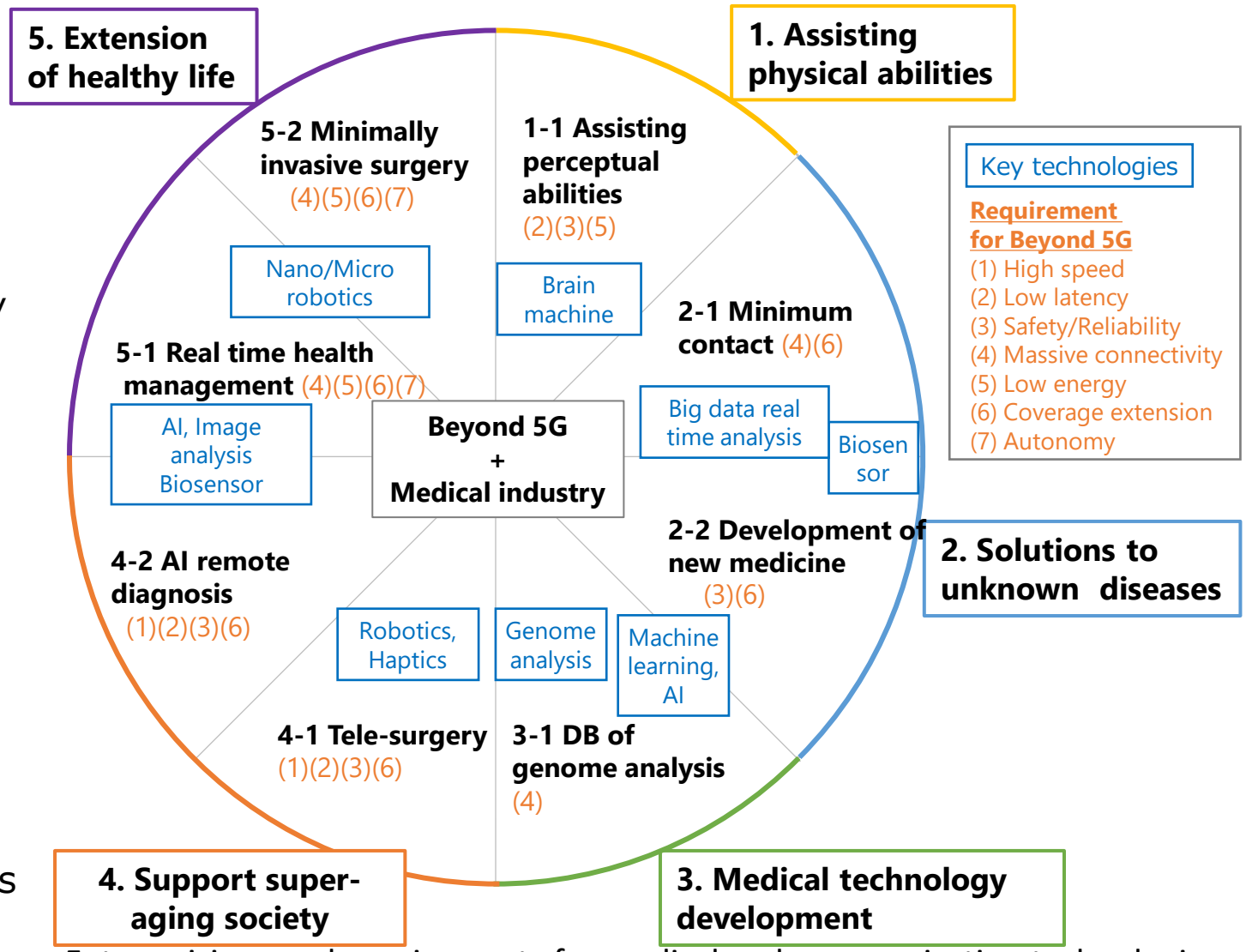
Use cases with Beyond 5G

1-1 Assisting perceptual abilities
Augmented human, Brain machine
2-1 Minimum contact, monitoring infections
Positioning, Centralized management of health status
3-1 DB of genome analysis
Personalized medicine, AI-based drug discovery
4-1 Tele-surgery
Robotics, AI based surgery
5-2 Minimally invasive surgery
Nano/Micro robotics, Energy harvesting

Beyond 5G requirements

Tele-surgery
- **Tens of Gbps** throughput
- **10^{-7}** reliability

Minimally invasive surgery
- **up to tens of millions/km²** connectivity
- Autonomous communication control of devices



Future visions and requirements for medical and communication technologies

4.12.2 Government

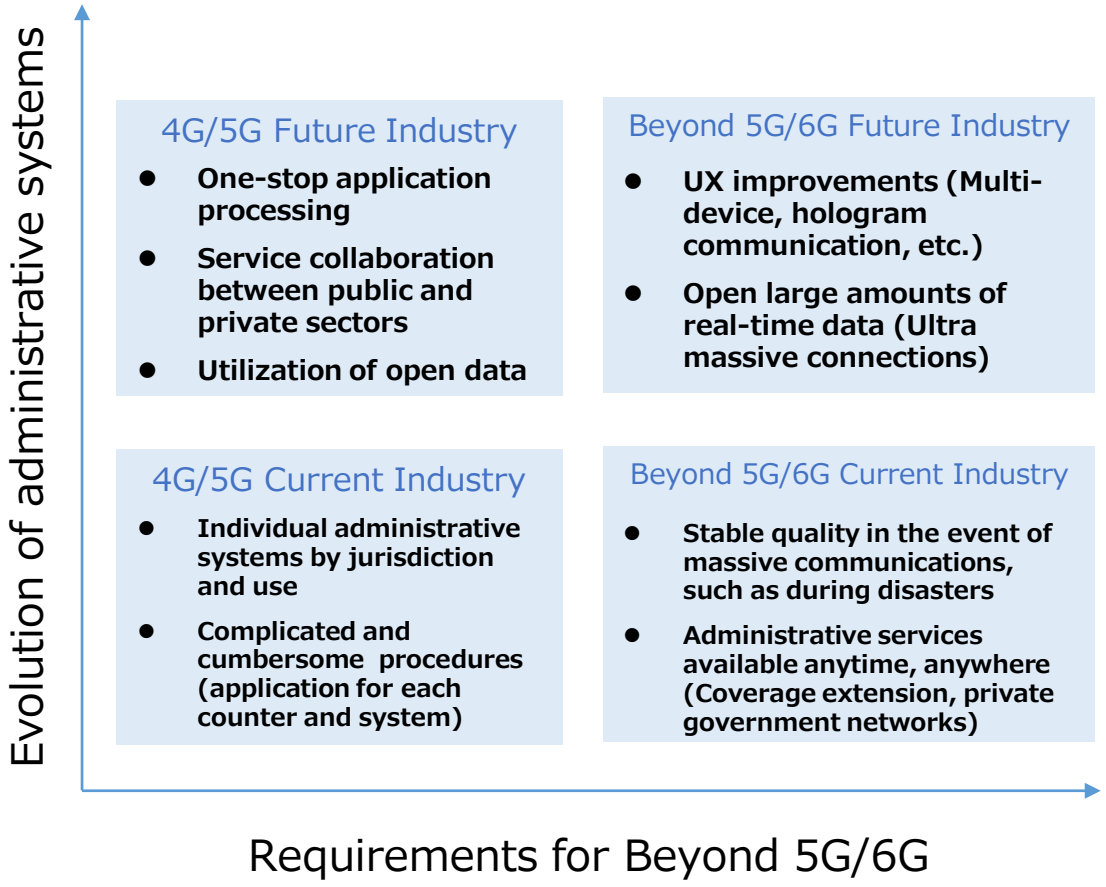
Current State Analysis and Challenges

1. Government administrative systems established individually for each jurisdiction or use (system collaboration is difficult)
2. Regulations and practices that impede digitization (seals, etc.)
3. Complicated and cumbersome procedures (application for each system and processing at administrative counters)

Future Vision

1. Collaboration and integration between systems
   - ✓ One-stop processing of operations across jurisdictions in response to events (Birth, marriage, moving, etc.)
2. User-friendly UX
   - ✓ Administrative services open to anyone at anytime and anywhere (eliminating the digital divide)
3. Service collaboration between public institutions and private sectors
4. Utilization of open data from government

What is required for Beyond 5G/6G



4.13 Restaurant

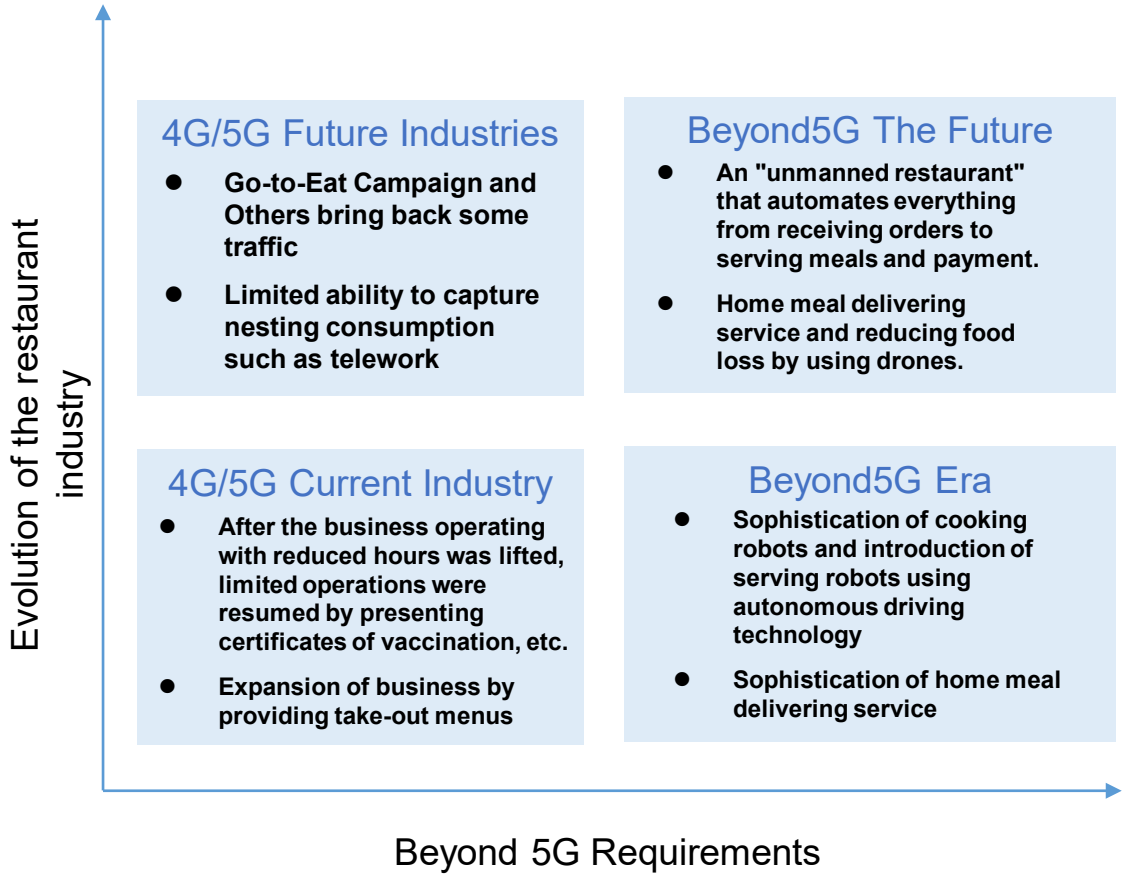
Current Situation Analysis and Issues

1. Business operating with reduced hours and voluntary suspension of business have been forced by the repeated declaration of an emergency.
2. Due to the recent business operating with reduced hours cancellation, the number of stores that reopen due to the presentation of certificates of vaccination, etc., has increased.
3. The biggest challenge now seems to be to regain lost customer traffic due to the pandemic.

Expected future vision

1. Revival of a restaurant where a large number of people can enjoy dining together without presenting a vaccination certificate or a negative certificate.
2. Provision of a mechanism that enables smooth presentation electronically when the need for presentation of these certificates continues
3. Reduced service hours and labor costs through the introduction of cooking / serving robots, ordering terminals, and cashless payments
4. Respond to a variety of takeout needs and reduce food losses in conjunction with home meal delivering service

What is required for Beyond 5G?



