Beyond 5G/6G R&D Status of NICT

October 25, 2022

Hideyuki Tokuda, Ph.D.
President, National Institute of Information and Communications Technology
Professor Emeritus, Keio University

National Institute of Information and Communications Technology

Japan's only public research institute specialising in ICT

NICT Personnel and Budget

- Location: HQ in Koganei, Tokyo
- Personnel: ~ 1300
- Researchers: ~730
- Budget: ~$260M + α (2020)
- 5th Mid-to-Long Term Plan: April 2021 – March 2026

Public Services:

- Japan Standard Time
- Space Weather Forecast
- Wireless Equipment Testing & Calibration
- Cybersecurity Training

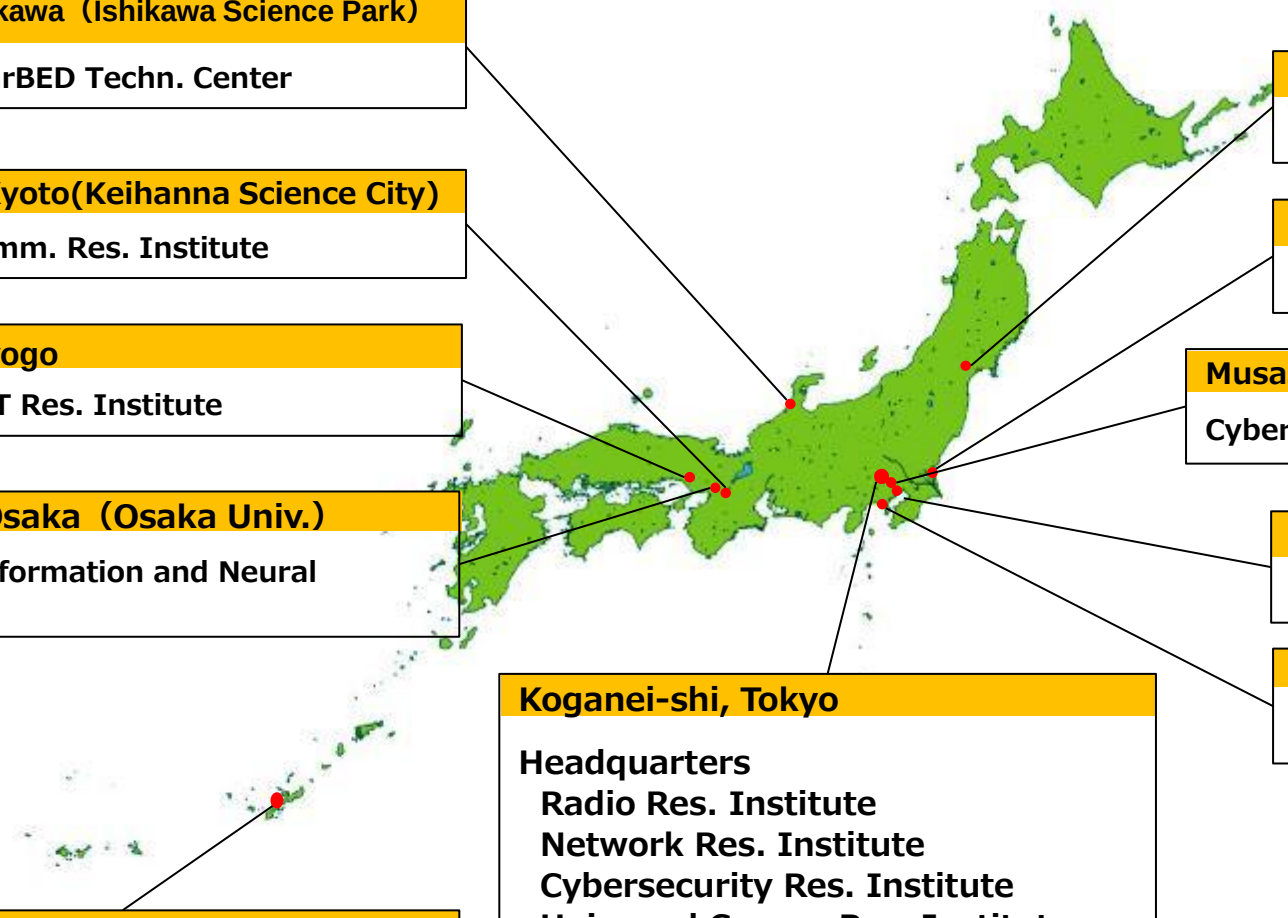
5 Main Research Areas:

- Advanced Electromagnetic Wave Technology
- Innovative Networks
- Cybersecurity
- Universal Communication
- Frontier Science

Funding Agency:

- Domestic ICT Projects
- US-Japan Projects
- EU-Japan Projects
- ASEAN-IVO Projects
- Taiwan-Japan Projects

NICT Facilities



Nobi-shi, Ishikawa（Ishikawa Science Park）
Hokuriku StarBED Techn. Center

Seika-Cyo, Kyoto(Keihanna Science City)
Universal Comm. Res. Institute

Kobe-shi, Hyogo
Advanced ICT Res. Institute

Suita-shi, Osaka（Osaka Univ.）
Center for Information and Neural Networks

Onna-son, Okinawa
Okinawa Electromagnet Techn. Ctr.

Sendai-shi, Miyagi（Tohoku Univ.）
Resilient ICT Research Ctr.

Kashima-shi, Ibaraki
Kashima Space Techn. Ctr.

Musashino-shi, Tokyo
Cybersecurity Recurrent Evolution . Ctr.

Chiyoda-ku, Tokyo
Innovation Ctr.

Yokosuka-shi, Kanagawa（YRP）
Wireless Network Res. Ctr.

Koganei-shi, Tokyo

Headquarters
- Radio Res. Institute
- Network Res. Institute
- Cybersecurity Res. Institute
- Universal Comm. Res. Institute
- Advanced ICT Res. Institute
- Beyond 5G R&D Promotion Unit
  - Terahertz Technology Res. Ctr.
- Quantum ICT Collaboration Center
- Open Innovation Promotion HQs.
  - ICT Testbed R&D Promotion Ctr.

Oversea Centers

- North-America Center (Washington D.C., U.S.)
- Europe Center (Paris, France)
- Asia Center (Bangkok, Thailand)

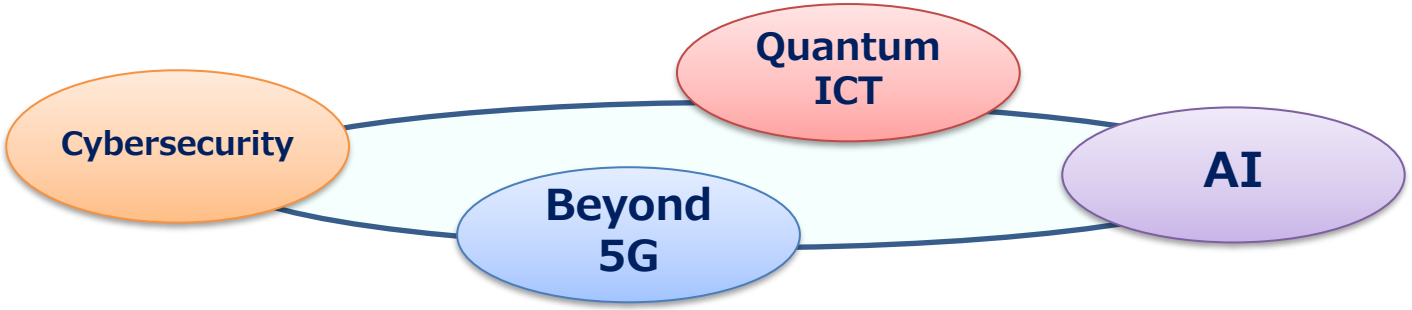
*Silicon Valley Representative (Sunnyvale, U.S.)

