Beyond5G R&D Status Update In Japan

Aki Nakao

Chair of International Committee, Beyond5G Promotion Consortium

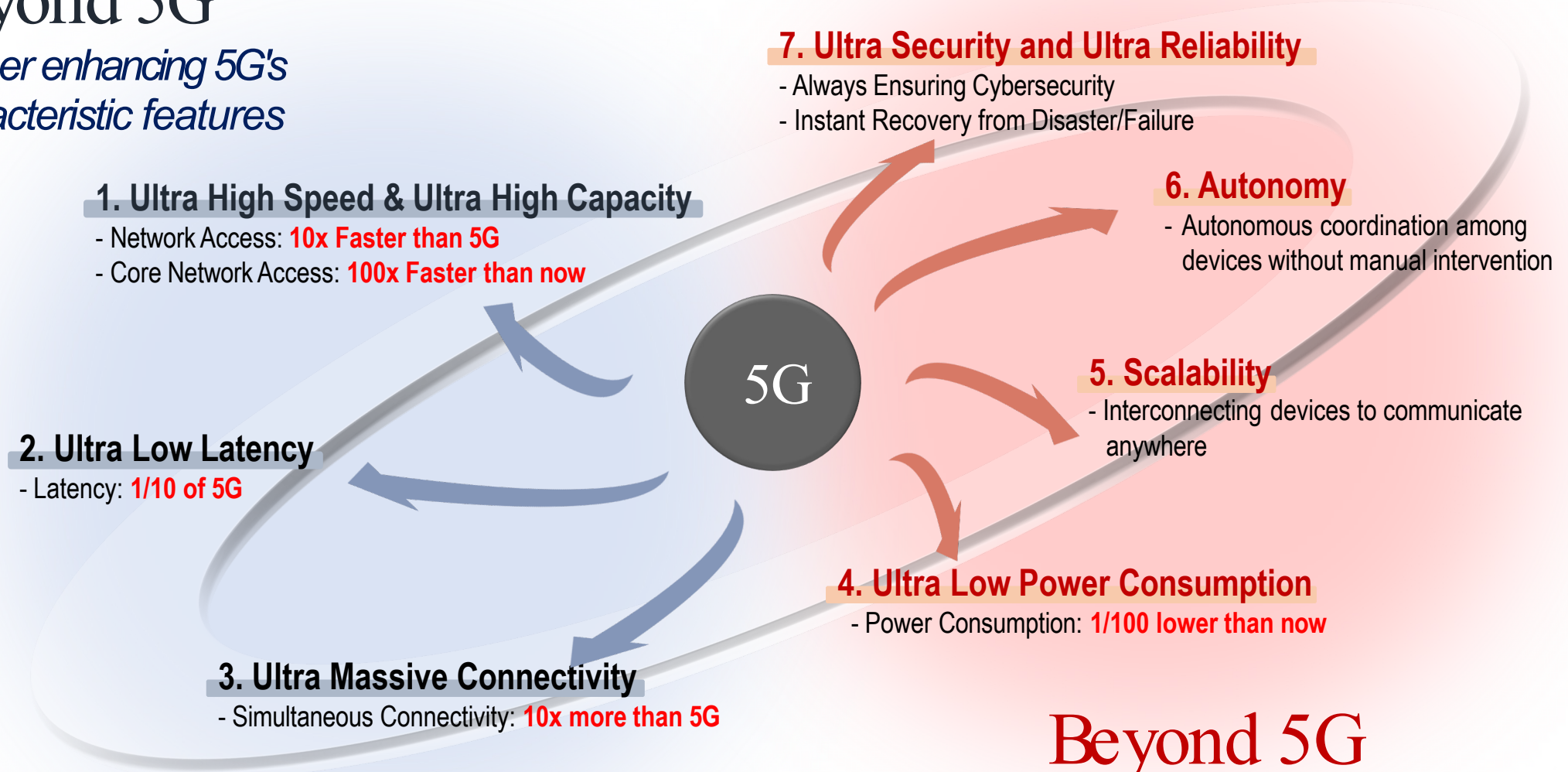Professor, School of Engineering, The University of Tokyo

Aki Nakao

- Professor, Department Head of Systems Innovation, School of Engineering, the University of Tokyo
- Special Advisor to the President of the University of Tokyo
- Director of Next Generation Cyber Infrastructure Institute, the University of Tokyo

- Member of Science Council of Japan
- Chairman of International Committee of Beyond5G Promotion Consortium
- Chairman of Network Architecture Committee of 5GMF
- Chairman of 5G/Beyond5G Committee of Space ICT Forum
- Community Informatization Adviser to the Ministry of Internal Affairs and Communications, Japanese Government
- Chairman of Local5G Promotion Research Group
- Founder of FLARE SYSTEMS

Key Features for Beyond 5G/6G

Beyond 5G
*Further enhancing 5G's characteristic features*

1. Ultra High Speed & Ultra High Capacity
- Network Access: **10x Faster than 5G**
- Core Network Access: **100x Faster than now**

