

# Beyond 5G/6G White Paper

- English version 0.9 -

April 2021



National Institute of Information and Communications Technology

## IAFI Workshop "Looking beyond 5G- Future Technology trends towards 6G"

Iwao HOSAKO

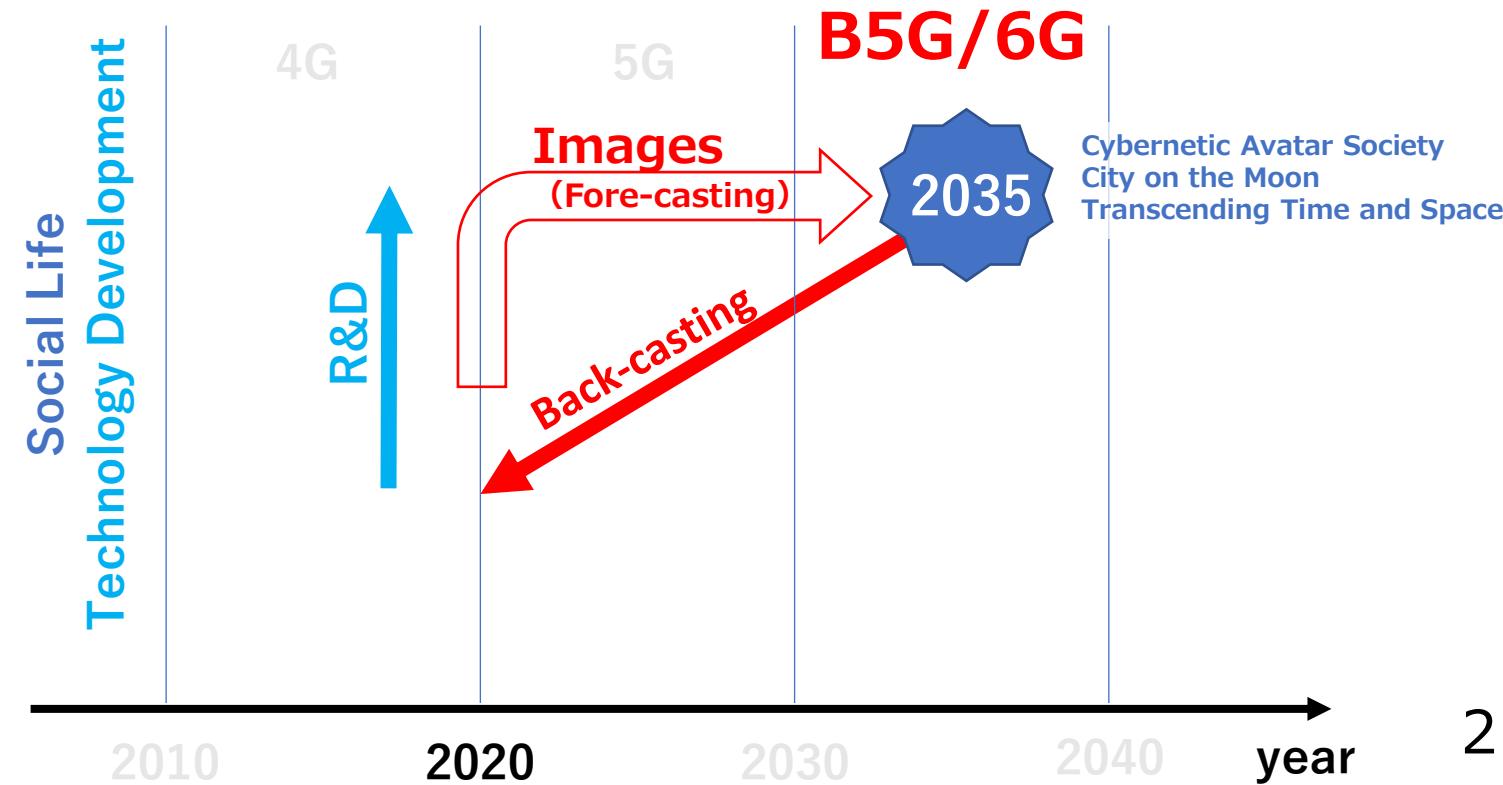
**National Institute of Information and Communications  
Technology(NICT), JP  
Beyond 5G R&D Promotion Unit  
& Terahertz Technology Research Center**