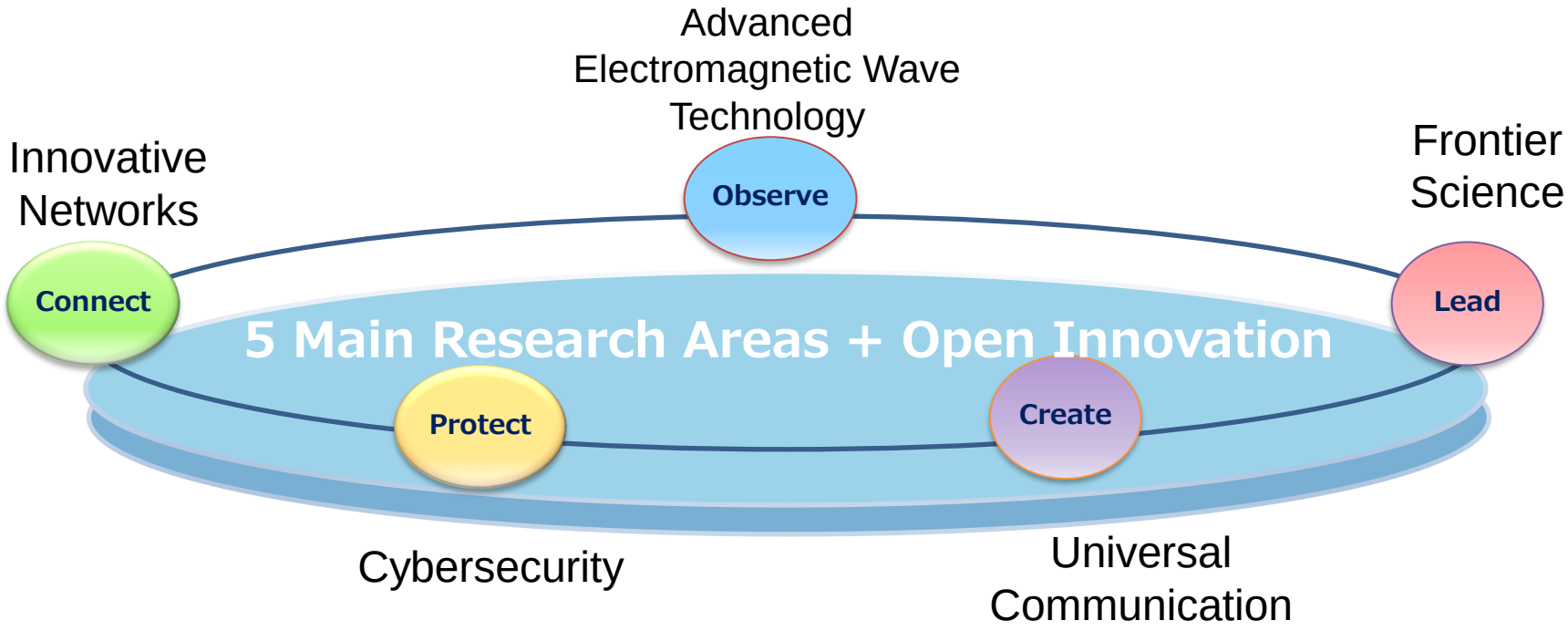
NICT Beyond 5G/6G R&D Strategy

New ICT Strategies for the Beyond 5G Era

From the Information and Communications Council, ICT Strategy Council

The four strategic fields





Highlights in the Four Strategic Fields

Beyond 5G

- B5G public call R&D funds
- B5G establishment of open testbeds

Quantum ICT

Quantum security hub in Koganei

Cybersecurity

- Establishment of Cybersecurity Nexus
- Collaboration hub for industry-academia-government collaboration for information gathering, analysis and personnel development

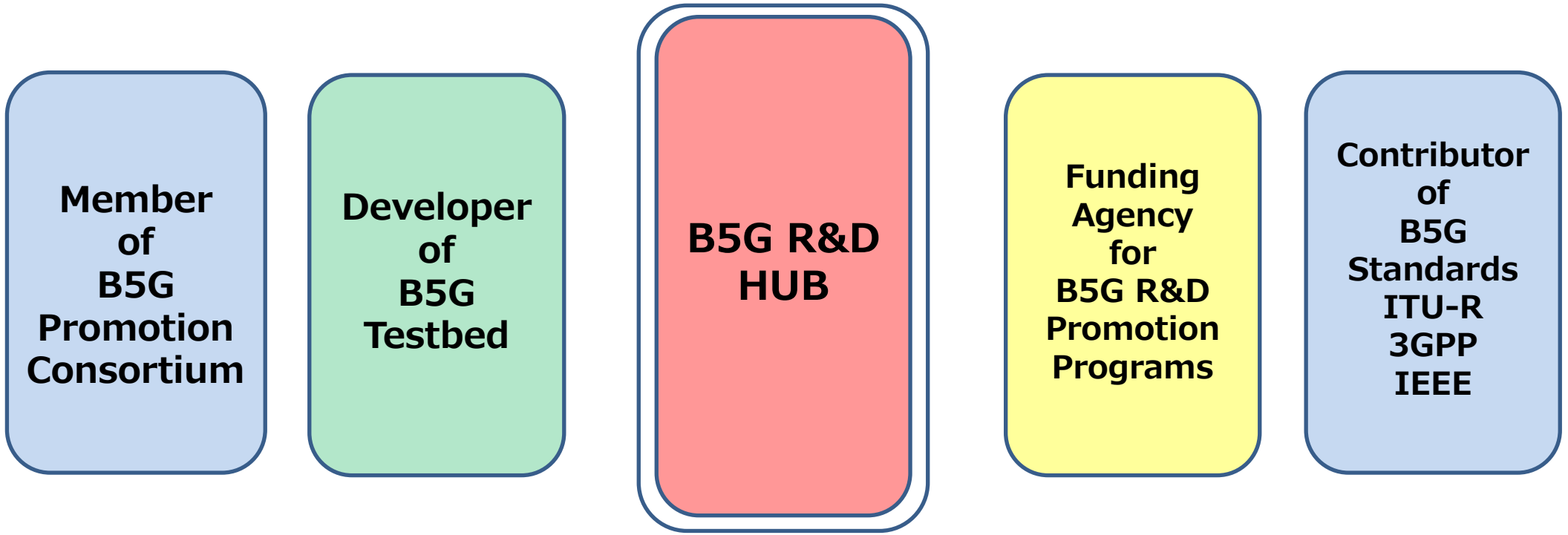
AI

Establish AI (for language processing) computer environment in the Keihanna region.

A Future with *N* (203x) (by NICT 2022)

NICT's Role for B5G/6G Development

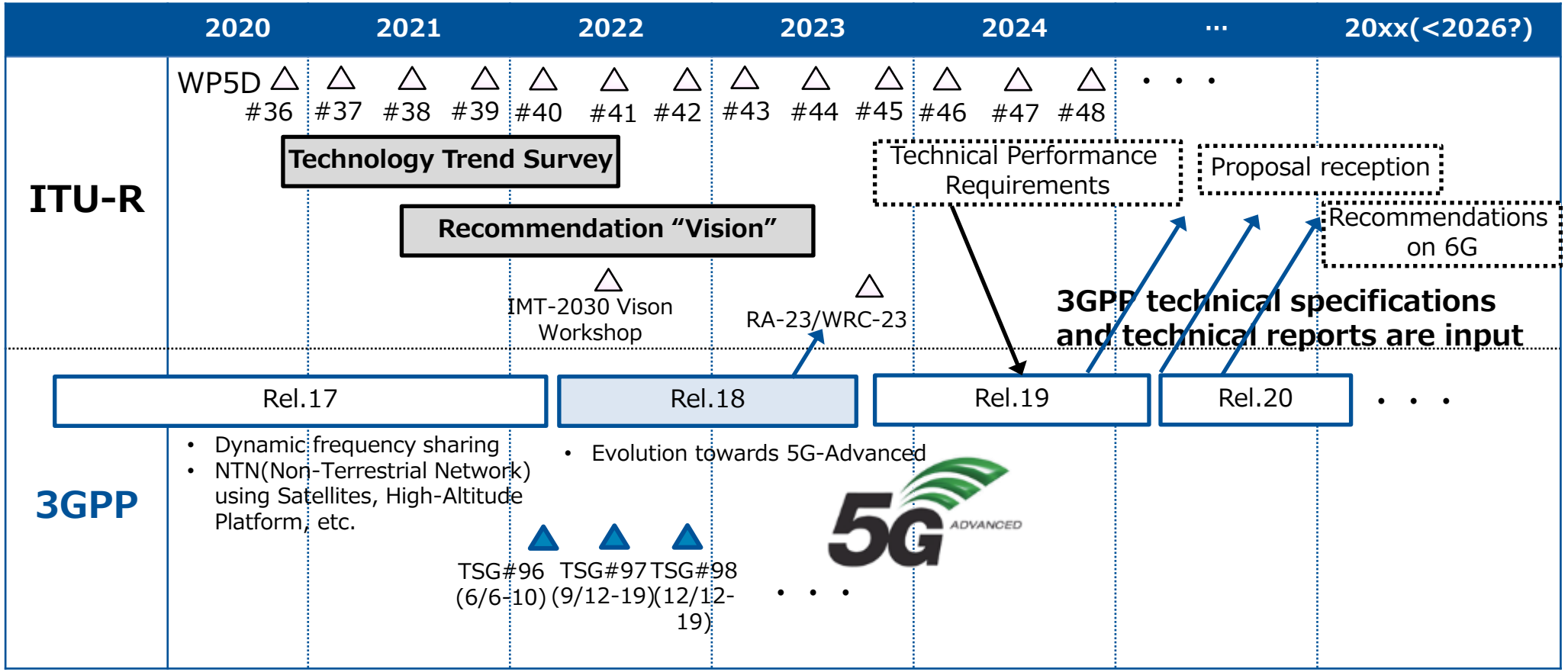
- NICT is a R&D HUB for B5G/6G Development in Japan
- NICT offers a B5G Testbed for Developers
- NICT serves as a Funding Agency of B5G R&D Promotion Programs
- NICT is a member of B5G Promotion Consortium
- NICT is a contributor of B5G Standards (ITU-R, 3GPP, IEEE, etc)