2. Ultra Low Latency
- Latency: **1/10 of 5G**

3. Ultra Massive Connectivity
- Simultaneous Connectivity: **10x more than 5G**

7. Ultra Security and Ultra Reliability
- Always Ensuring Cybersecurity
- Instant Recovery from Disaster/Failure

6. Autonomy
- Autonomous coordination among devices without manual intervention

5. Scalability
- Interconnecting devices to communicate anywhere

4. Ultra Low Power Consumption
- Power Consumption: **1/100 lower than now**

5G

Beyond 5G
Adding new features that contribute to the creation of new values

Beyond 5G/6G R&D Challenges
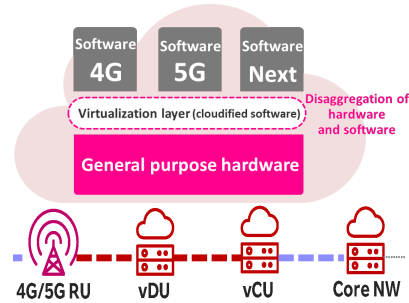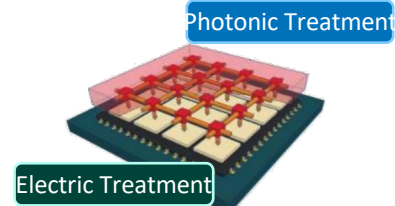

Challenge 1 — All photonics network technology
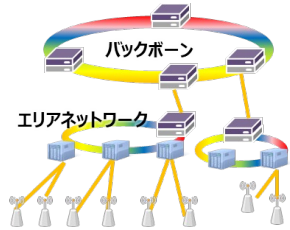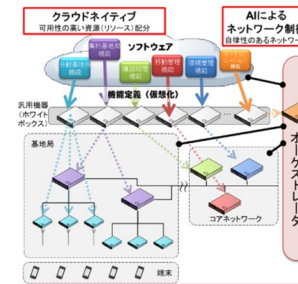
Challenge 2 — Open network technology

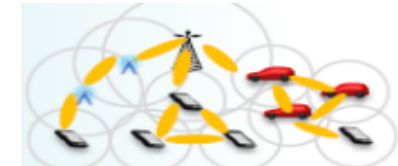**Challenge 3** — Device technology

Challenge 4 — Network orchestration technology

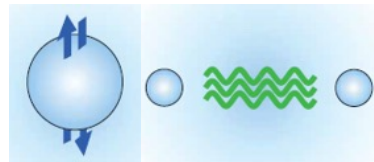**Challenge 5** — Wireless network technology

Challenge 6 — NTN (HAPS/ satellite network) technology

Challenge 7 — Quantum network technology

Challenge 8 — Terminal and sensor technology
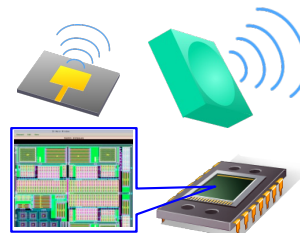
Challenge 9 — E2E virtualization technology
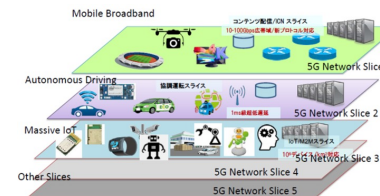
Challenge 10 — Beyond 5G service and application technology

Beyond 5G Policy Recent Updates in Japan

EUR 1 = JPY 160

Research organizations In Japan (Private companies, universities, etc.)

Funded in spring 2021

About 70 projects implemented

Initial Fund
<For FY2021–FY2022>
\30 billion (about €188 million)
(+\30 billion [about €188 million]: R&D)
(+\20 billion [about €125 million]: Test beds)

Commission /Grant

Additional budget

Funded in spring 2023

New Fund
<For FY2023–>
\81.2 billion (about €508 million)

Grant/ Commission
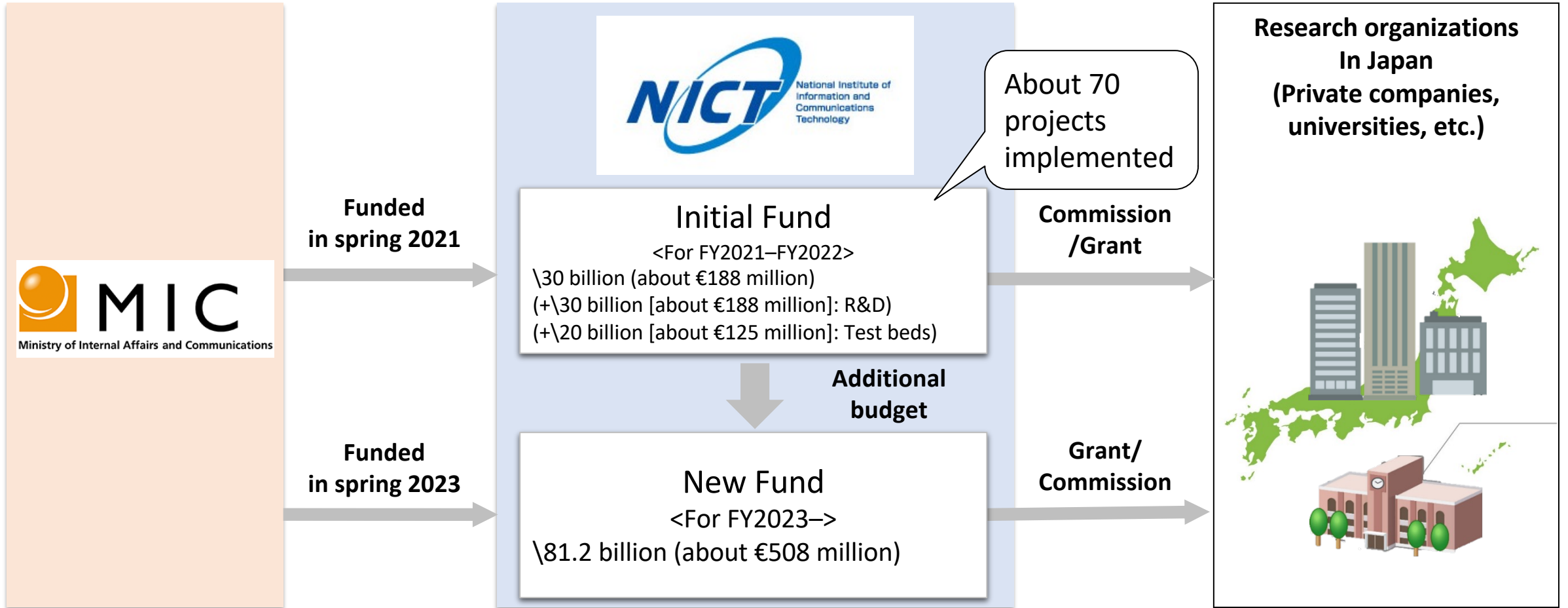
G7 Digital and Tech Ministers' Meeting in Takasaki, Gunma