4.14 Entertainment and Leisure (1)

Current State Analysis and Issues

1. Opportunities to enjoy entertainment in virtual space have increased due to the effects of COVID-19
2. Diversification of entertainment is accelerating due to integration with social media, mainly in the younger demographic
3. Challenges to support massive traffic and low latency communication for interaction

Expected future vision

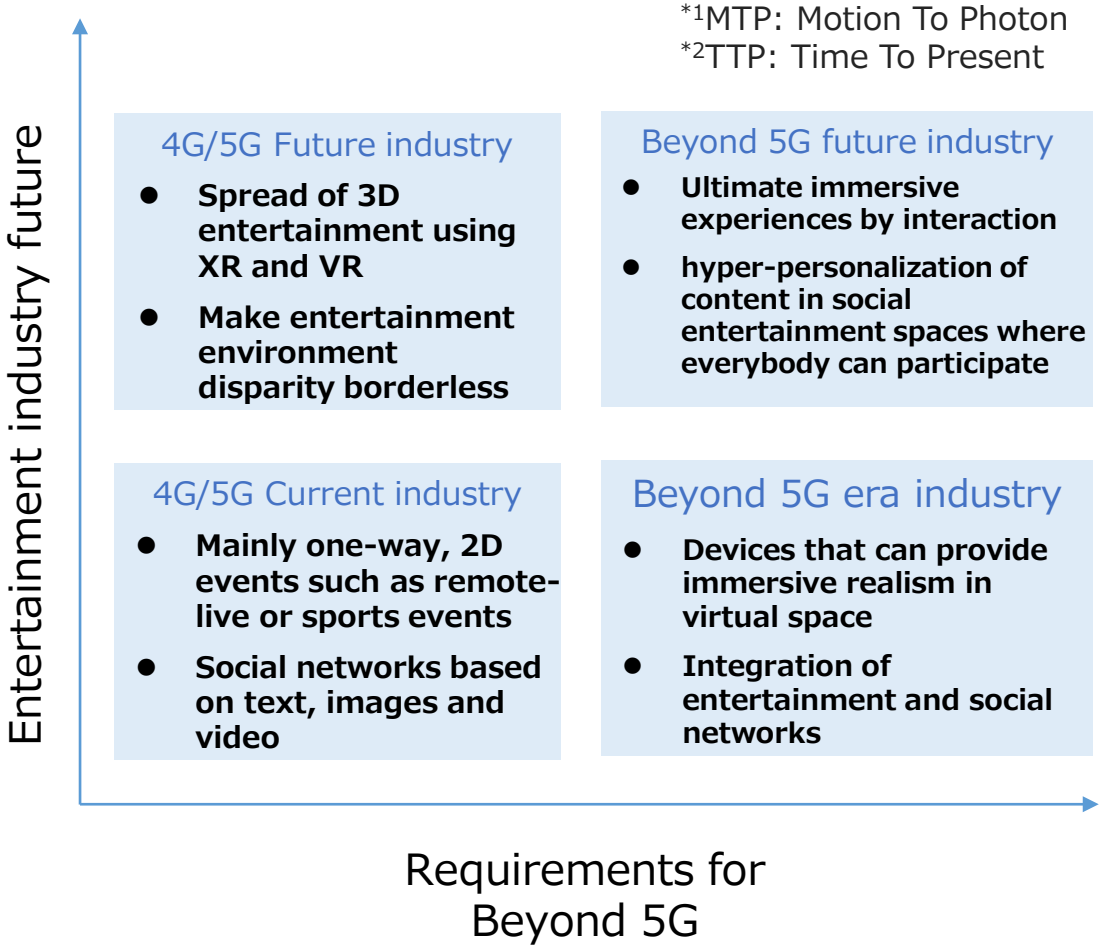
1. Provide the ultimate immersive experience that fully stimulates the five senses
2. Integrate virtual and real for entertainment
3. Integrate entertainment and social
4. High-grade content creator support and hyper-personalization of content
5. Borderless entertainment services

What to expect in Beyond 5G

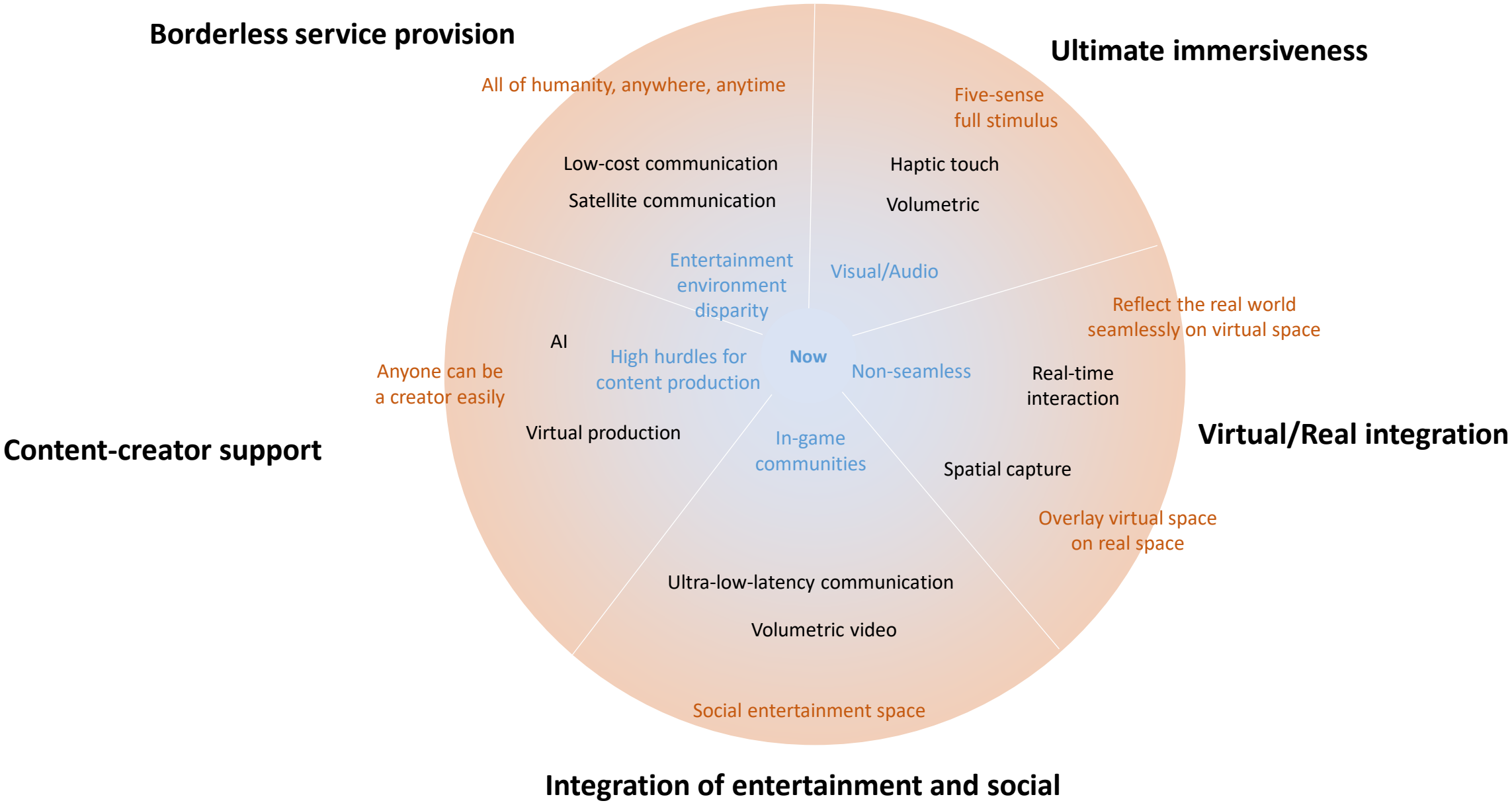
Example : Interactive Live Music Use Case

- High data rate : **48-200Gbps** (Raw data)
- Low latency : MTP[*1] **10ms**, TTP[*2] **70ms**

[*1]MTP: Motion To Photon
[*2]TTP: Time To Present



4.14 Entertainment and Leisure (2)



4.15.1 Space (1)

To protect the people's lives on earth, it is required to contribute to solving social issues by space utilization. By developing of space utilization technology, efforts to expand the living area and activity area to space are required.

Current Situation Analysis

- ✓ Space utilization is mainly preceded by national government, specific industries, R&D and satellite broadcasting
- ✓ New efforts are required by utilizing space and space development technology to solve social issues.

Social Issues

1. Japan's aging society and population decline
2. Global warming, intensification of natural disasters
3. Shift to clean energy, energy competition
4. Increased pandemic risk and realization of "New normal"
5. Realization of a society that affirms diverse ways of life

Expected Future Image

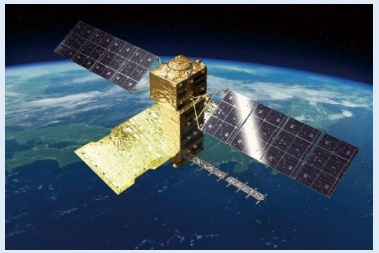
1. Communication to protect life

Smart communication infrastructure using space

Source: Smart City Public-Private Partnership Platform HP

2. Protect life by space data

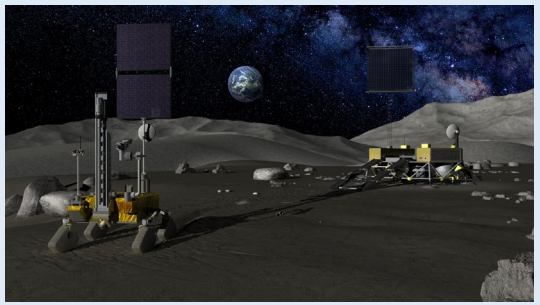
Space-generated data from a secure and resilient environment



Source: JAXA observation satellite HP

3. Utilization of space environment

Expanding the area of human activity to space



Source: JAXA

4. Adapt space to lifestyle

Realizing each diverse lifestyle using space

Source:JAXA/Adobe.stock.com

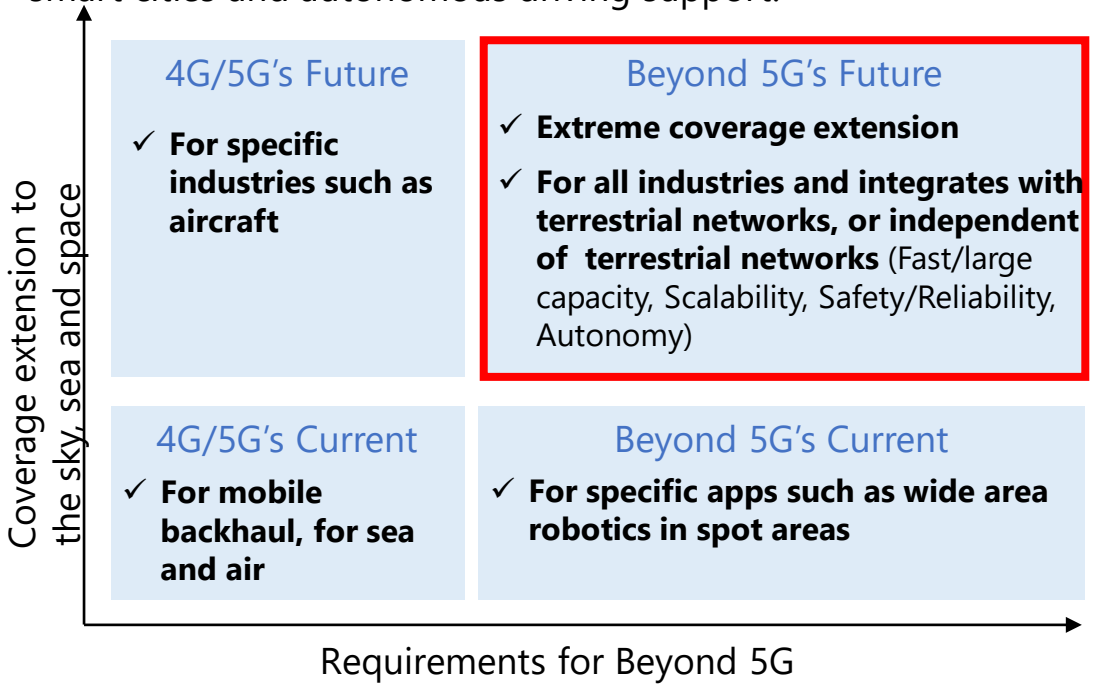
4.15.1 Space (2)

Fast/large capacity, scalability, safety, reliability, autonomy and low latency are required as requirements for 5G and beyond toward expected future image to protect the people's lives on earth.

The requirements of 5G and beyond

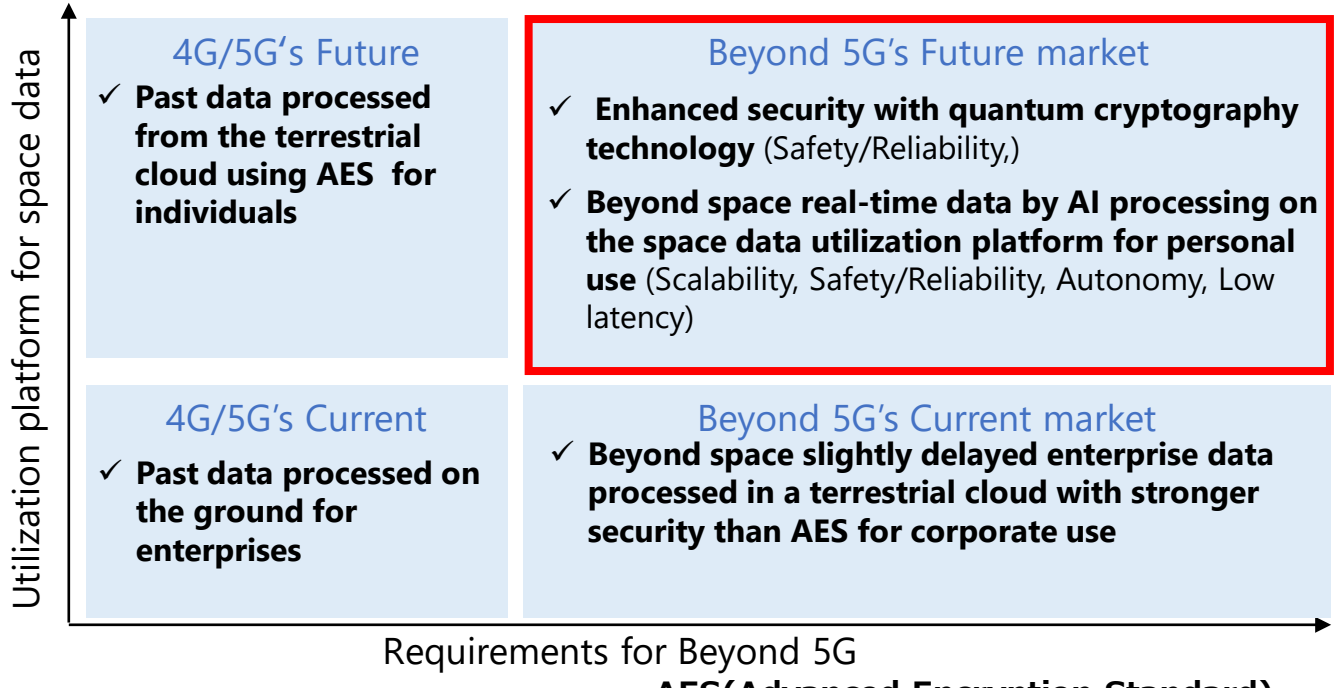
Coverage extension to the sky, sea and space

Fast/large capacity(approximately **several dozens of Gbps** by low/medium earth orbit satellite), scalability, safety/reliability and autonomy as Beyond 5G's performance are required for smart cities and autonomous driving support.



