

NICT's View on Advanced PNT Service and Seamless and Robust Communication Service

Proposal for SA1 Rel-20 part B SID

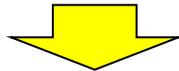
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(PNT: positioning, navigation and timing)



Motivation

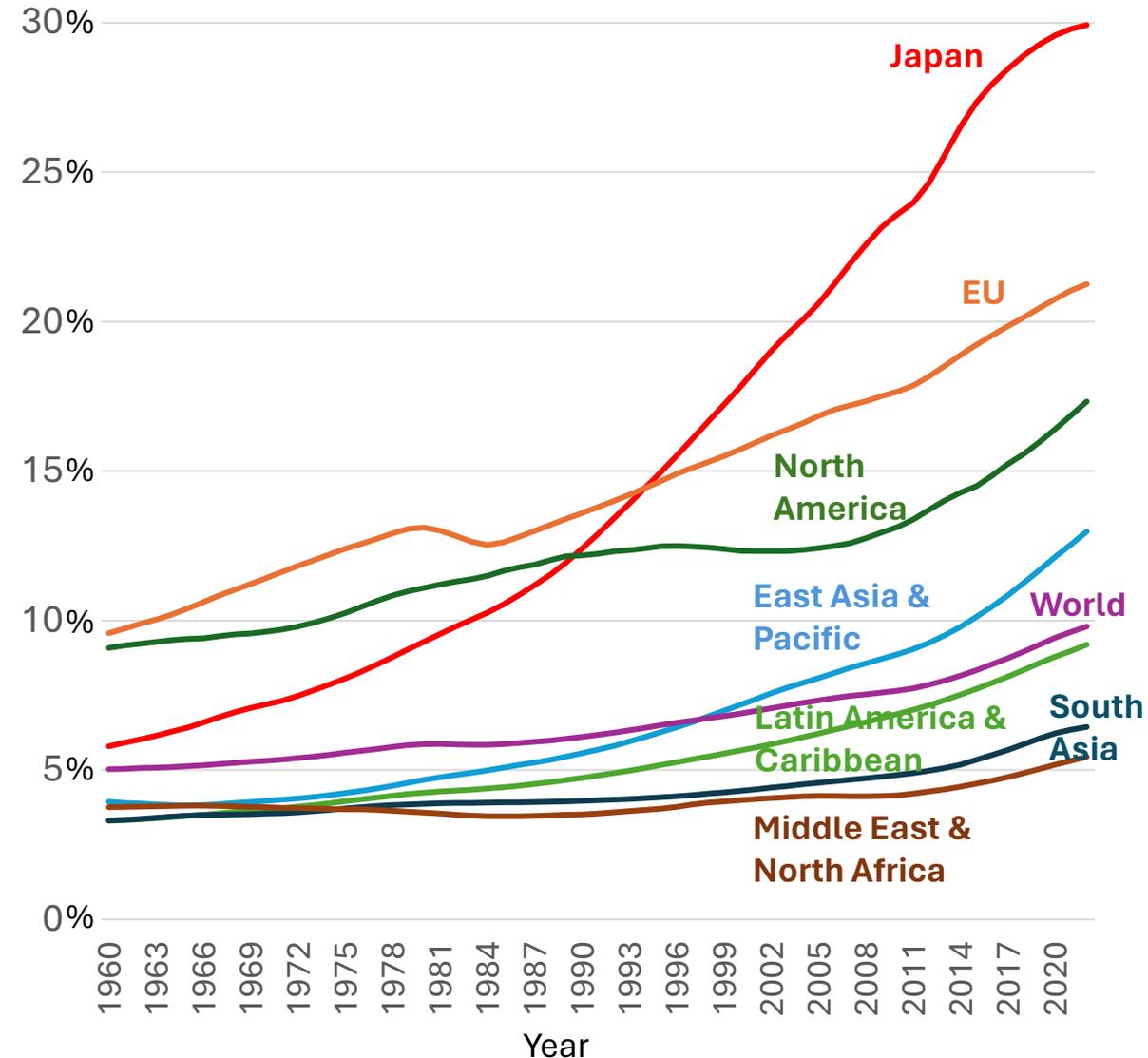
- **The world is aging (see the graph).** Japan is the highest country suffering from issues caused by the aging population.
- **The aging population causes labor shortage.** Japan is facing the intense labor shortage in various industry areas.



