New Use Cases and Strategies for Promoting Terahertz Wave Communications Based on IEEE 802.15.3-2023

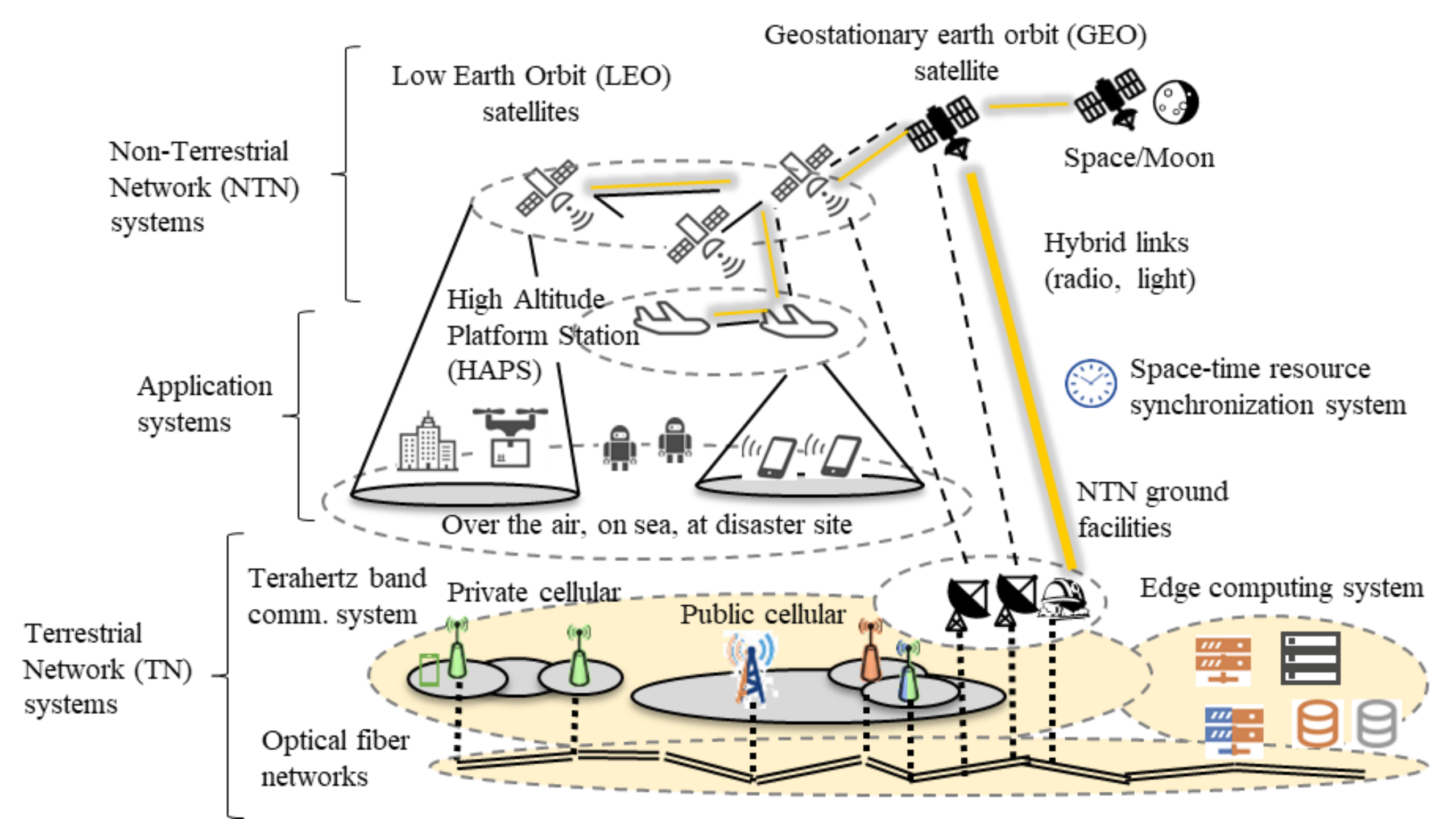
NICT
Beyond 5G R&D Promotion Unit

Executive Director: Iwao Hosako

Introduction of NICT

Brief introduction of NICT (Video)