Beyond 5G/6G Standardization Activities

Standardization Activities for Beyond 5G/6G

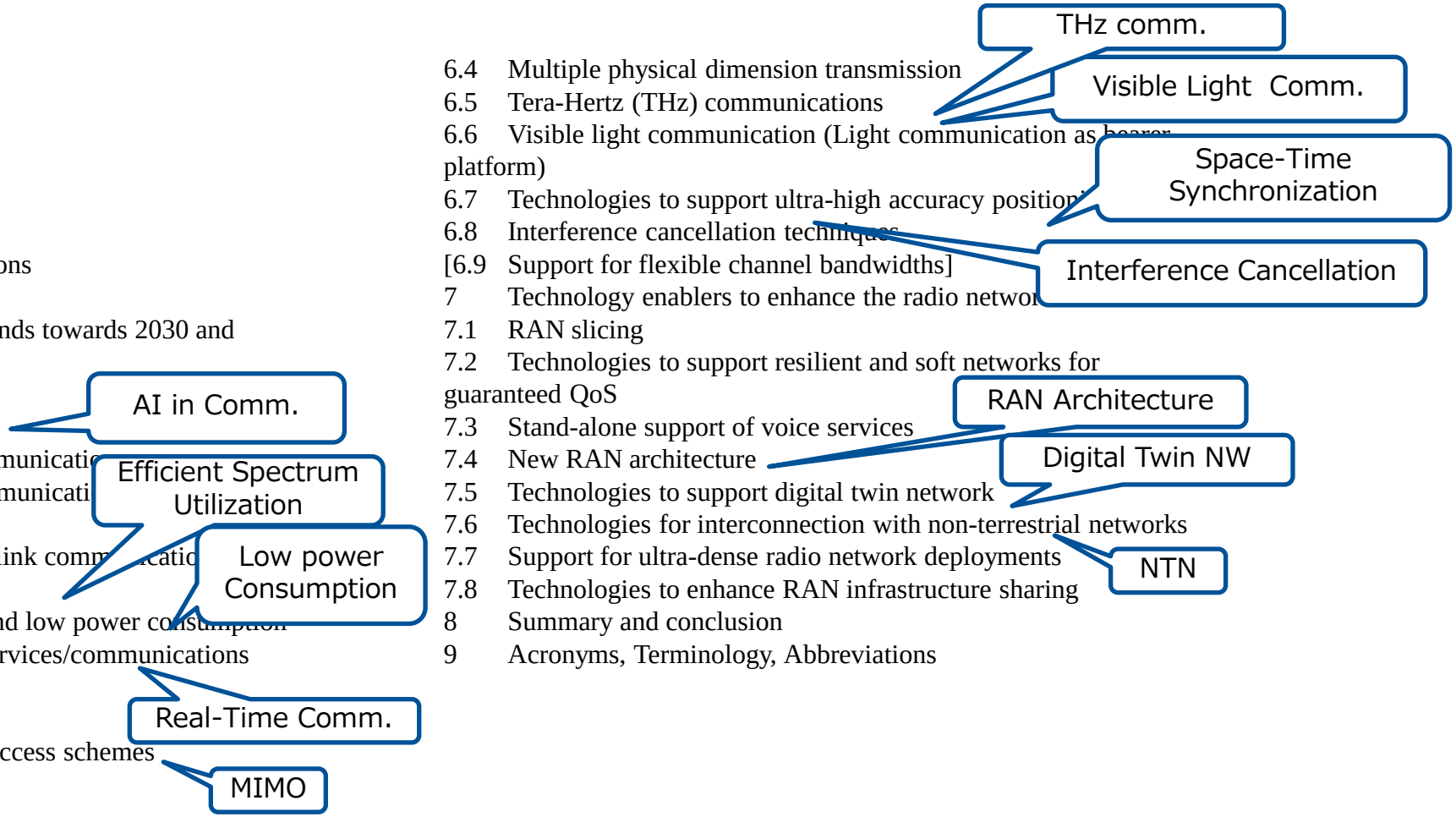
- The ITU-R SG5 WP5D has complete **Future Technology Trend Report on 6G** in 2022. **Recommendation "Vision"** will be formulated in June 2023.
- 3GPP started its next period **"Release 19"** to consider "**5G-Advanced"**. The Release 18 agenda items will be set by the end of 2021.
- From March 2021, NICT has submitted contributions and participated in the discussion on Terahertz, Space-Time Synchronization, and Non-Terrestrial Network (NTN) as NICT technology seeds related to Beyond 5G.



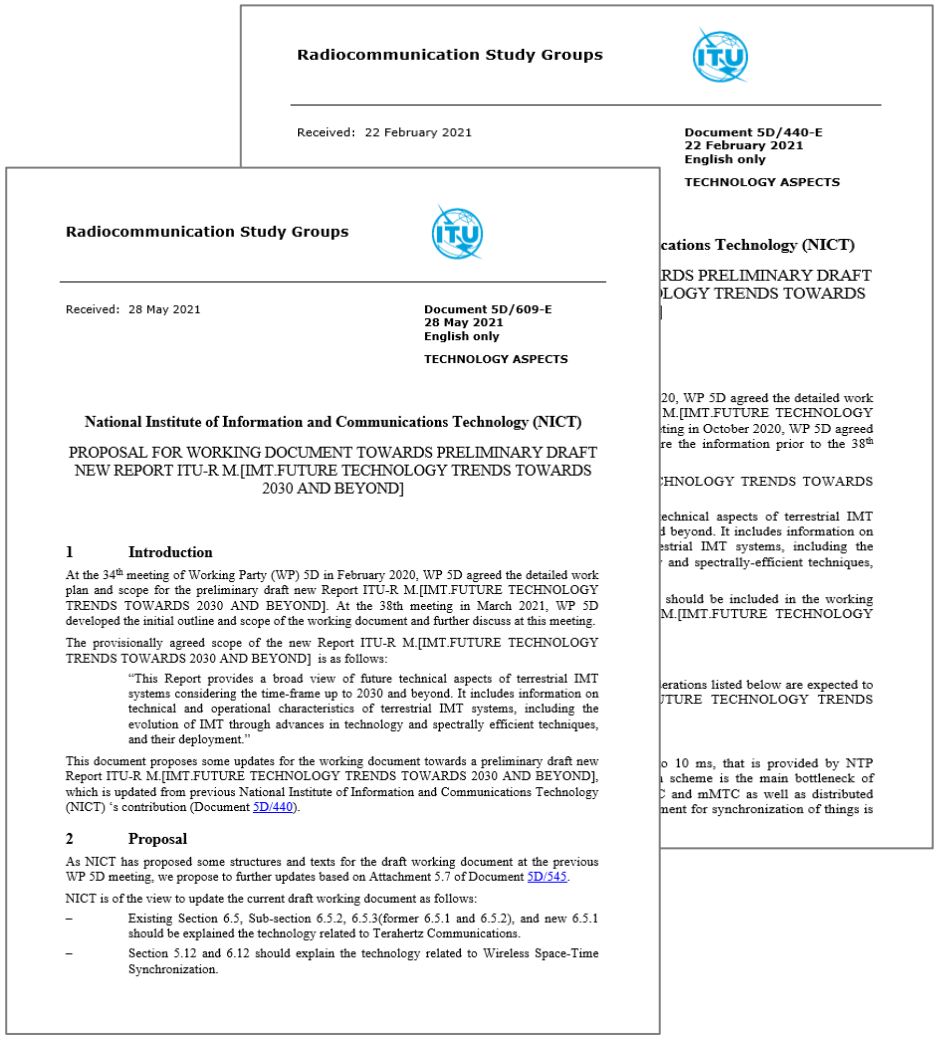
ITU-R (WP5D) IMT-2030's Report (5D/1078 Annex5.4)