Utilization platform for space data

Scalability, safety/reliability, autonomy and low latency as Beyond 5G's performance are required for utilization platform for data observed and generated in space.



AES(Advanced Encryption Standard)

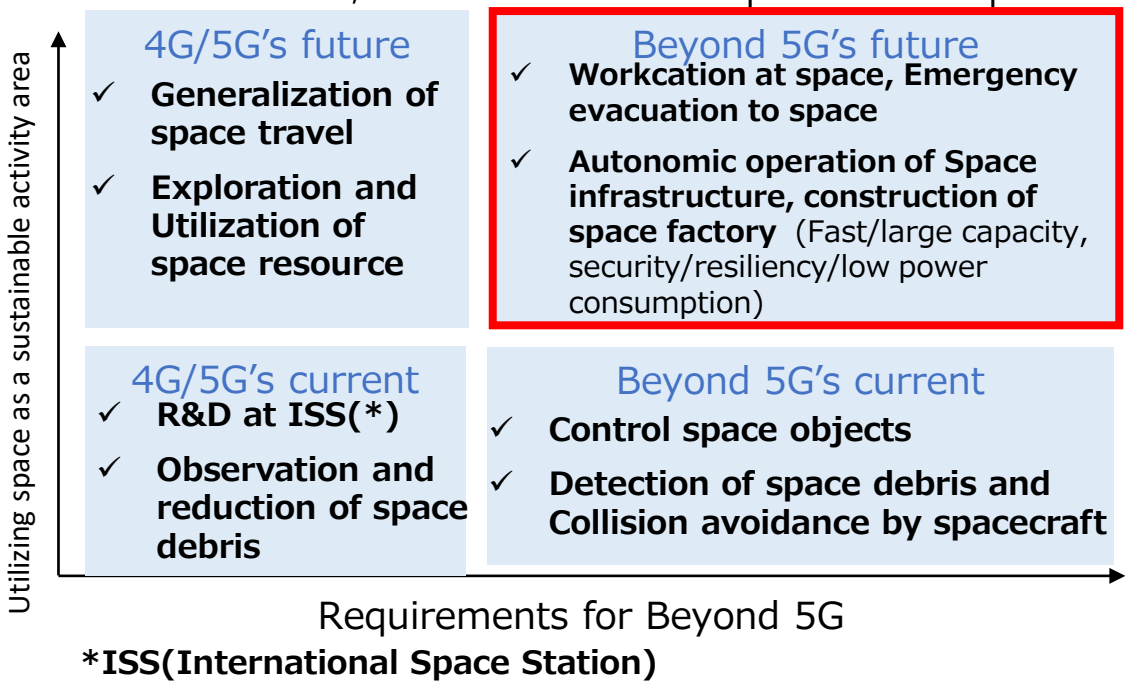
4.15.1 Space (3)

Fast/large capacity, security/resiliency, low latency, scalability and low power consumption are required as requirements for 5G and beyond toward expanding the area of human activity to space and realizing each various lifestyle using space.

The requirements of 5G and beyond

Utilizing space as a sustainable activity area

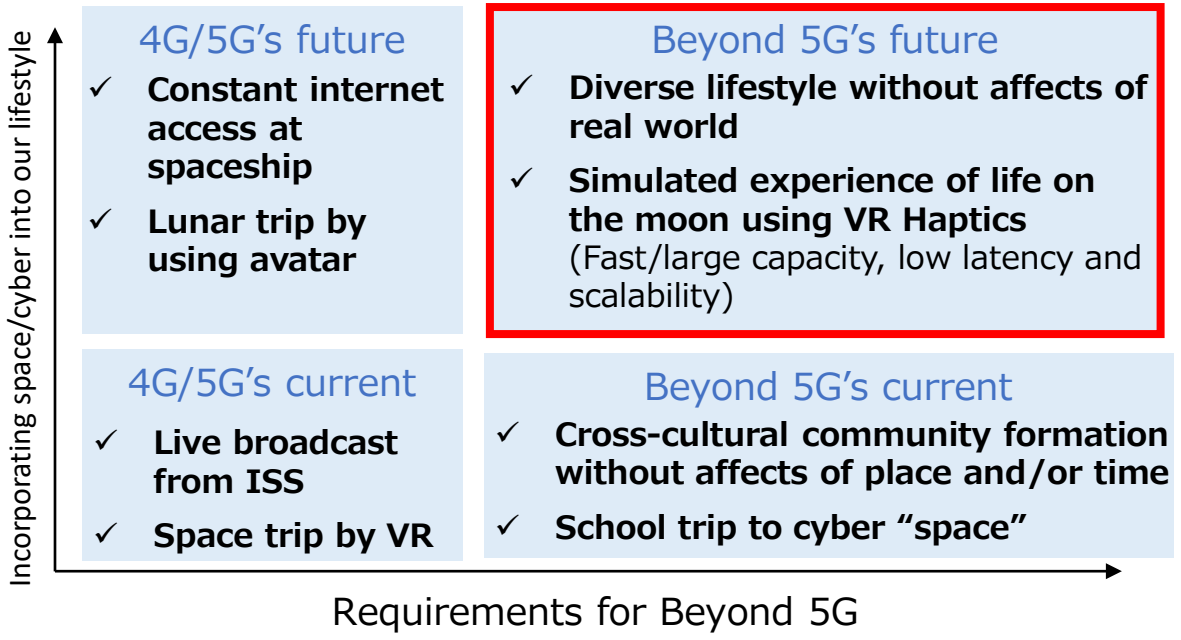
Fast/Large capacity and security/resiliency as Beyond 5G's performance are required for utilization space as a human activity area (moon and/or planets) sustainably. In addition, since the installed resources are limited, it is vital to realize low power consumption.



*ISS(International Space Station)

Incorporating space/cyber into our lifestyle

Fast/Large capacity, low latency and scalability as Beyond 5G's performance are required for cross-cultural communication by using space/cyber which has no border.



4.15.2 HAPS (1)

Sustainable and Ultra-wide Coverage is required to address social issues raised in the SDGs.

Current status and issues

- ✓ Several companies are already experimenting with stratospheric communications using various HAPS platforms. In order for HAPS to be widely adopted, following regulatory issues need to be addressed.
  - ✓ Aviation: International rules for the stratospheric flight, common compliance test procedures for HAPS aircraft.
  - ✓ Spectrum: Additional identification for HAPS in WRC-23(*), international scheme for frequency coordination with neighboring countries

* Candidate bands: 694-960MHz, 1710-1885MHz, 2500-2690MHz

Future Vision

①Efficient coverage for rural area

At an altitude of around 20 km, HAPS can provide ultra-wide coverage and connect directly to existing user terminals.

②Resilient NW to natural disasters

HAPS is invulnerable to weather and can move anywhere, providing a resilient NW in the event of natural disasters, such as Typhoon and Tsunami.

③Carbon neutral NW

HAPS can provide a zero-emission operation using solar, hydrogen or other energy sources.

Source: SoftBank Corp.

4.15.2 HAPS (2)

The unique capabilities for Beyond 5G are required to provide Sustainable and Ultra-wide Coverage.

What are required for Beyond 5G

Use cases

- **Connecting the unconnected**
  Efficient coverage extension to the uncovered and undercovered areas
- **Disaster recovery**
  Resilient NW that can continue to operate (or be quickly restored) in the event of natural disasters.
- **Urban air mobility**
  3D coverage for urban air mobility such as flying cars and drones
- **IoT**
  Ultra-wide coverage for IoT such as sensors, home appliances, machines, and cars

Capabilities

- **Maximum Horizontal Coverage**
  Maximum radius of the area covered by a single base station (in km/BS).
  (Covering up to **tens to hundreds of kilometers** in radius.)
- **Maximum Vertical Coverage**
  Maximum altitude of the area covered by a single base station (in km/BS).
  (Covering **around ten kilometers above ground**.)
- **Carbon Neutrality**
  Capability to provide coverage area with zero carbon emissions during operation.

※It is assumed that the same devices used in terrestrial IMT systems can also be used, and the required latency are equivalent to those of eMBB usage scenario of IMT-2020.

4.15.3 Society (1)

Social infrastructure to review the social system according to population composition and to protect human lives and property from natural disasters

Current Situation Analysis

- ✓ The population continues to decline
- ✓ The ratio of people aged 65 and over to the total population is the highest in the world
- ✓ Natural disasters caused by climate change (e.g. typhoons, floods) and geographical factors(e.g. earthquakes, volcanoes)

Issues

1. How to solve for the labor shortage
2. How to spend a long life meaningfully
3. How to protect human lives and property from natural disasters

Expected Future Images

1. Labor force

Advances in capacity enhancement technologies and remote work will increase the number of workers and improve productivity

2. Transportation

Enhanced personal mobility and infrastructure system that allows individuals to go where they want to go

3. Disaster avoidance

Distribution all at once of personalized emergency bulletins according to personality, location and situation

4. Disaster assistance

Communication system capable of exchanging information without worrying about securing power supply or outside of service area even in case of disaster

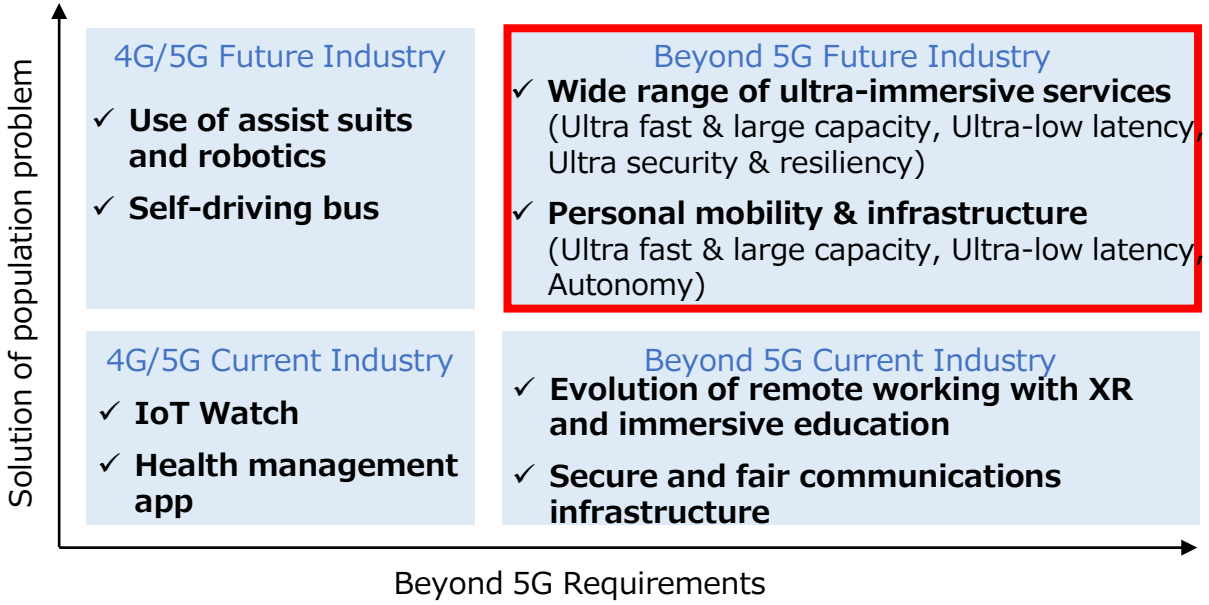
4.15.3 Society (2)

Beyond 5G requires Ultra fast & large capacity, Ultra-low latency, Ultra security & resiliency, Autonomy and Scalability for its expected future realization, to solve social issues