Background


Geostationary earth orbit (GEO) satellite
Low Earth Orbit (LEO) satellites
Non-Terrestrial Network (NTN) systems
Space/Moon
Hybrid links (radio, light)
High Altitude Platform Station (HAPS)
Application systems
Space-time resource synchronization system
Over the air, on sea, at disaster site
NTN ground facilities
Terahertz band comm. system
Private cellular
Public cellular
Edge computing system
Terrestrial Network (TN) systems
Optical fiber networks

STARLINK

5G

Wi Fi

Bluetooth

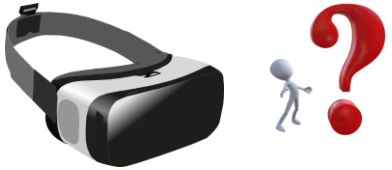
STARLINK

6G

Wi Fi

Bluetooth

Tera-Link



From Future Society to R&D

From Visions to R&D

Extract functional architecture and characteristics from the visions

Japan's Vision: Society 5.0

(CPS: Cyber-Physical System)
A universal concept in a future society that will utilize many digital twins

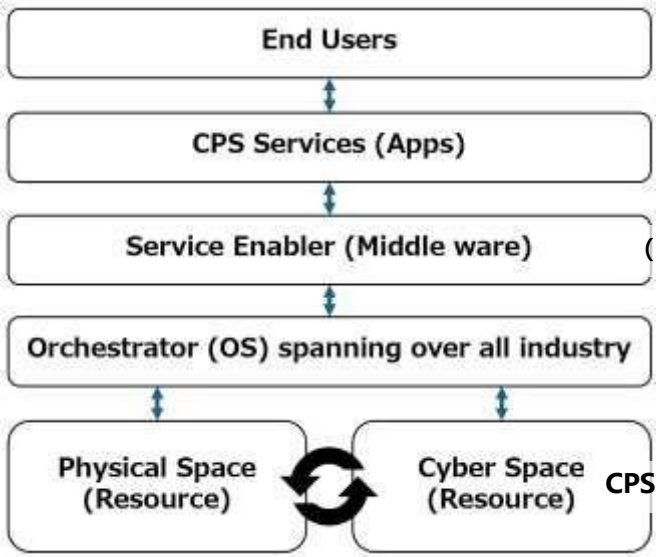
detailing

NICT's Technology Vision

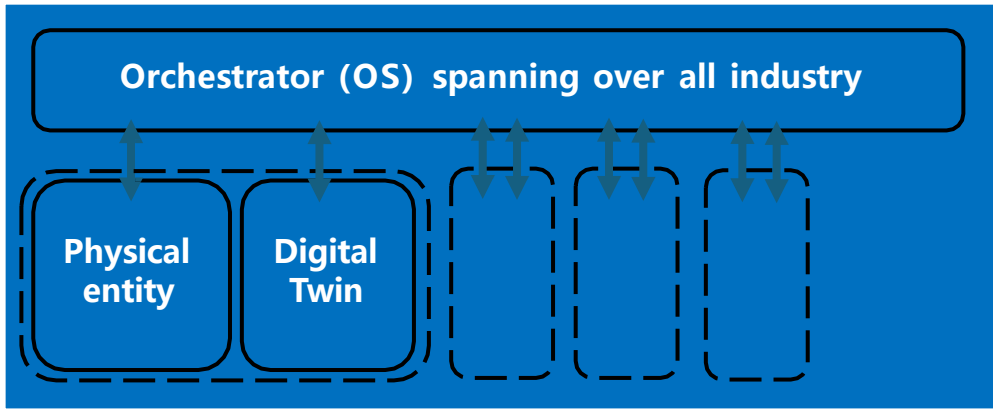
MIC's Vison

Extract an Architecture

Architecture (internal structure of Society 5.0)