NICT envisions the following 6G services to respond to the above challenges.

- **Advanced positioning and timing service**, which realizes full autonomous machines such as autonomous driving, autonomous construction and remote care, etc.
- **Seamless and robust communication service**, by which human robots are allowed to autonomously select and access to suitable networks among public, non-public, terrestrial and non-terrestrial networks.

Population ages 65 and above (% of total population)



Population ages 65 and above (% of total population) | Data (worldbank.org)

Solution to labor shortage: Communications under Space-Time Synchronization (STS)

Precision Positioning is a key for autonomous operations anticipated in 6G.

	Transport 	Construction, Manufacturing 	Care services
Solution using M2M	Autonomous driving in a dedicated lane with road-side assistance	Multiple autonomous machineries in no GNSS availability	24 hours/7 days Monitoring using trackers and alarm system
Enabler: Advanced Positioning & synchronization technique (See extra slides)	<p>mm-wave Road-side Equip.</p>	<p>Tunnel Construction</p>	<p>2nd floor 1st floor IoT sensors</p>

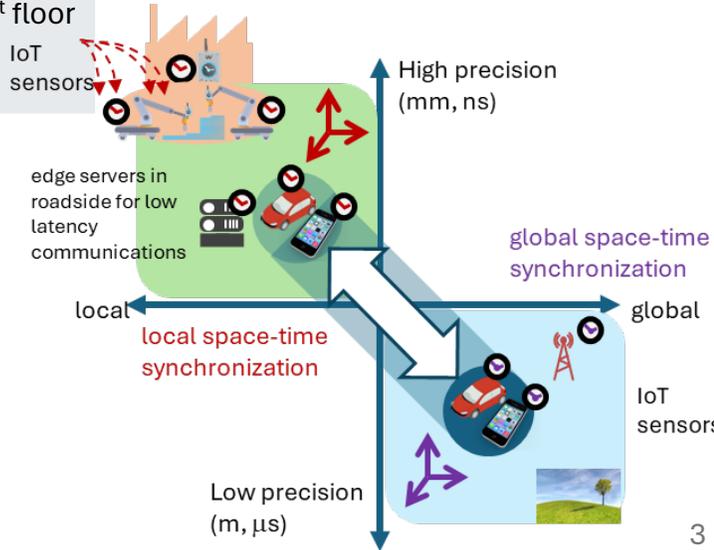
space-time synchronization = sharing common coordinate axis of not only time, but also positions

Study that NICT proposes toward 6G

- Universal coordinate system for positions (“**UTC-like for position**”)
- Requirement for positioning capability in various use cases
- Scheme of local STS for precision, reliability, and availability.
How to connect global and local coordinate system?

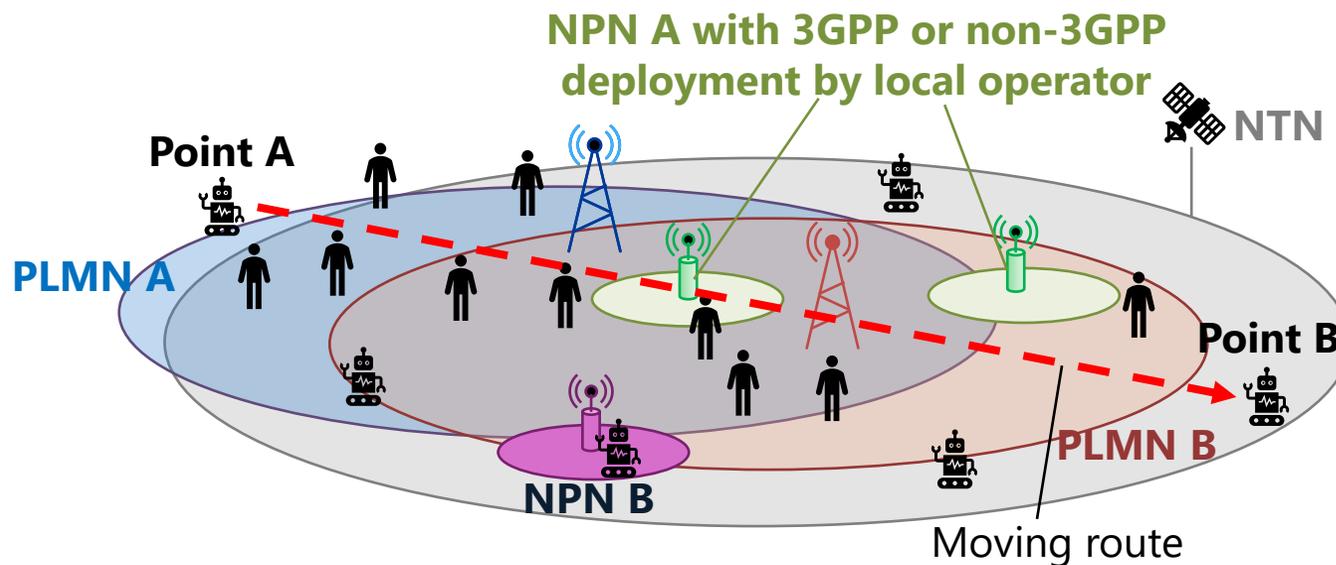
Not only time, but also positions.