- On April 29 and 30, 2023, the Japanese Government held the G7 Gunma Takasaki Digital Technology Ministers' Meeting in Takasaki City, Gunma Prefecture.
- As a result of this meeting, "Ministerial Declaration The G7 Digital and Tech Ministers' Meeting" was adopted, which includes "G7 Vision of the future network in the Beyond 5G/6G era" in the context of **"Secure and Resilient Digital Infrastructure"**

※In addition to representatives from the G7 countries and the EU, representatives from India, Indonesia, Ukraine, ERIA, ITU, OECD, the United Nations and the World Bank also participated.

Ministerial Declaration of The G7 Digital and Tech Ministers' Meeting (Excerpt)

20. In addition to these efforts to improve security and resilience of current digital infrastructure, we note the importance of sharing a vision for the next generation network in the Beyond 5G/6G era, and endorse the G7 Vision of the future network in the Beyond 5G/6G era. We are committed to enhancing cooperation on research, development, and international standards setting, toward building digital infrastructure for the 2030s and beyond. [Annex 2]

G7 Vision for future networks in the Beyond 5G/6G era [Annex 2]

We share a common vision for future networks with the following elements.

①**End-to-End High-capacity and Ultra-low latency:**

Not only radio access network but also the whole network architecture should be considered in designing and developing critical technologies and standards for future networks.

②**Energy Efficiency and Environmental Impacts:**

In order to minimise the energy consumption and environmental impacts associated with increased data traffic, a significant reduction in overall network power consumption and development of eco-designed network equipment are essential factors for a sustainable digital society.

③**Multi-layered network:**

Network connectivity should be enhanced through developing and deploying multi-layered networks with terrestrial networks, submarine cables, and non-terrestrial networks (NTN), such as Low Earth Orbit (LEO) Satellites and High-Altitude Platform Station (HAPS), and we recognise the importance of seamless interoperability between these networks.

④**Frequency Efficiency:**

With smaller cell diameters in the same spectrum a higher frequency reuse rate can be achieved. This may reduce the energy consumption of mobile networks, such as Beyond 5G/6G networks.

In addition to the above elements, we recognise that openness, interoperability, and modularity are important elements of future networks in the Beyond 5G/6G era.

G7 Action Plan for Building a Secure and Resilient Digital Infrastructure [Annex 3] (Excerpt)

We endeavour to enhance cooperation on research, development, and international standardization, toward building digital infrastructure in the Beyond 5G/6G era. In that regard, we recognise the importance of measuring and monitoring the evolution of energy consumption and environmental footprint indicators through recurrent data collection and use of indicators based on known and stable methodology.

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Vision of Beyond 5G Network Architecture

Services

Network Platform
- Multi Network Orchestrator
- Open-RAN Base
- Controller — Carrier A, Carrier B — Fixed Core Network
- Controller — Space Network
- Controller — Carrier C, Carrier D — Mobile Core Network

Network Infrastructure
- Controller

Devices and Terminals
- Photoelectric fusion device and Computing
- Smartphone
- Factory and Robot
- IoT, Camera
- Drone
- Self-driving Car

Innovative and attractive services and content are expected to flourish.

<Key concepts and elements >

-Not only RAN* but also whole network architecture should be considered.

-End-to-end high-capacity and ultra-low latency networks are desired.

-Energy efficiency should be realized throughout the networks.

-Communication coverage areas are expected to expand to sky, ocean, and space.

-Security and resilience are essential factors.

Support variety of mission-critical devices/systems/services

RAN: Radio Access Network

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International Landscape on Beyond5G/6G and MoU with Beyond5G Promotion Consortium

Europe

Hexa-X Project
- Launched in January 2021. A project to conduct research and development on 6G over the next two years and a half.
- A total of 25 companies and universities participated, including **Nokia and Ericsson**, and others.

6G Infrastructure Association (6GIA)
- The organization represents the private side of the 5GPPP, a research program that is part of Horizon 2020.
- European ICT businesses, including **Nokia and Ericsson**, participated.

6G Innovation Centre (6G IC)
- Established by the University of Surrey in November 2020. Conducting research focused on advanced telecommunications engineering that integrates the physical and virtual worlds. More than 70 companies and universities are participating.

Finland

MoU

6G Flagship Project
- A project on 6G R&D led by the University of Oulu (with cooperation from Nokia and others). A plan to invest approximately 250 million euros (approximately 33 billion yen) over eight years from 2019 through 2026.
- The white paper *Key Drivers and Research Challenges for 6G Ubiquitous Wireless Intelligence* was released in September 2019. White papers on all 12 areas, including elemental technologies and use cases, were issued in June 2020.

MoU

United States

Next G Alliance
In October 2020, the Next G Alliance was launched, led by the North American industry (Alliance for Telecommunications Industry Solutions, ATIS for short). Corporations, including **Intel and Cisco**, are participating. Created a Next G Roadmap and promoting discussions on standardization for 6G realization.