# Beyond 5G/6G White Paper

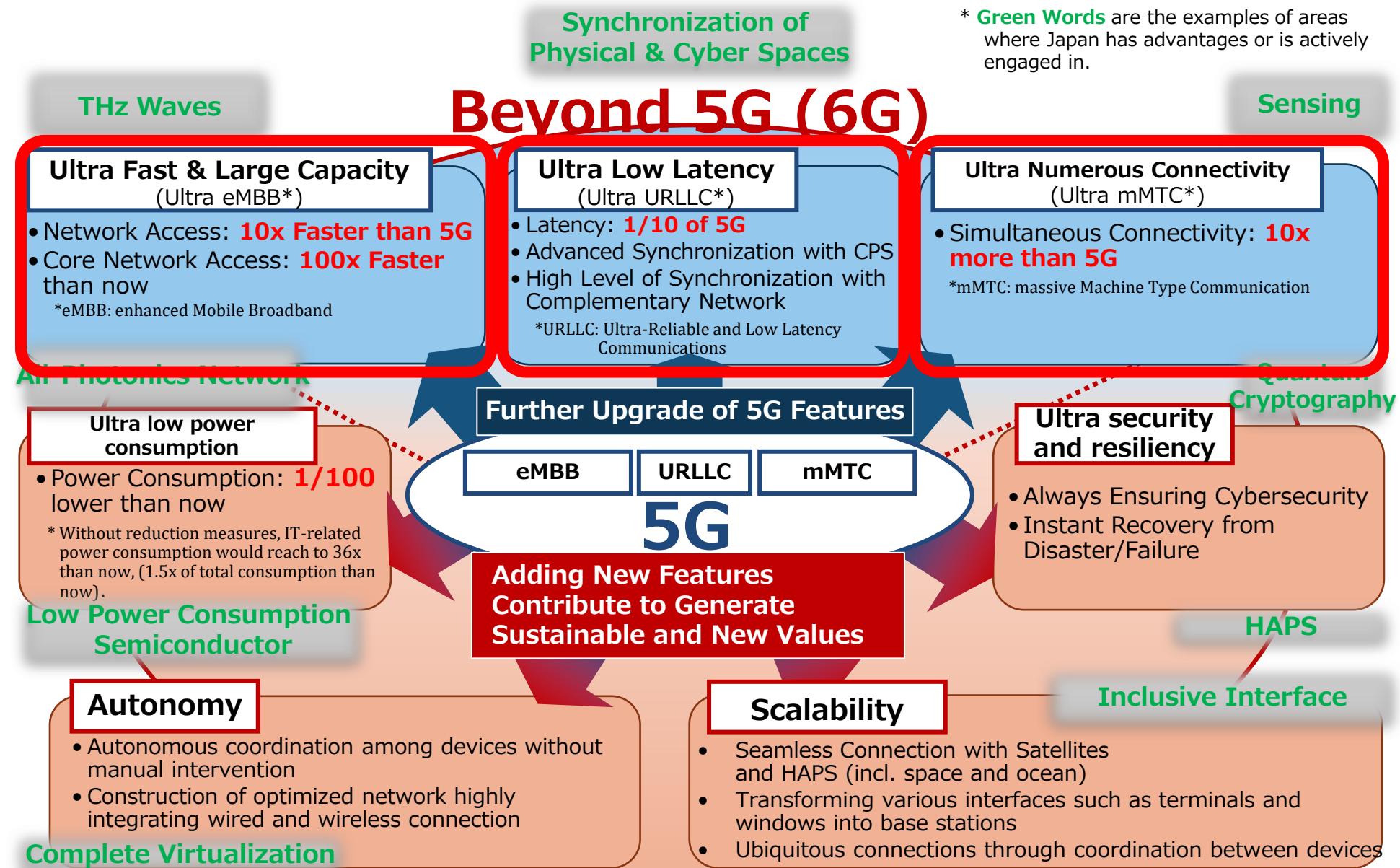
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- We created three scenarios, "Cybernetic Avatar Society," "City on the Moon," and "Transcending Time and Space," which are **images of social life around 2035**, and identified the necessary key technologies by **back-casting from the future society described in these scenarios**.
- 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**.