Detailing below the orchestrator



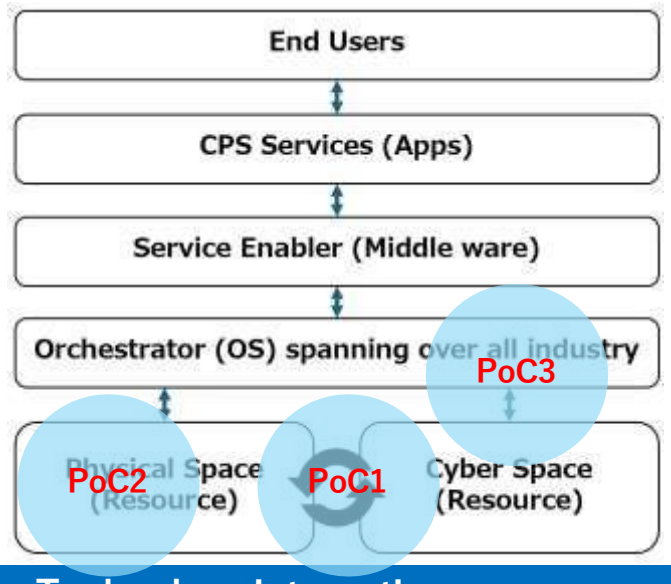
Extract characteristics

Features of Society 5.0 on which Beyond 5G will be based

- The number of systems grows to an infinite number, and the number of possible combinations becomes enormous (too large for humans to handle)
- Promising services may emerge from the vast number of combinations
- Orchestrators will have a bird's-eye view of the entire system and link systems across industries.
- Even when systems are linked across industries, AI can propose system combinations that humans have never thought of, and countless new value-added services can be realized.
- Even small system providers, which have been difficult to enter the market, will be given opportunities to enter the market and play an active role.

- Deployment of the vision domestically and internationally
- Activities for PoC and social implementation

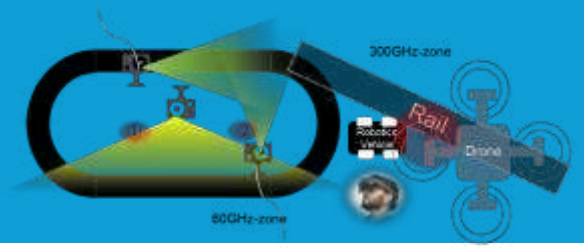
R&D: Beyond 5G technology-integrated service PoC initiatives



- Technology integration
- Deepening of cross-disciplinary discussions
- Activation of collaborative matching

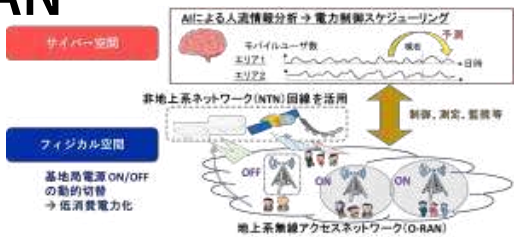
- The three examples on the right are needed for interface extraction, etc.
- To create new services, it is necessary to test a huge number of combinations of systems
- It is desirable to have an innovation center: a place where it is possible to test a huge number of combinations and where the private sector can/should easily participate.

B5G PoC 1: Digital Twin Construction & Optimal Actuation with THz/MMW Wave Comm.