Platforms for Advanced Wireless Research (PAWR)
An advanced wireless communications research platform (testbed) built by the National Science Foundation (NSF) in four cities. About 30 companies, including Intel and Qualcomm, participated in the construction.

MoU

MoU

Korea

Ministry of Science and ICT (MSIT)
Issued the 6G R&D Promotion Strategy in August 2020. Invested 200 billion won (approximately 20 billion yen) in core technology development over five years. Also provided companies and research institutions with a package of funding and strategies to secure standard patents.

Germany

6GKom Project
- The first project in Germany, funded by the Federal Ministry of Education and Research of Germany (October 2019 through September 2023). The design of the hardware infrastructure for 6G is underway.
- The Fraunhofer IZM Institute took the lead, and several universities participated.

China

Ministry of Industry and Information Technology (MIIT)
- In January 2020, MIIT announced that IMT-2020, the main driver of 5G in China, was expanded to IMT-2030 and that research on next-generation standards was on the way.

Ministry of Science and Technology (MoST)
- In November 2019, MoST announced the start of 6G R&D. At the same time, two organizations were established: A governmental organization to be responsible for promoting 6G research and a technical organization consisting of 37 universities, research institutes, and companies.
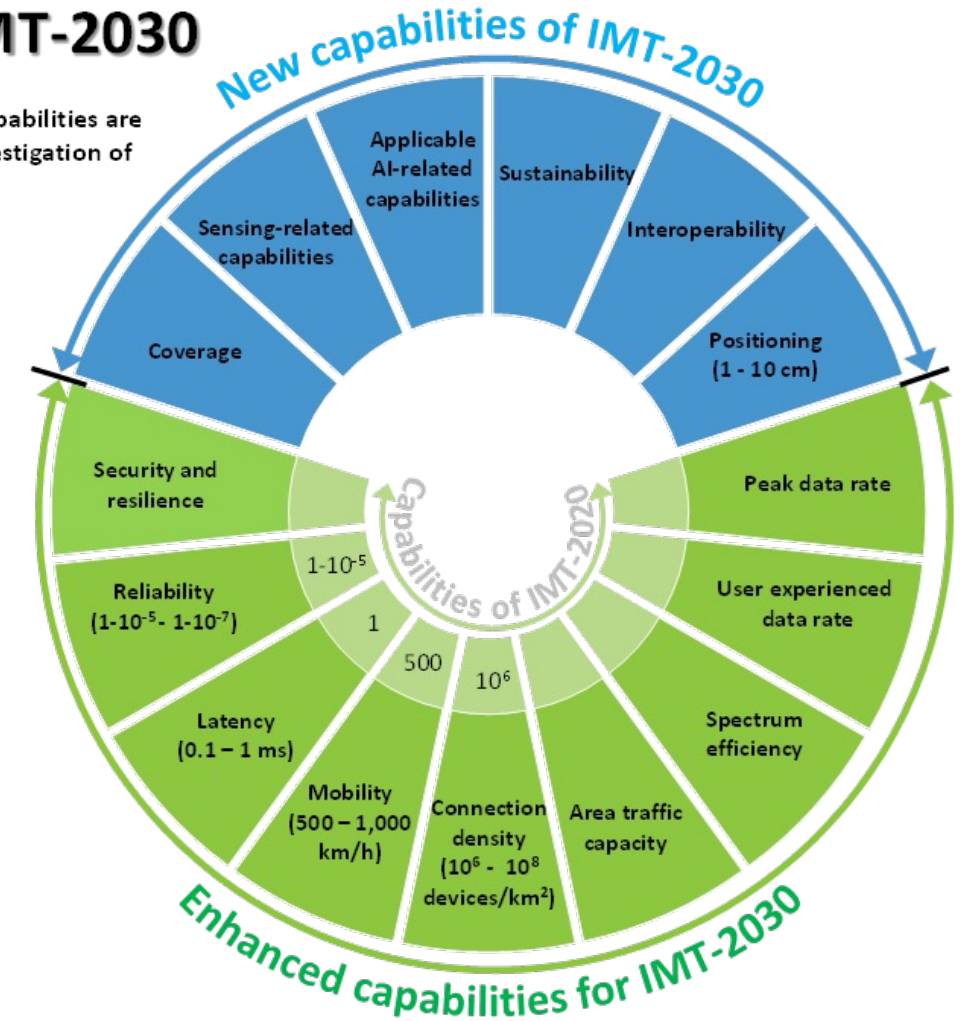
➡ **Utilizing the framework of the MoU to promote specific collaboration with like-minded countries**

ITU-R New Recommendation on the "IMT-2030 Framework" (November 2023)

- **Peak data rate**: Values of 50, 100, 200 Gbit/s are given as possible examples applicable for specific scenarios, while other values may also be considered.

- **User experienced data rate**: Values of 300 Mbit/s and 500 Mbit/s are given as possible examples, while other values greater than these examples may also be explored and considered accordingly.

- **Spectrum efficiency**: Values of 1.5 and 3 times greater than that of IMT-2020 are given as possible examples, while other values greater than these examples may also be explored and considered accordingly.

- **Area traffic capacity**: Values of 30 Mbit/s/m^2 and 50 Mbit/s/m^2 are given as possible examples, while other values greater than these examples may also be explored and considered accordingly.

