Research and Development: Beyond 5G/IoT Testbed with High Reliability and High Elasticity

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National Institute of Information and Communications Technology (NICT)

Agenda

- Introduction of “Beyond 5G/IoT Testbed with High-Reliability & High-Elasticity”

- Examples of research and development using our testbed

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- Introduction of “Beyond 5G/IoT Testbed with High-Reliability & High-Elasticity”

- Examples of research and development using our testbed

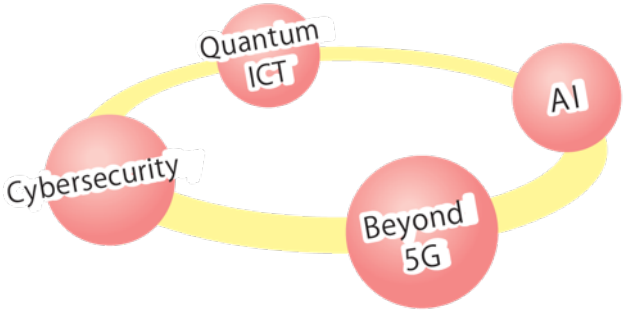
About NICT

President TOKUDA Hideyuki

Japan's **only national** research and development agency specializing in the field of Information and Communications Technology (**ICT**)

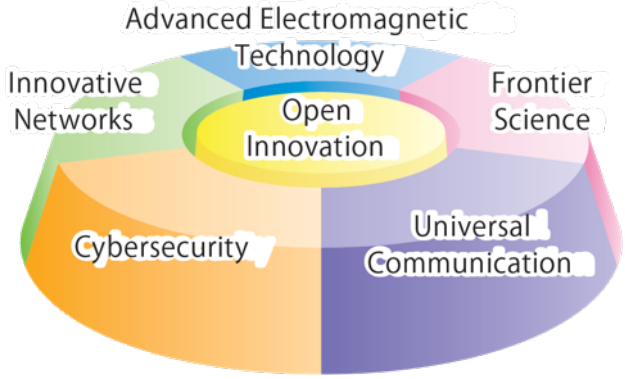
5 priority areas based on a new ICT technology strategy

① Advanced electromagnetic technology
② Innovative networks
③ Cybersecurity
④ Universal communication
⑤ Frontier science



4 strategic research fields

① **Beyond 5G**
② AI
③ Quantum ICT
④ Cybersecurity



Cyber-Physical-System

(Ref. NICT Beyond 5G/6G White Paper –English version 3.0-, https://beyond5g.nict.go.jp/images/download/NICT_B5G6G_WhitePaperEN_v3_0.pdf)

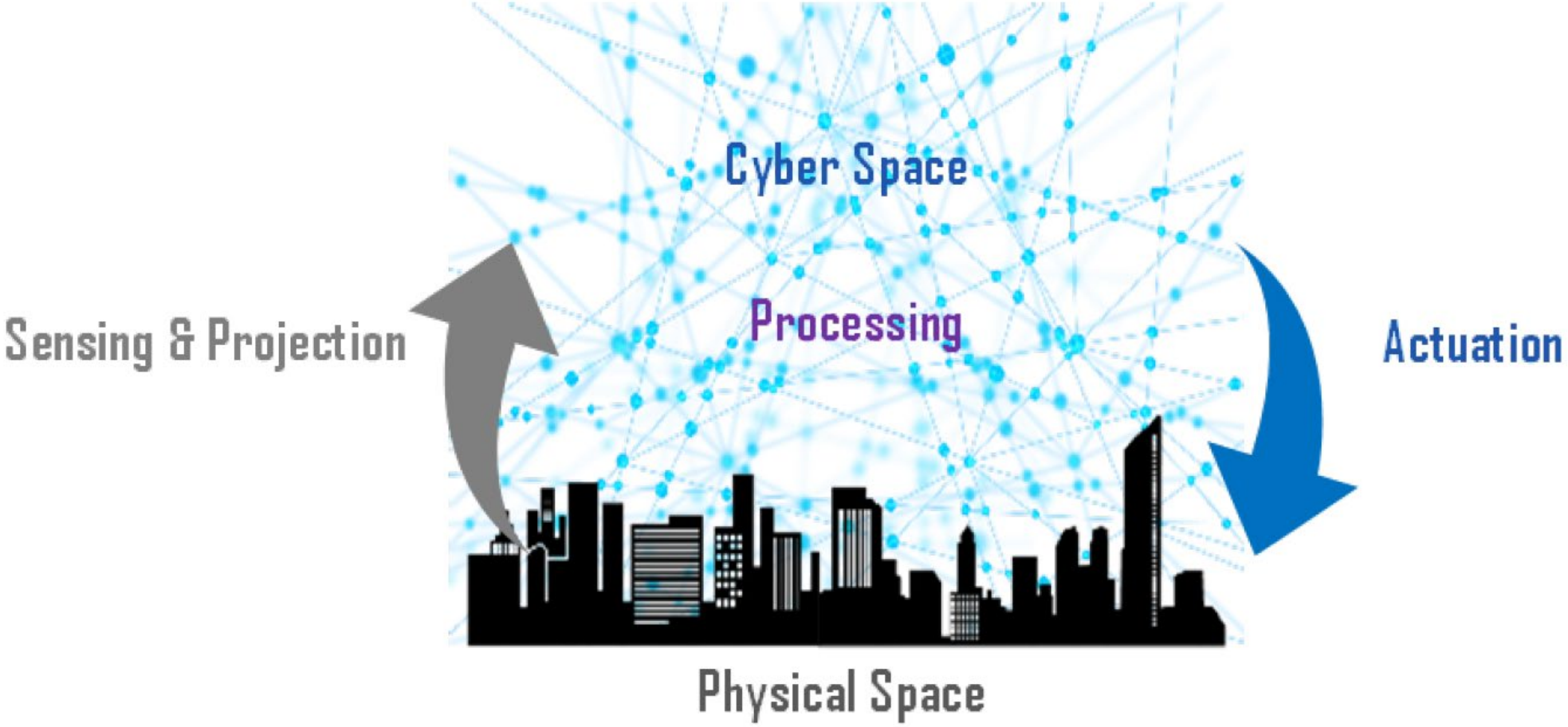


Figure 1.1 Realization of a “cyber-physical system” that measures events (big data) in physical (real) space, projects them into cyberspace, finds solutions (optimal solutions), and actuates the physical space event.

Beyond 5G/6G Functional Architecture

(Ref. NICT Beyond 5G/6G White Paper –English version 3.0-, https://beyond5g.nict.go.jp/images/download/NICT_B5G6G_WhitePaperEN_v3_0.pdf)

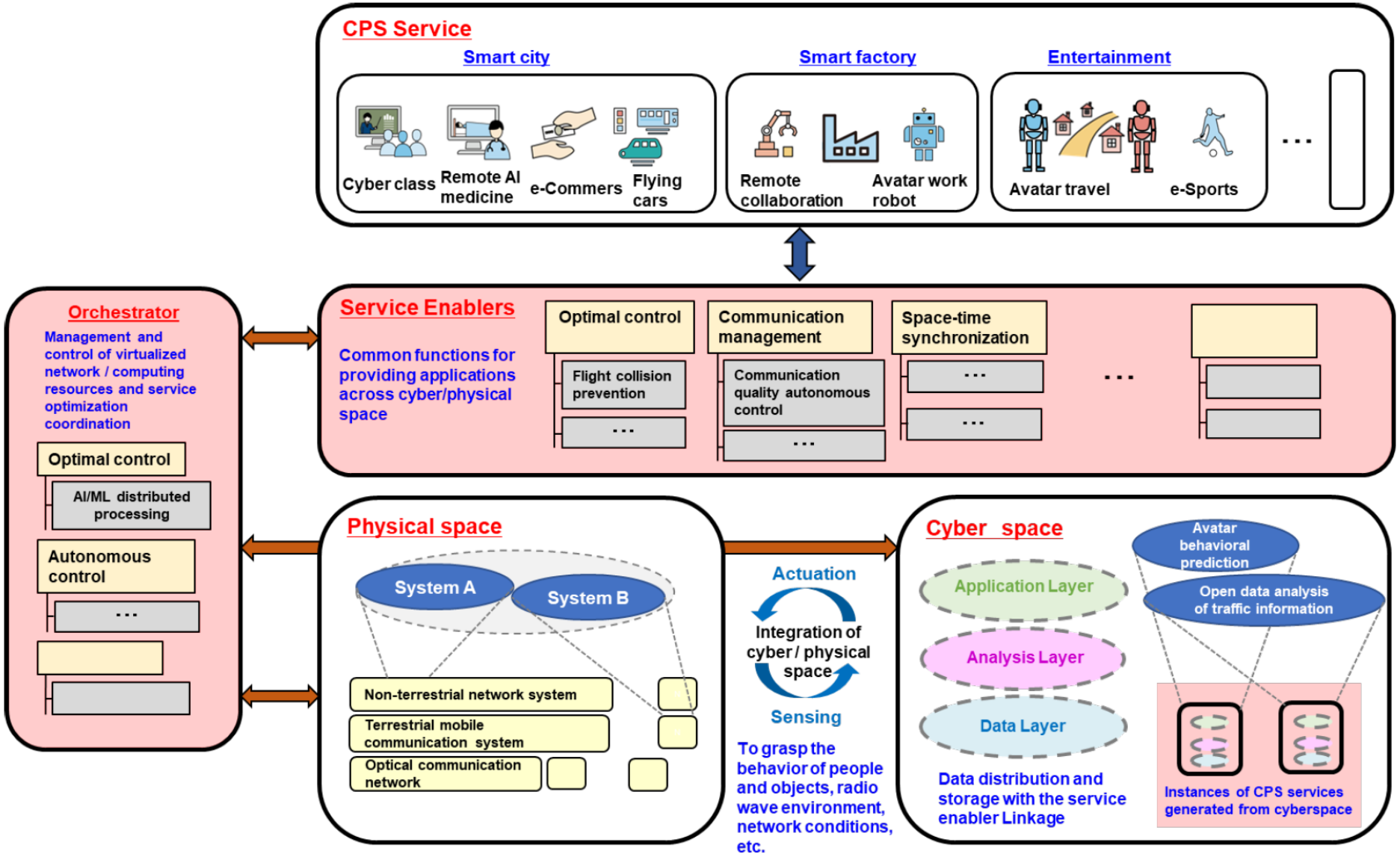
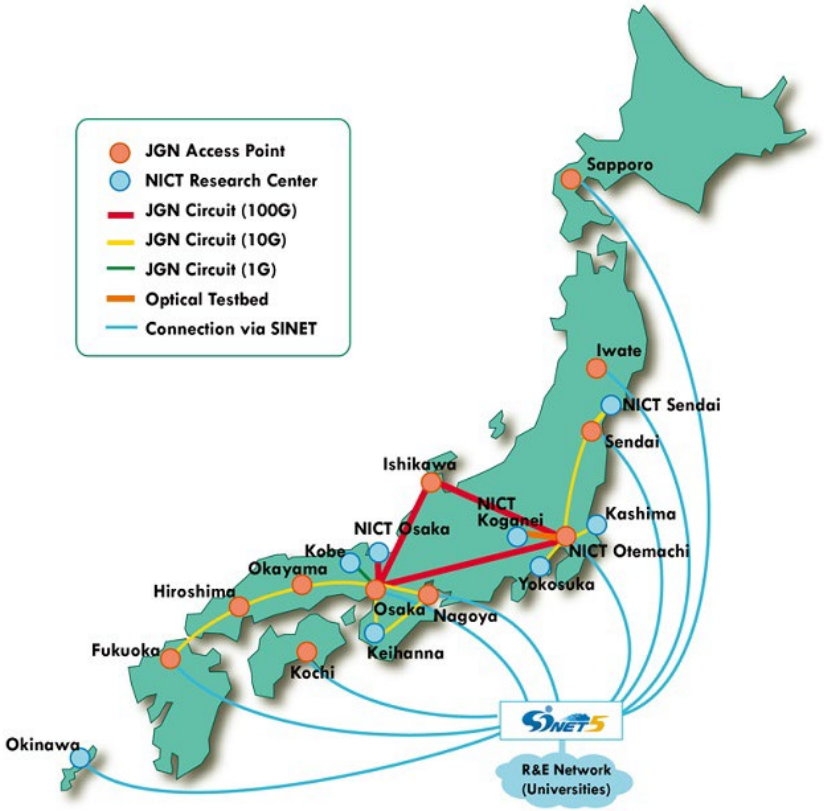


Figure 2.1 Beyond 5G/6G Functional Architecture

JGN

- A *Network Testbed* operated by NICT
  - JGN has been operated since 1999
- JGN has International and Domestic networks
  - 100 Gbps Backbone Network in Japan
  - 100 Gbps International Connections
- JGN supports cutting-edge Network Experiments
  - High-Seed App: Uncompressed 8K Video Transmission
  - Time-Sensitive App: Next-Generation ICT-supported Surgery, etc.
- We have been collaborating with NII/SINET to extend Network Reachability in Japan



JGN global interconnections

StarBED

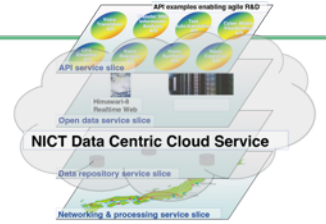
- A cluster of 1000 or more PCs dedicated to diverse huge-scale verifications
  - Hardware-as-a-Service
  - Common OS and software work
  - Realtime network emulation
  - Can allow “ERROR” by separation from Internet
  - Can verify behavior of malware in isolated environment

Beyond 5G/IoT Testbed with High-Reliability & High-Elasticity

- NICT launched Beyond 5G/IoT Testbeds Services from Oct. 2022.