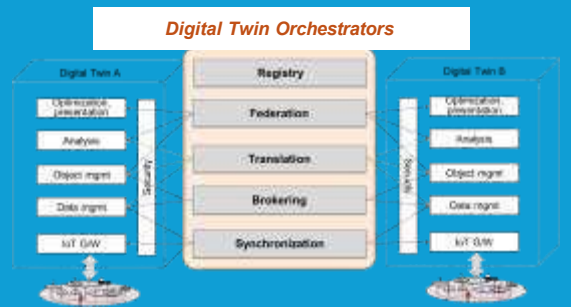
NICT, RWTH, & U. TOKYO

B5G PoC 2: Communication quality control and power saving management through TN/NTN coordination by O- RAN



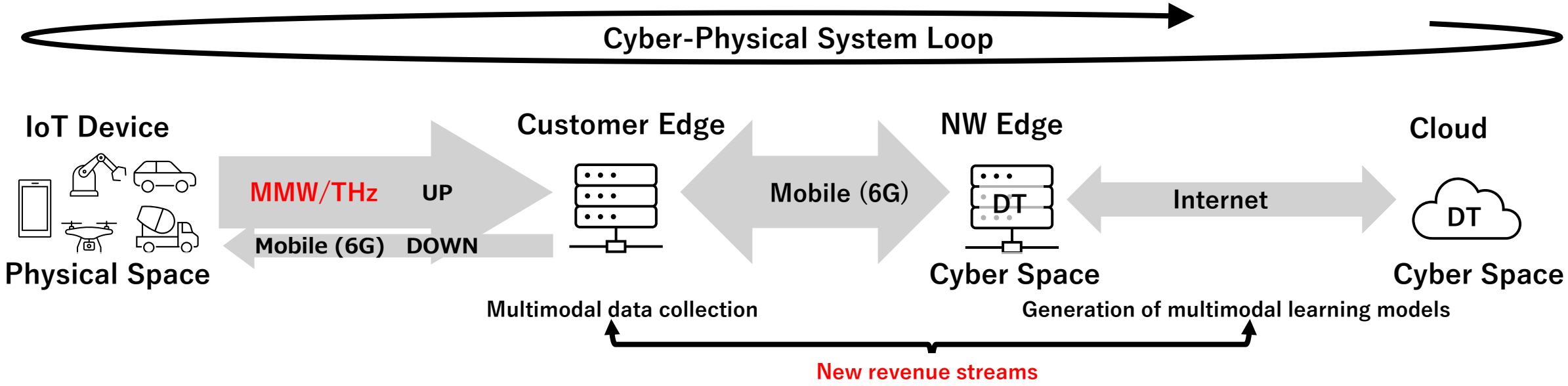
NICT & SUTD

B5G PoC 3 : Collaborative orchestration between digital twins



NICT（TBD）and NICT（TBC）

MMW/THz wireless used in conjunction with mobile comm. systems in Society 5.0



- In Society 5.0, a large amount of data obtained from physical spaces must be supplied to digital twins in cyberspace.
  - MMW/THz wireless are promising channels for uploading this data.
- Operating them in a complementary manner to mobile comm. (6G) promotes the creation of multimodal AI models in cyberspace.
  - These AI generate new revenue streams through data sales and fees for their use.

What is the IEEE802.15.3-2023

What is the IEEE 802.15.3-2023 (High Data Rate)

Initial project started March 2000
–New MAC/PHY combination

Completed 2003
=> **IEEE Std 802.15.3-2003**

1st Revision project
– Roll-up of all amendments
=> **IEEE Std 802.15.3-2016**

2nd Revision project
– Roll-up of all amendments
– With Amendment for a THz-PHY
- Include all new frequency bands above 275 GHz identified by WRC 2019
- Fix RIFS timing parameter issue
- Replace reference to IEEE Std 802.1D by reference to IEEE Std 802.1Q
- Introduce two new modulation schemes (16-APSK, 32-APSK)

=> **IEEE Std 802.15.3-2023**

2000 **WRC19** 2025

300 GHz Band +

1st amendment failed to complete
– UWB PHY, but unable to get 75% approval

3rd amendment added MMW alternative PHY
– Supports beam forming, aggregation
=> IEEE Std 802.15.3c-2009

5th amendment for a THz-PHY
– MAC inherited from IEEE Std 802.15.3e-2017
=> IEEE Std 802.15.3d-2017