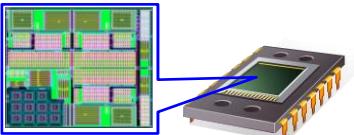
# Key Features for Beyond 5G (6G)



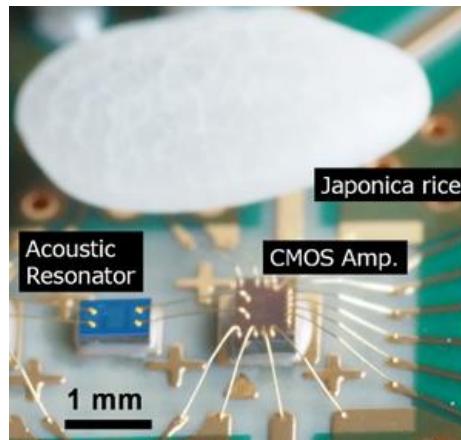
# Technologies for Beyond 5G / 6G

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

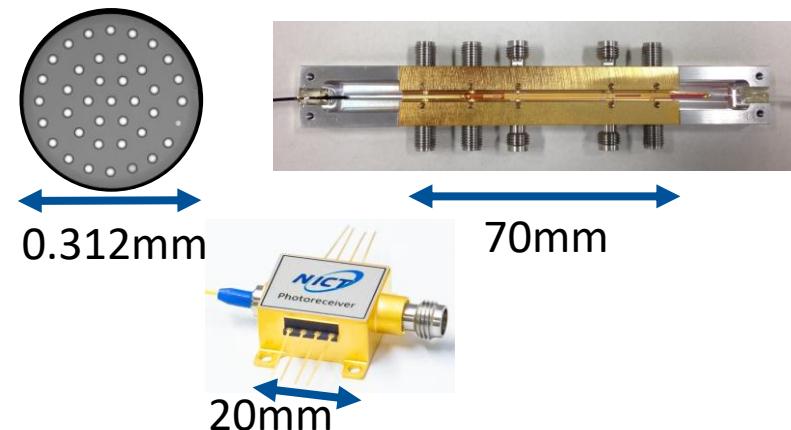
THz Band Silicon Semiconductor



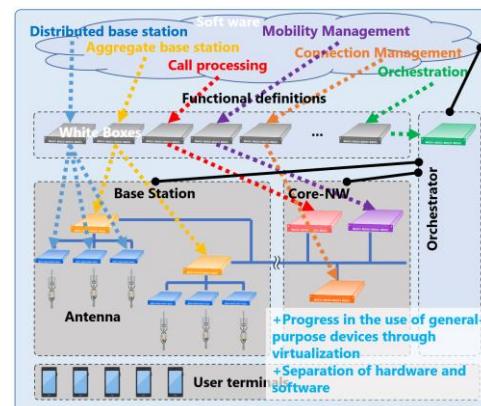
**Space-time synchronization**  
+Inter terminal coordination  
+Non-GPS location  
+Remote synchronization