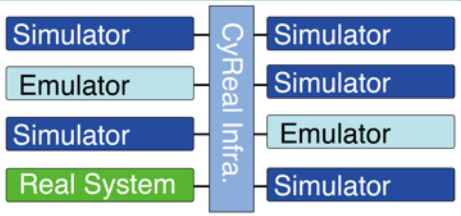
Goal: Accelerating Research & Development and Social Demonstration toward the Realization of B5G through Collaboration among Diverse Players using Testbed

DCCS - Data Centric Cloud Service:
Providing the Environment for developing services on B5G era that utilize and analyze various data in combination by using the B5G network.



Platform Layer

CyReal Demonstration Environment:
CyReal environment mounted on StarBED enables the introduction of simulation by the incorporation of physical events



Middleware Layer

StarBED

Network Layer

JGN

B5G Mobile Environment:
Providing verification environment on DU/CU and core parts with B5G hardware and software

B5G Reliable Virtualization Infrastructure:
Providing B5G Virtual Computing Environment that utilizes hardware resources extensively and can prevent network service failures

Yokosuka

Kashi

NICT Otemachi

Cyclical Evolution

Based on
- External Trend & Cooperation

Embodying
- Cyber-Physical Fusion
- Coordination of Services and Networks

Functional **Expansion**

software-based **Advancement**

NICT
Previous Testbeds
Network Testbeds
JGN & StarBED

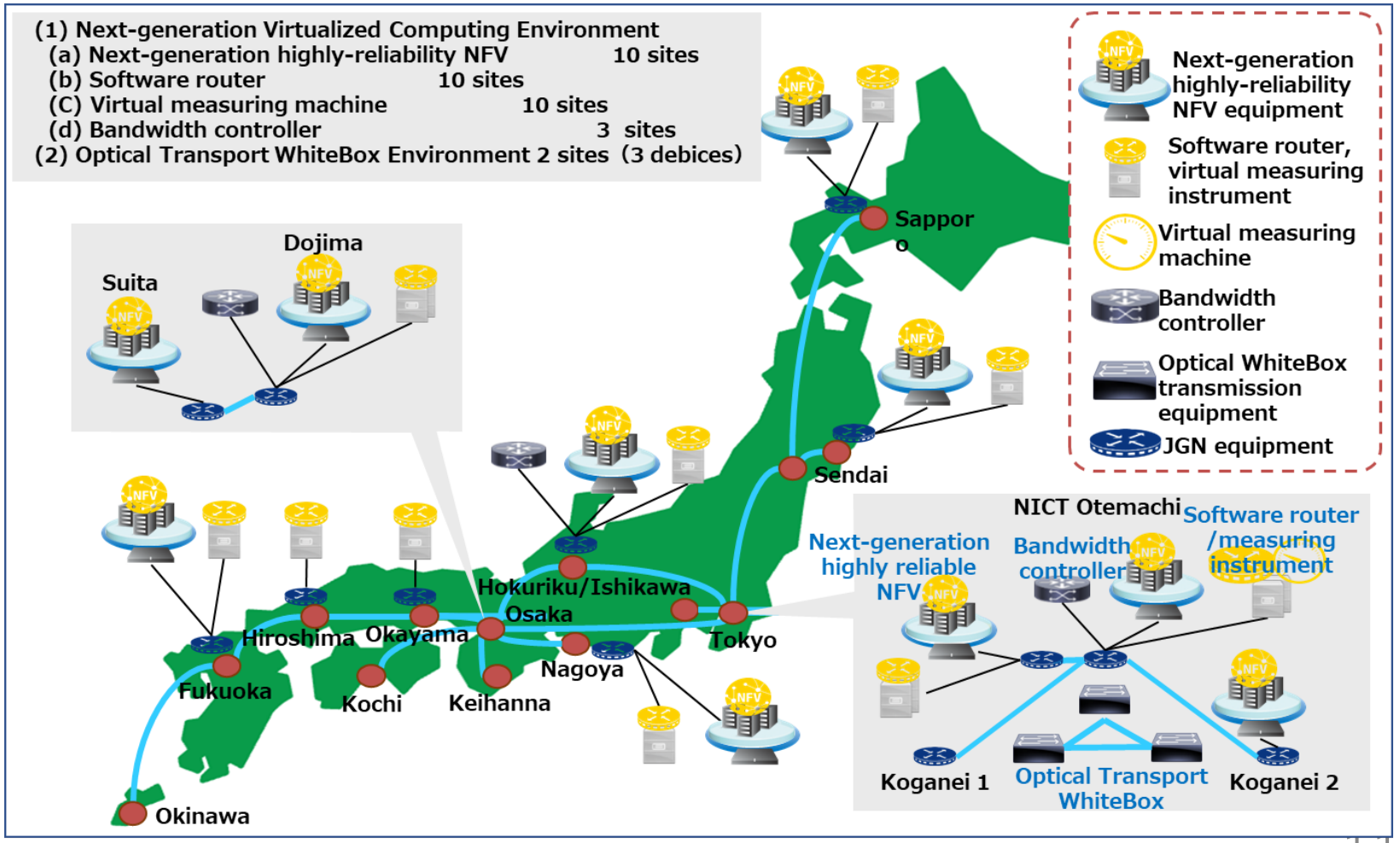
Outline of “1. B5G reliable virtualization infrastructure”

1-1. Next generation virtualized ICT service environment: From Oct. 2022

- Evaluations of the high speed and high reliability services that enable flexible resource allocation by softwarized network functions and virtualization technologies

1-2. Optical whitebox environment: From Oct. 2022

- Opened optical transport whitebox to evaluate enhanced optical transmission by disaggregation, HW/SW separation technologies



Outline of “2. B5G mobile environment”

2-1. Mobile application demonstration environment：From Oct. 2022

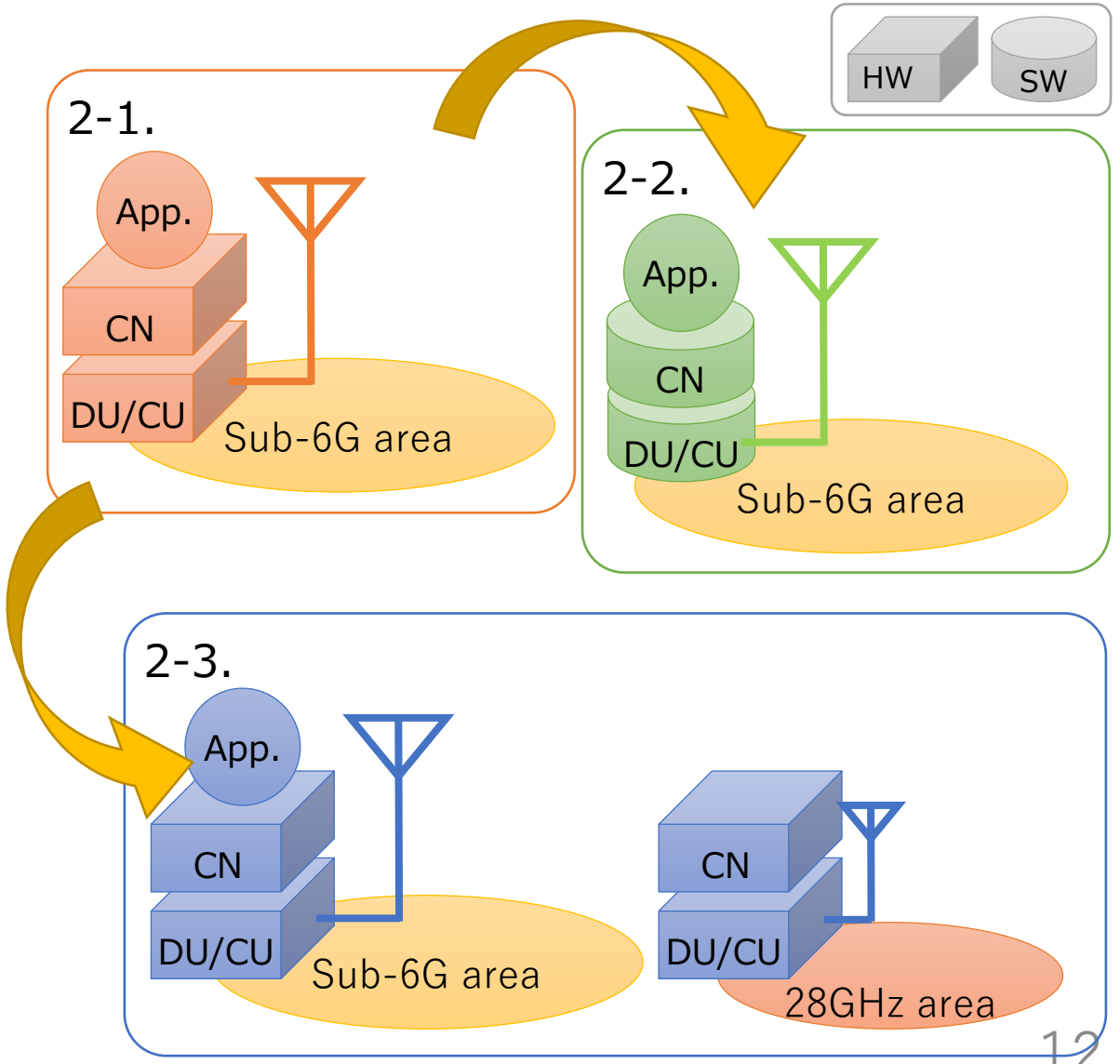
- Mobile network environment employing HW base stations (BSs) that enables evaluations of application technologies exploiting 5G network assuming enhancement toward B5G

2-2. Mobile network development environment：From Oct. 2022

- Mobile network environment employing cloud native BSs that enables performance evaluations for BS customizations by softwarized technologies such as C-Plane slicing