Future Technology Trends (FTT) and Recommendation

1 Introduction
2 Scope
3 Related ITU-R documents
3.1 ITU-R Resolutions
3.2 ITU-R Recommendations
3.3 ITU-R Reports
4 Overview of emerging services and applications
4.1 New services and application trends
4.2 Technology Drivers for future technology trends towards 2030 and beyond
5 Emerging Technology trends and enablers
5.1 Technologies to use AI in communications
5.2 Technologies for integrated sensing and communicati
5.3 Technologies to support convergence of communicati architecture
5.4 Technologies for integrated access and superlink comm icatio
5.5 Technologies to efficiently utilize spectrums
5.6 Technologies to enhance energy efficiency and low power consumption
5.7 Technologies to natively support real-time services/communications
5.8 Technologies to enhance trustworthiness
6 Technologies to enhance the radio interface
6.1 Advanced modulation, coding and multiple access schemes
6.2 Advanced Antenna Technologies
6.3 In-band Full Duplex communications
6.4 Multiple physical dimension transmission
6.5 Tera-Hertz (THz) communications
6.6 Visible light communication (Light communication as bearer platform)
6.7 Technologies to support ultra-high accuracy positioni
6.8 Interference cancellation techniques
[6.9 Support for flexible channel bandwidths]
7 Technology enablers to enhance the radio networ
7.1 RAN slicing
7.2 Technologies to support resilient and soft networks for guaranteed QoS
7.3 Stand-alone support of voice services
7.4 New RAN architecture
7.5 Technologies to support digital twin network
7.6 Technologies for interconnection with non-terrestrial networks
7.7 Support for ultra-dense radio network deployments
7.8 Technologies to enhance RAN infrastructure sharing
8 Summary and conclusion
9 Acronyms, Terminology, Abbreviations



Proposal documents from NICT



Radiocommunication Study Groups

Received: 22 February 2021

Document 5D/440-E
22 February 2021
English only

TECHNOLOGY ASPECTS

cations Technology (NICT)

RDS PRELIMINARY DRAFT
LOGY TRENDS TOWARDS

20, WP 5D agreed the detailed work
M.[IMT.FUTURE TECHNOLOGY
ting in October 2020, WP 5D agreed
re the information prior to the 38th

CHNOLOGY TRENDS TOWARDS

echnical aspects of terrestrial IMT
d beyond. It includes information on
strial IMT systems, including the
and spectrally-efficient techniques,

should be included in the working
M.[IMT.FUTURE TECHNOLOGY

erations listed below are expected to
TURE TECHNOLOGY TRENDS

o 10 ms, that is provided by NTP
scheme is the main bottleneck of
C and mMTC as well as distributed
nent for synchronization of things is

Radiocommunication Study Groups

Received: 28 May 2021

Document 5D/609-E
28 May 2021
English only

TECHNOLOGY ASPECTS

National Institute of Information and Communications Technology (NICT)

PROPOSAL FOR WORKING DOCUMENT TOWARDS PRELIMINARY DRAFT NEW REPORT ITU-R M.[IMT.FUTURE TECHNOLOGY TRENDS TOWARDS 2030 AND BEYOND]

1 Introduction

At the 34th meeting of Working Party (WP) 5D in February 2020, WP 5D agreed the detailed work plan and scope for the preliminary draft new Report ITU-R M.[IMT.FUTURE TECHNOLOGY TRENDS TOWARDS 2030 AND BEYOND]. At the 38th meeting in March 2021, WP 5D developed the initial outline and scope of the working document and further discuss at this meeting.

The provisionally agreed scope of the new Report ITU-R M.[IMT.FUTURE TECHNOLOGY TRENDS TOWARDS 2030 AND BEYOND] is as follows:

"This Report provides a broad view of future technical aspects of terrestrial IMT systems considering the time-frame up to 2030 and beyond. It includes information on technical and operational characteristics of terrestrial IMT systems, including the evolution of IMT through advances in technology and spectrally efficient techniques, and their deployment."

This document proposes some updates for the working document towards a preliminary draft new Report ITU-R M.[IMT.FUTURE TECHNOLOGY TRENDS TOWARDS 2030 AND BEYOND], which is updated from previous National Institute of Information and Communications Technology (NICT) 's contribution (Document 5D/440).

2 Proposal

As NICT has proposed some structures and texts for the draft working document at the previous WP 5D meeting, we propose to further updates based on Attachment 5.7 of Document 5D/545.

NICT is of the view to update the current draft working document as follows:

– Existing Section 6.5, Sub-section 6.5.2, 6.5.3(former 6.5.1 and 6.5.2), and new 6.5.1 should be explained the technology related to Terahertz Communications.

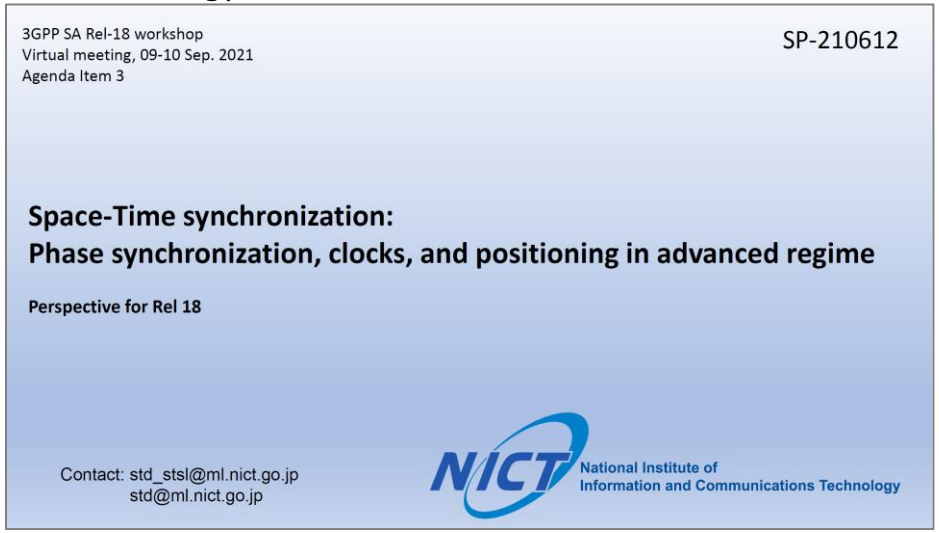
– Section 5.12 and 6.12 should explain the technology related to Wireless Space-Time Synchronization.

◀ Contributions to ITU-R WP5D (5D/440, 5D/609)

Proposals for the realization of Beyond 5G / 6G for Terahertz, Space-Time synchronization, and Non-Terrestrial Network (NTN).

▼ Contribution to 3GPP SA Rel.18 Workshop (SP-210612)

Proposal of ultra-low latency and high-precision positioning technology by Space-Time synchronization technology.



3GPP SA Rel-18 workshop
Virtual meeting, 09-10 Sep. 2021
Agenda Item 3

SP-210612

Space-Time synchronization:
Phase synchronization, clocks, and positioning in advanced regime

Perspective for Rel 18

Contact: std_stsl@ml.nict.go.jp
std@ml.nict.go.jp

National Institute of
Information and Communications Technology

Future Tech Trends Draft New Report (Document 5D/TEMP/677-E)

- NICT contributed related text concerning Wireless Space-Time Synchronization technology that can enable ultra low latency and high precision location at millimeter level.

5.7 Technologies to natively support real-time services and communications

Two technology components are considered to achieve real-time communications with extremely low latency. The first one is accurate time and frequency information shared in the terrestrial network. When network nodes are equipped with compact atomic clocks, their high holdover performance can dramatically reduce synchronization iterations. The high frequency accuracy obtained from the atomic clocks also reduces the frequency offset between transmitter and receiver, leading to the low bit error ratio particularly in high carrier frequency. The collection of the time differences among node clocks facilitates the estimation of more stable and robust time using the maximum likelihood method, and the result can be delivered back to each node for their self-corrections. **Wireless space-time synchronization**, where clocks are synchronized at pico-second level together with the determination of positions, is another method on which low latency communication protocol can be built with a capability of autonomous and distributed operations. Such synchronized network supports the schedule management in edge processing in mobile backhauls. The common time and frequency can be traceable to the standard time or frequency by linking one node to the precision time/frequency source.

（中略）

The benefit of these two technologies can be further enhanced by adopting time-sensitive communications protocols, which enables the prioritization of latency-sensitive or mission-critical traffic, facilitating to real-time communications. Resource management can be supported by leveraging application-domain information on the predictability of actual resource requirements by considering the context and traffic characteristics. Periodic transmissions can be pre-scheduled with given and precise time boundaries while AI and ML tools can be used to schedule algorithms. Resource allocation for real-time communications may also span over a multi-dimensional solution space comprising multi-RAT, multi-link, etc. These would be managed by a dedicated real-time management function that would track resource needs, availability, and surrounding environment.

NICT contributed

6.6 Technologies to support ultra-high accuracy positioning

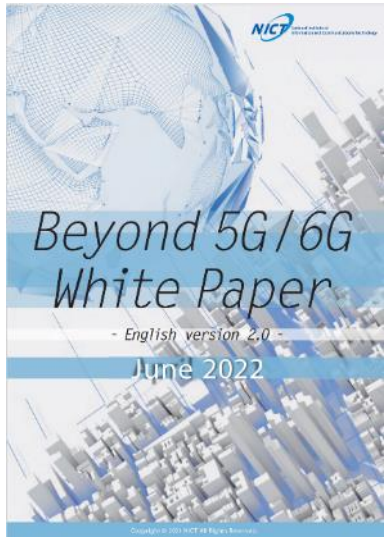
（中略）

Precision of synchronization is critical to positioning technologies that are based on time of flight (ToF) measurement of traveling waves, such as ultrasonic sound, light, and radio wave. Another positioning technology that requires synchronization is the stereo vision-based positioning. As the synchronization technology matures better toward 2030, it is conceivable that **wireless space-time synchronization** in future IMT to be available by around 2030, enabling Location Based Services to fully equipped with higher precision localization capability.