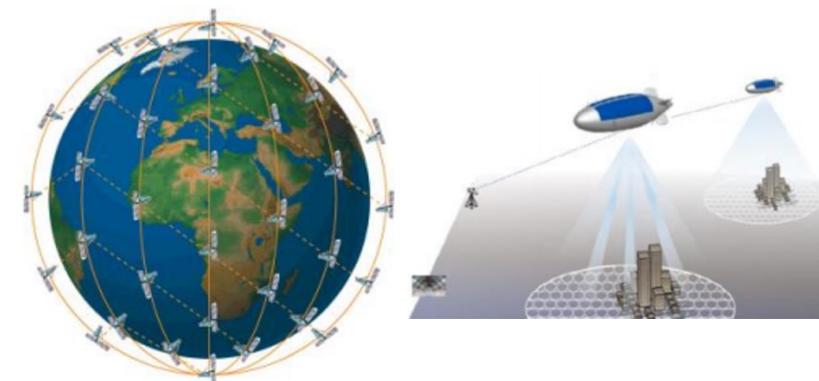
**Increasing the capacity of the core network  
Multi-core fiber, multi-mode fiber, etc.**



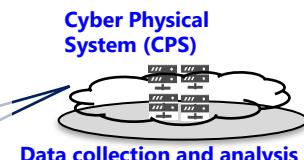
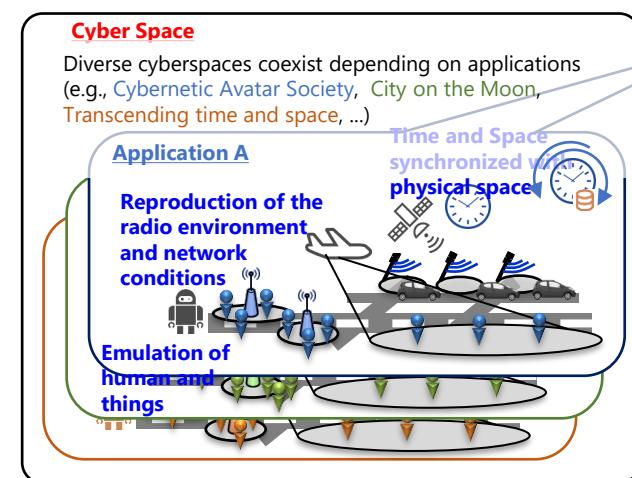
**Virtualization**  
+Cloud native  
+Highly available resource allocation  
+Network Control with AI  
+Autonomic networks