Capabilities of IMT-2030

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

New capabilities of IMT-2030:
- Sensing-related capabilities
- Applicable AI-related capabilities
- Sustainability
- Interoperability
- Positioning (1 - 10 cm)
- Coverage

Enhanced capabilities for IMT-2030 / Capabilities of IMT-2020:
- Security and resilience
- Reliability (1-10^{-5} - 1-10^{-7})
- Latency (0.1 – 1 ms)
- Mobility (500 – 1,000 km/h)
- Connection density (10^6 - 10^8 devices/km^2)
- Area traffic capacity
- Spectrum efficiency
- User experienced data rate
- Peak data rate

Recommendation ITU-R M.2160-0 (11/2023)

Standardization Bodies Related to Beyond 5G/6G

Additional support for standardization activities

EUR 1 = JPY 160

**Research organizations
In Japan
(Private companies,
universities, etc.)**

NICT — National Institute of Information and Communications Technology

MIC — Ministry of Internal Affairs and Communications

**Funded
in spring 2021**

Initial Fund
<For FY2021–FY2022>
\30 billion (about €188 million)
(+\30 billion [about €188 million]: R&D)
(+\20 billion [about €125 million): Test beds)

**Commission
/Grant**

**Additional
budget**

**Funded
in spring 2023**

**will be
provided
in spring 2024**

New Fund
<For FY2023–>
\81.2 billion (about €508 million)
+ \19 billion (about €119 million)

**Grant/
Commission**

Additional funding, including support for standardization activities

Beyond5G International Conference 2024 in Tokyo Feb1-2, 2024

Conference Overview

February 1 (Thu.) –February 2 (Fri.) , 2024

Hotel New Otani Tokyo (banquet room FUYO)
(4-1 Kioi-cho, Chiyoda-ku, Tokyo)

Ministry of Internal Affairs & Communications (MIC)
and Beyond 5G Promotion Consortium (co-hosted)

Hybrid format (onsite participation or live streaming)

https://beyond5g-conference.jp/en/

Program for Day1,February 1st(Thu)

Opening Remarks	13:30–13:35

Makoto Gonokami**   President, RIKEN(President of B5GPC)

Special Speech(Government)①	13:35–14:55

Mark Cullinane   Director of Bilateral and Regional Affairs, Cyberspace and Digital Policy Bureau, U.S. Department of State

Kyeongrae Cho   Director of Innovation Network Team Ministry of Science and ICT, Korea

Laura Eiro*   Director General, The Ministry of Transport and Communications of Finland

Tina Klüwer**   Director General German Federal Ministry of Education and Research Directorate 5 – Research for Technological Sovereignty and Innovation

Speech(Overseas vendors)	15:10–17:10

Magnus Ewerbring   Chief Technology Officer, Asia-Pacific Ericsson

Wen Tong   CTO, Wireless Huawei Technologies

Peter Vetter   President, Bell Labs Core Research, Nokia

John Smee   Senior Vice President Engineering Qualcomm Technologies, Inc.

Speech(Domestic vendors)	17:10–17:55

Nozomu Watanabe*   Corporate Executive BU-CTO Telcom Services Business Unit NEC Corporation

Mototaka Taneya   EXECUTIVE MANAGING OFFICER CHIEF TECHNICAL OFFICER HEAD OF R&D SHARP CORPORATION

Shingo Mizuno*   Corporate Executive Officer EVP, Vice Head of System Platform Business (in charge of Network Business)Fujitsu Limited

Special Speech①	17:55–18:15

Seizo Onoe   Director of the Telecommunication Standardization Bureau International Telecommunication Union (ITU)

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Program for Day2,February 2nd(Fri)

Special Speech②	9:30–9:50

Hideyuki Tokuda   President National Institute of Information and Communications Technology(Vice President of B5GPC)

Report(B5GPC)	9:50–10:35

Morio Toyoshima   National Institute of Information and Communications Technology, Network Research Institute, Wireless Networks Research Center

Iwao Hosako   Executive Director of the unit National Institute of Information and Communications Technology

Takehiro Nakamura   Chief Standardization Officer NTT DOCOMO

Speech(Domestic carriers)	10:35–12:00

Sachiko Oonishi   Executive Vice President, Head of Research and Development Market Strategy NTT

Toshikazu Yokai   Chief Network Officer, Managing Executive Officer Deputy General Manager of Technology Sector KDDI CORPORATION

Tomohiro Sekiwa   Senior Vice President & CNO SoftBank Corp.

Ryoji Osaka   Executive Advanced Technology Engineering Division Manager, Rakuten Mobile

Special Speech(Government)② 　13:30–14:50

Yasuo Tawara	Director General of the Global Strategy Bureau, MIC, Japan
Holly Creek	Acting Director of Digital Infrastructure,Department for Science, Innovation & Technology,UK
Ravi A Robert Jerard*	Deputy Director General (Standards-R&D-Innovation), Department of Telecommunications, Ministry of Communications, India
Hermano Barros Tercius**	Secretary of Telecommunications, Ministry of Communications, Brazil

Speech(Overseas organizations) 　14:50–15:50

David Young	VP, Technology & Solutions and Managing Director, NextG Alliance ATIS
Colin Willcock	Chairman of the Governing Board, 6G-IA
Pathak Rajesh Kumar	Director General Bharat 6G Alliance, New Delhi,India

Panel Discussion 　16:00–17:00

Akihiro Nakao	Professor Graduate School of Engineering, The University of Tokyo (International Committee Chairman of B5GPC)
Matti Latva-aho	Director,6G Flagship, Univ. Oulu, FINLAND
Abhimanyu Gosain	Northeastern University, PAWR
HyeonWoo LEE	Professor, DanKook University, Korea

Closing Remarks 　17:00–17:05

Susumu Yoshida	Chairman, The Fifth Generation Mobile Communications Promotion Forum(5GMF) (Vice-President of B5GPC) Professor Emeritus of Kyoto University