（中略）

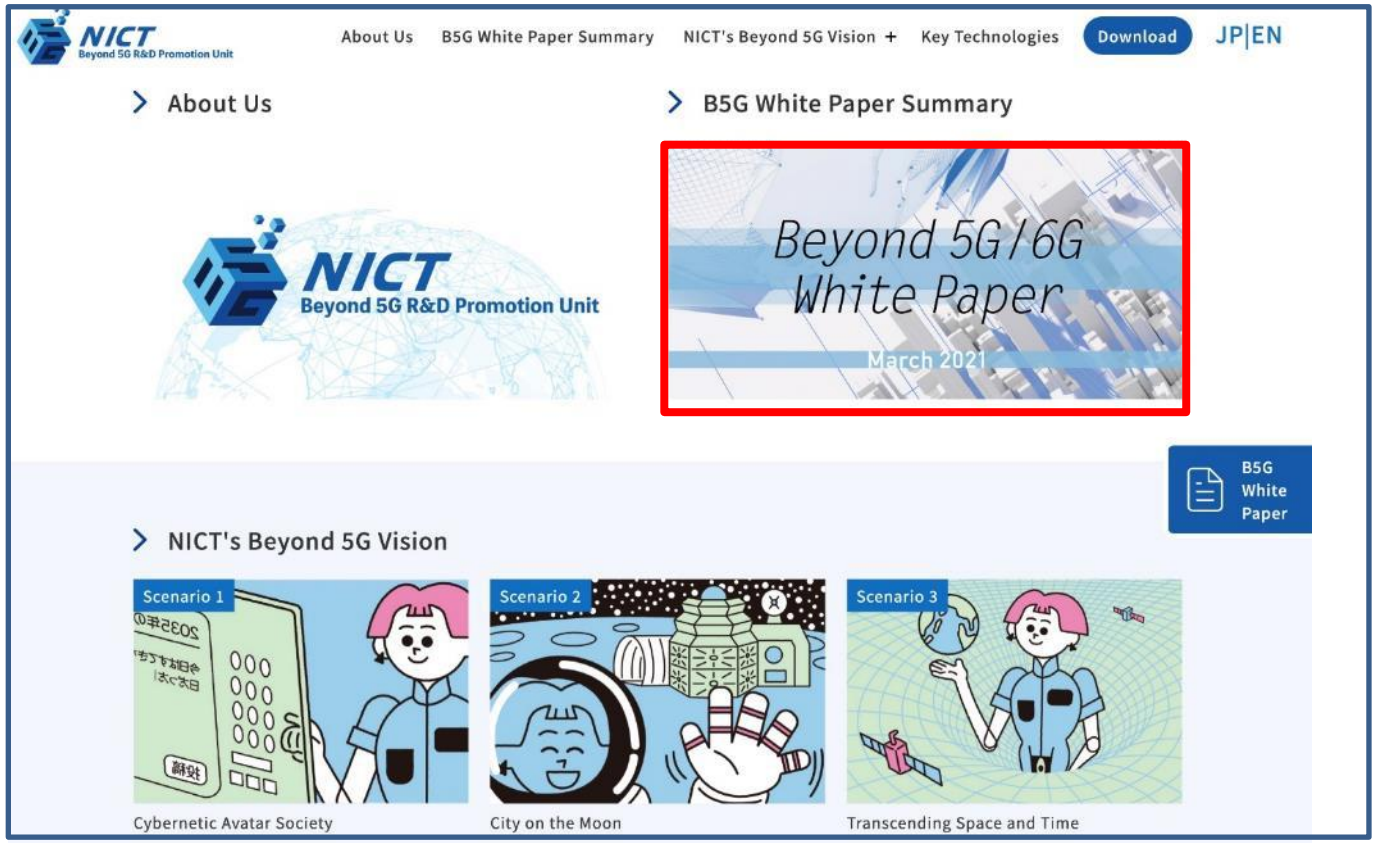
NICT contributed

NICT Beyond 5G/6G White Paper Ver. 2.0



NICT Beyond 5G/6G White Paper Ver. 2.0

■ It summarizes the **scenarios**, the **use cases** that appear in the scenarios, the **key technologies** and **requirements** to realize them, the **R&D roadmap**, and the **deployment strategy**.



(Source: https://beyond5g.nict.go.jp/en/index.html)

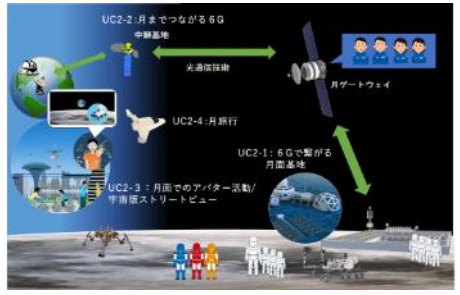
Some videos of Beyond 5G scenarios

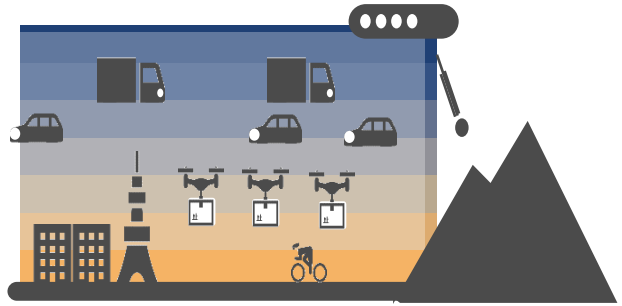
[NICTchannel - YouTube]

Scenarios 1 to 3 are available on YouTube “NICTchannel”.

NICT B5G/6G White paper: 4 Scenarios

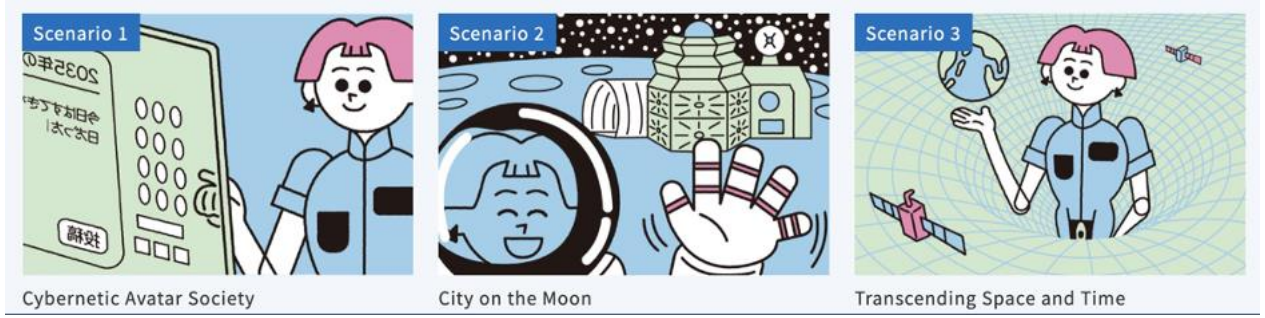
- Scenario 1 – Cybernetic Avatar Society (CAS)
  - Cybernetic Avatar Society (CAS) is one in which people can maximize their abilities and share the skills and experiences of diverse people.
  - Safe and secure Society 5.0: A society where anyone can play an active role freely by using CA, free from time, space, and physical constraints.
- Scenario 2: City on the Moon (COM)
  - Cybernetic Avatars on the Moon
  - Moon Travel, Street View in Space
- Scenario 3: Vertical Flow of People, Things and Information (IoVT)
  - Autonomous Drone, Sky-car, Sky-truck
  - Warehouse in the stratosphere