What is Required for Beyond 5G

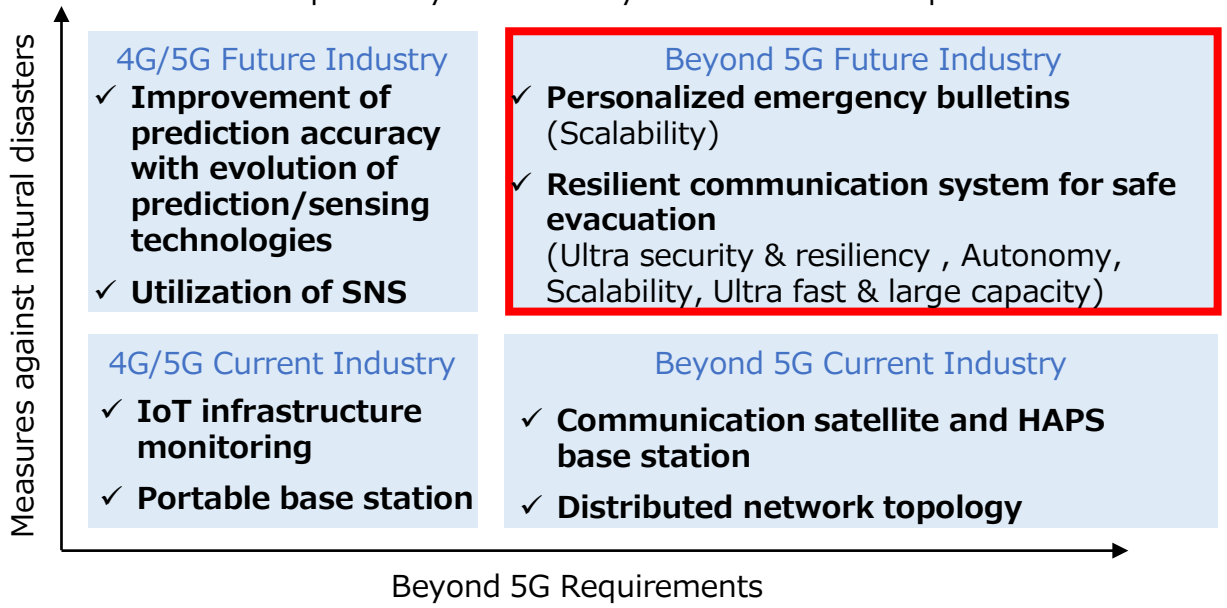
Solving social issues / Creating a sense of purpose for life

Ultra fast & large capacity, Ultra-low latency, Ultra security & resiliency and Autonomy are required to ensure augmented reality technology, robotics and safety of personal mobility



Reducing damage / Protecting lives and properties

Autonomy, Scalability, Ultra fast & large capacity, and Ultra security & resiliency are required for simultaneous distribution of full-personalized emergency bulletins and information sharing in disasters, and guaranteeing more than 10Mbps at anytime and anywhere should be required.

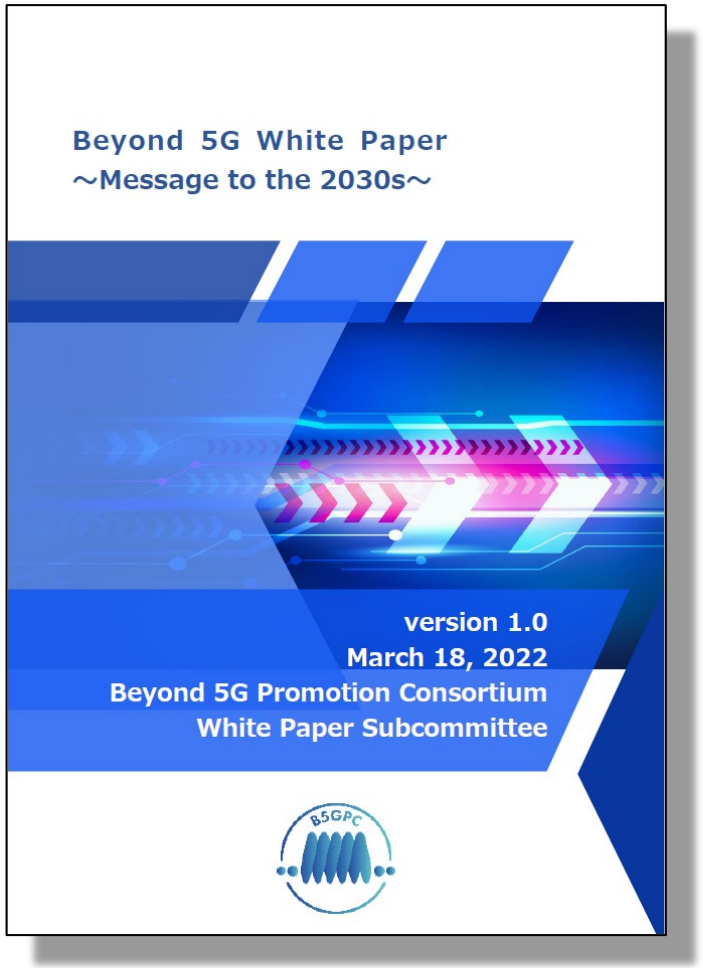


Beyond 5G White Paper(ver.1.0)
～Message to the 2030s～
【Beyond 5G technologies】

Technology Working Group,
White Paper Subcommittee, B5GPC

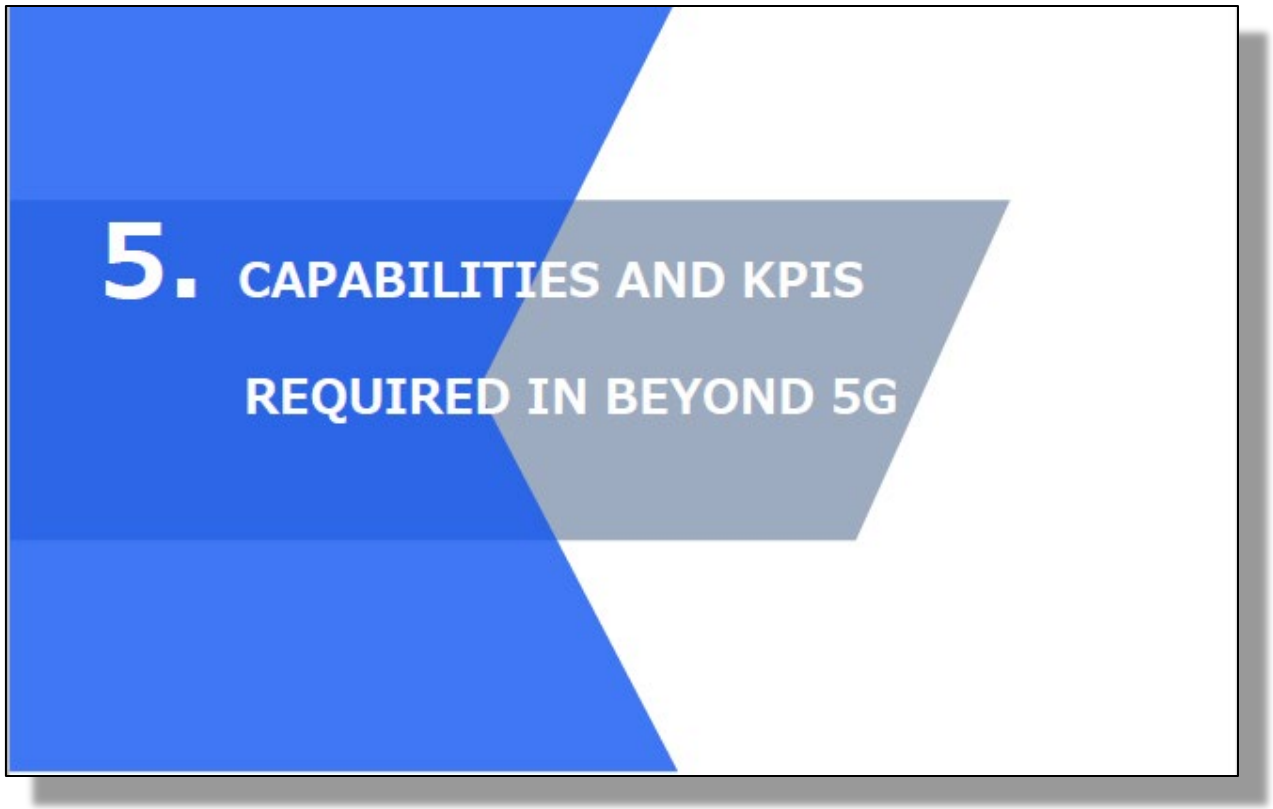
Mar. 18, 2022

Table of Contents (Technology Working Group section)

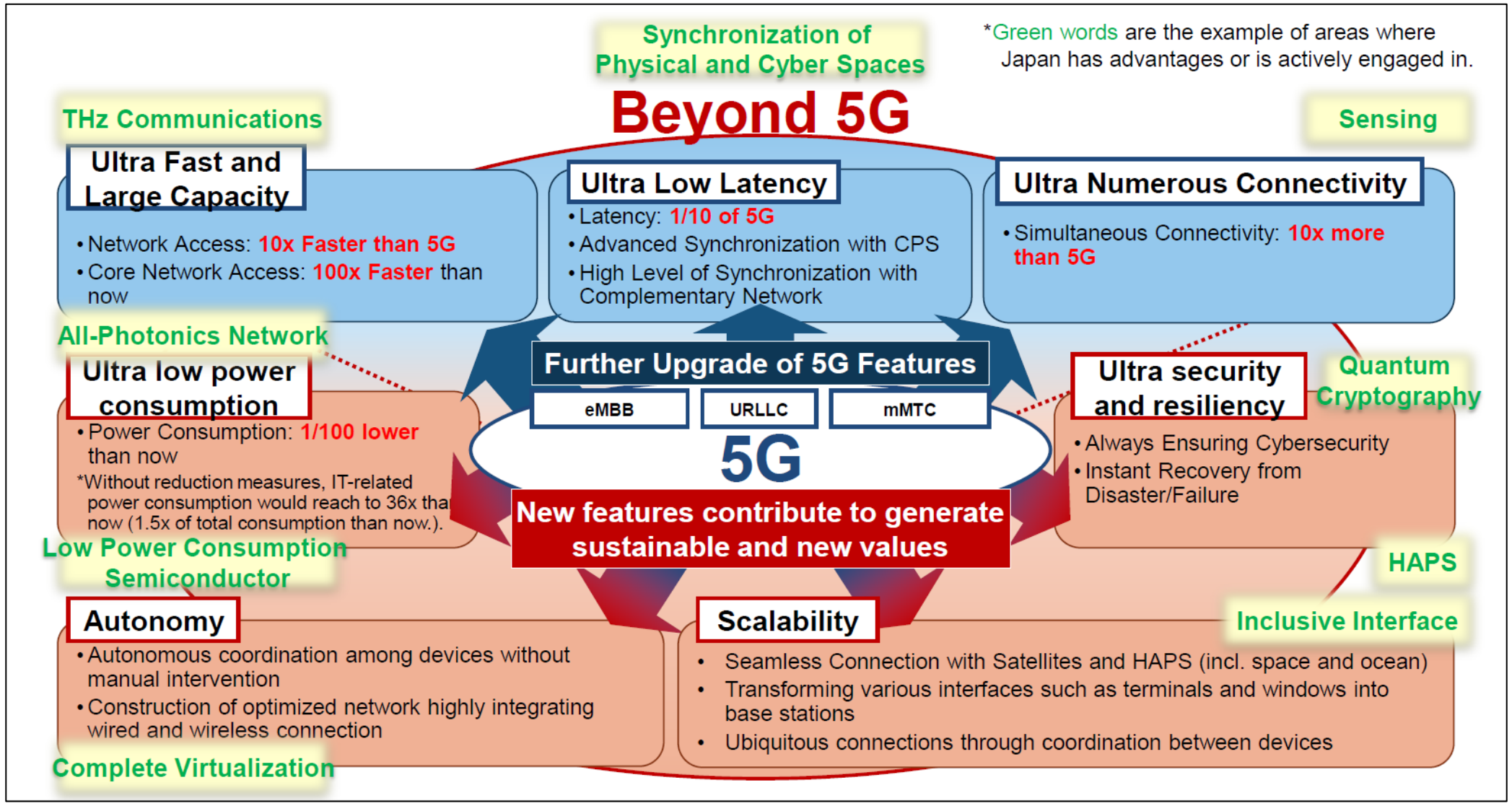


https://b5g.jp/output.html

5. Capabilities and KPIs required in Beyond 5G (5.2)



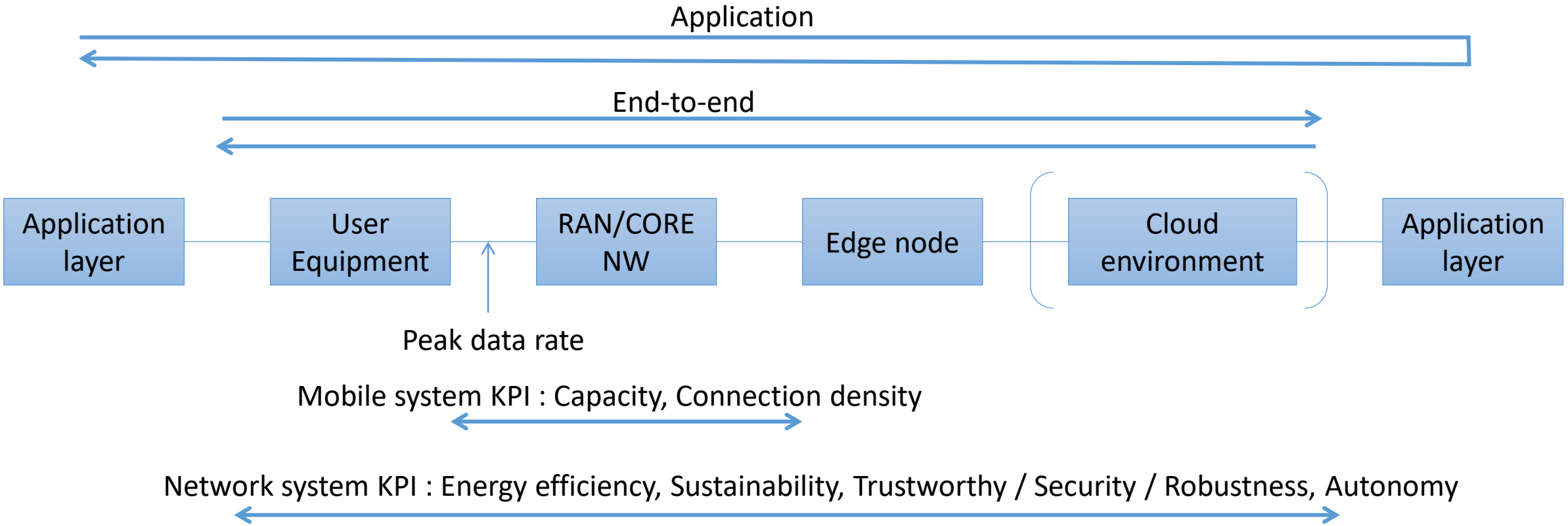
5.2.1 Key Features for Beyond 5G



"Beyond 5G Promotion Strategy Roundtable Recommendations", Beyond 5G Promotion Strategy Roundtable (June 2020).