Piconet

2nd amendment to fix MAC issues
=> IEEE Std 802.15.3b-2005

4th amendment for a specific 60 GHz PHY
– for High-Rate Close Proximity (HRC
=> IEEE Std 802.15.3e-2017

Pairnet

amendment to extend MMW
p to 71 GHz
IEEE Std 802.15.3f-2017

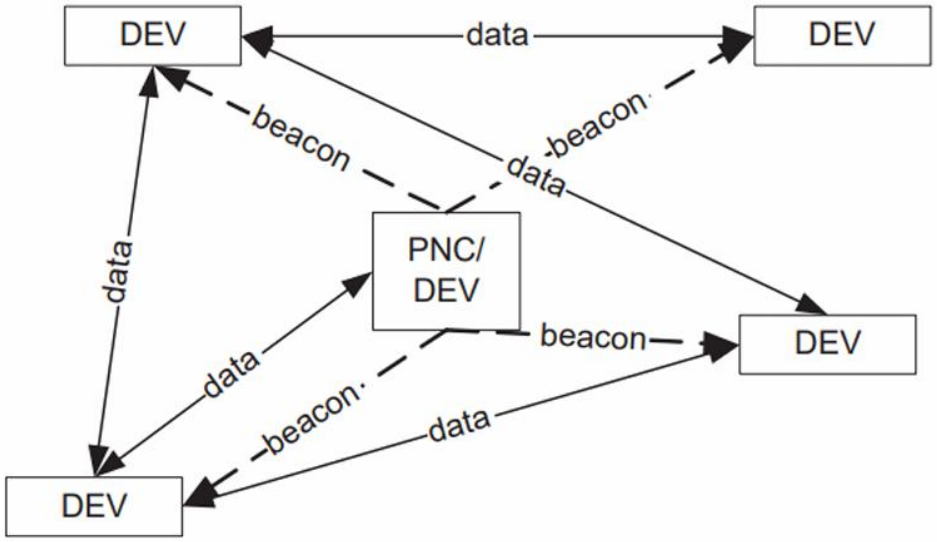
2.4 GHz Band

60 GHz Band +

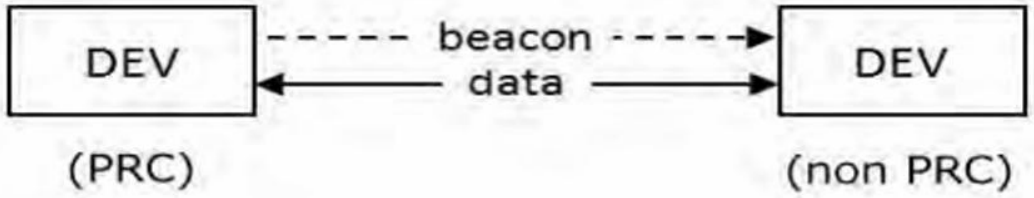
Piconet vs. Pairnet

Ultra-high frequency, ultra-wideband, narrow beam, and Pairnet leads to the following features

- Ultra-high data rates (～10Gbit/s, ～ 100 Gbit/s)
  3e 3d
- Short link establishment times (～2 ms)
- New dynamic use cases
  in addition to traditional static P2P use cases such as Close Proximity P2P, Intra-DV, DC, F/B-hauls