**Coverage expansion  
Satellite constellations, HAPS, etc.**



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

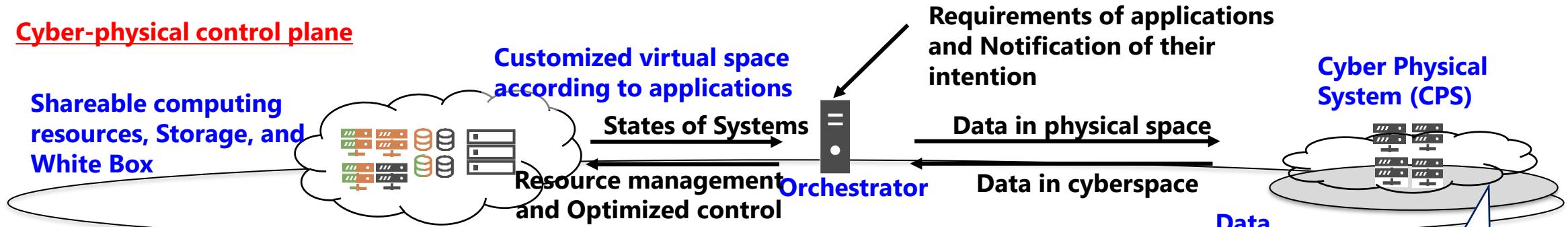


# Trends in network-related technologies

| Technical Field             | Technical Area                                    | Present                | Before 2030                                      | After 2030   |  |
|-----------------------------|---|------------------------|--|--|--|
| Mobile Communication System | Bandwidth Expansion                               | MMW                    | Terahertz  |  |  |
|                             | Non-Terrestrial Networks                          |                        | HAPS/LEO-Constellation                           |  |  |
|                             | LPWA/WLAN   | LTE-M/NB-IoT/WiFi-6    | NR-Light, Next-Generation IoT, WiFi-X            |  |  |
| Network Technology          | Optical   | Signal Multiplexing    | Wavelength Division Multiplex(Single Core Fiber) | Space Division Multiplex (Multi-Core / Multi-Mode Fiber) |  |
|                             |   | Bandwidth Expansion    | Broadband Technology (C+L band)                  | Ultra-Broadband Technology (Including U, S, O, T -bands) |  |
|                             | Quantum Communication                             |                        | Quantum Cryptography                             | Quantum Security Network                                 |  |
|                             | Disaggregation                                    |                        | Photonic Disaggregated Computing                 |  |  |
|                             | Network Slicing                                   | Network Virtualization | Slicing (Policy Based)                           | Zero Touch Operation                                     |  |
|                             | Edge Computing                                    | MEC(Area-IX/CDN)       | Slicing (AI Based)                               |  |  |
|                             | Data-Centric Technology                           |                        | Edge AI  |  |  |
| AI / Big-Data               | Quantum Computing                                 |                        | Hybrid ICN                                       | ICN / CCN  |  |
|                             | AI  |                        | Quantum Annealing                                | Quantum Gating   |  |
|                             | Reality Augmentation Technology/Sharing of Senses |                        | Brain-fusion AI                                  |  |  |
|                             | XR  |                        | General Purpose AI                               |  |  |
|                             |   |                        | Digital Twin                                     | Tele-Presence  |  |
|                             | Sensory Transmission                              |                        |  |  |  |
|                             |   |                        | Tele-Presence                                    |  |  |

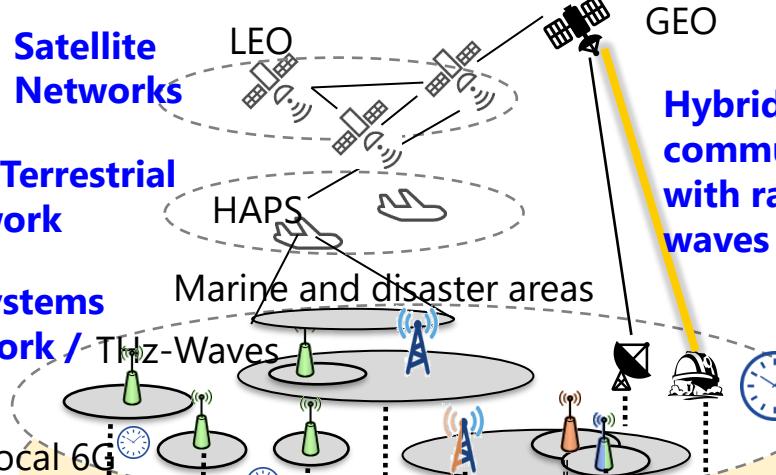
# Overview of functional structure of Beyond 5G / 6G

## Cyber-physical control plane

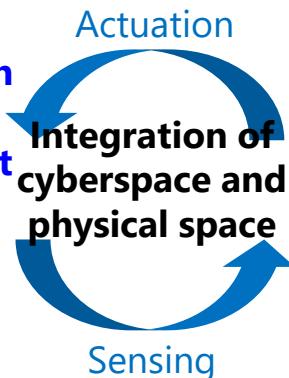


## Physical Space

Automatic selection of appropriate wireless system



+ Utilization of time and space resources in both physical and cyber space



+ Understanding human and object behavior, radio environment, network conditions, etc.

## Cyber Space

Diverse cyberspaces coexist depending on applications (e.g., Cybernetic Avatar Society, City on the Moon, Transcending time and space, ...)