5.2.2 Consideration of Target Key Performance Indicators for Beyond 5G

User experienced KPI (end-to-end): Data rate, Latency/Jitter, Reliability, Coverage, Mobility, Position accuracy



Applicable parts of the target KPIs

5.2.2 Target KPIs for Beyond 5G (Quantitative indicators)

User experienced data rate (DL/UL)	10-100Gbps typical and 1Gbps everywhere
Peak data rate (DL/UL)	100Gbps or higher
Capacity	100 times of IMT-2020
Latency	1msec for general use case, 0.1msec for localized communication use case (one-way)
Jitter	1msec or less
Response	100msec round trip application response (including expected application dependent processing delay)
Reliability	10^{-6} -10^{-7} (RAN)
Positioning accuracy	Order of cm (and more)
Connection density	10^{6} - 10^{7} devices /km^2
Energy efficiency	100 times of IMT-2020
Mobility	1000 km/h
Area coverage	100% land coverage Coverage expansion to land, sea, air, and space
Area coverage/HAPS	Horizontal coverage: tens to hundreds of kilometers in radius Vertical coverage: a few kilometers above the ground

5.2.2 Target KPIs for Beyond 5G (Qualitative indicators)

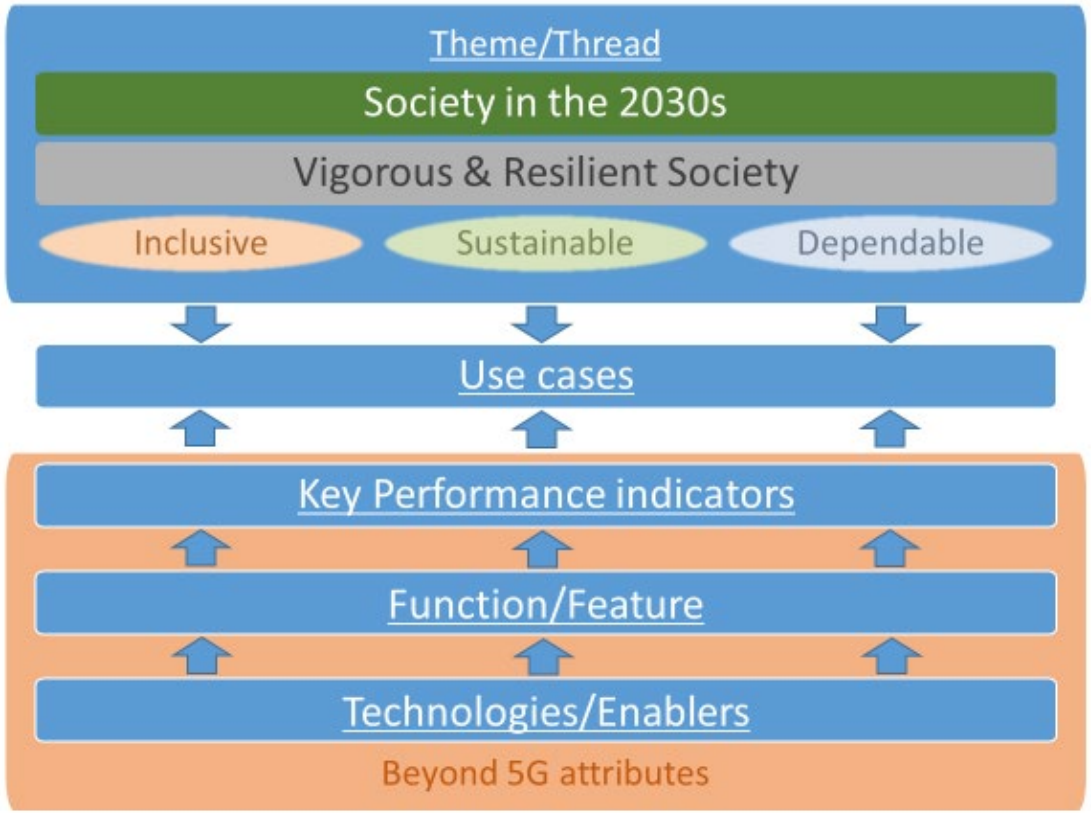
Sustainability	• Reduce the environmental impact of equipment (use of environmentally friendly materials, improved reusability) • Equipment longevity (software extensibility and modular structure of HW) • Carbon neutrality (use of renewable power sources)
Trustworthy / Security / Robustness	• Cryptographic processing speeds exceeding the peak data rate (100Gbps and more) • Support for 256-bit key length for post-quantum cryptography • Instantaneous recovery from disasters and failures
Autonomy	• Zero-touch, autonomous coordination of devices • Building optimal beyond wired and wireless networks • Achieve full automation that simultaneously satisfies labor-saving, flexibility, and speed in all workflows, from construction to operation
Scalability	• Seamless connections with satellites and HAPS, make terminals, windows, and other devices as base stations, and communication at everywhere through cooperation of every device • Open interfaces (Network API, application API)

6. Technology trends

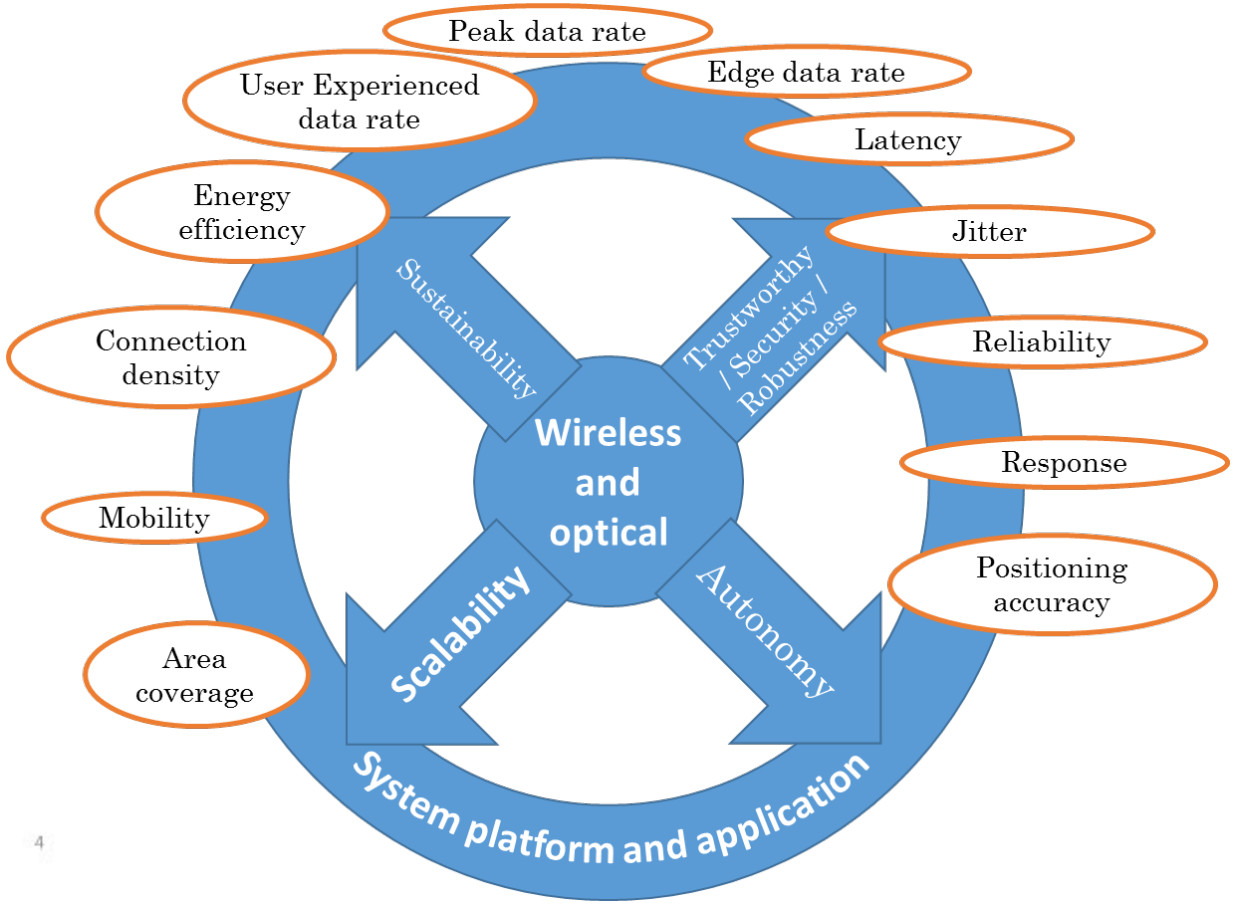
6.1 Observations of technology trends towards Beyond 5G

As mentioned in the previous chapters, various efforts are being made to develop technologies for Beyond 5G in order to meet the market demands and expectations for the 2030s and to contribute to the achievement of the target KPIs described in Chapter 5.2. Before going into the role of these technologies and their implications in Chapter 6.2-6.7, we describe an overview of market demand and deployment below, and also touch upon the perspective of Global Commons.