Piconet



Pairnet

Transfer-Jet X（IEEE802.15.3e）Device

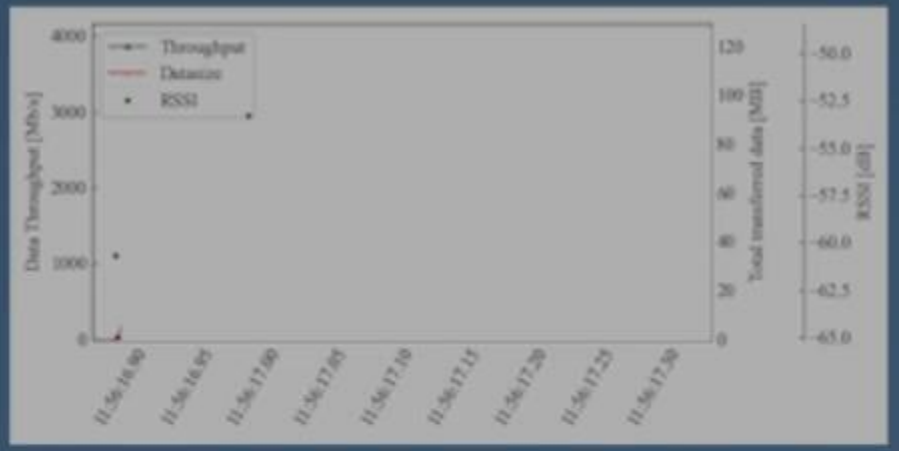
Parameter	Value
Center Carrier Frequency	60.48 GHz or 62.64 GHz
Bandwidth	2.16 GHz
Data Rate	～ 6 Gbps
Transmission Distance	A few cm to several 100 m (antenna dependent)
Link Establishment Time	< 2 ms
Standards	IEEE 802.15.3e, TransferJet X
RF Connection I/F	WG-15 UG-385/U
I/F	USB, 10 Gigabit Ethernet
Local Storage	> 200 GB（On module Realized by UFS）

Demo Videos of the New UC

New Use Case (Video)

3e@60 GHz

Case : Passing at 8.3 km/h



Case : One side hovering


3d@300
GHz

Strategies for Promoting THz Comm.

Strategic Plans for scalable deployment

Transfer-Jet X（IEEE802.15.3e）

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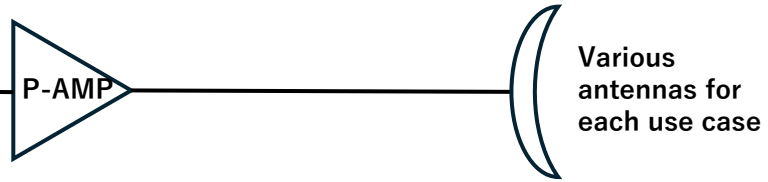
Upconvert to 252-262 GHz band
- Can be regarded as IEEE802.15.3d signal



Technical strategies embedded in IEEE802.15.3e/3d

	PHY		MAC	Topology
	Bands	Bandwidth		
3e	60 GHz	2.16 GHz	Almost same	Pair-Net
3d	300 GHz	8 bandwidths (2.16, 4.32, 8.64,,) (Multiples of 2.16 GHz)		

- Avoidance of over-specification allows incremental upgrades to meet cost and market requirements
  - 60 GHz band (3e) → 300 GHz band (3d)
  - 2.16 GHz bandwidth (3e) → 2.16 GHz multiples of bandwidth (3d) Multi-chip enables higher speeds
- Link establishment time ~few ms
  - Create new use cases