2-3. Mobile base station development environment: From Oct. 2022

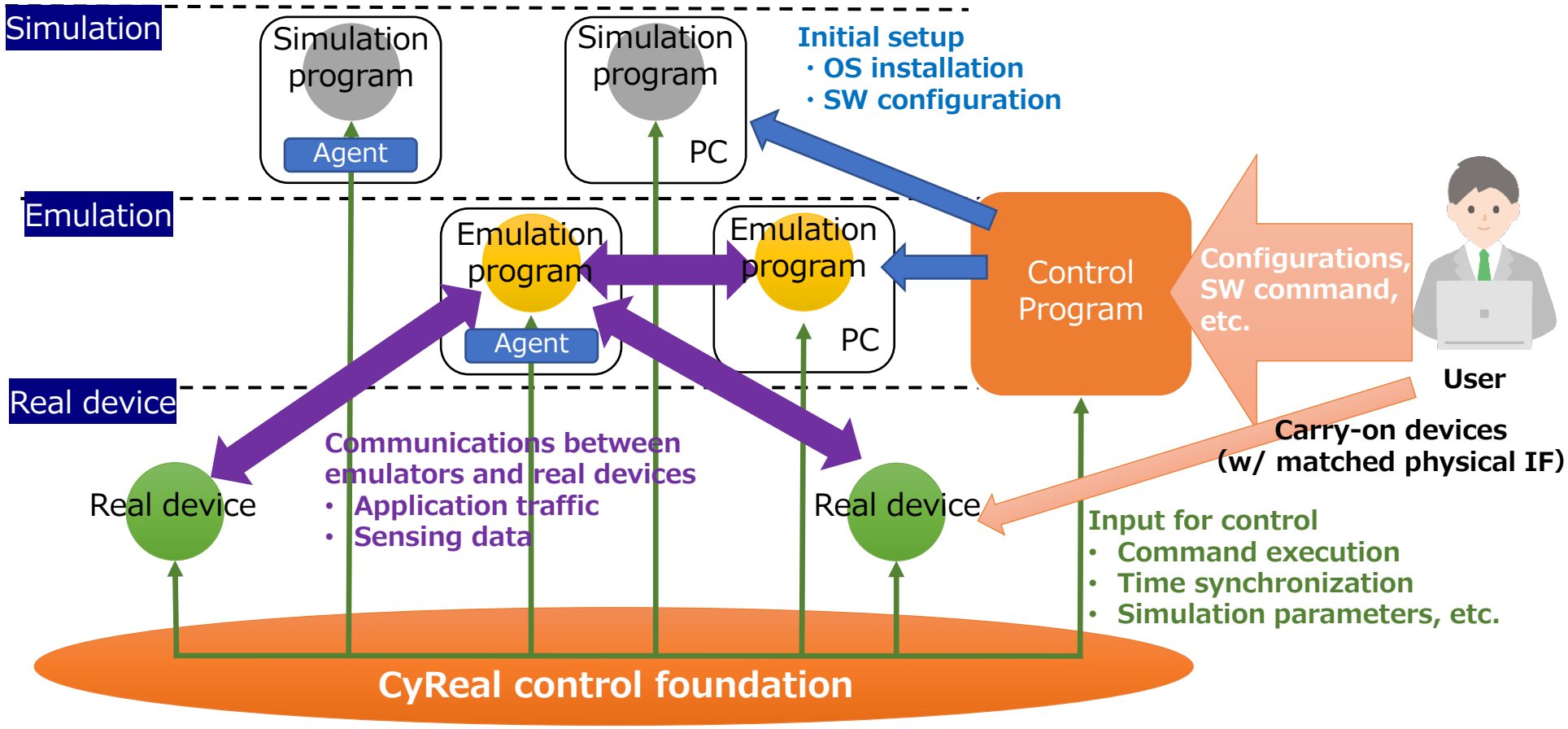
- Proof test environment that provides heterogeneous BSs(28GHz, Sub-6GHz) and multi-band terminals to evaluate heterogeneous area association performances



Outline of “3. CyReal demonstration environment”

3. CyReal demonstration environment：From April 2023

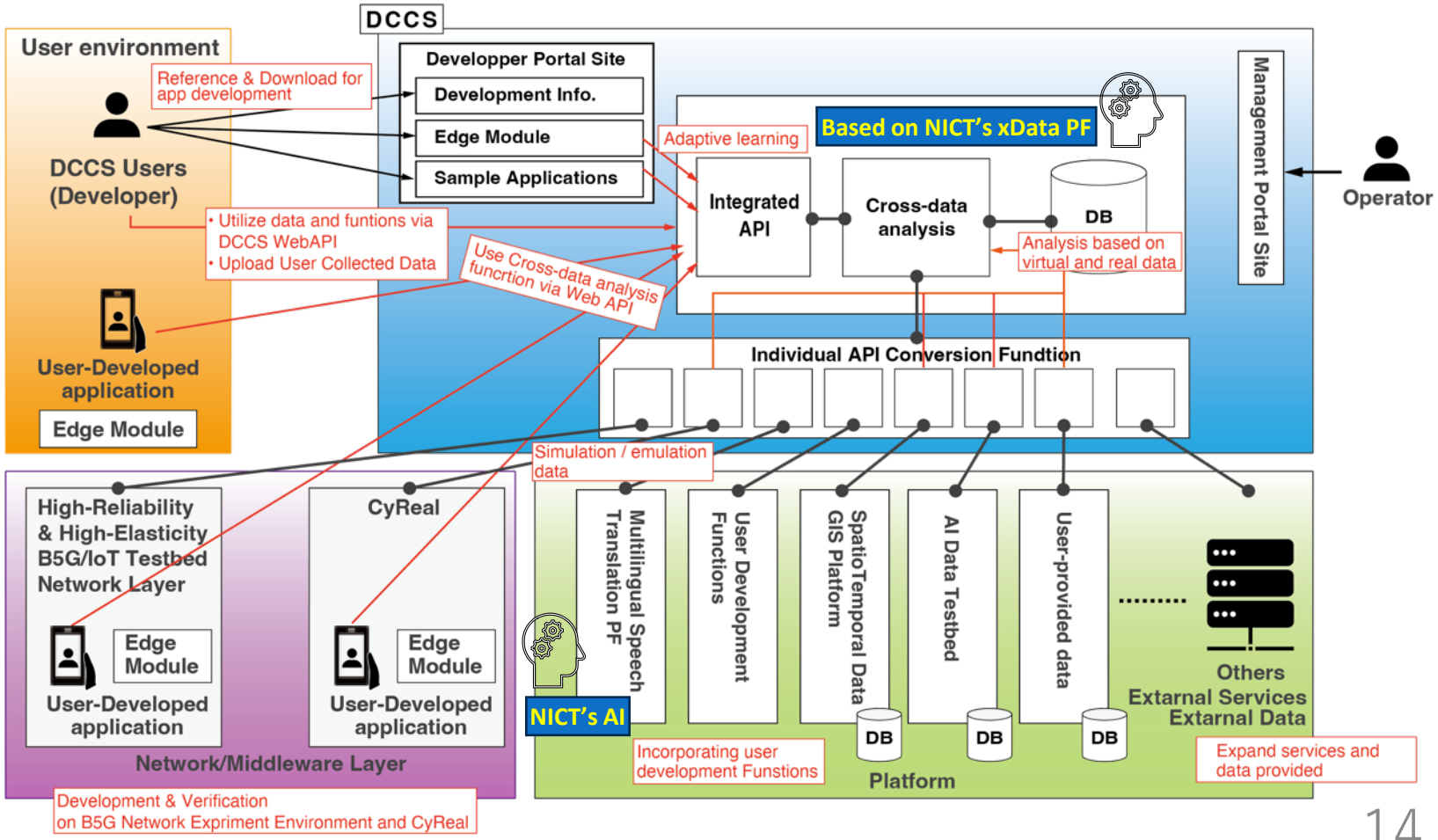
- Evaluaton environment that employs combinations of simulation, emulation and real device where users can handle necessary programs on the StarBED PCs
- Parameters of the evaluation environment is flexibly customized via OS control, VM setup and network configurations



Outline of “4. DCCS (Data Centric Cloud Service)”

- Provide Data and Functions as Web API
  - Diverse Data and Functions to utilize it are provided as Web API
  - Users can develop Application and Services by utilizing these Data and Functions
  - User-owned data can also be uploaded and applied to DCCS for various processing

- APIs and Developer Portal
  - The APIs are Python-base and easy to code
  - Support Application Development by providing the Developer Portal with Sample programs and documentation for API specifications and usage, etc.



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- Examples of research and development using our testbed

NICT Demonstrations at SC23

SC23 Denver, CO | i am hpc.

The International Conference for High PerformanceComputing, **Networking**, Storage, and Analysis

DENVER, CO • NOV 12–1

Over 14,000 Attendees and 438 Exhibitors

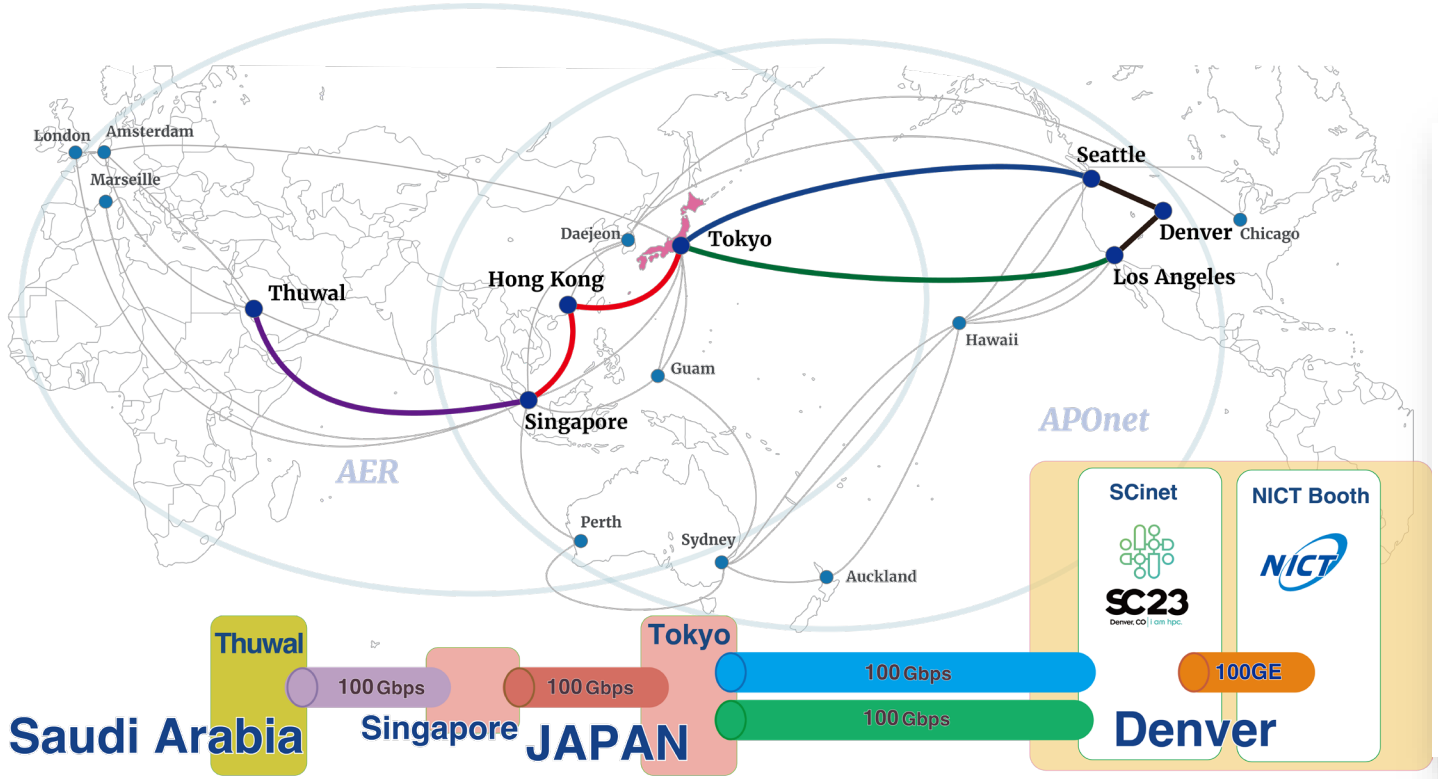
- **The Only International Exhibition** that allows **demonstrations of Intercontinental high-speed circuits** in excess of 100 Gbps.
- The network used at the SC is designed, built, and operated by **SCinet**, which consists of volunteer Networking Experts from Universities, Institutes and Companies around the world.
- Major research, development and educational networking organizations from around the world participate.