Not only global, but also local

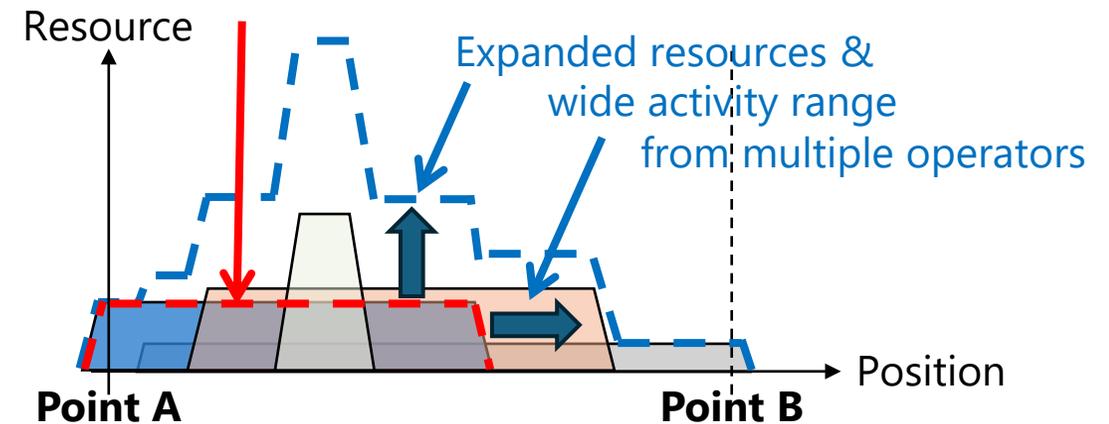


Solution to labor shortage: Human Robot Society under Heterogeneous Mobile Network

- In human robot society, human robots representing human perform remote operations in various daily life scenes, care centers, disaster sites, plants, etc.
- Seamless and robust communication service is required to support human robot society, which is enabled by heterogeneous mobile network where multiple resources from multiple operators are maximally utilized.



Limited resources & activity range from only PLMN A



PLMN: public land mobile network, NPN: non-public network, NTN: non-terrestrial network