6.1.1 Market demands

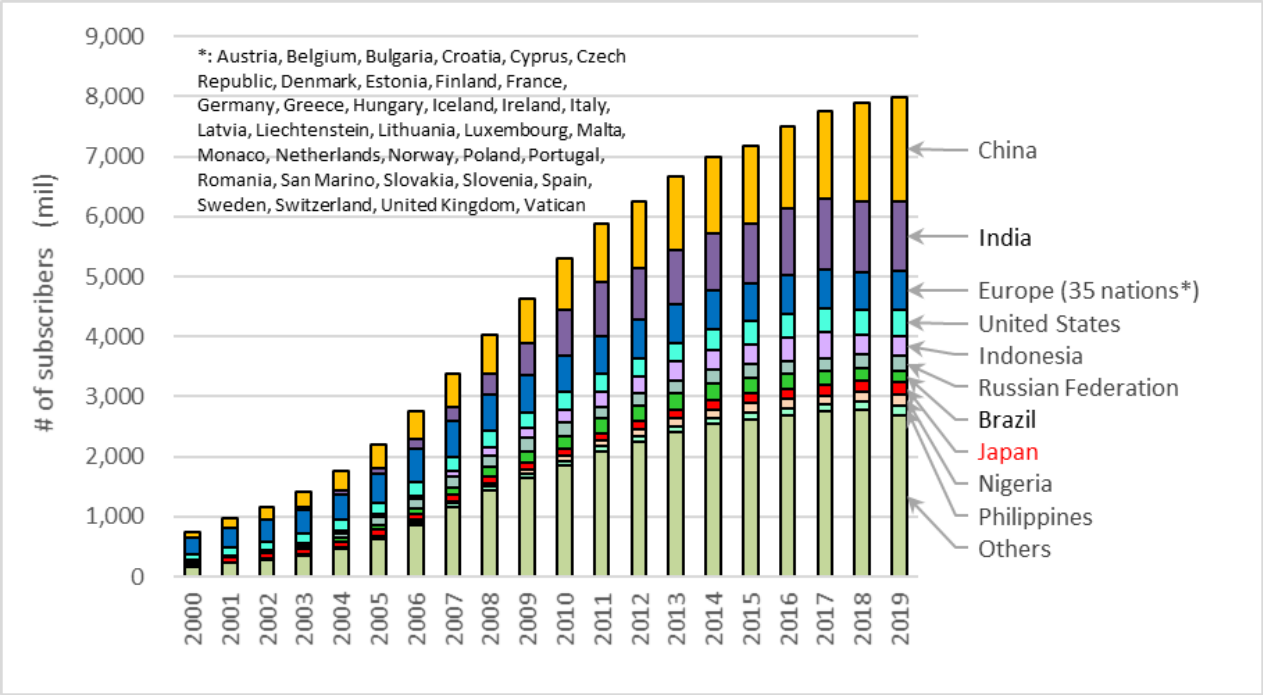


Technologies and enablers supporting societies in the 2030s

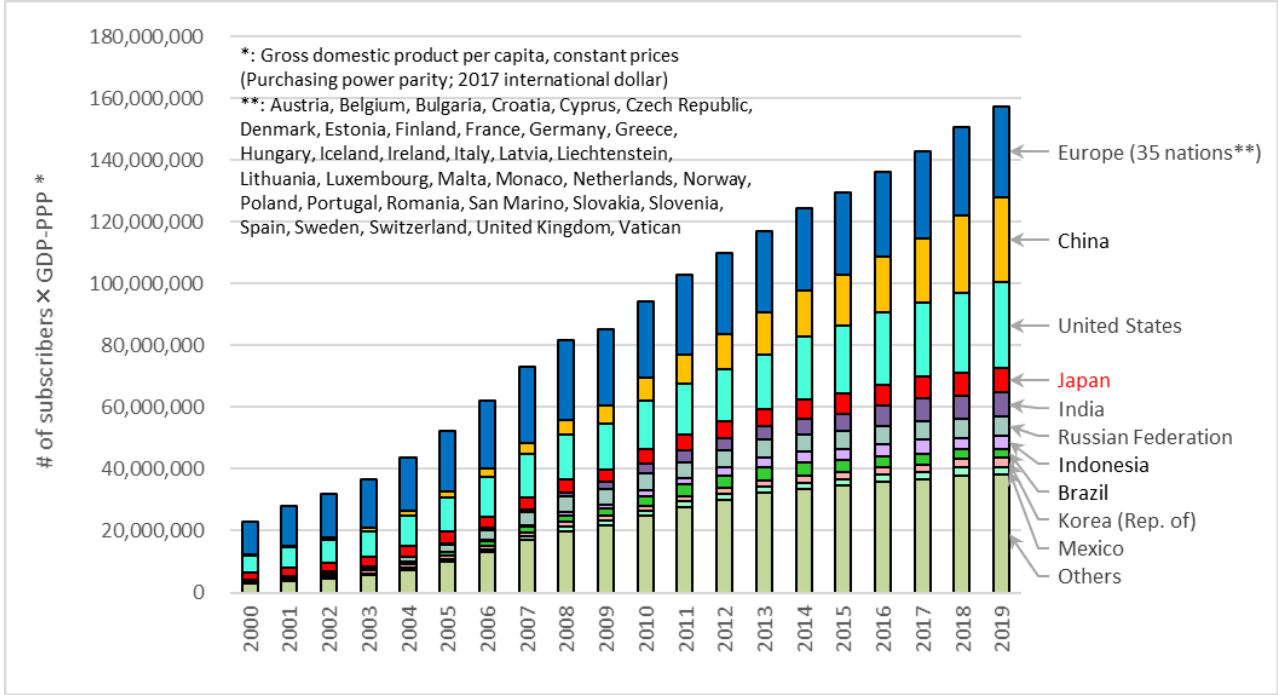


Technologies supporting the Target Key Performance Indicators

6.1.2 Deployment aspect



Number of mobile phone subscriptions worldwide [1]

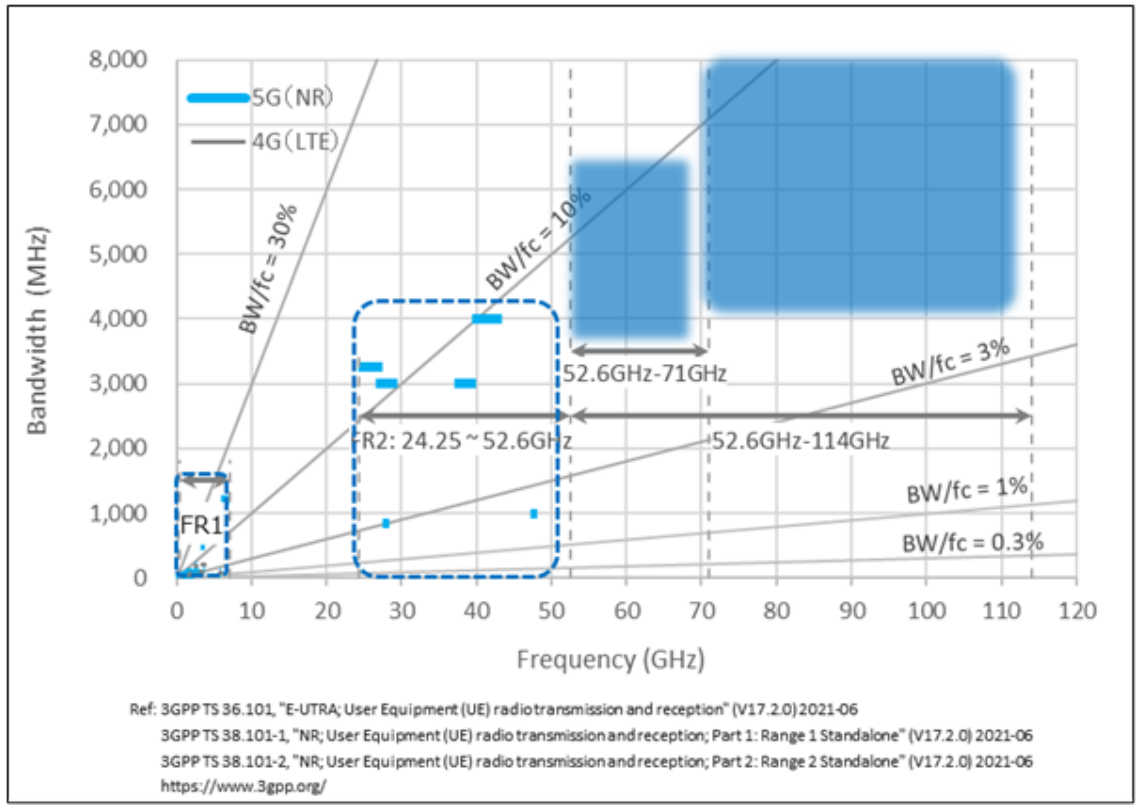


Number of subscribers multiplied by GDP-PPP [1][2]

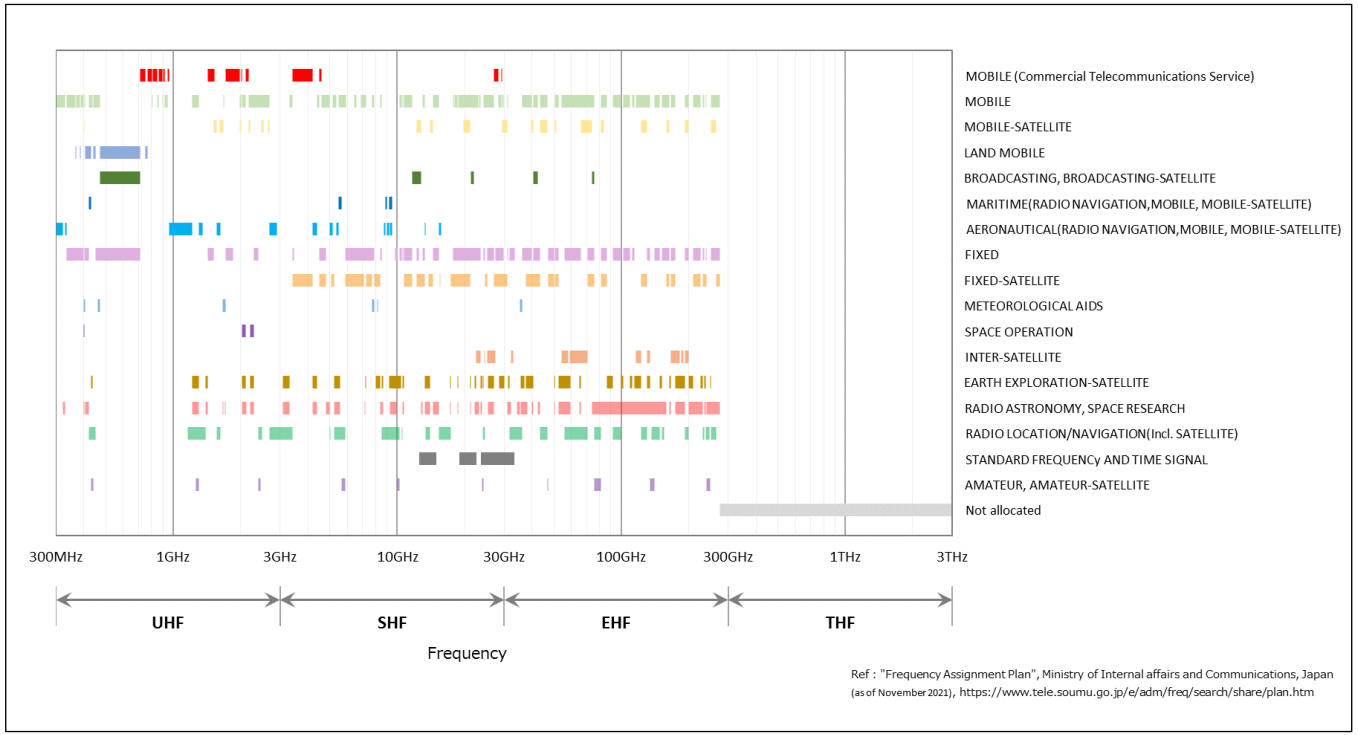
*Gross domestic product (GDP) per capita-purchasing power parity

[1] “Mobile-cellular subscriptions (excel)”, International Telecommunication Union, Telecommunication Development Sector (ITU-D), (November 2021).
[2] “World Economic Outlook Database”, International Monetary Fund, October 2021.

6.1.3.1 Trends in radio frequency resource utilization



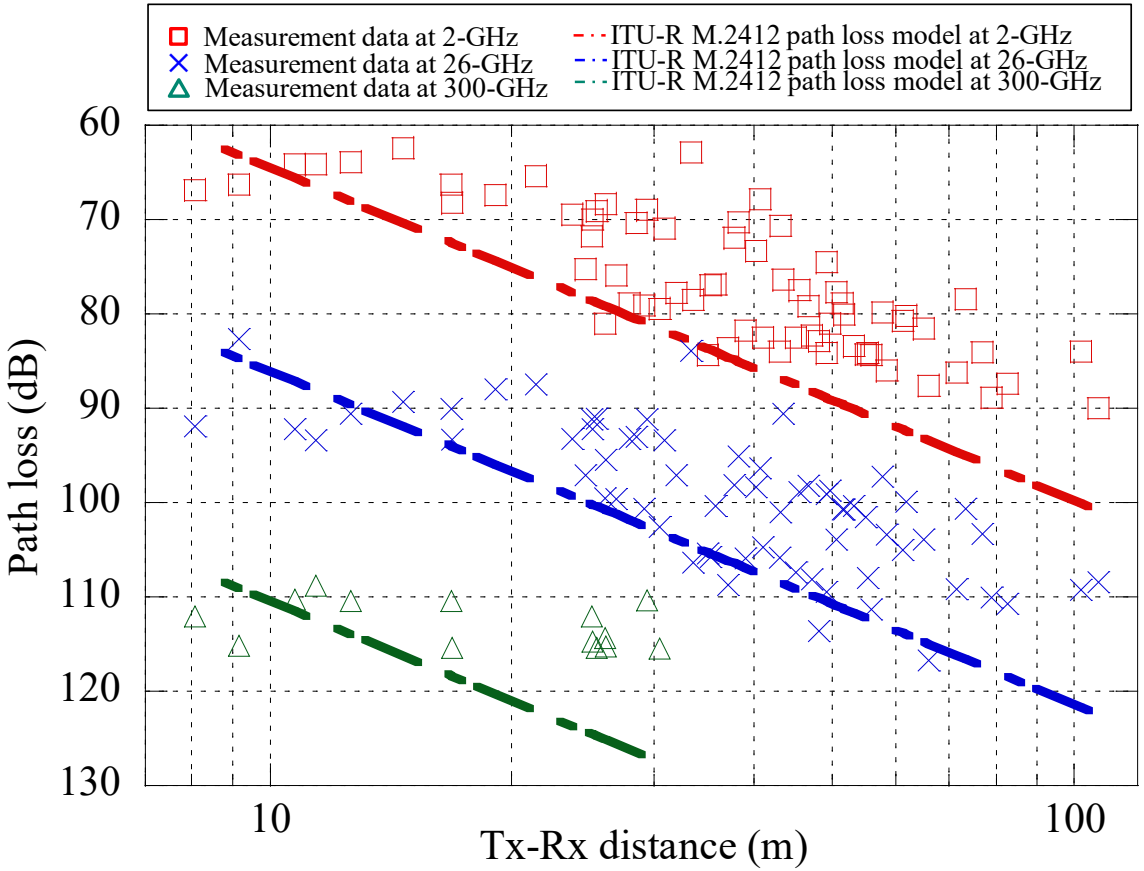
Frequency bands defined for 4G and 5G in the 3GPP specifications [1] [2] [3]



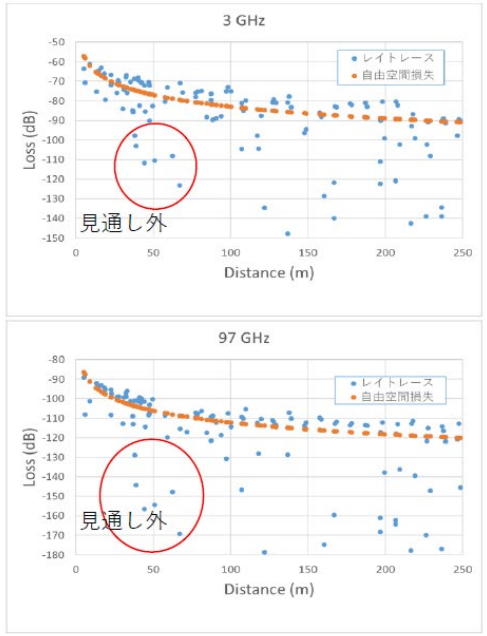
Frequency assignments in Japan [4]