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- Objectives
  - Landscape mapping on Non-Terrestrial Network (NTN)
  - Identification of potential domestic companies contributing NTN technologies
  - Activation of NTN area with international collaborations
  - Aiming for a role of NTN global consortium
- Past activities
  - FY2021
    - First trial of the landscape mapping on four areas (HAPS, HTS, Satellite IoT, and Maritime domain)
  - FY2022
    - Continuous discussion on NTN area
    - Exchanging the opinions among WG members
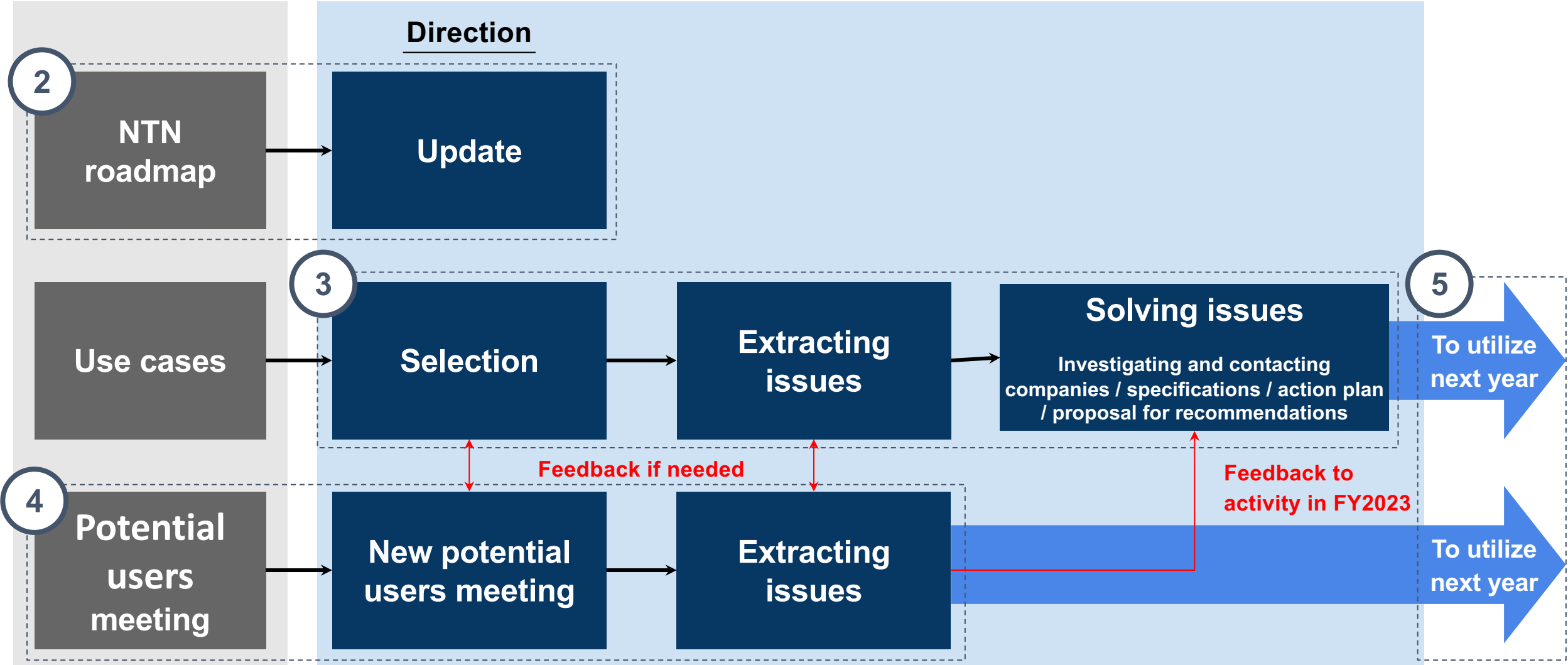   - New use case study through cross-industrial association

Working items		Coordinator	Participation members	Contents
① Recruiting members		Secretary	Rakuten Mobile VIAVI Solutions SoftBank Huawei Japan Ericsson Japan Space Compass KDDI	
② Trends, standardization and dissemination	Information exchange	Secretary		- Information exchange in WG
	NTN roadmap	Rakuten Mobile		- Update on NTN technologies
	Report	VIAVI Solutions		- Making the activity report
	Website	Secretary		- Publication on the website
③ Solving issues and making specifications	Use case selection	SoftBank		- Study on NTN use cases
	Extracting issues	SoftBank		- Extracting the important use cases for NTN
	Investigating companies	VIAVI Solutions		- Investigating potential companies
	Contacting companies	-		- Contacting potential companies
	Specifications / action plan	Huawei Japan		- Investigating the challenges and difficulties for NTN
④ Opinion exchange among industries	Studying agenda	Ericsson Japan		- Study on the agenda
	Potential Users Meeting	Ericsson Japan		- Holding the meeting - Hearing the opinions among potential users
	Extracting issues / summary	**Space Compass** (HAPS) **KDDI** (Satellite)		- Extracting the issues for NTN - Summarizing the issues
⑤ Proposal	Recommendations for institution / standardization	-		- Proposing the recommendations

Observer	Tokyo Metropolitan University (Prof. Ishii), NTT DOCOMO

	2022	2023	2024	2025	2026	2027	2028	2029	2030

Satellite BB

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

★ Viasat Viasat-3 / Echostar Jupiter-3 / Konnect VHTS (VHTS)

★ Intelsat-42,43 / Superbird-9 (SDS)

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

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

LEO Constellation Advanced Higher Throughput Capacity

★ Starlink Gen-1(High Latitude region)