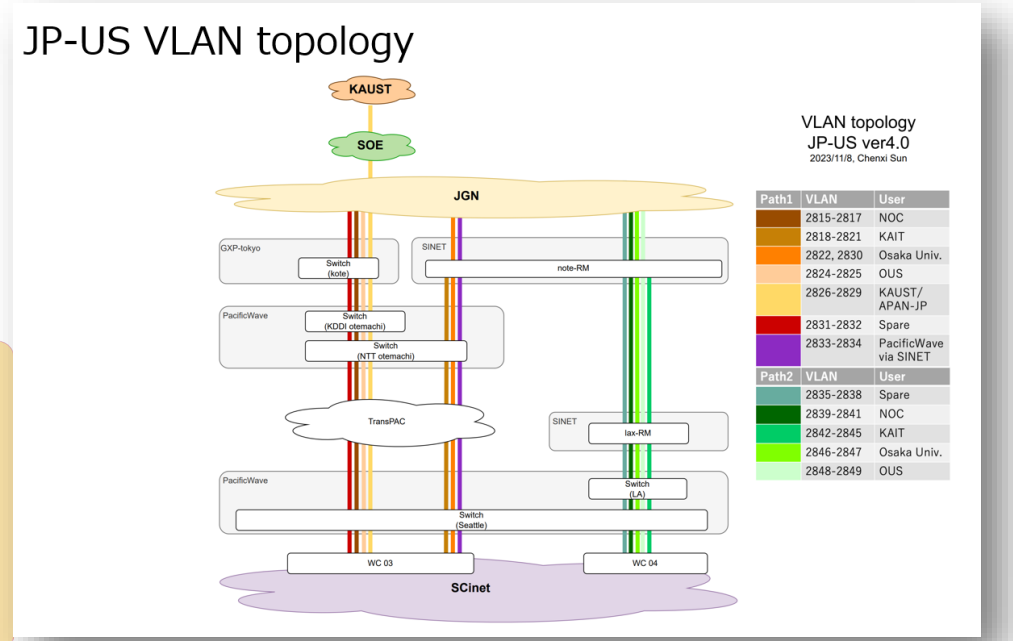
NICT Demonstrations at SC23

- Five s (NREs)

  including the 100Gbps Transfer experiments were **Successfully** carried out at NICT Booth.

  With two 100Gbps Paths between *Denver* and *Tokyo* over the Pacific Ocean and the US.





Five NREs at NICT Booth #781

	Organization	NRE title
1	Kanagawa Institute of Technology (KAIT)	NRE-028 : Uncompressed 8K video processing using SRv6-based service functionchaining between Japan and U.S.
2	Osaka University	NRE-029 : Performance Evaluation of DTNs Towards Research-EnhanceD ONION (RED ONION)
3	Nara Institute of Science and Technology (NAIST)	NRE-030 : Distributed Machine Learning over Heterogeneous Edge Computing Resources
4	Okayama University of Science (OUS)	NRE-031 : Long-Distance Streaming for SBC MD System
5	APAN-JP	NRE-024 : Exploring FDT, QUIC, BBRv2 and HTTP/3 protocols in High Latency WAN paths for use on Data Transfer Nodes

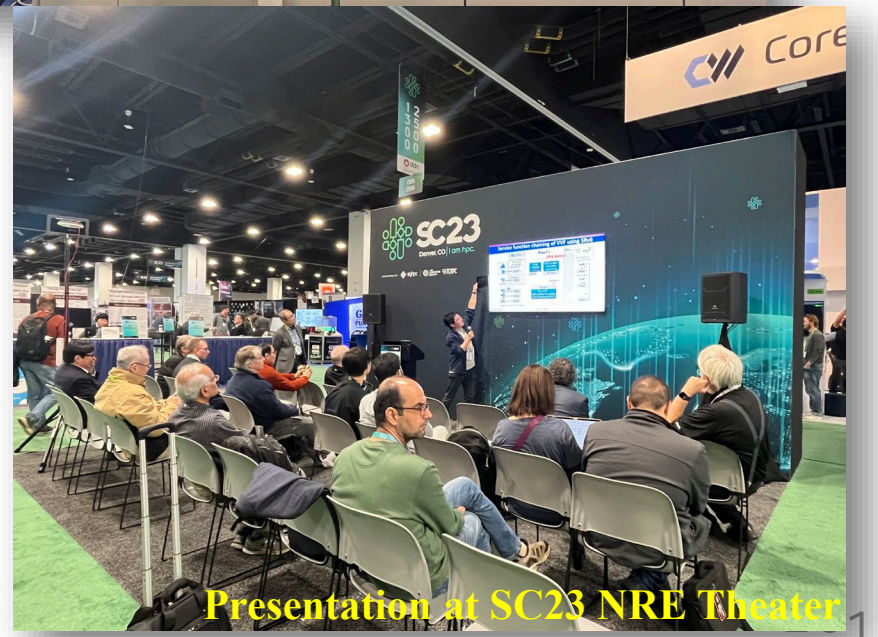
5 out of 32 NREs at SC23 were performed at NICT booth

Demonstration by KAIT

- **NRE-28: Uncompressed 8K video processing using SRv6-based service function chaining between Japan and U.S.**

  Real-time editing and distribution of uncompressed 8K video

  - Uncompressed 8K live video stream was transferred from Japan to SC23 venue and shown.
  - Multiple 8K video sources in **JGN** and SINET6 were edited in real time and shown on the display at the venue by remotely operating the **VVFs** (Virtual Video-handling Functions) from the venue.



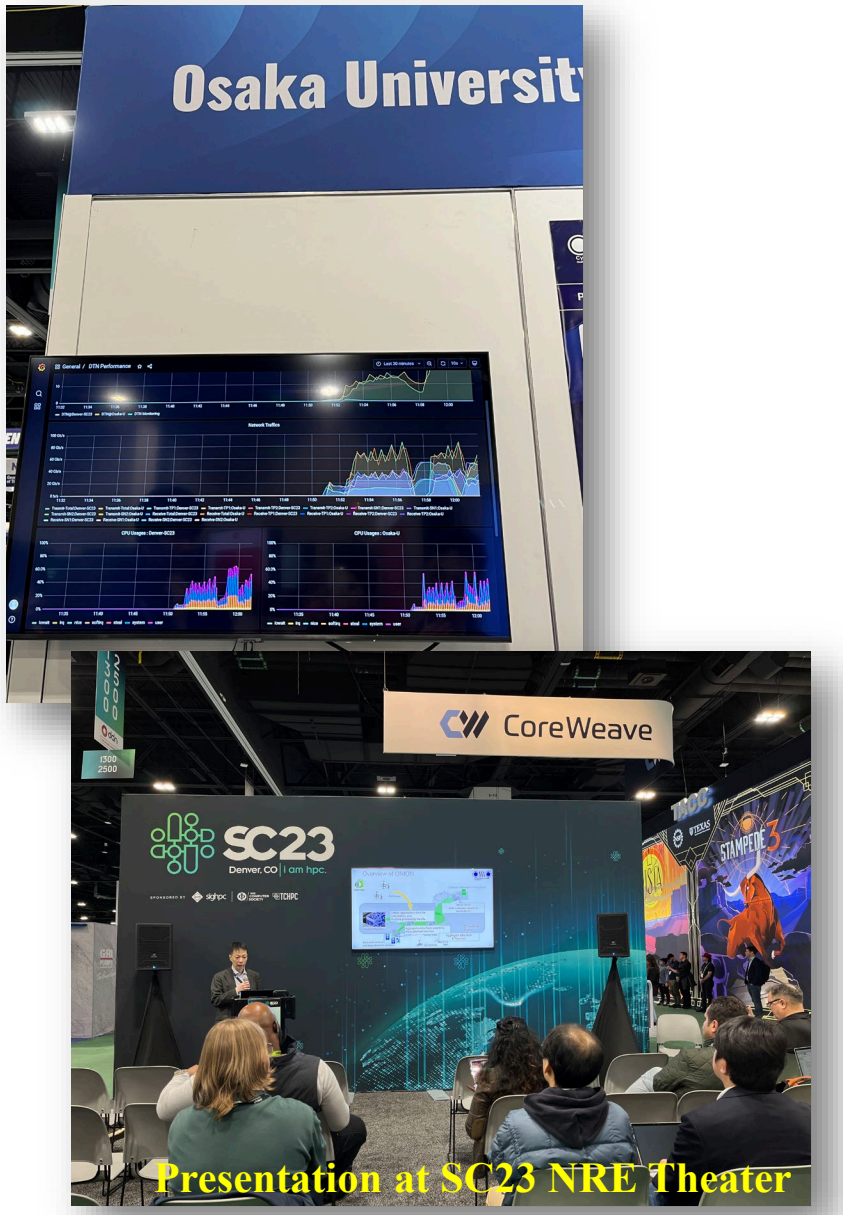
Presentation at SC23 NRE Theater

Demonstration by Osaka University

- **NRE-29: Performance Evaluation of DTNs Towards Research-EnhanceD ONION (RED ONION)**

  Performance evaluation for development of **RED ONION** for sharing large amount of research data

  - Osaka University has been working on data aggregation infrastructure named ONION (Osaka university Next-generation Infrastructure for Open research and open innovation) and exploring the development of RED ONION for transferring large amount of research data with DTNs on high-speed closed network in campus.
  - Performance evaluation was conducted to obtain the measurement results of throughput performance of data transfer between Osaka University in Japan and NICT booth in SC23 venue Denver, USA.



Demonstration by NAIST

- **NRE-30: Distributed Machine Learning over Heterogeneous Edge Computing Resources**

Demonstration of **Hierarchical Federated Learning** using PiK8kE Testbed*

- **Hierarchical Federated Learning** reduces the average latency of the entire Federated Learning environment by the edge computing resources are grouped into clusters based on their locations or other criteria, and the model parameters are aggregated hierarchically from the edge resources and then to the central server.
- Demonstration of Edge computing resources deployed across multiple sites in the US, Japan, and other Asian regions are interconnected with **JGN** and EdgeVPN.io, a P2P-based overlay network software, creating scalable virtual Ethernet network across distributed edge nodes was shown at the venue.

* PiK8kE Testbed ... An evolving international testbed for federated edge computing on Raspberry Pi 4 and Jetson Nano devices using Kubernetes

Demonstration by OUS

- **NRE-31: Long-Distance Streaming for SBC MD System**

  Performance evaluation of **MD (Multi-Display)** middleware operating on SBCs (Single-Board Computers as Raspberry Pi), and evaluation experiments for long-distance screen streaming transfer and receiver functionality.

  - In this demonstration, wide-area network was utilized to perform streaming transmission of application screens between SC23 Denver and Tokyo Otemachi.
  - In the experiment, the screen rendering speed (FPS) was measured and compared with the local environment. The screen resolutions of WGX, Full-HD, and 4K were compared for the purpose of this demonstration.

❖ Evaluation and Comparison with existing middleware on Raspberry Pi3 (4 display nodes)

- SAGE2 on Raspberry Pi3 : 1.2 fps
- Display Cluster : 2.1 fps
- Proposal Method: 23.2 fps

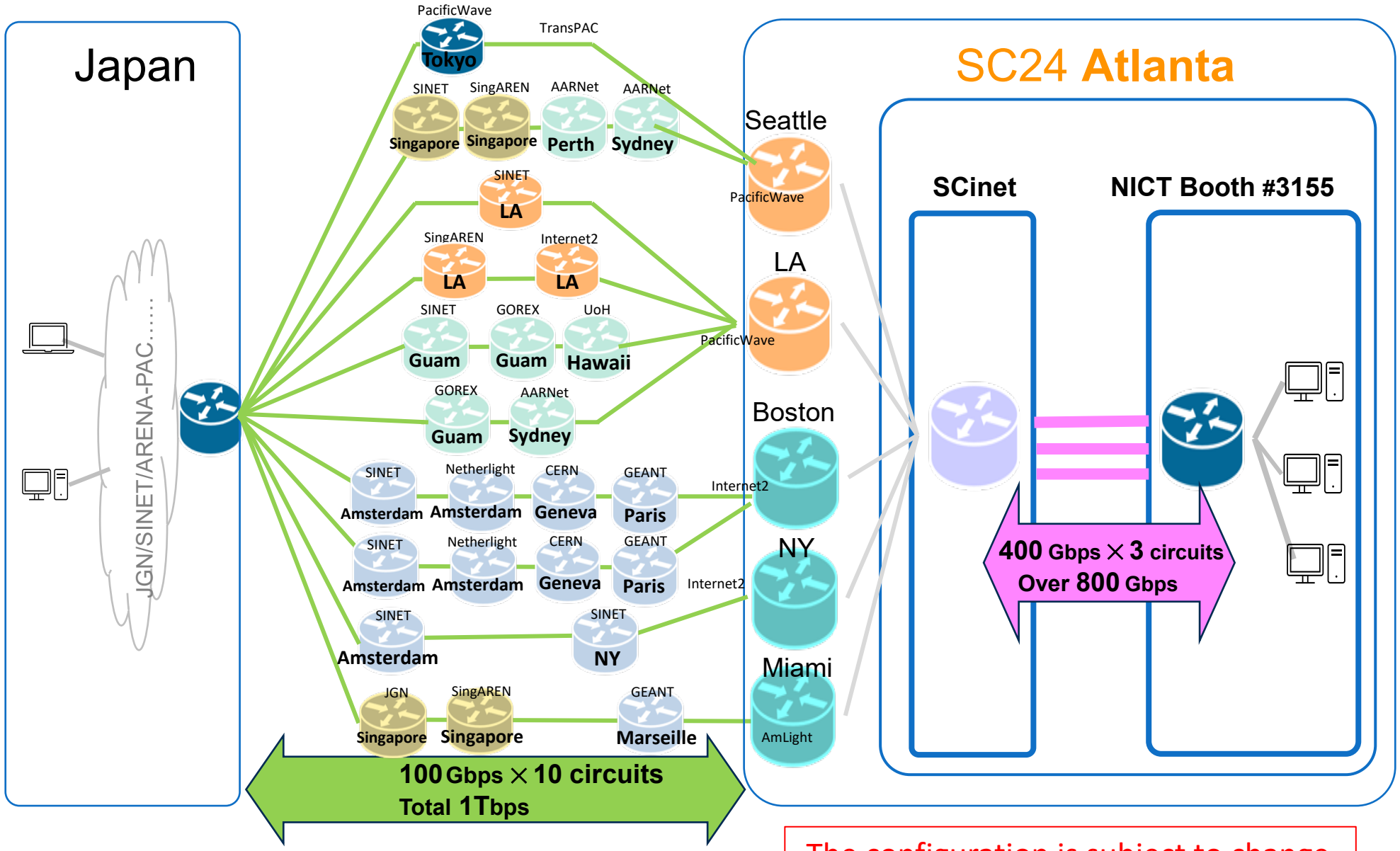
NICT booth at SC23

NICT Demonstrations at SC24

- NICT will have demonstrations at SC24, Atlanta, US, Nov 17-22, 2024.