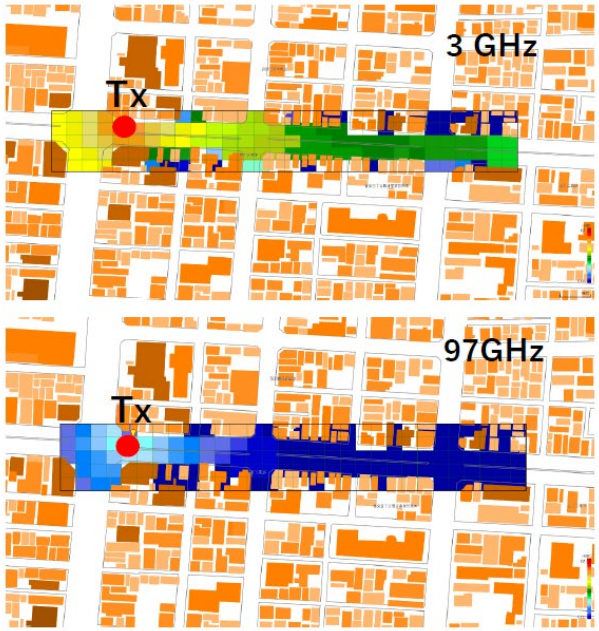
[1] "E-UTRA; User Equipment (UE) radio transmission and reception", 3GPP TS 36.101, (V17.2.0) 2021-06.
[2] "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone", 3GPP TS 38.101-1, (V17.2.0) 2021-06.
[3] "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone", 3GPP TS 38.101-2, (V17.2.0) 2021-06.
[4]「周波数割当計画」総務省 (2021年11月時点の情報により作成).

6.1.3.2 Studies related to Radio Propagation [1/2]



Measurement of path loss characteristics [3]

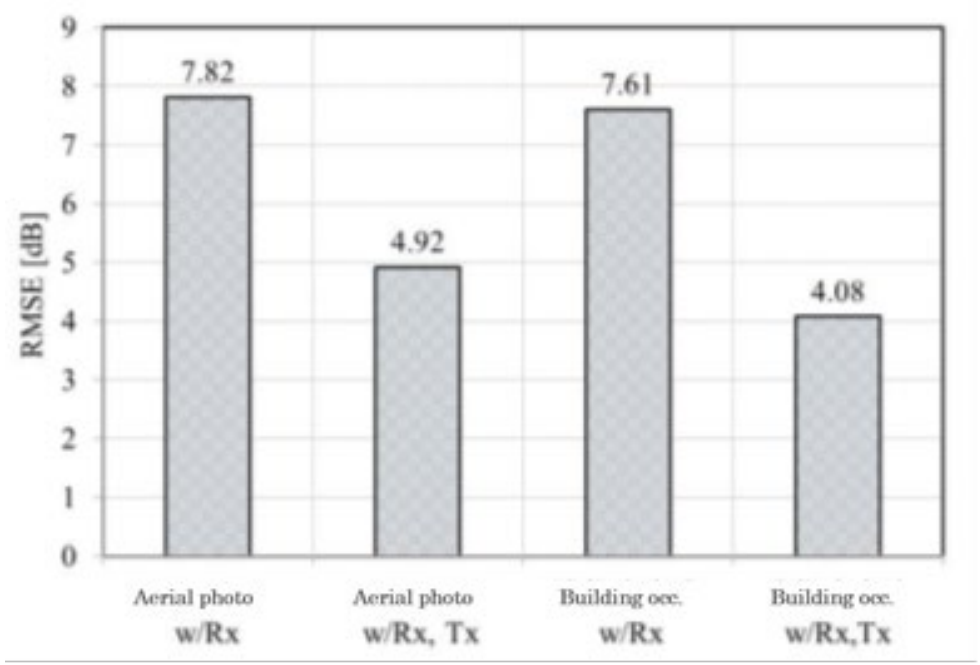




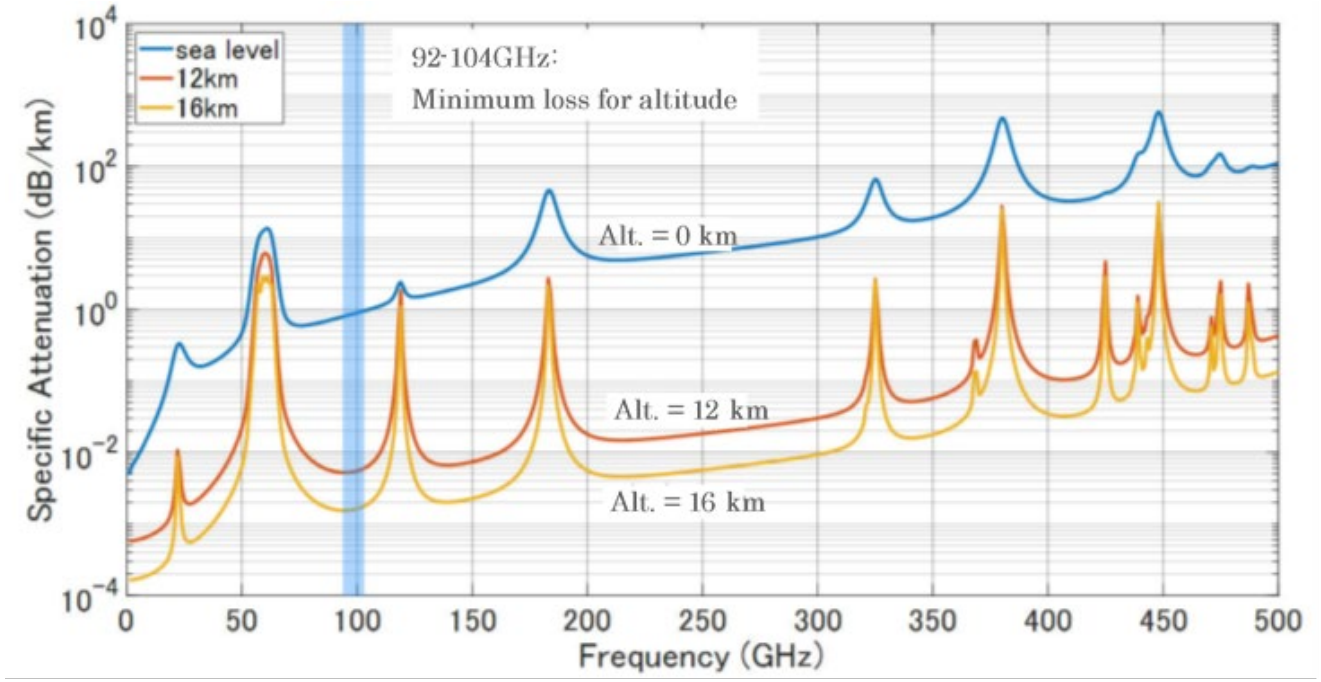
Ray-tracing and free-space propagation model comparison (Outdoor street canyon) propagation[4]

[1] M. Inomata et.al, “Radio Propagation Characteristics for Pioneering Terahertz Wave Bands in 6th Generation Mobile Communication Systems,” IEICE Technical Report RCS2020-98 (2020-10).
[2] M. Inomata et.al, “Path Loss Characteristics from 2 to 100 GHz Bands in Urban Microcell Environment for 6G,” IEICE Technical Report, A·P2021-51 (2021-08).
[3] ITU-R M.2412, “Guidelines for evaluation of radio interface technologies for IMT-2020,” Sep. 2017.
[4] Y. Oda, “Technical study on radio wave propagation characteristics of Terahertz wave”, Planning and Strategy Committee of Beyond 5G Consortium, (in Japanese, Feb. 2021).

6.1.3.2 Radio Propagation related studies [2/2]



Root mean square error (RMSE) from the measurement results[1][2][3]

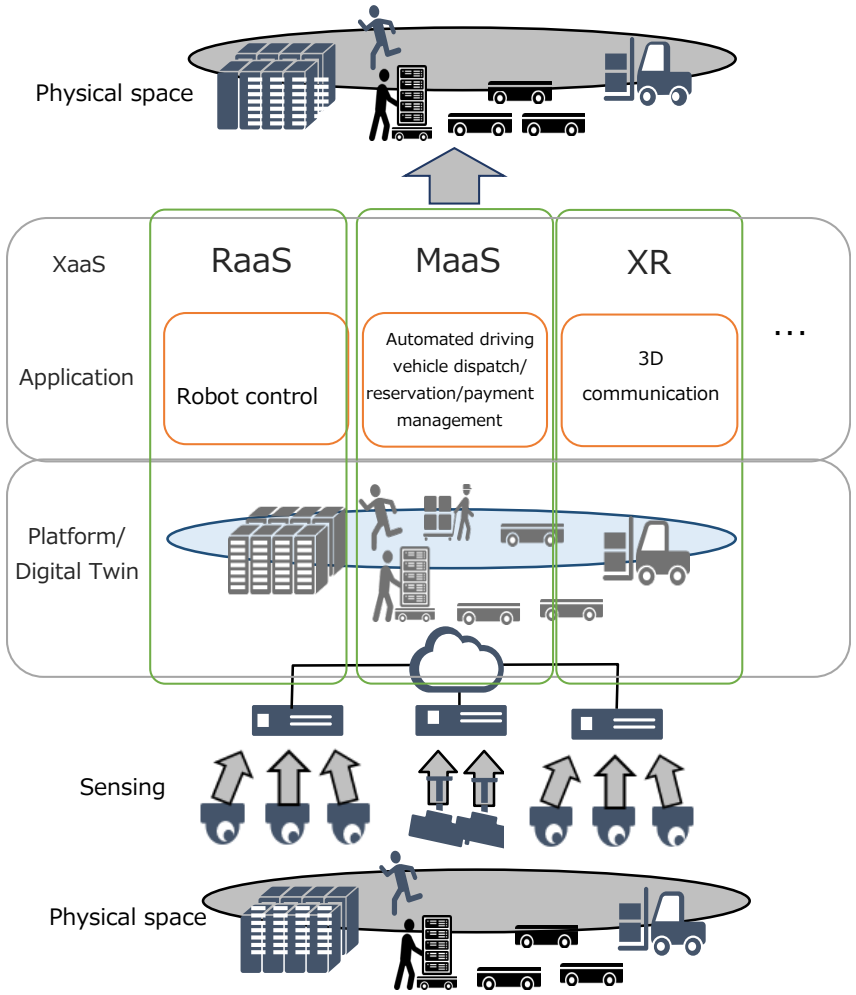


Propagation losses due to atmospheric gases and related effects[4][5]

[1] T. Hayashi, T. Nagao and S. Ito, “A study on the variety and size of input data for radio propagation prediction using a deep neural network,” 202014th European Conference on Antennas and Propagation (EuCAP), 2020.
[2] T. Nagao and T. Hayashi, “Study on radio propagation prediction by machine learning using urban structure maps,” 2020 14th European Conference on Antennas and Propagation (EuCAP), 2020.
[3] T. Nagao and T. Hayashi, “Geographical Clustering of Path Loss Modeling for Wireless Emulation in Various Environments,” [Manuscript submitted for publication] 2022 15th European Conference on Antennas and Propagation (EuCAP), 2022.
[4] T. Kawanishi et.al, “THz communications for non-terrestrial-networks”, [Manuscript submitted for publication] (in Japanese, Mar. 2022)
[5] Recommendation ITU-R P.676-12(2019), Attenuation by atmospheric gases and related effects.

6. Technology trends (6.2 to 6.7)

6.2 System Platform and Application



Service (XaaS) and Platform/Application technologies in CPS

* A part of figures is provided by NEC.

Promotion of Society 5.0

A human-centered society that achieves both economic development and solution of social issues through a system that brings about a high degree of integration between cyberspace (virtual space) and physical space (real space), i.e., the Cyber-Physical System (CPS).

■ Considerations of communication infrastructure technology and associated platform and application technology.

Examples of fundamental technologies for XaaS in CPS

- Estimation of object location and posture with the digital twin
- Object recognition/identification with the digital twin
- Real-world prediction using the digital twin
- Robot control for safety, acceptability, and efficiency
- Physical space reconstruction and augmentation
- Multimodal interaction

6.3 Trustworthiness (Security, Privacy, and Resilience)

Trustworthiness technologies need to be integrated into the Beyond 5G network

■ **Trustworthiness network technologies**
- **Multi-lateral trust model with distributed ledger technology**
- **Confidential computing**
- **Security functions, analysis technologies, and support**

■ **Other trustworthiness technologies**
- **AI Security**
- **Security for Quantum Computing**

Security considerations for seven Beyond 5G features (Revision of [1])

Features	Security requirements
Ultra-fast & large capacity	•High speed encryption/decryption •New security monitoring and processing methods
Ultra-low latency	•Seamless security architecture •Lightweight security
Ultra-numerous connectivity	•Efficient authentication/authorization •Efficient security processing and monitoring mechanisms
Ultra-low-power consumption	•Security mechanisms in hardware •Lightweight security architecture
Ultra-security and resiliency	•New security monitoring and defensing mechanisms •Security mechanisms for confidentiality, integrity, and availability •Resilience mechanism for attacks/failures •Privacy-preserving mechanisms •Trustworthiness of network including different nodes and domains •Accounting, accountability, validation of delivered services
Autonomy	•Trust mechanism without trusted parties
Scalability	•Interoperable security mechanism between different networks/domains

[1] Yutaka Miyake, “International Coordination in the R&D (4) Security,” Beyond 5G International Conference. Nov. 10, 2021.