★ Starlink Gen-1(maritime)

★ OneWeb Gen-1(High Latitude region)

★ Amazon Kuiper

★ Telesat Lightspeed

OneWeb Gen-2
Starlink Gen-2

Further Throughput Improvement : Optical Link (Satellite-Satellite, Satellite-Terrestrial), Large-scale, Resource Optimization, V/E Band (feeder Link)

Further Capacity Improvement : Increase the number of satellite (1,000 – 10,000 order)

Satellite IoT & Mobile Direct

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

★ Lynk   ★ AST SpaceMobile

★ Bullitt   ★ Starlink & T-mobile / KDDI

★ Apple & Globalstar   ★ Project Stardust

★ Echostar Mobile   ★ OQ Technology

★ Lacuna Space   ★ Skylo

★ Sateliot

HAPS

Solar Panel Lightweight/High Efficiency   Next Gen Solar Pane

Battery high density/high cycling   Next Gen. 400 ~ 500 Wh/kg   Gen after Next Gen 600 ~ 1000 Wh/kg

Payload multi-cell/high capacity

★ SoftBank HAPS

★ Space Compass HAPS

Beyond 5G International Conference 2024

ITUPublications

International Telecommunication Union
Radiocommunication Sector

World Radiocommunication Conference 2023 (WRC-23)

Provisional Final Acts

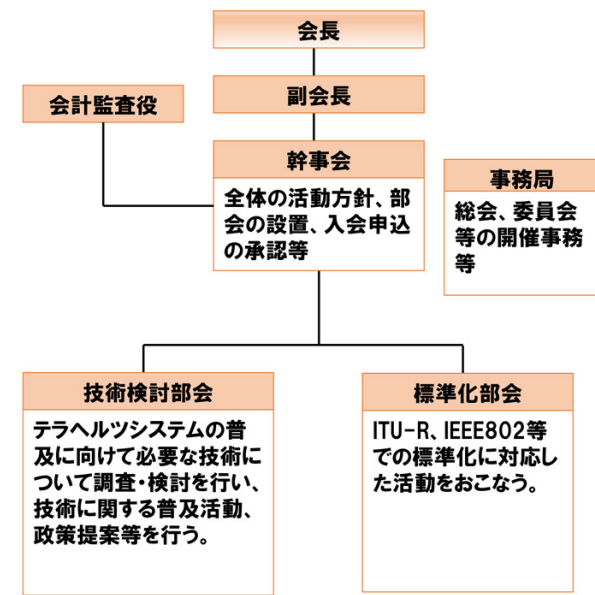# MMW＆THz : What we can see from the results of the WRC-23

Contents 1: Activity report of the 6G working group of the Terahertz Consortium (positioned as part of the activities of the High Frequency WG of the B5G Consortium International Committee: Dr. Hosako is the WG leader)

- ☐ Activities in FY2022 after the last international conference (Qct. 2022)
- ☐ Activities for FY2023
  Discusses MMW dissemination methods and their expansion to THz waves.
  - ☐ As materials for discussion, interviews have so far been held with two operators and two vendors.
  - ☐ Discussions will be held after the hearings and recommendations will be made (in FY2024).

Content 2: Activities Plans for FY2024

- ☐ The things regarding MMW and THz-wave frequencies decided at WRC23 and the proposed actions to be taken are presented.

Beyond 5G Consortium, International Committee,
High Frequency Working Group, WG-Chair : **Iwao Hosako** (NICT)

ITUWRC
DUBAI2023
20 November - 15 December 2023
Dubai, United Arab Emirates

ITU

NICT
Beyond 5G R&D Promotion Unit

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Terahertz Systems Consortium

6G Working Group Activity Report for FY2022 after Oct. 2022 and FY2023

- **Examine system requirements for F/B-haul and Small Cell Access Link as a possible use case.**
- **Summarize the degree of device performance required for the above system.**
- **Discussion on MMW dissemination methods and their expansion to THz waves**

（The above activities are positioned as part of the activities of the High Frequency WG of the B5G Consortium International Committee）

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.
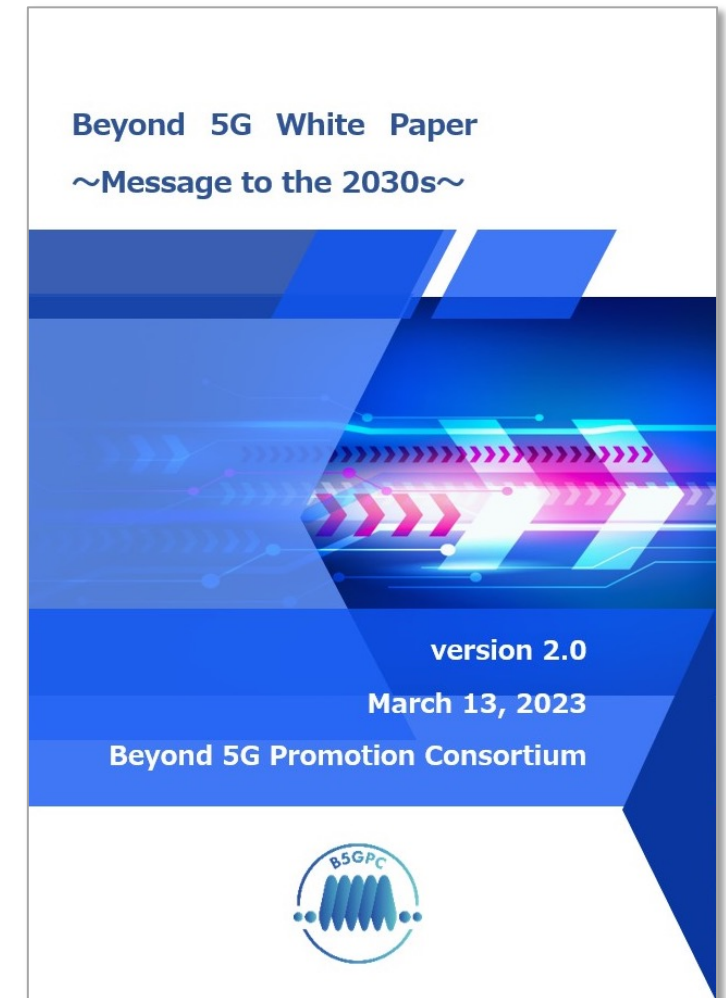
Chapter 5. Capabilities and KPIs required in Beyond 5G