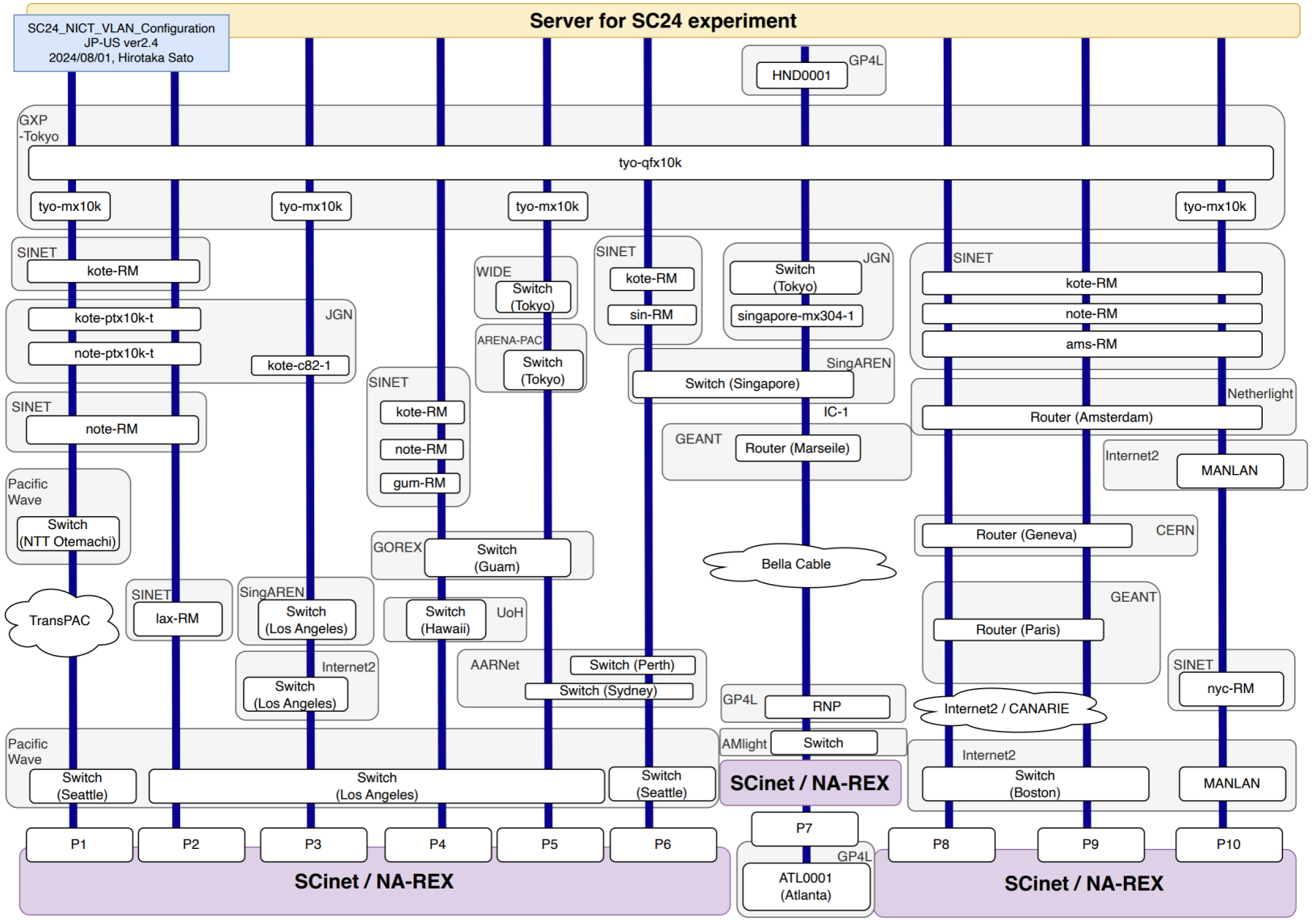
- We are going to construct the network with ten 100Gbps paths between *Atlanta* and *Tokyo* for 800Gbps data transfer experiments in global network.

Network Configuration: from Japan to SC24 venue



The configuration is subject to change.

Network Configuration: details



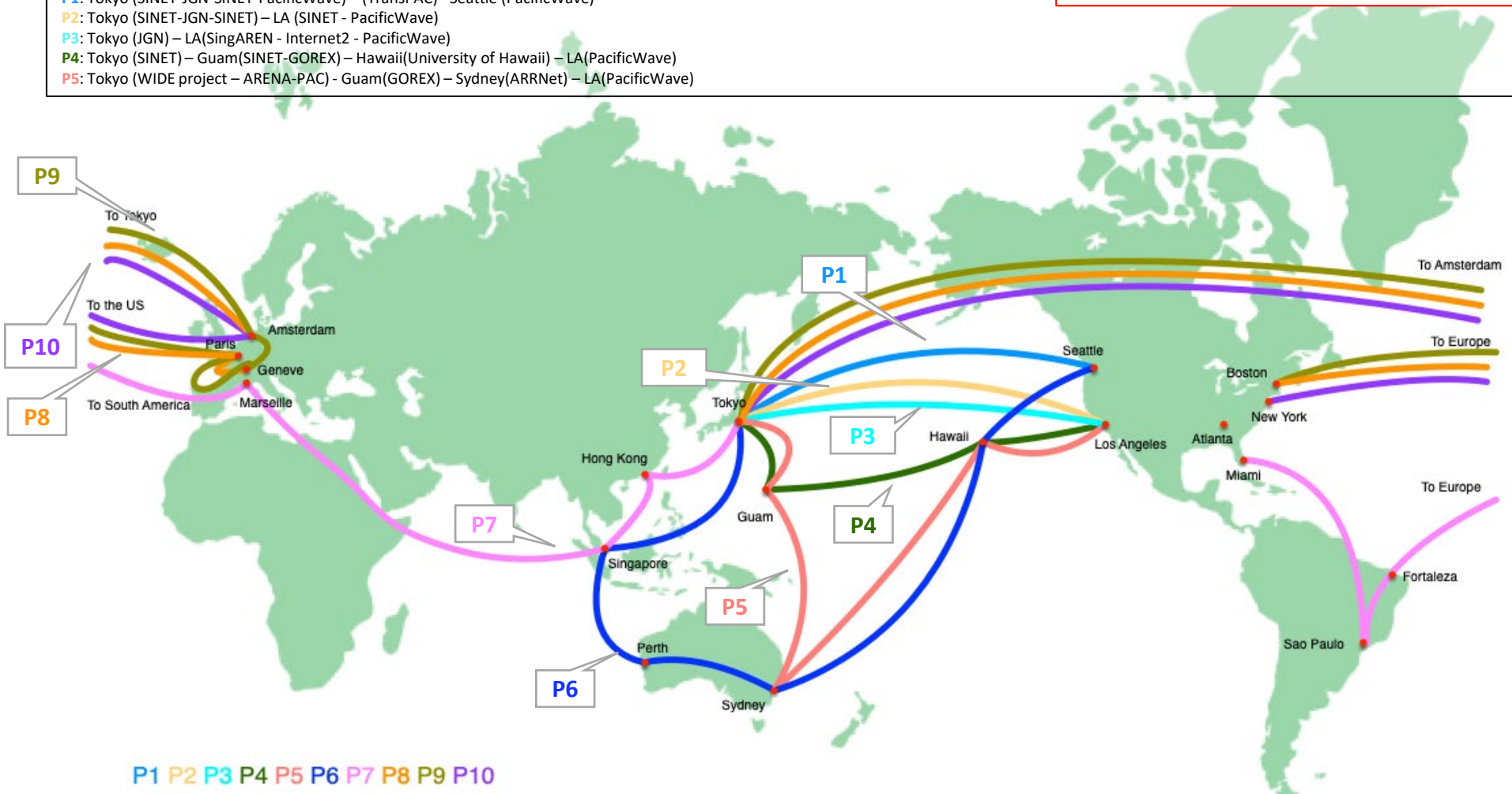
The configuration is subject to change.

Network Configuration: US-Japan network

Path No. : Network connection point (Organization)

P1: Tokyo (SINET-JGN-SINET-PacificWave) – (TransPAC) - Seattle (PacificWave)
P2: Tokyo (SINET-JGN-SINET) – LA (SINET - PacificWave)
P3: Tokyo (JGN) – LA(SingAREN - Internet2 - PacificWave)
P4: Tokyo (SINET) – Guam(SINET-GOREX) – Hawaii(University of Hawaii) – LA(PacificWave)
P5: Tokyo (WIDE project – ARENA-PAC) - Guam(GOREX) – Sydney(ARRNet) – LA(PacificWave)

The configuration is subject to change.

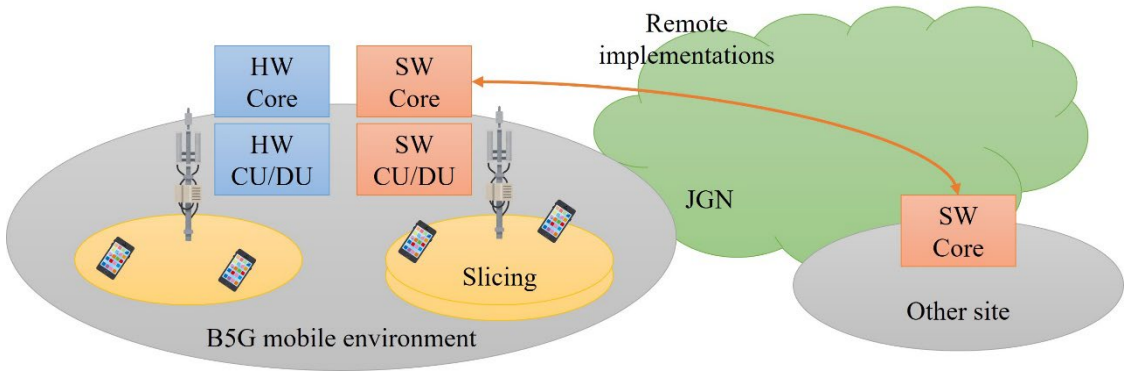


P6: Tokyo (SINET) - Singapore(SINET-SingAREN) – Perth (ARRNet) - Sydney(ARRNet) – Seattle (PacificWave)
P7:Tokyo (JGN) – Singapore(JGN - SingAREN) - Marseille (GEANT) – Bella Cable – Brazil (RNP) – Miami (AmLight)
P8: Tokyo (SINET) – Amsterdam (SINET – Netherlight) – Geneva (CERN) - Paris (GEANT) – Internet2/CANARIE – Boston(Internet2)
P9: Tokyo (SINET) – Amsterdam (SINET – Netherlight) – Geneva (CERN) - Paris (GEANT) – Internet2/CANARIE – Boston(Internet2)
P10: Tokyo (SINET) – Amsterdam (SINET – Netherlight) – NY (Internet2 – SINET – Internet2)