Strategic Plans for scalable deployment

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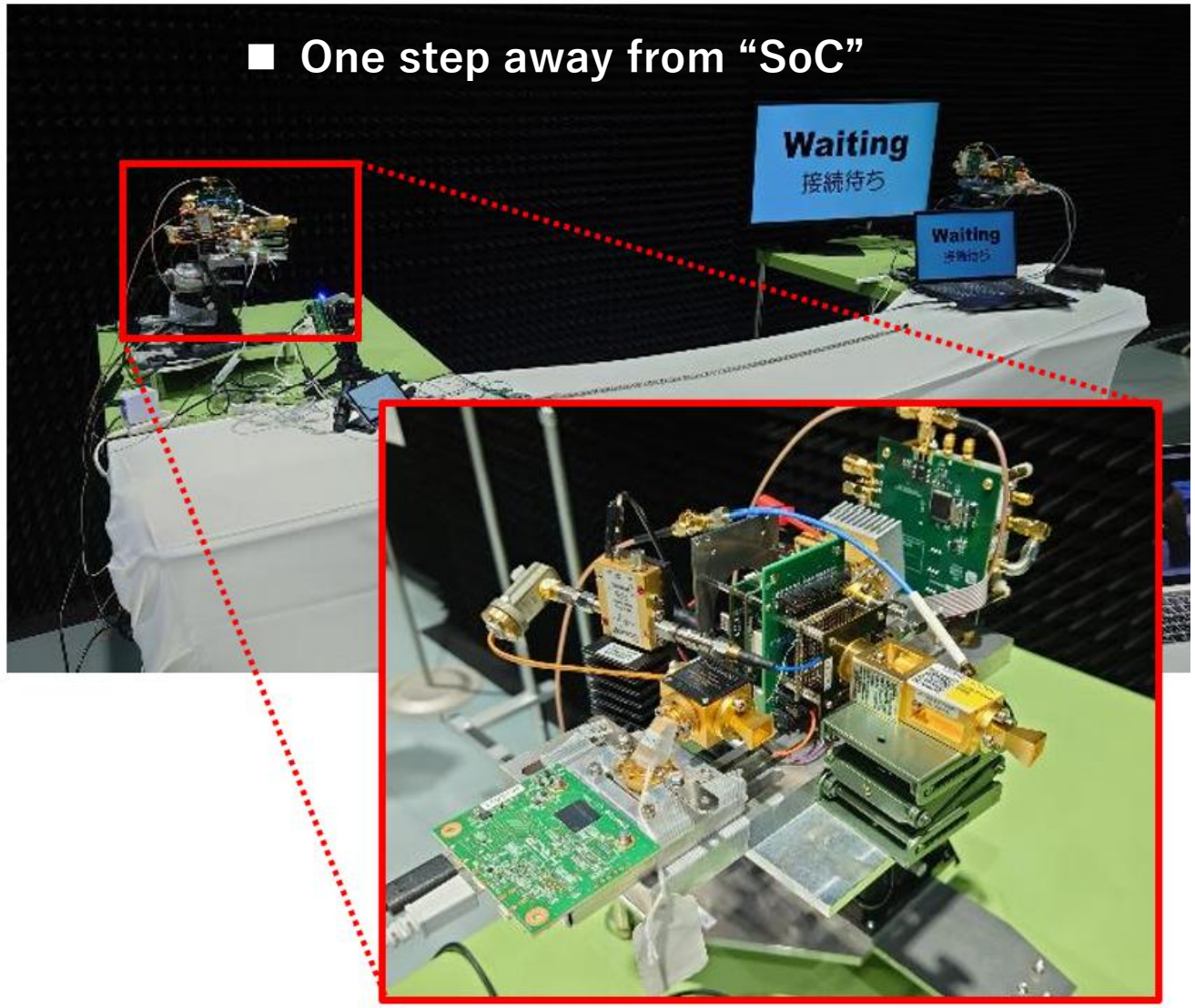
P-AMP

Various antennas for each use case

■ One step away from “SoC”