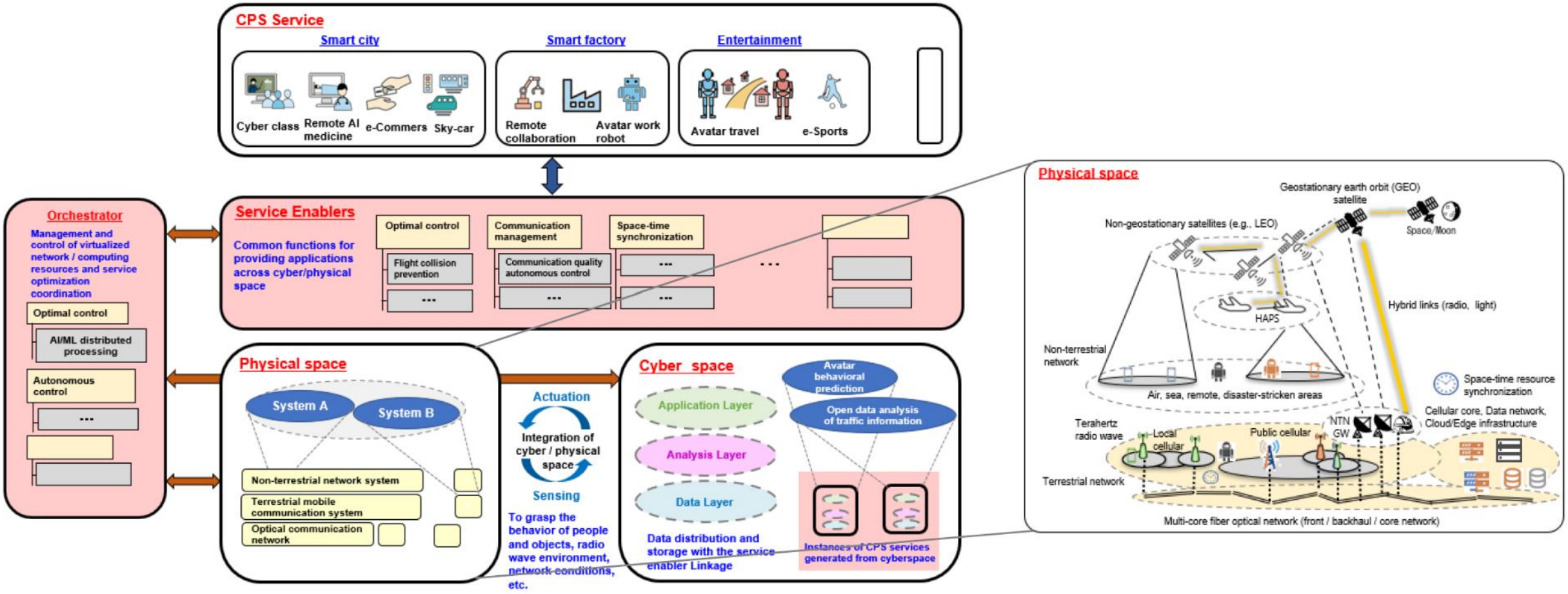


NICT B5G/6G White paper: 4 Scenarios

- Scenario 4: Light and Shadow of the Cyber World
  - Cyber Trouble Counseling Room
  - UC-1: Issues in AI Agent
    - It is not preferable from the viewpoint of privacy protection to analyze and convert personal interests, beliefs, habits, temperaments, etc. of specific individual consumers into data.
    - Separation of data/privacy protection and analysis
  - UC-2: Issues of fairness, accountability and transparency (FAT), ethics and values in AI



B5G Architecture for open service framework



An open platform is expected to accommodate various systems and promote flexible service creation where ICT and other technologies are optimally integrated.

Key technologies for Beyond 5G

T1. Ultra-high-speed and high-capacity wireless communication		
	T1.1	Terahertz wave
	T1.2	All-optical network (high-capacity optical fiber communication)
	T1.3	All-optical network (optical and radio convergence technology)
T2. Ultra-low latency and ultra-multi-source connection		
	T2.1	Edge computing technology
	T2.2	Adaptive wireless network construction technology
	T2.3	Adaptive wireless network application technology
	T2.4	Autonomous localization, tracking and reservation technologies for radio wave radiation space
	T2.5	Autonomous M2M network construction technology with super multi-connection
T3. Wired and wireless communication and network control technology		
	T3.1	Network control technology (Zero-touch automation)
	T3.2	Frequency allocation and sharing management
	T3.3	Private wireless system management (Local Beyond 5G)
	T3.4	Advanced wireless emulator
T4. Multi-Layer wireless systems - NTN		
	T4.1	Satellite and non-terrestrial communication platform
	T4.2	Optical satellite communication
	T4.3	Maritime communication
	T4.4	Underwater and submarine communication
	T4.5	Cooperative control of multi-layered networks

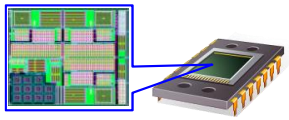
T5. Space-time synchronization		
	T5.1	Wireless Space-Time Synchronization
	T5.2	Chip-Scale Atomic Clock
	T5.3	Generation and sharing technology for reference time
T6. Ultra-security and reliability		
	T6.1	Emerging security technology
	T6.2	Cyber security technology based on real attack data
	T6.3	Quantum cryptography
	T6.4	Electromagnetic environmental technology
	T6.5	Resilient ICT
	T6.6	Sensing
T7. Ultra-realistic and Innovative Applications		
	T7.1	Brain information reading, visualization, and BMI technology
	T7.2	Intuition measurement, transmission and assurance technologies
	T7.3	Real 3D avatars, multisensory communication and XR technology
	T7.4	AI analytics and dialogue technology using language and extra-linguistic information
	T7.5	Edge AI behavioral support
	T7.6	Simultaneous multi-lingual interpretation, paraphrase and summarization technology
	T7.7	Automated driving
	T7.8	Drones

- **The key technologies are extracted and categorized from the use cases.**
- **Beyond 5G/6G Services are created with proper combination of the technologies.**

Technologies for Beyond 5G / 6G

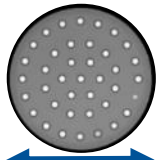
Increasing the capacity of wireless communications
(Using terahertz band, etc.)

THz Band Silicon Semiconductor



THz Band Compact antenna

Increasing the capacity of the core network
Multi-core fiber, multi-mode fiber, etc.

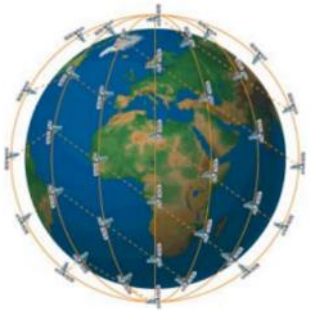


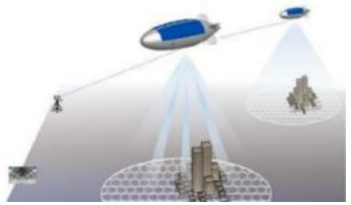
0.312mm

70mm

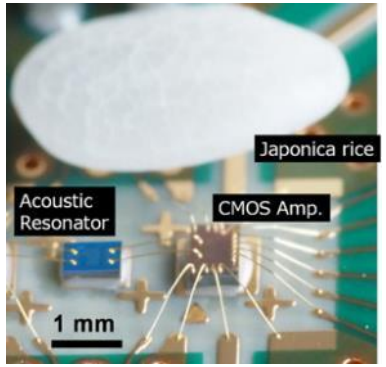
20mm

Coverage expansion/NTN
Satellite constellations, HAPS, etc.

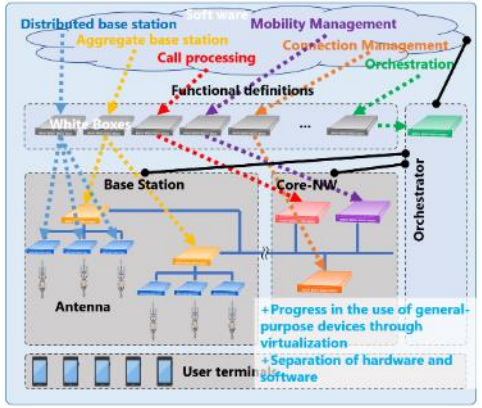




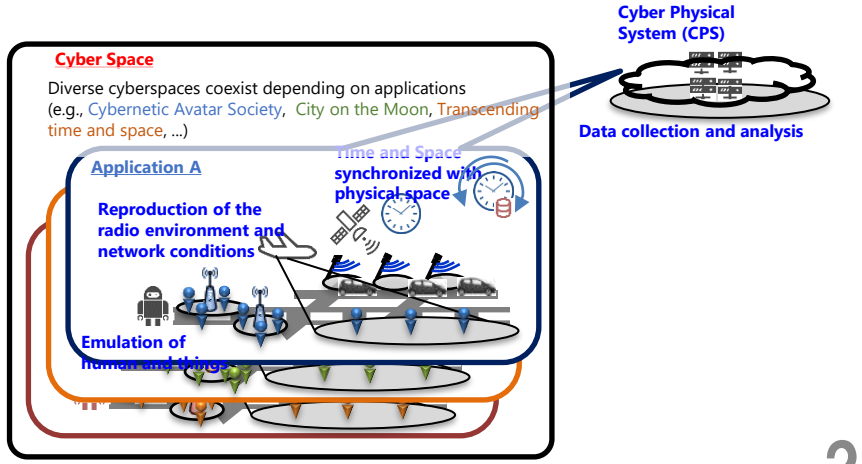
Space-time synchronization
+Inter terminal coordination
+Non-GPS positioning system
+Remote synchronization



Virtualization
+Cloud native
+Highly available resource allocation
+Network Control with AI
+Autonomic networks



Network slicing
Network functions and resources can be dynamically managed and flexibly selected.