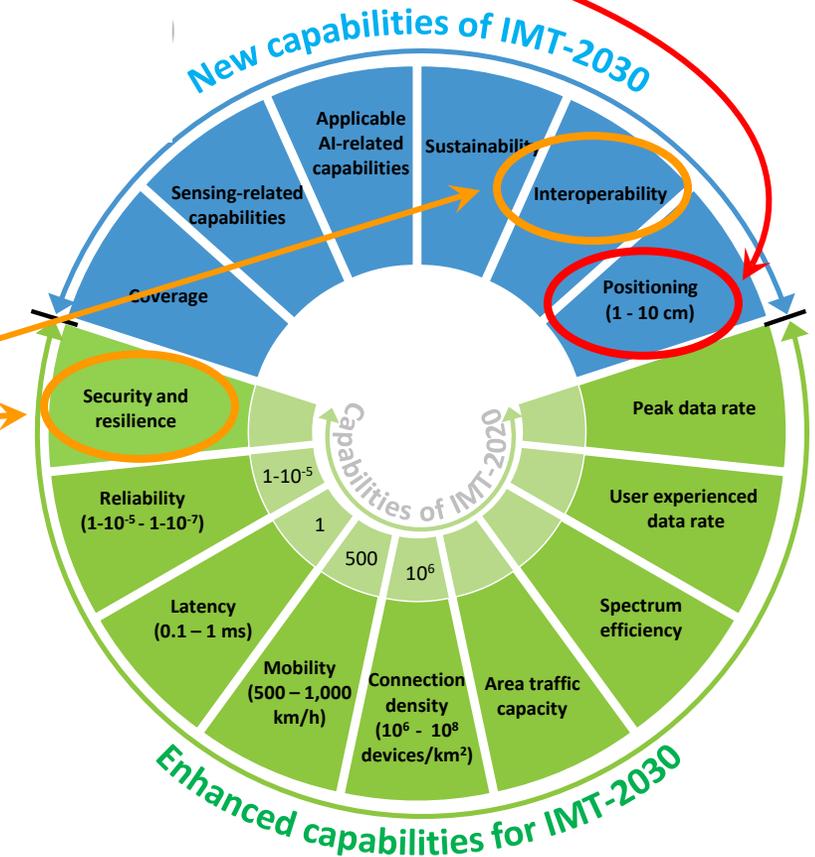
Justification and Objectives

1. Study on Advanced Position and Timing Service

- Justification: the current precision of positioning and timing could prevent from full autonomous operations in various use cases.
- Objective: this study identifies new use cases and corresponding requirements for the advanced precision of space and time service.

2. Study on Seamless and Robust Communication Service

- Justification: current networks are incompatible with needs to flexibly select and access to suitable networks among public, non-public, terrestrial and non-terrestrial networks. This incompatibility fails to provide robots with seamless and robust end-to-end communication environment.
- Objective: this study identifies new use cases and corresponding requirements for seamless and robust communication service.



Appendix

Emerging technology to support STS

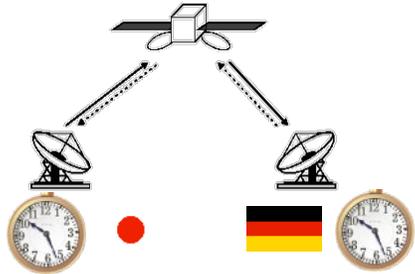
	Advanced GNSS positioning	Miniature atomic clocks	Wireless interferometry based on carrier phase	Cluster clock algorithm
What achieved	GNSS positioning in cm level	Stable clocks based on atomic transition	Wireless synchronization in ns level	Virtual common clock based on many local clocks
Where used	Supplement information from GNSS	Local oscillator in gNB, AGV	Positioning Clock synchronization Sensing	Clock network with gNB, UEs
Keyword	RTK High accuracy correction service	GNSS-free GNSS anchor	Positioning Synchronization	Resilience

Technical Background

a. Phase synchronization of network

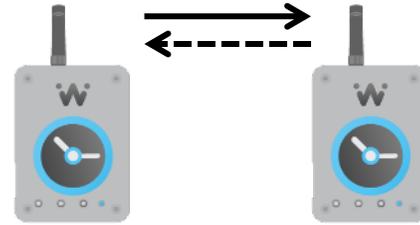
New technique for precision synchronization in pico-second level has been developed.

Existing technology



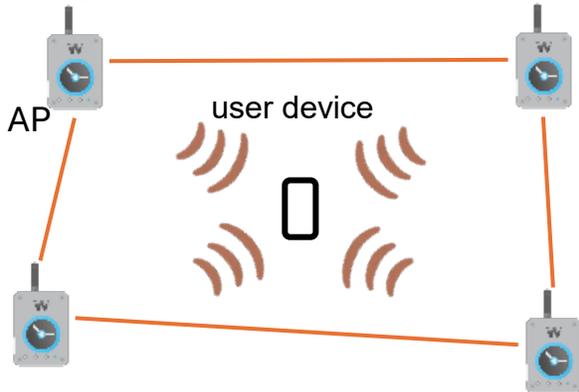
measurement of **clock difference** and **transmission delay** via satellite communication. Using carrier-phase for the ultimate precision.

New!