Strategic Plans for scalable deployment

Bundle multiple IEEE802.15.3e

Transfer-Jet X（IEEE802.15.3e）

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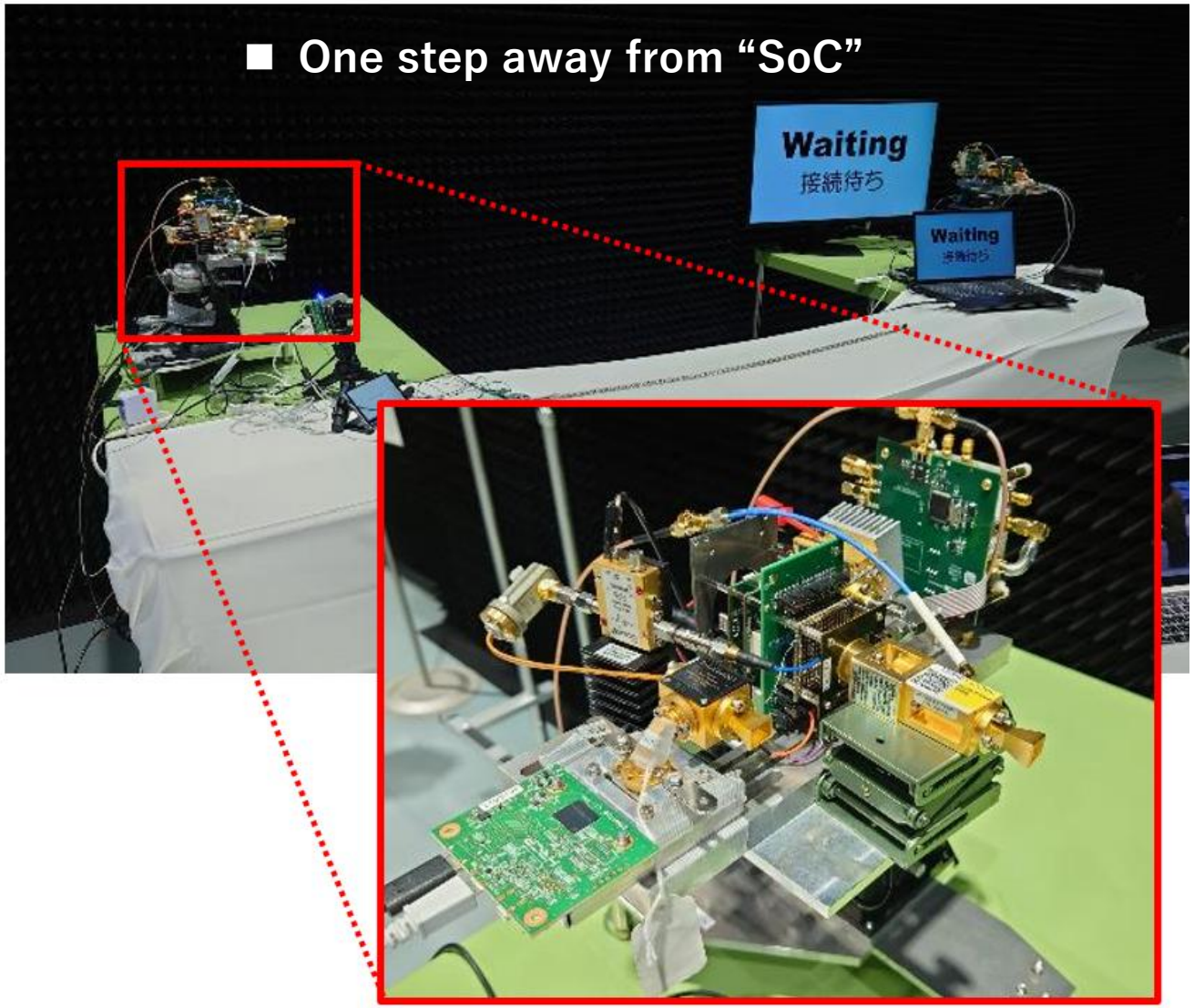

Summary

- A mobile-centric ecosystem is emerging that integrates technologies such as NTN, Wi-Fi, and Bluetooth.
  - Although THz communication was initially conceived for 6G, it is now anticipated to be adopted in subsequent phases (Day 2).

- Future society will be shaped by cyber-physical systems, in which continuous interaction between digital twins and the physical world drives intelligent functions.
  - High-speed THz links are ideal for uploading rich sensor data to the cloud for multimodal learning, which is difficult to achieve with conventional mobile systems.
  - Consequently, THz links are increasingly recognized as a complementary uplink channel for mobile networks.

- IEEE 802.15.3e/3d standards enable the scalable deployment of THz technology from 60 to 300 GHz.
  - These standards feature ultra-fast, ultra-short link establishment times and support mobility on both ends.