- 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, together with the symbol figure of Beyond 5G, the six usage scenarios and the target KPI (Quantitative and Qualitative).
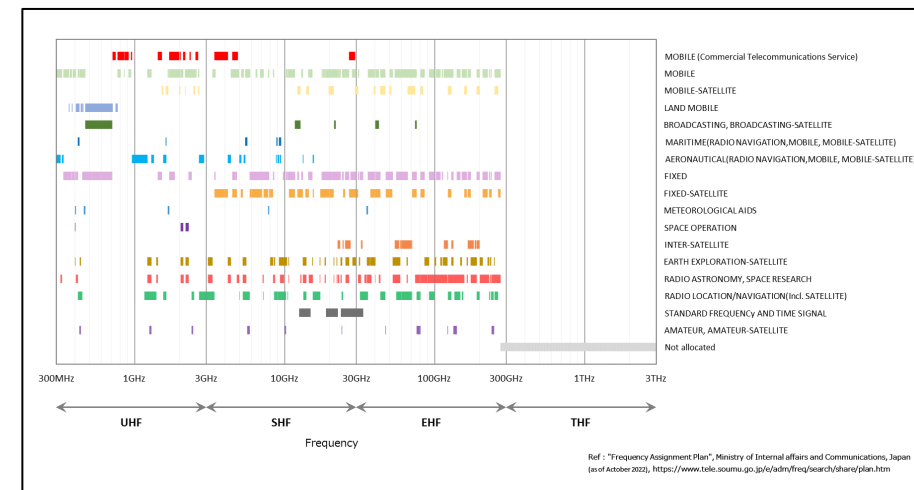
Chapter 6. Technology trends

- 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

Beyond 5G White Paper
~Message to the 2030s~

version 2.0
March 13, 2023
Beyond 5G Promotion Consortium

https://b5g.jp/en/output/

# Update Plan of The White Paper Ver. 3.0

- Update spectrum aspects
  - Capture results of APG23-6 and WRC-23 for future IMT spectrum
  - Add survey of radio frequency on the range of 7125 MHz to 15.35 GHz in Japan
    - Evaluate existing radio systems, their level of usage, possibilities of contiguous and wider spectrum for IMT
    - Focus on 7125 – 8400 MHz and 14.8 – 15.35 GHz
    - Consideration for future actions

- ## Develop "Supplementary Volume" on 6G technologies
  - ### Summarize advanced technical study results on major technical topics for 6G in Japan
    - Contributed by both of industry and academia (**58** contributions)
  - ### Aiming global information sharing for discussion and contribution to standardization fora (Developed in English)
  - ### Supplementary volumes planned
    - Cell-Free Distributed MIMO
    - Radio technologies for higher frequency
    - Technologies on repeaters and reflectors
    - End-to-end network architecture
    - AI/ML
    - Sensing
    - Sustainability and Energy efficiency
    - NTN

- ## New Beyond 5G architecture will be presented
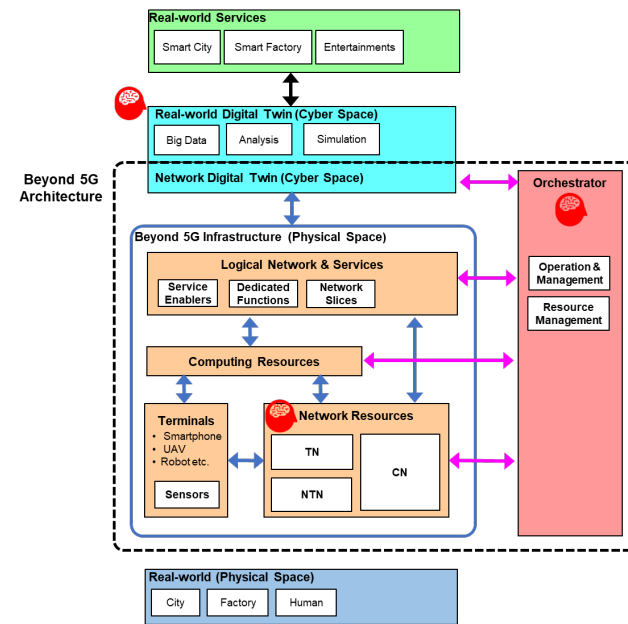
Beyond 5G architecture (tentative)

Japan's Next Strategy, coming this summer

June 2020

「**Beyond 5G Promotion Strategy**」(MIC)

January 2021
Amendment of NICT Act Launching Temporary Beyond 5G R&D Fund on NICT

June 2022
Interim Report by the Information and Communications Council

December 2022
Amendment of NICT Act Launching Permanent Beyond 5G R&D Fund on NICT

March 2023
The Beyond 5G R&D Fund started

November 2023
Resume the Review of the Information and Communication Council

Around summer 2024

Next Strategy (MIC)