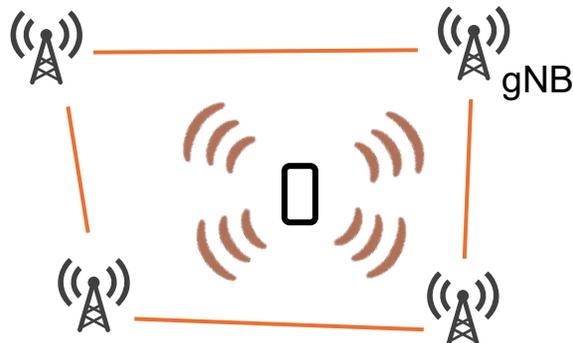
Synchronization of **clock difference** and **distance** via wireless communication. Using carrier phase for precision and reduced bandwidth

Wireless Power Transfer



Phase synchronized RU's enable constructive interference for WPT

Carrier Phase positioning



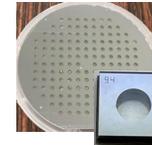
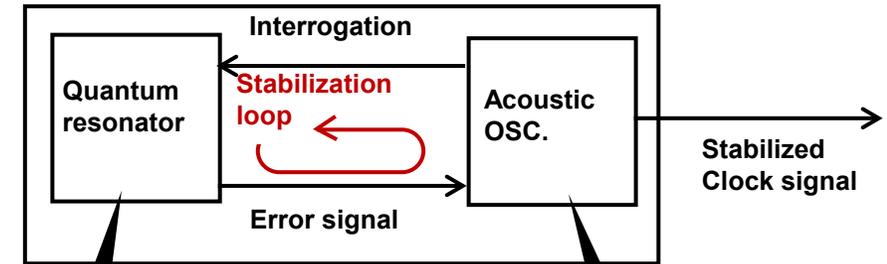
Phase synchronized APs enable precise positioning

b. Clocks in terrestrial network

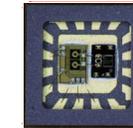
Distributed clock system where **chip-scale atomic clocks** are distributed over RAN.

<Advanced technologies for cost and size reduction>

Atomic clock



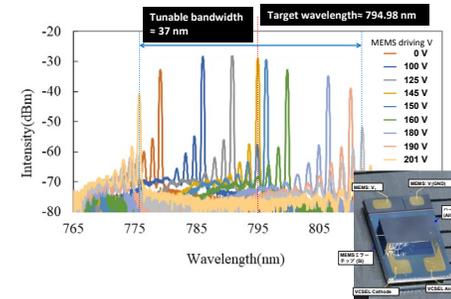
Rb gas cell processed in 4inch line



BAW OSC. in 3mmx3mm LTCC PKG

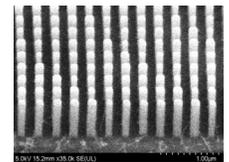
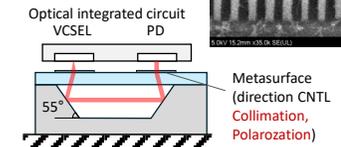
<Laser handling technologies for tuning and folding the optical pass>