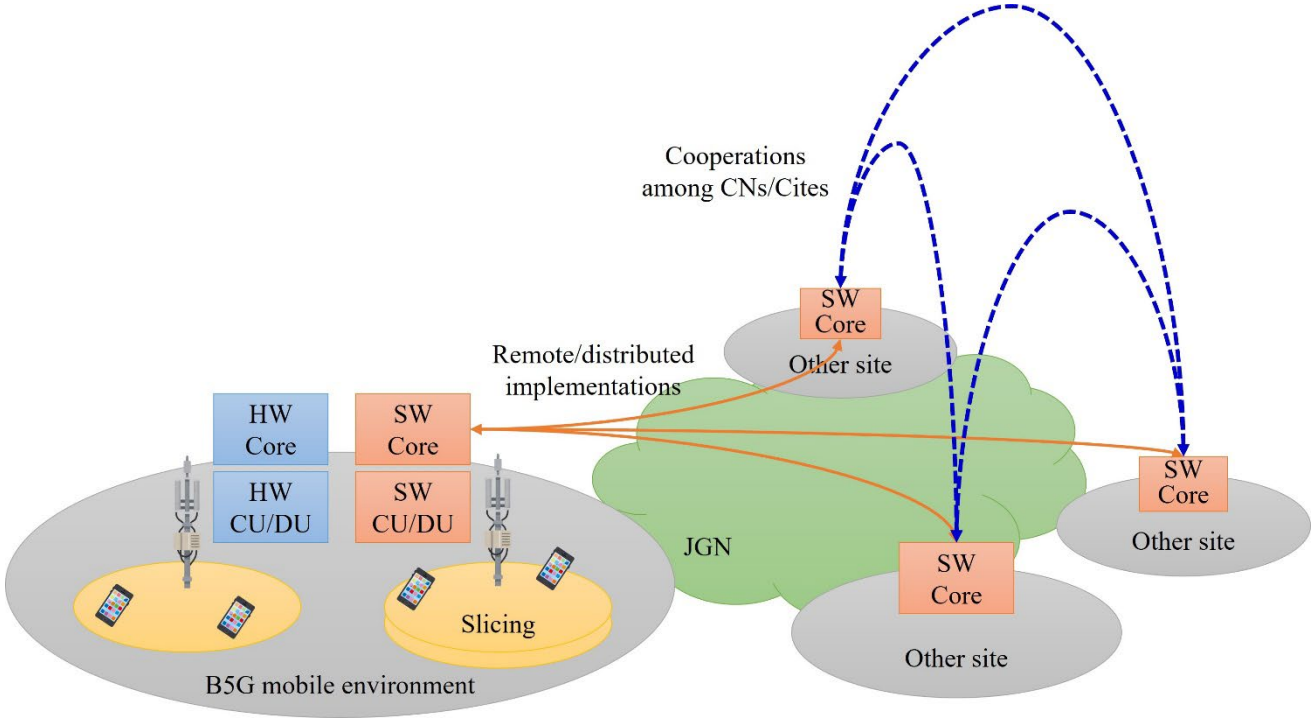
Special Thanks: RARE, GP4L, RENATER

Example of R&D using B5G mobile environment

- Evaluation of a resource allocation scheme assumes two main managements to realize effective radio resource utilizations:
  - Dynamic resource allocation by the slicing technology in CU/DU units
  - Network support by the remote and distributed CNs



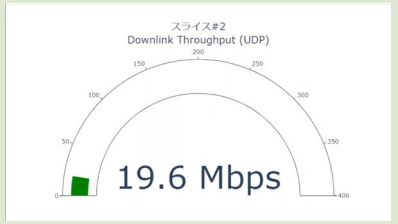
A concept of resource allocation by slicing



Further management by the core configurations

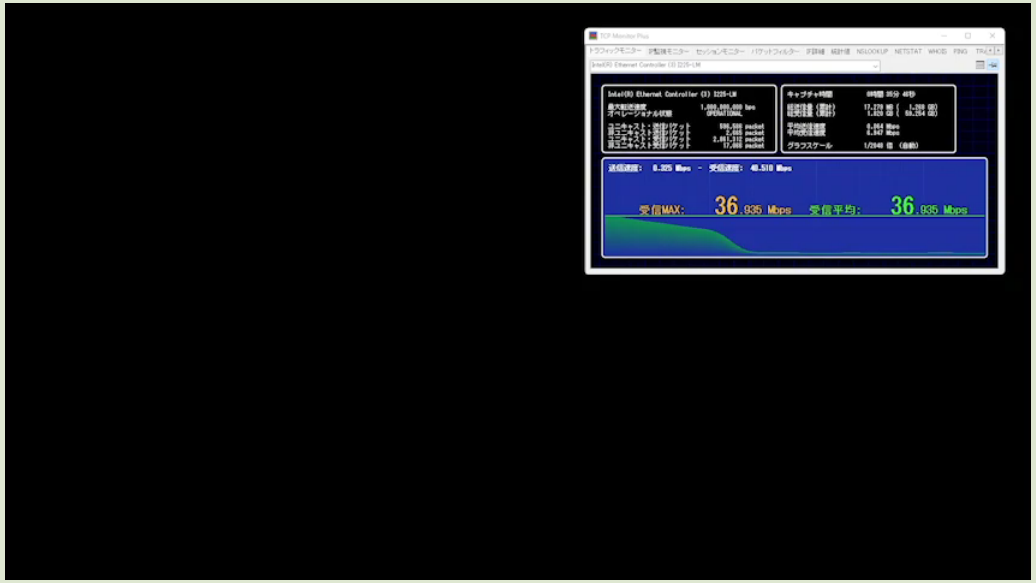
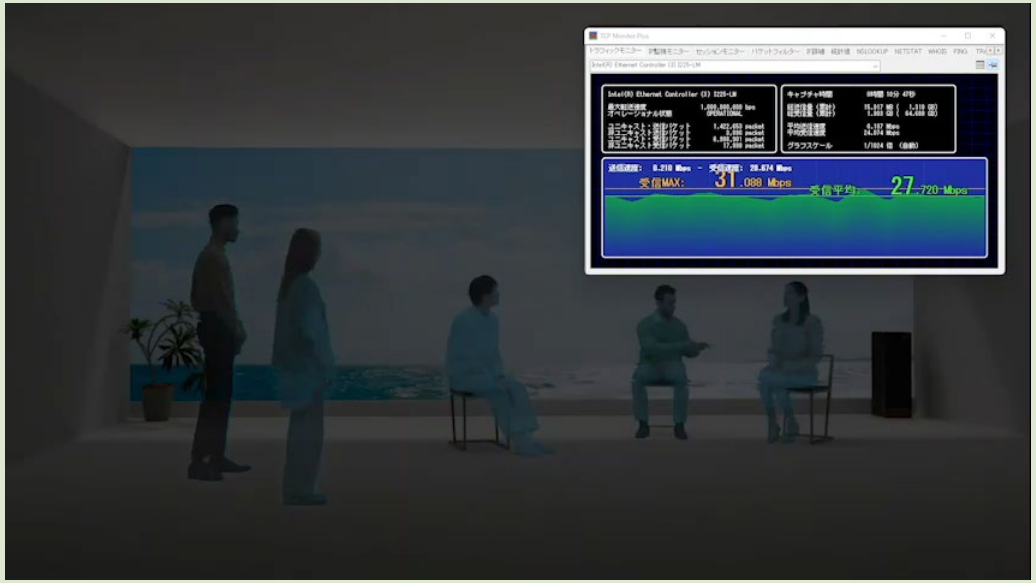
Slicing technology evaluation in the B5G mobile environment (1)

- The demonstration shows the performances among the different bandwidth employed slicing cases

	“Broadband” slicing	“Narrowband” slicing
Through-put		
Movie		

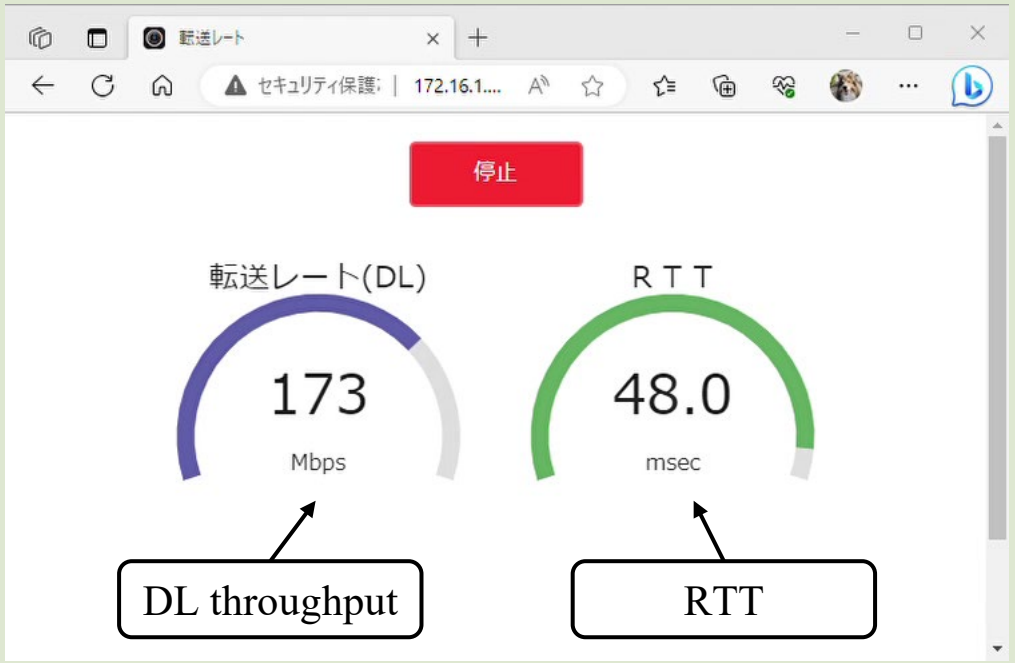
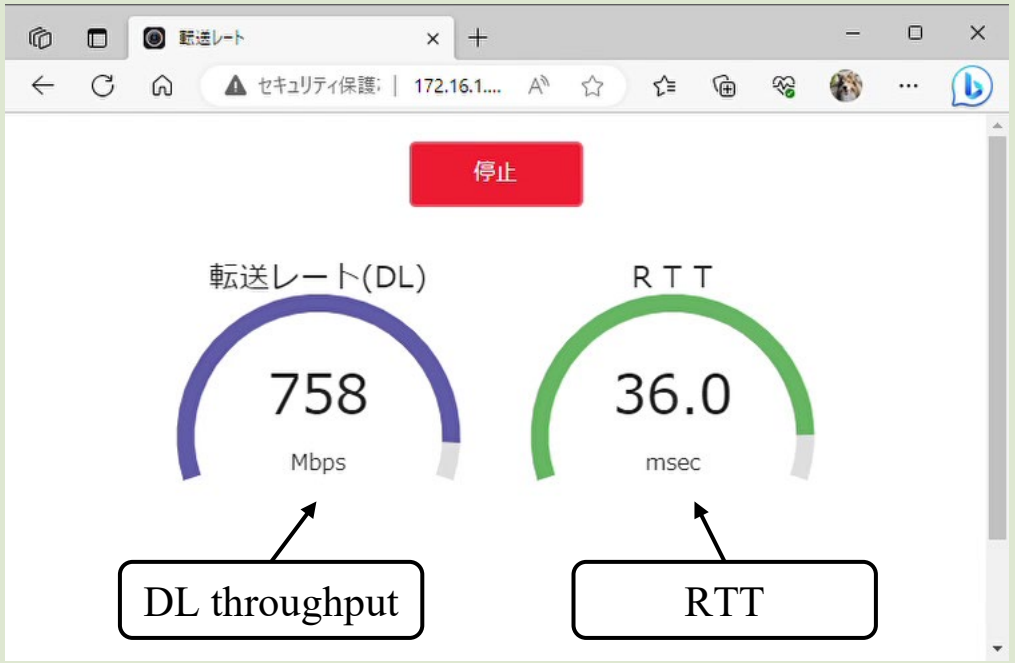
Slicing technology evaluation in the B5G mobile environment (2)