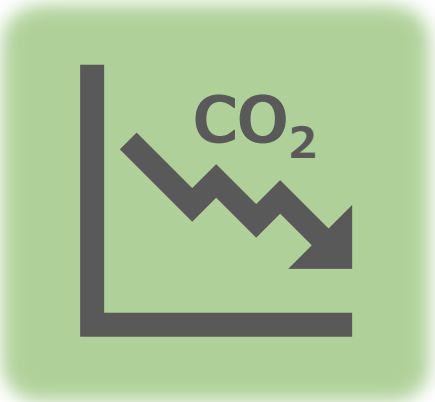
6.4 Network energy efficiency enhancement

Goal of energy efficiency for Beyond 5G

- By introducing the green design concept and native AI capability, the overall energy efficiency across the Beyond 5G network (defined in bits per Joule) will be improved, e.g., 100-fold.
- Keeping the total energy consumption (in unit of Joules) lower than that of 5G, while also ensuring optimal service performance and experience.

Technologies and research directions

- Framework for designing and evaluating the energy efficiency of networks
- Hardware aspect (especially power amplifier efficiency)
- Network aspect (service provision in accordance with traffic dynamics in time and space)
- Renewable energy, passive transmission
- Distributed network to solve the centralized AI training and inference power problem



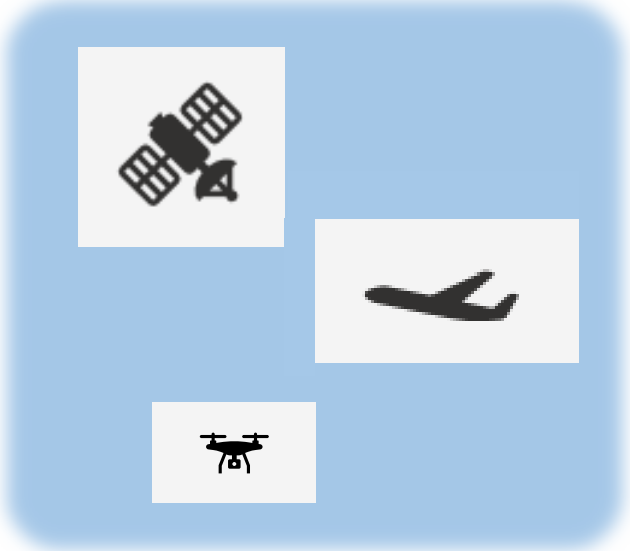
Non-terrestrial networks (NTN) enhance the coverage of future IMT from ground through the air toward space, which enables ubiquity of communications, and is expected to enable new use cases, such as effective connection with unmanned systems, monitoring (video and data), mobile eMBB, IoT, logistics systems, and backhaul (especially for emergencies), and smartphone integration.

■ **Research and development initiatives for 2030s:**

High throughput and capacity, Low latency, Massive connection for IoT, Optical laser communications, Optimal route selection and multi-connectivity technology, Quantum cryptography communications, Autonomous operations, Edge computing technology

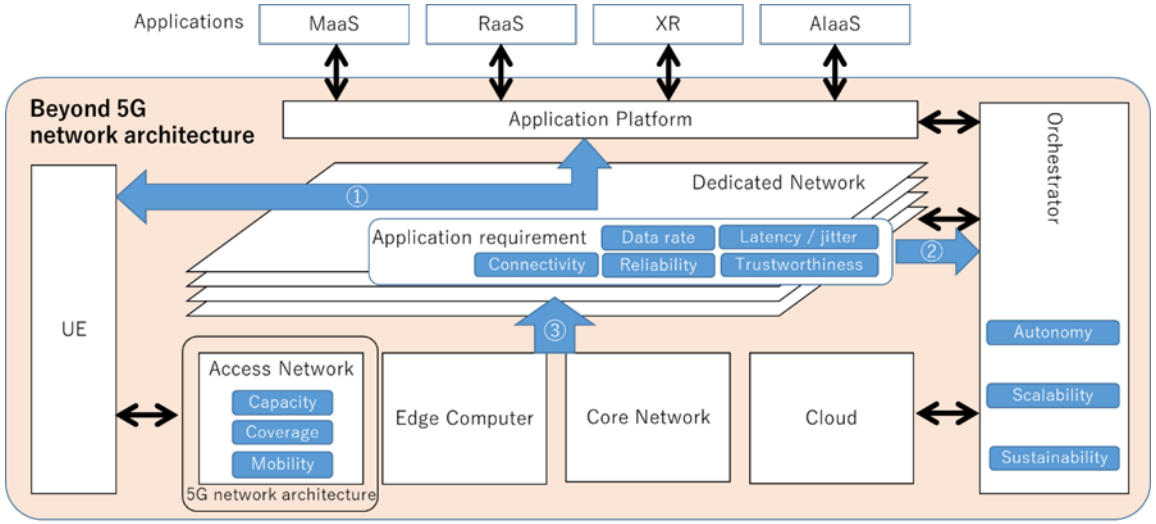
■ **Non-terrestrial networks (NTN) :**

- High Altitude Platform Station (HAPS)
- Satellite communications
- UAV(Unmanned Aerial Vehicle)-assisted Wireless Communications



6.6 Network architecture

1. Beyond 5G architecture embodies Beyond 5G infrastructure and is able to provide not only the optimal RAN and core network functions but the overall Beyond 5G functions for end-to-end communications.
2. Beyond 5G architecture is able to consider performance for end-to-end communications and user experienced quality.
3. Beyond 5G architecture provides both computing resources and network resources to utilize ubiquitous sensors and AIs.



Beyond 5G network architecture features:
① Control for end-to-end communication.
② Application QoE aware
③ Integration of both network and computing resource.

- Network architecture
  - Virtualized RAN and core network
  - Computing resource distribution with vRAN
  - IP connectivity between service entities
  - Network AI architecture
- User/application-centric communication architecture
  - User-centric architecture
  - Application-aware network optimization
- Autonomous network operation

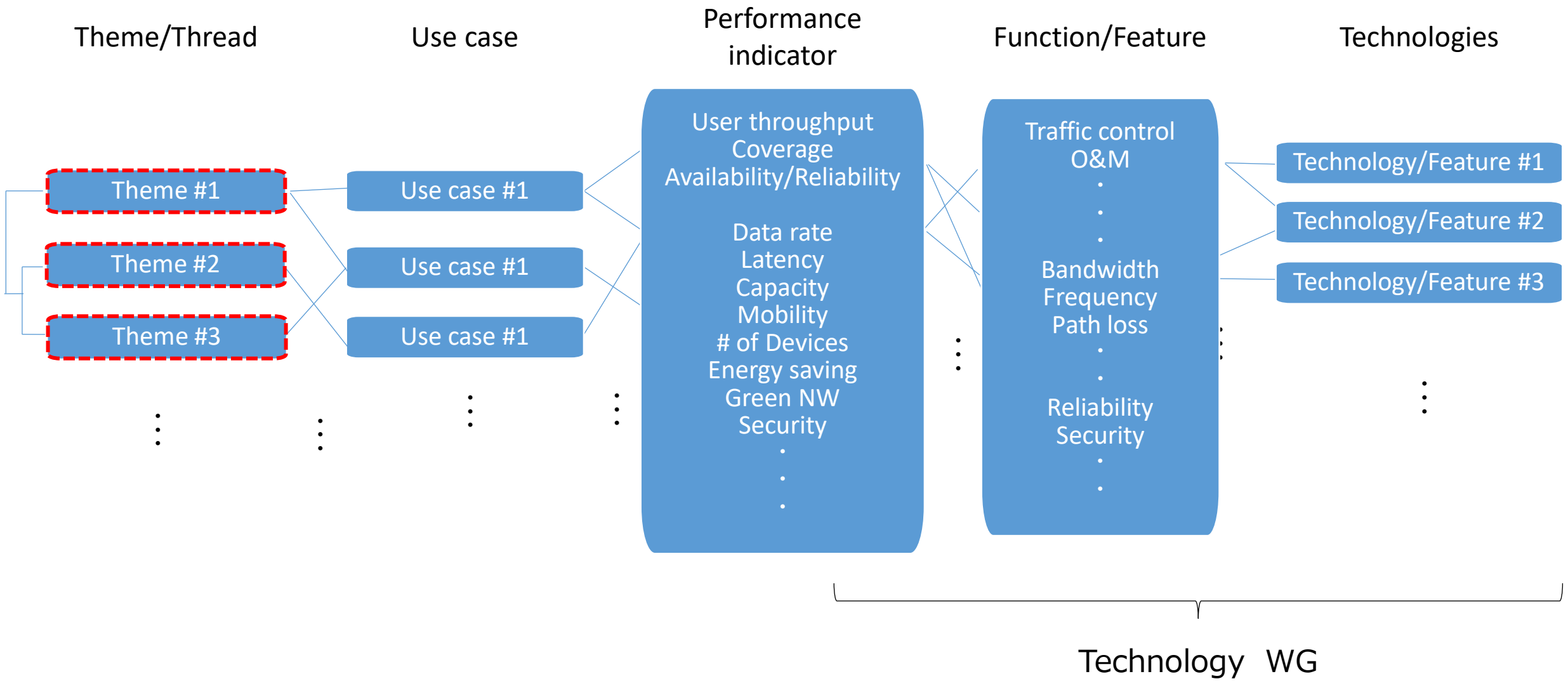
6.7 Wireless and optical (1/2)

Clause	Title	Features, strengths	Value	Role	Technical overview
6.7.1	New Radio Network Topology	Radio network topology utilizing advanced NW elements	High stability, low power consumption, high flexibility	high-capacity communications regardless of users' locations	distributed antennas, repeaters/relays, Reconfigurable Intelligent Surface (RIS)
6.7.2	Technology for wider bandwidth and advancement of frequency utilization	Wider bandwidth utilizing millimeter and terahertz waves, ultra-massive MIMO system	Wider bandwidth enables optimized use of spectrum, covering new use cases, improving user experience	Processing massive amounts of data from any location instantly and accurately.	Radio propagation models and simulation, advanced device technology, spectrum sharing etc.
6.7.3	Further advancement of RAT/air interface	Radio access technology (RAT) and air interface specialized in Beyond 5G	Ultra-high capacity and data rate	Bridging the digital divide, providing better environmental awareness	New waveform, modulation, coding, multiple access, full duplex schemes, and advanced MIMO/massive MIMO
6.7.4	Technology to support extreme ultra-reliable and low latency communications	Extremely low latency communication at end-to-end by high-precision space-time synchronization	Supporting mission-critical industries etc.	Reduction of energy and frequency resources through the efficient data transfer	Extremely low latency of about 1 ms or less on the end-to-end basis
6.7.5	Technology to enhance energy efficiency and low power consumption	A long history of improving spectral efficiency and power consumption	Providing sustainable and carbon-neutral communication systems	Contributing to carbon neutrality by eliminating unnecessary energy consumption	Energy harvesting technologies, advanced resource management of the network resources
6.7.6	Integrated sensing & communications and high-accuracy localization	High-resolution sensing by high-frequency radio wave feature, pico-second level synchronization accuracy with wireless space-time synchronization	Building an intelligent digital world using High-resolution and high-accuracy sensing, localization (including positioning)	Mutual functioning of sensing and communication functions for digital twin	Integration of sensing and communication functions at different levels of the communication systems

6.7 Wireless and optical (2/2)

Clause	Title	Features, strengths	Value	Role	Technical overview
6.7.7	Management of radio access/core network and other wireless systems	Providing large capacity and low latency communications via radio resource management etc.	Flexible services, effective use of finite radio resources	Providing required communication services using available radio resources	Integration of various wireless technologies, Core network management
6.7.8	Technology for native AI-based communication	Improving the overall system performance by deeply integrating AI	More efficient in terms of power consumption and spectrum utilization	To revolutionize wireless network architecture and air interface design.	AI-enabled intelligent PHY and MAC controller, AI-enabled intelligent protocol and signaling
6.7.9	Optical communication technology	A decades-long history of optical technology development, a high-speed nationwide optical network	Providing efficient, large-capacity, comfortable and stress-free communication services	To support a sustainable society as part of the advanced communication infrastructure	Multi-core fiber, photonics-electronics convergence technology
6.7.10	Radio over Fiber(RoF)	Large-capacity mobile fronthaul transmission, power and space saving of base stations	Large-capacity mobile fronthaul transmission, power and space saving of base stations	Large-capacity mobile fronthaul transmission, power and space saving of base stations	Intermediate Frequency over Fiber（IFoF) technologies
6.7.11	Optical wireless and acoustic communications	Complementary solution to the radio communication systems, providing positioning or sensing services	Unlicensed spectrum, low cost, low-power-consumption communication, security, communication service underwater	Complementary solution to the radio communication systems, providing positioning or sensing services	Integrated Sensing and Communication with Optical Wireless（ISAC-OW）technologies

【Appendix】Use case to technology mapping exercise



Thank you