MEMS wavelength tuner



Optical pass design based on meta-surface

All optical elements are integrated in single layer



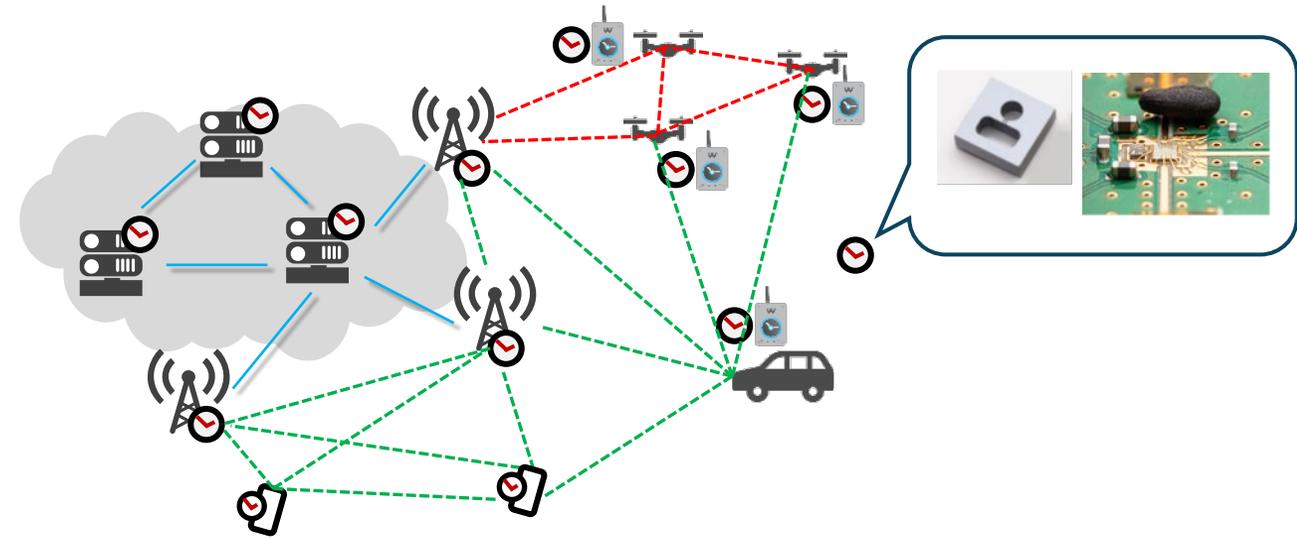
Possible evolution as a system

Carrier phase synch. (Wi-Wi) x Atomic clock chip
+ self clock-correction policy

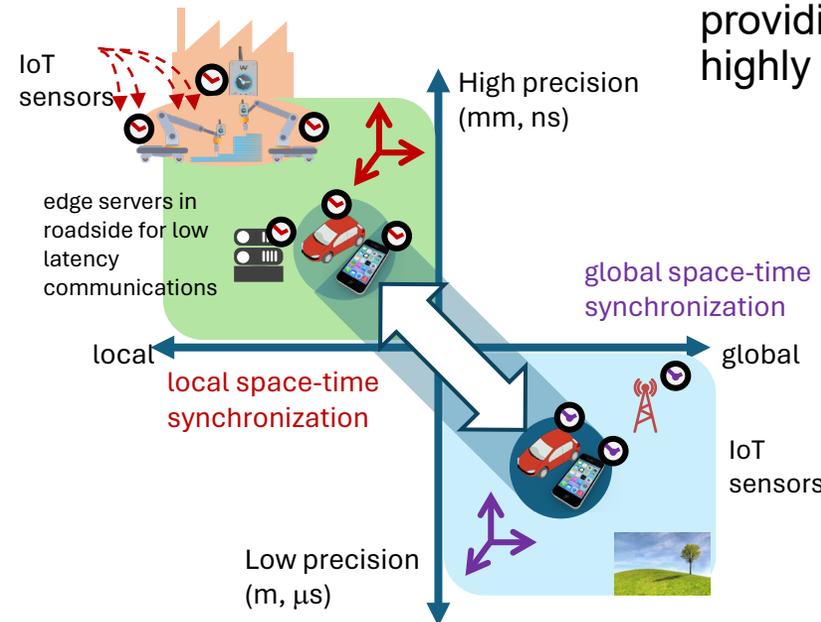
=Decentralized synchronization (Cluster clock)

- ✓ Flexible
- ✓ Robust
- ✓ Reliable
- ✓ Inclusive
- ✓ Resilient
- ✓ **Good stability**

In addition to UTC time and GNSS positions, locally defined time and positions will be useful due to their flexibility, availability, and precisions.



Space-Time Synchronization is the critical key technology that allows indoor/outdoor localization and clock synchronization in high precision, providing infrastructure of M2M, V2X, and even highly energy-efficient communications



Use Case of Human Robot Society

Human robots (in blue) act in real scenes (in black) to represent humans who are not there and provide XR presence for humans who are there, to provide care services for humans who need help, or to perform operations on behalf of humans at disaster sites, plants, etc. Seamless, robust, and high throughput communication will be required.

XR teleconf. among 3D avatars with haptic devices



Refresh body and soul by XR activities



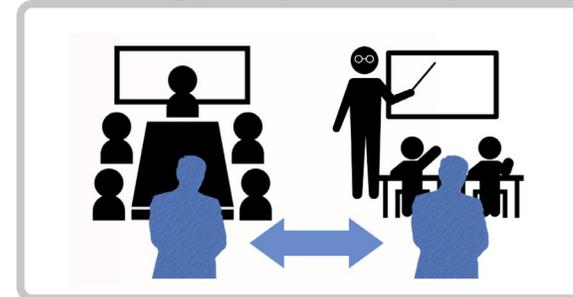
Training and Operating in case of disaster



Remote controlling an assistive devices



Simultaneously participate in multiple meetings



Low delay remote work by a local avatar robot



<https://beyond5g.nict.go.jp/en/future/diary/index.html>