- The demonstration shows the guaranteed bandwidth performance by using the slicing technology

	W/O guaranteed bandwidth	W/ guaranteed bandwidth
Results		

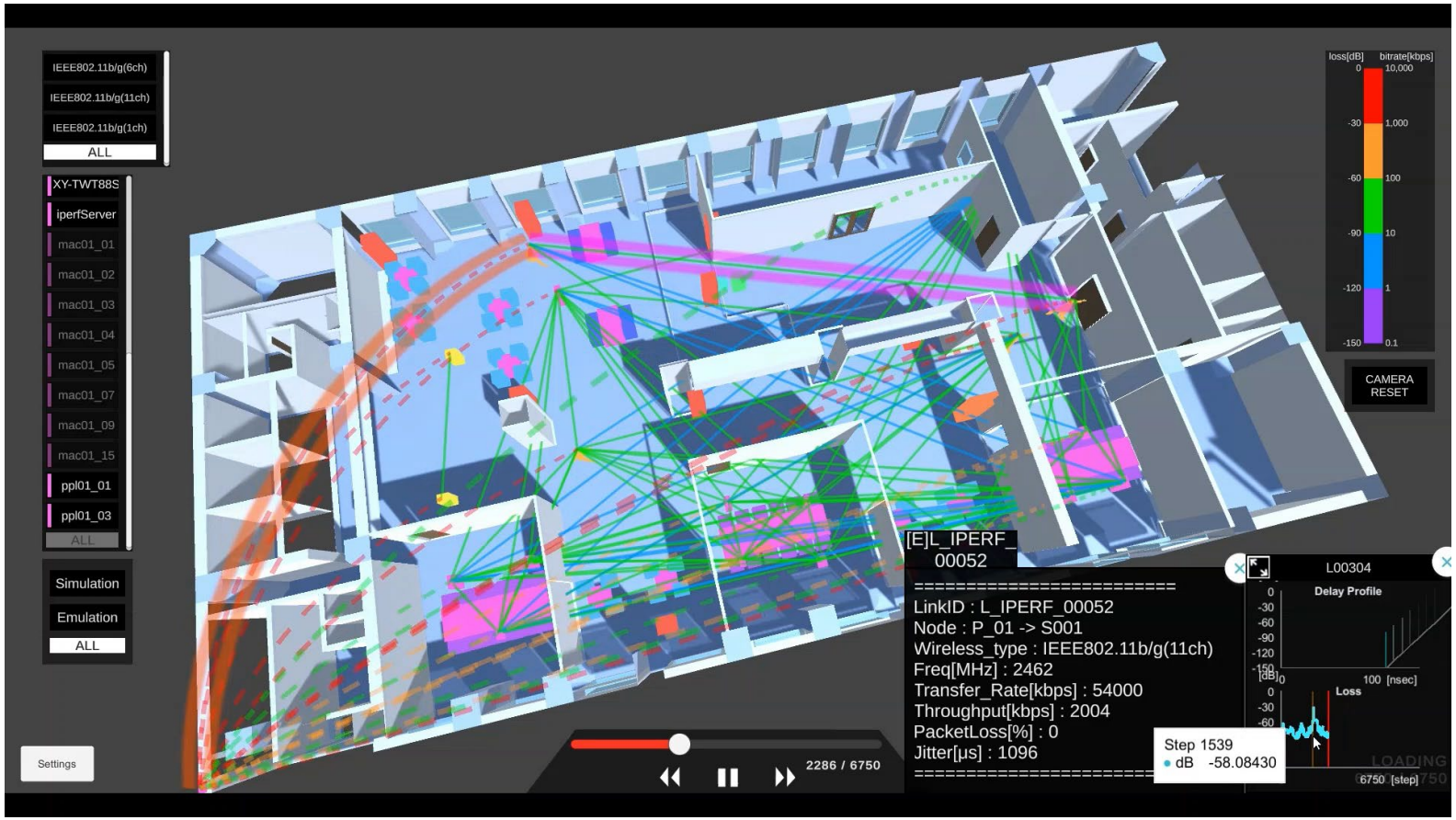
CN deployment evaluation in the B5G mobile environment

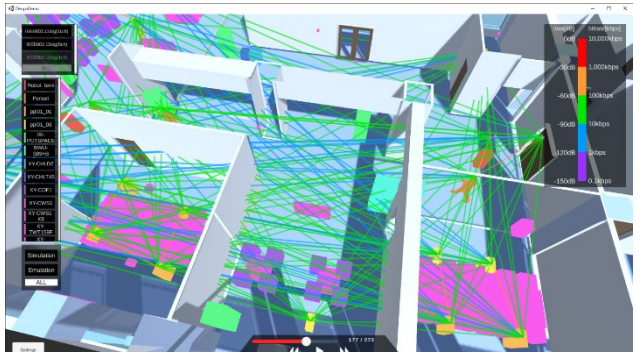
- The demonstration shows the performance differences according to the CN deployments

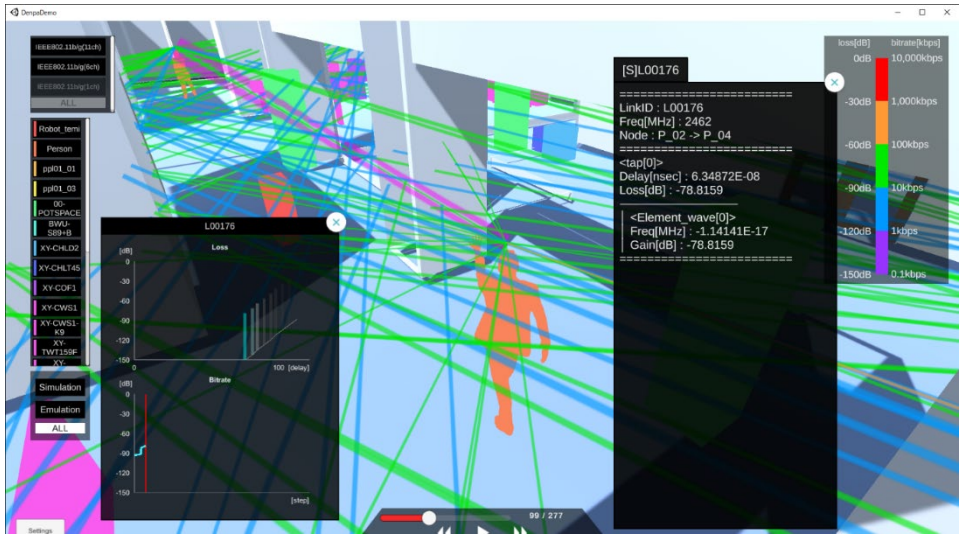
CN in Hokuriku site		CN in Tokyo site	
			
Median of DL throughput	**Median of RTT**	**Median of DL throughput**	**Median of RTT**
250 Mb/s	**60 ms**	**800 Mb/s**	**25 ms**

Testbed activities related to the CyReal demonstration environment

- The wireless emulation can be enabled by CyReal demonstration capabilities
  - The visualization of the emulation for the smart office scenario that shows signal strength and data exchange performance between allocated radio devices







This research is conducted under the contract "R&D for the realization of high-precision radio wave emulator in cyberspace" (JPJ000254) made with the Ministry of Internal Affairs and Communications (MIC) of Japan.

Wireless emulation demonstration for the smart office scenario

API and data provided on DCCS (as of Sep 2024, add functions sequentially)

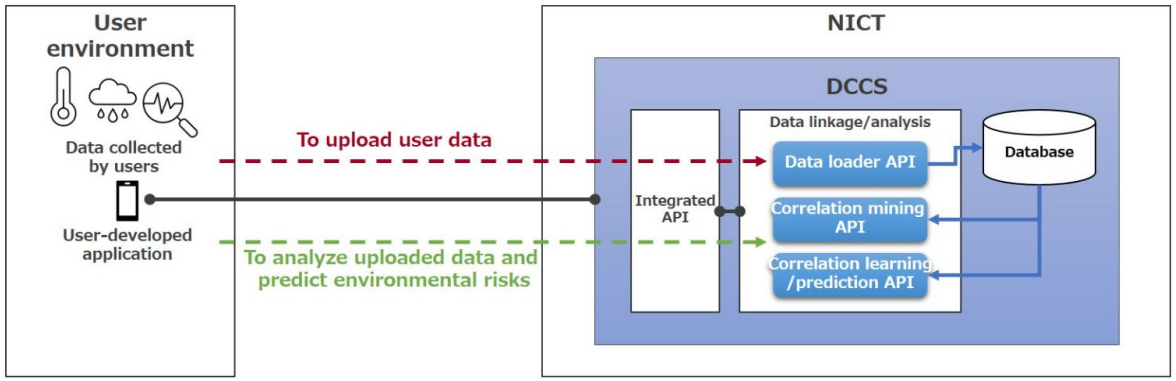
■ Short-term Environmental Quality Prediction

A sample program that predicts the Air Quality Index (AQI), which indicates air quality.

Currently it is provided to DCCS users as code examples for uploading, learning, and predicting data using the data linkage and analysis function (xDataPF) API.

【Overview/Features】

- Collect data from "Soramame-kun" (https://soramame.env.go.jp/), which provides atmospheric data measured by the Japan Meteorological Agency, and upload them to DCCS.
- Learn and predict air quality index using deep learning algorithms using "Soramame-kun" data as input.
- Output the prediction results as a "risk map" (GeoJSON format) that is mapped geographically.
- For a risk map display example, refer to "DCCS Sample Application" (the next slide).
- Python is used for the sample program. The source code can be modified to develop users' own prediction system using user-owned data.

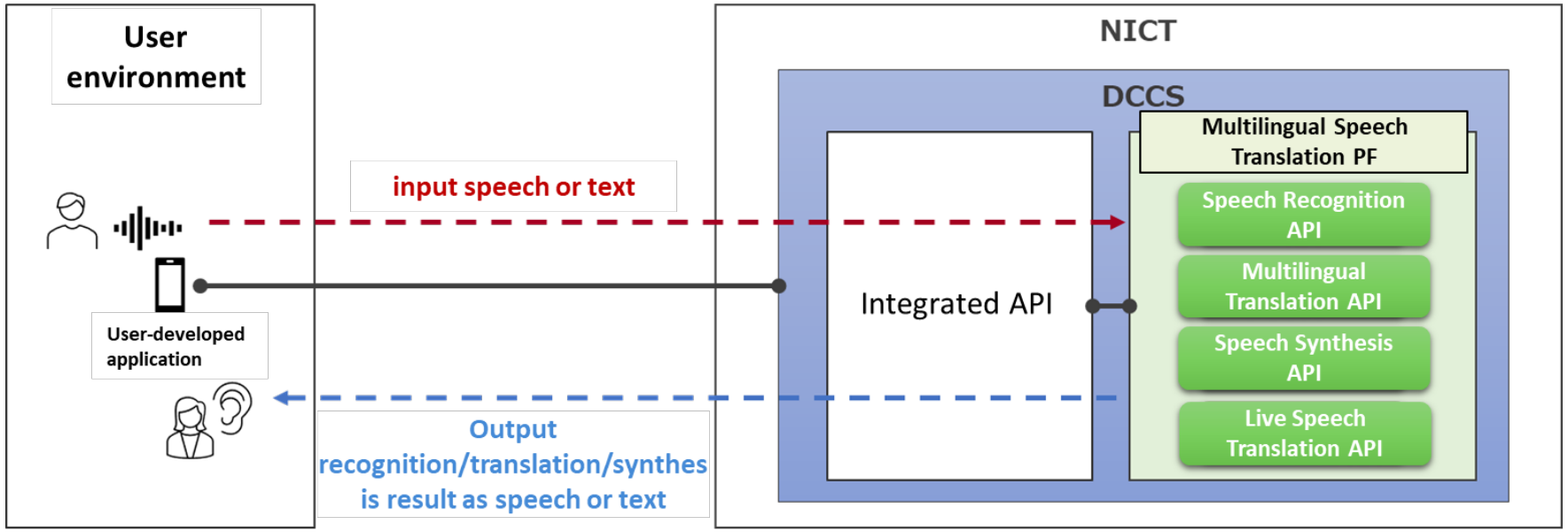


Usage image of Environmental Quality Short-term Prediction, etc.