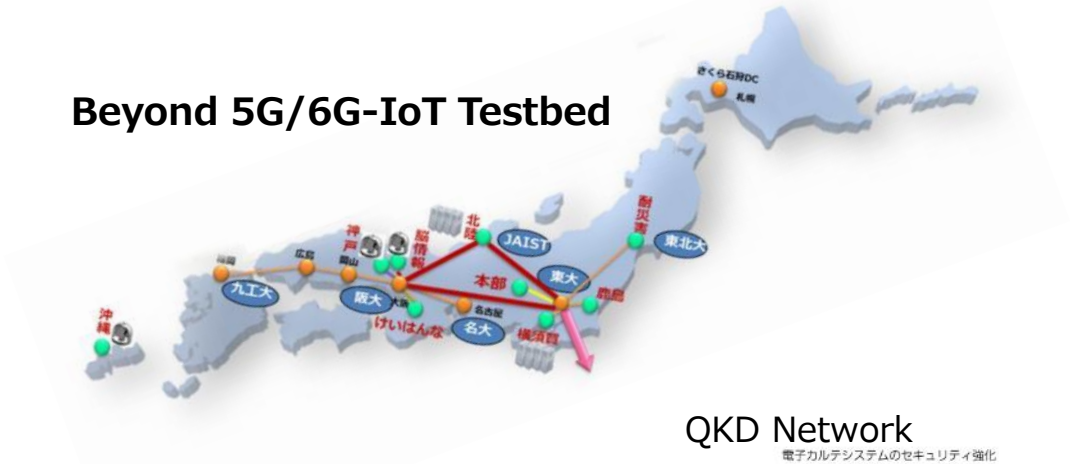


Open B5G R&D Testbed & Platform

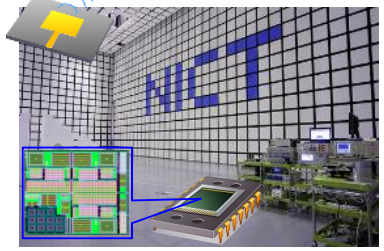
■ Extend and improve testbed environment to accelerate B5G development

- **Highly reliable and highly plastic Beyond 5G/6G-IoT testbed**
- **Beyond 5G/6G Transmission Infrastructure Technology Development Environment**
- **Ultra-high-speed optical communication technology development facilities supporting Beyond 5G / 6G**

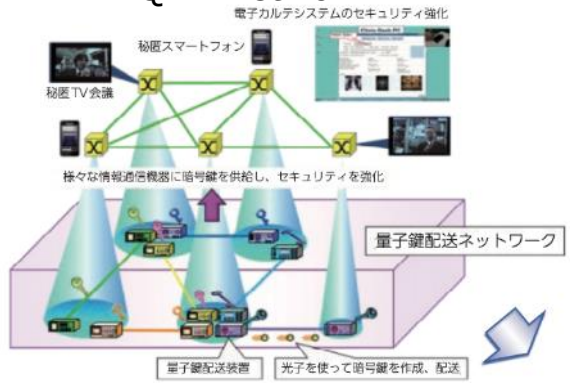
Beyond 5G/6G-IoT Testbed



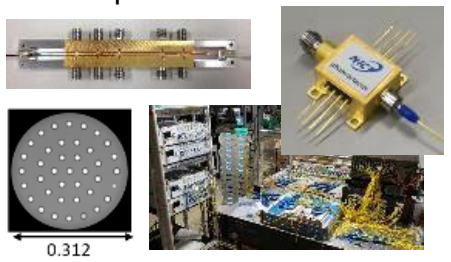
Terahertz Testbed



QKD Network



Ultra High Volume Optical Network



Optical Comm. Testbed

NICT Beyond 5G/6G R&D Promotion Program

- B5G R&D Projects Call 2.0(April 22, 2022)
- B5G R&D Projects Call 2.1(April 28, 2022)

Beyond 5G R&D Promotion Programs

NICT R&D Laboratories

B5G R&D Projects

+

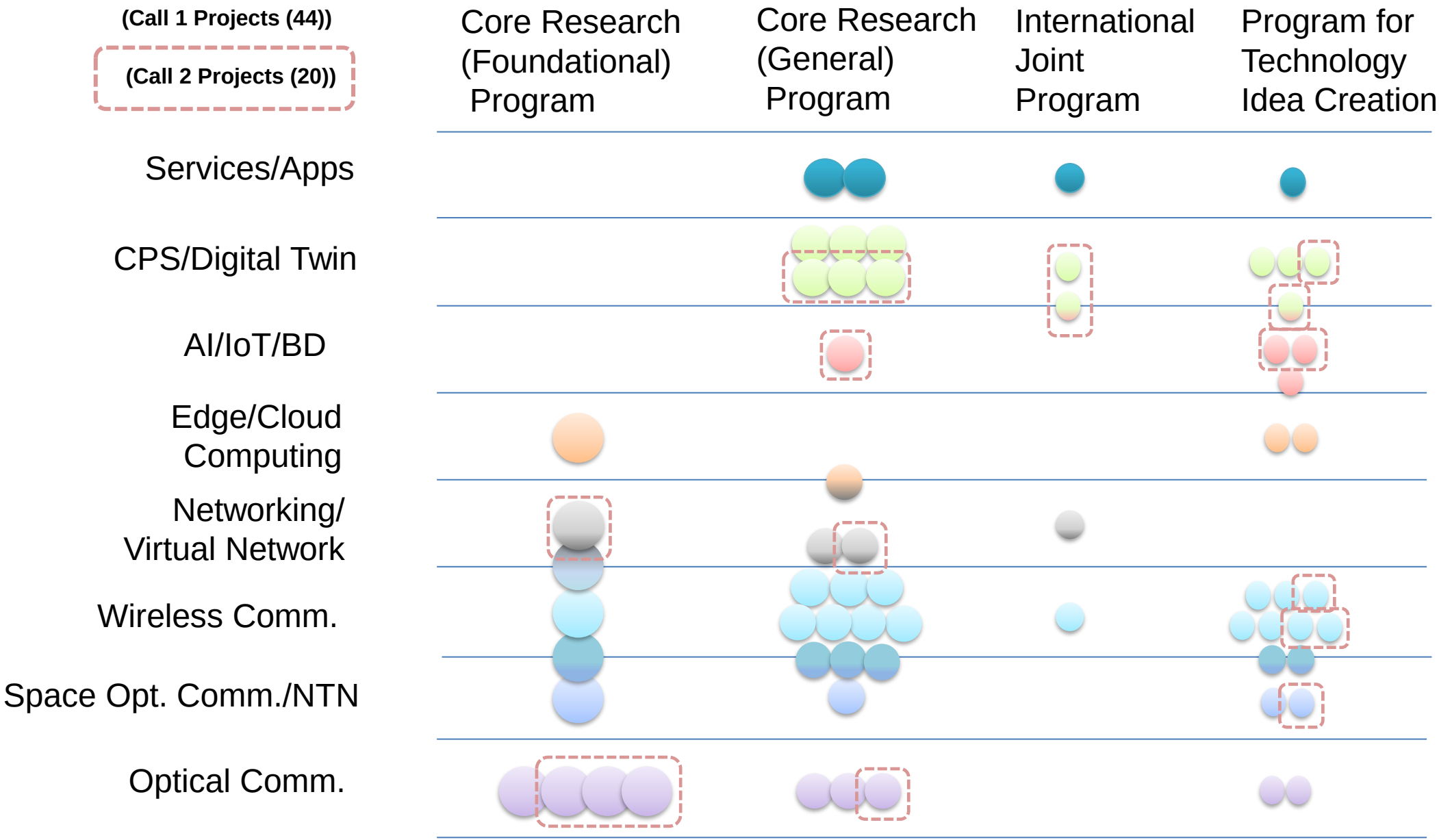
Beyond 5G R&D Promotion Programs
FY2020-FY2025: Call 1(2020/2021)、Call2(2022)、…

Core Research (Foundational) Program※	Core Research (General) Program	International Joint Program	Program for Technology Idea Creation
6 projects (2020/2021) **4** projects (2022) Budget：0.5B～x.0Byen/year R&D Period: 3-5 years	**20** projects (2021) **6** projects (2022) 0.3B～0.5Byen/year 3-5 years	**3** projects (2021) **2** projects (2022) 50M～100M yen/year 2-3 years	**15** projects (2021) **8** projects (2022) 50M～100Myen/year 2-3 years

(as of Aug. 2022)

※NICT gives detailed research plans with specific development goals for the public invitation

Beyond 5G R&D Promotion Programs
Call 1+ 2 Portfolio (as of Aug. 2022)



Beyond 5G R&D Project: SIG (Special Interest Group)