API and data provided on DCCS (as of Sep 2024, add functions sequentially)

Multilingual Speech Translation Platform

- Provide Speech Recognition, Multilingual Translation, and Speech Synthesis functions, and by linking these functions, it provides a function that sequentially translates input speech to output speech in the language you hope in real time (Live Speech Translation).



- Available in the following 13 languages

Object Language
Japanese, English, Chinese (simplified), Chinese (traditional), Korean, Thai, French, Indonesian, Vietnamese, Spanish, Myanmar, Filipino, Brazilian Portuguese

API and Data provided on DCCS (as of Sep 2024, Add functions sequentially)

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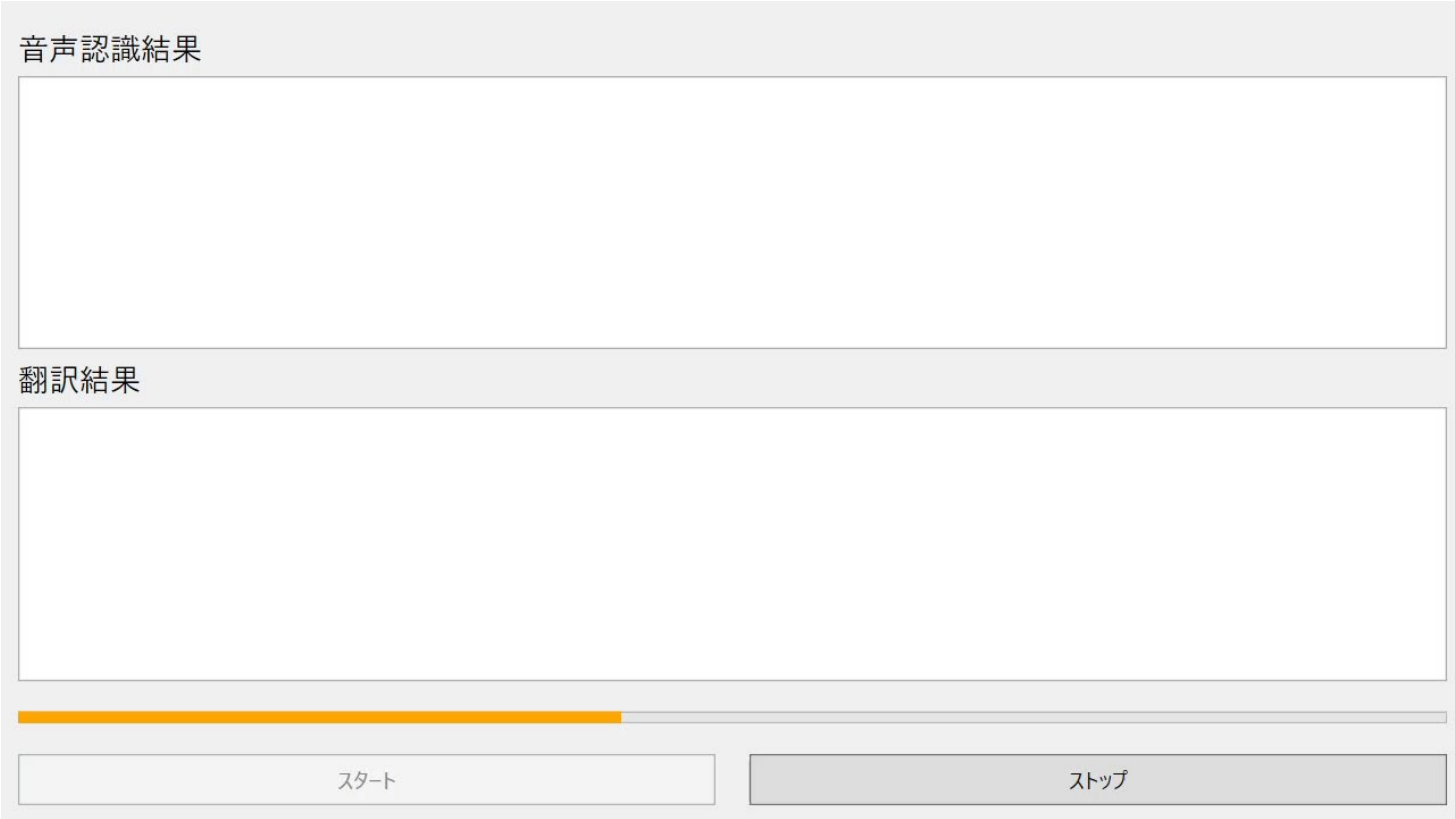
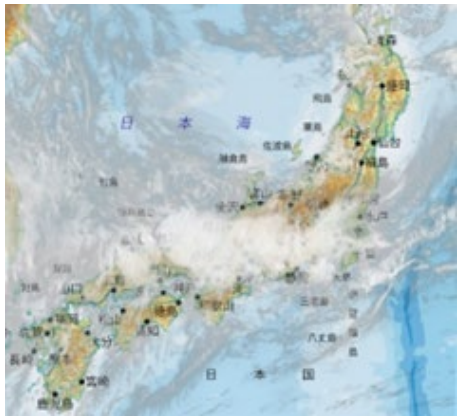


Data provided on DCCS (as of Sep 2024, add data sequentially)

Meteorological and Geographical information data

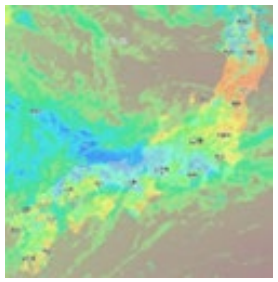
- Released the following Meteorological Data that is highly versatile and has user needs (Release the data to general users is in preparation)
- Other Meteorological·Geographic Information data are in preparation

1. Himawari Satellite data
   - numerical data
     - archive data : Himawari data (No.1 to No.9)
     - realtime data : Himawari-8/9 data within 24 hours
   - raster image
     - Visible imabe of Himawari-8/9 : Full disk, Japan Area, Target Area
     - Tile image of Himawari-8/9 : Japan Area, Asia/Oceania Area

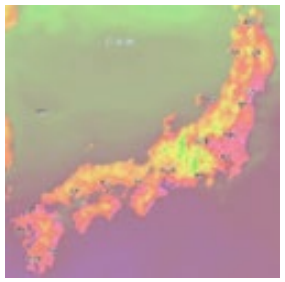


Tile image
of Himawari-8/9

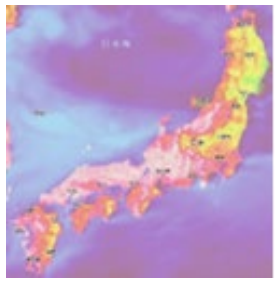
2. Public data of NPO Soloar Radiation Consortium
   (numerical data, raster tile image)
   - Global Solar Radiation
   - Surface Air Temperature
   - Surface Relative Humidity
   - Surface Wind Direction and Speed



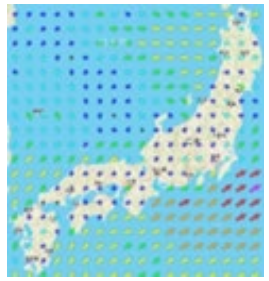
Global Solar Radiation



Surface Air Temperature



Surface Relative Humidity

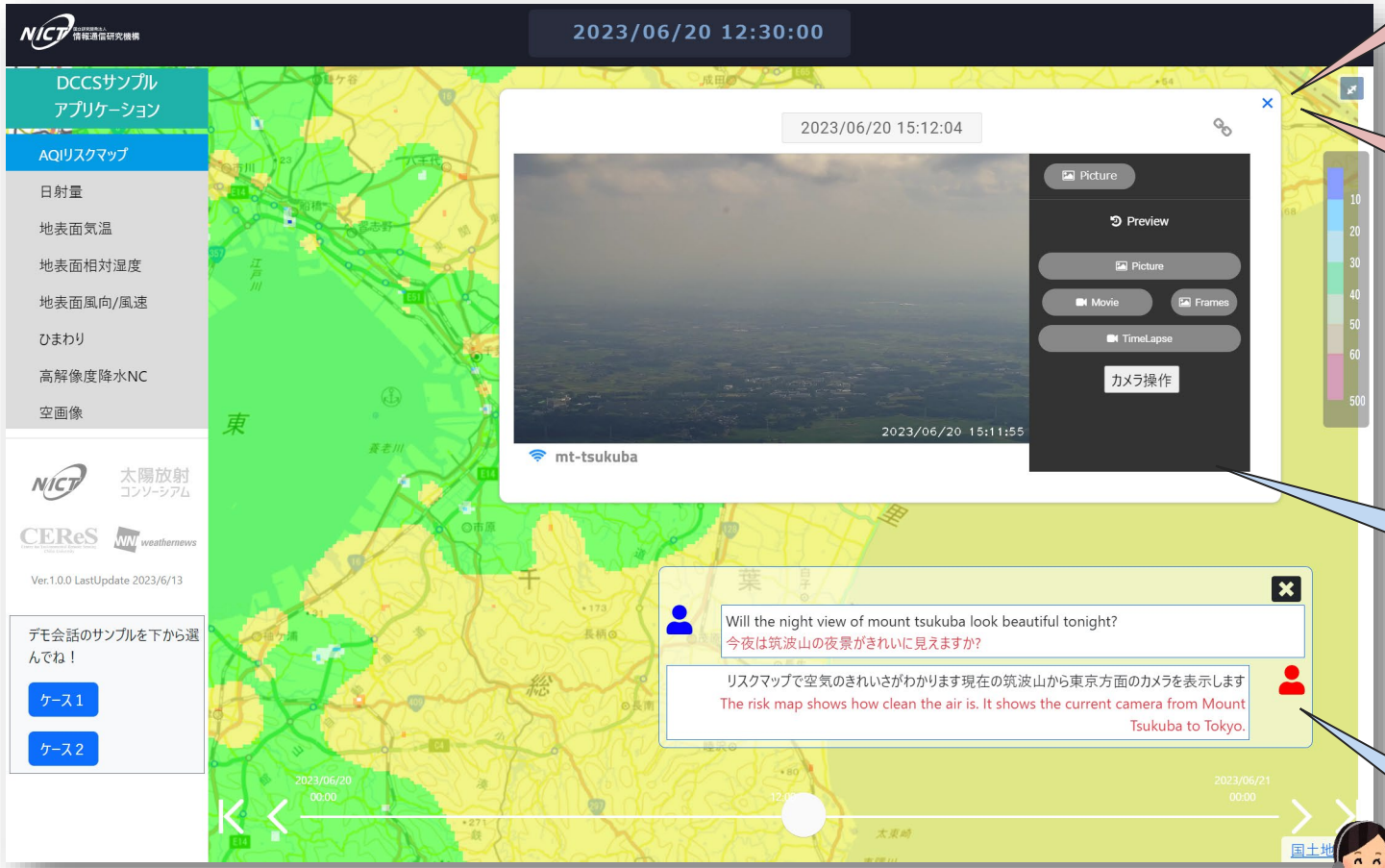


Surface Wind Direction and Speed

DCCS usage example

video demo

DCCS usage example



Display weather information and air quality prediction results on a map.
For communication between foreign visitors and tourist information centers.
Display real-time view of tourist spots mentioned in the conversation.

Now Available

Data linkage and analysis function

- AQI Risk Map（Short-term Environmental Quality Prediction）
  【related technology】xDataPlatform
  （NICT Big Data Integration Research Center）

NICT xData Platform

Now Available (including the functions to be ready)

GIS data and Meteorological data

- Global Solar Radiation
- Surface Air Temperature
- Surface Relative Humidity
- Surface Wind Direction and Speed
- HIMAWARI Image
- High-resolution Precipitation Nowcasts

【related technology】 Spatiotemporal Data GIS
（NICT ICT Testbed Research and Development Promotion Center ）

NPO Soloar Radiation Consortium

Japan Meteorological Agency

Weathernews Inc.

Visual IoT

- Sky Image（remote camera image）
- Remote Camera Operation

【related technology】 Spatiotemporal Data GIS
（NICT ICT Testbed Research and Development Promotion Center ）

Now Available

Multilingual Speech Translation Function

- Speech Recognition
- Machine Translation
- Speech Synthesis

【related technology】 Live Speech Translation
（NICT Advanced Speech Translation Research and Development Promotion Center ）

Summary

- Introduction of “Beyond 5G/IoT Testbed with High-Reliability & High-Elasticity”

- Examples of research and development using our testbed

Thank You