1 Purpose of SIG

- SIGs are grouped into several categories according to the interests of research and development implementers and technical fields. Main purpose is as follows:
  - Raise the effect of R&D results through interaction between members within the group and between groups
  - Trigger information exchange and coordinated activities related to intellectual property and standardization
  - Becomes an activity unit for social development and publicity of results, such as workshops

2 Configuration of SIG (as of October 2022)

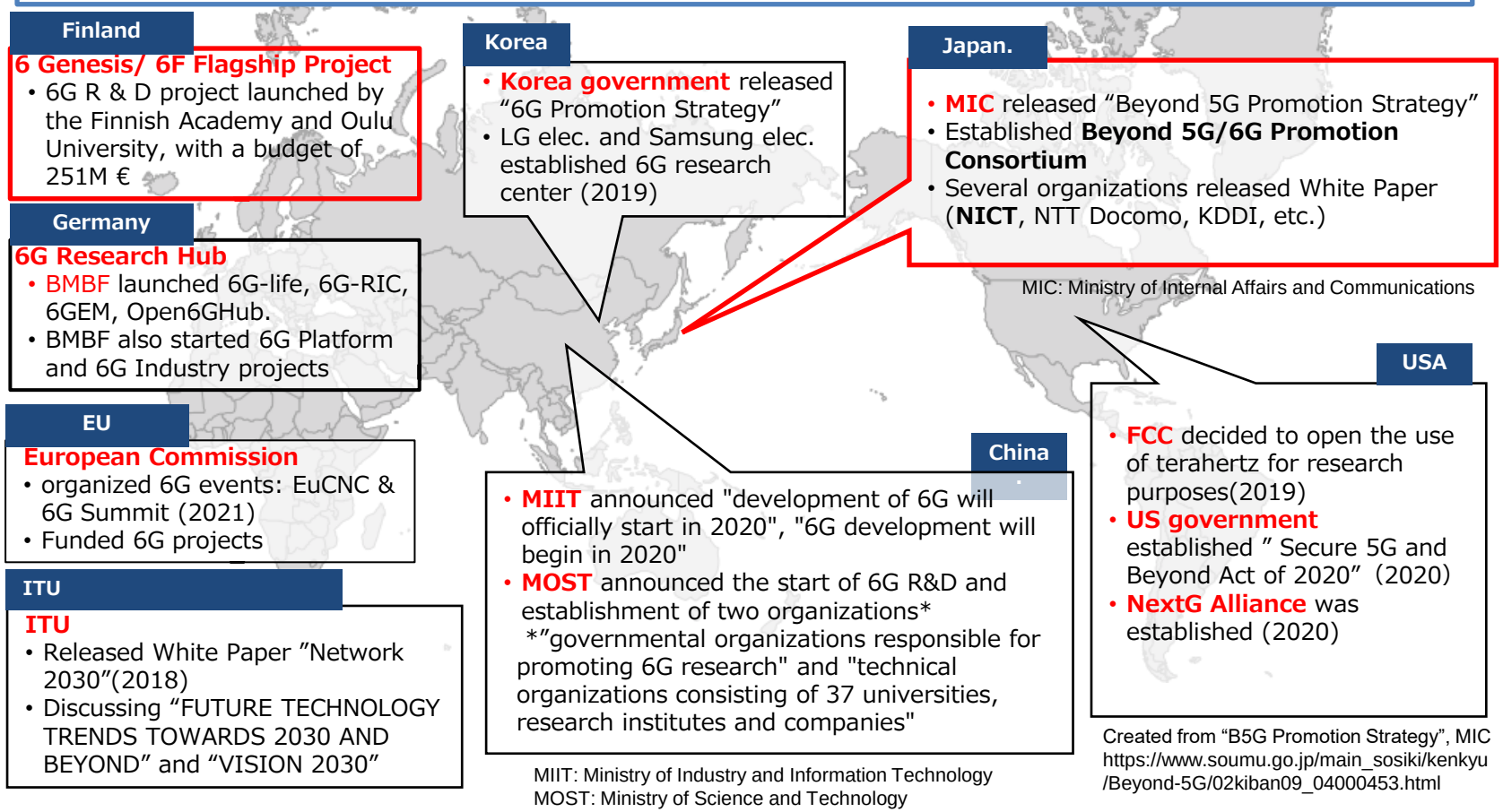
SIG	technical field
1	Computing using high-speed large-capacity communication, AI, robotics
2	Security, cyber-physical systems, IoT, smart cities
3	Network Convergence, Beyond 5G Architecture
4	Coverage extension, sensing

SIG	technical field
5	Advanced signal processing and protocols
6	Materials/Devices/Terminals
7	Millimeter/terahertz wave communication/sharing study
8	Optical wireless communication/Optical radio convergence communication

NICT– Oulu Univ. Cooperation

Beyond 5G / 6G Initiatives

- Discussions on use cases/requirements of Beyond5G/6G have been active, and several 6G projects, alliance/consortium have been established.



Finland

6 Genesis/ 6F Flagship Project
- 6G R & D project launched by the Finnish Academy and Oulu University, with a budget of 251M €

Germany

6G Research Hub
- BMBF launched 6G-life, 6G-RIC, 6GEM, Open6GHub.
- BMBF also started 6G Platform and 6G Industry projects

EU

European Commission
- organized 6G events: EuCNC & 6G Summit (2021)
- Funded 6G projects

ITU

ITU
- Released White Paper "Network 2030"(2018)
- Discussing "FUTURE TECHNOLOGY TRENDS TOWARDS 2030 AND BEYOND" and "VISION 2030"

Korea
- **Korea government** released "6G Promotion Strategy"
- LG elec. and Samsung elec. established 6G research center (2019)

Japan.
- **MIC** released "Beyond 5G Promotion Strategy"
- Established **Beyond 5G/6G Promotion Consortium**
- Several organizations released White Paper (**NICT**, NTT Docomo, KDDI, etc.)

MIC: Ministry of Internal Affairs and Communications

China
- **MIIT** announced "development of 6G will officially start in 2020", "6G development will begin in 2020"
- **MOST** announced the start of 6G R&D and establishment of two organizations*
  *"governmental organizations responsible for promoting 6G research" and "technical organizations consisting of 37 universities, research institutes and companies"

MIIT: Ministry of Industry and Information Technology
MOST: Ministry of Science and Technology

USA
- **FCC** decided to open the use of terahertz for research purposes(2019)
- **US government** established " Secure 5G and Beyond Act of 2020" (2020)
- **NextG Alliance** was established (2020)

Created from "B5G Promotion Strategy", MIC
https://www.soumu.go.jp/main_sosiki/kenkyu/Beyond-5G/02kiban09_04000453.html

Beyond 5G/6G Trials/Demos in 2025

- **Connected B5G/6G testbed**
  - Development of radical 6G use cases in both testbed
  - Testing and Verifying 6G capabilities with these testbed

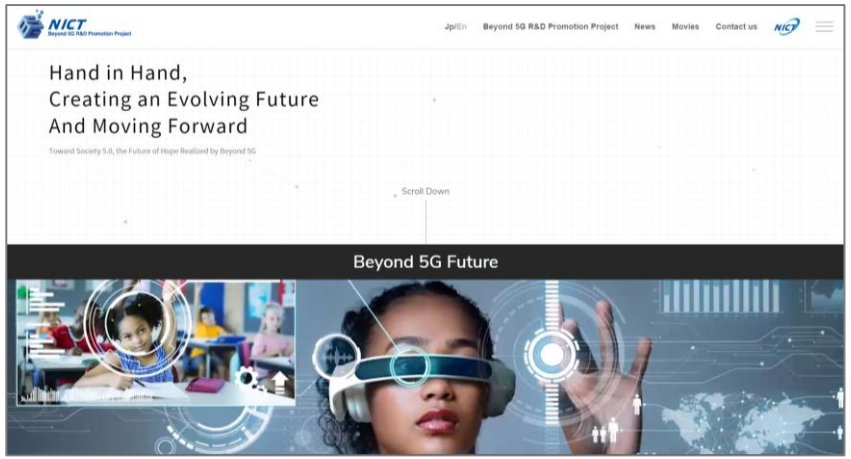
- **Joint Demonstrations**
  - **Expo 2025 Osaka, Kansai, Japan**
  - Demonstration of B5G/6G Interoperability
  - Demonstration of radical 6G use cases with interoperability

Beyond 5G R&D Project Portal Site

Portal site

- Published in March 2022. Project related information is posted as a portal site. We are providing notifications of new R&D recruitment and summaries of adopted R&D projects.
- English content is gradually expanded.

https://b5g-rd.nict.go.jp/en/



Brochure

Includes an overview and testbed overview.

https://b5g-rd.nict.go.jp/en/B5G_pamphlet_en_202204.pdf

Thank you

NICT will continue to contribute to create a better society by ICT

www.nict.go.jp