### Application A

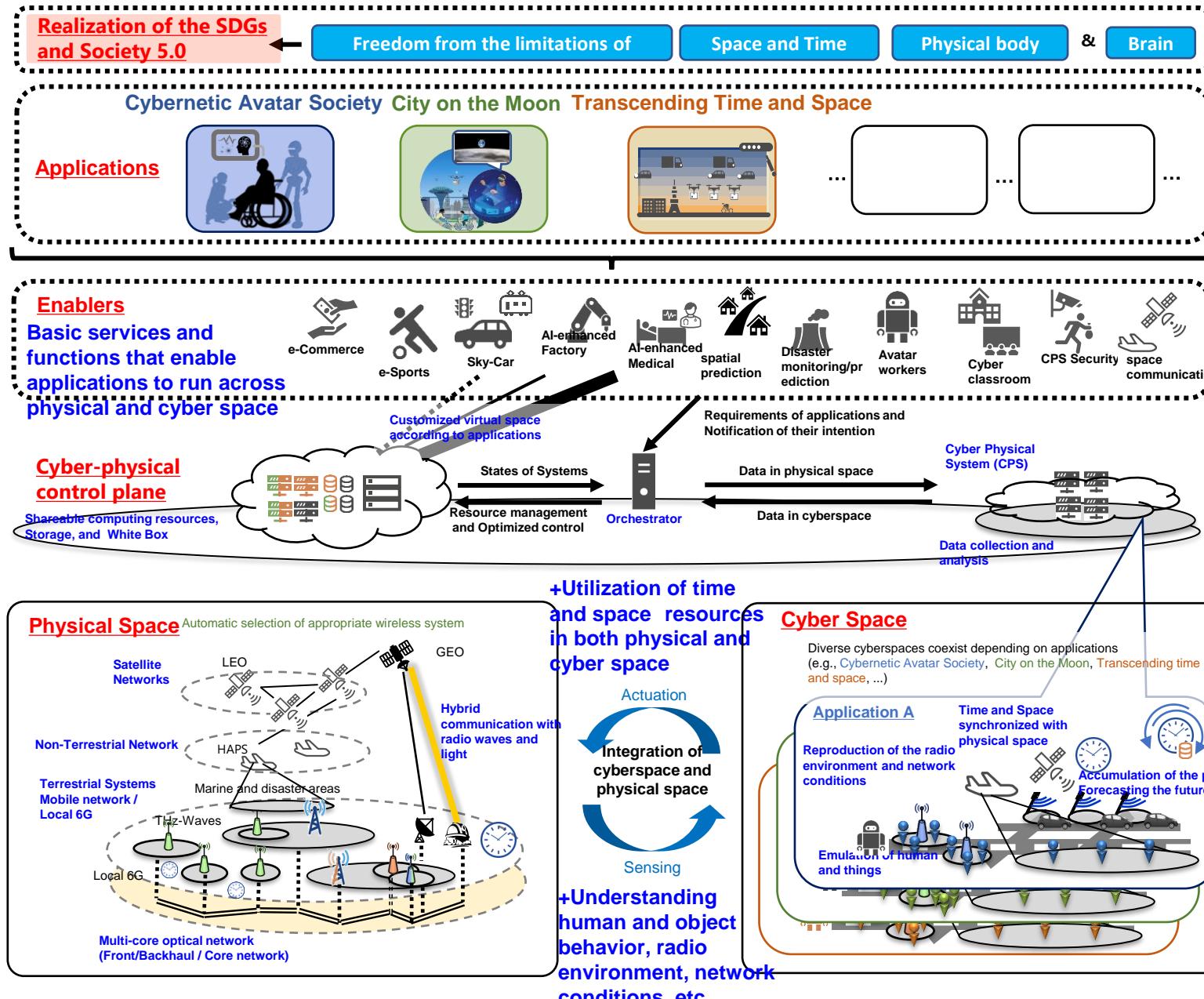
Reproduction of the radio environment and network conditions



Emulation of human and things

# Overview of functional structure of Beyond 5G / 6G

## Functional structure with specific contents

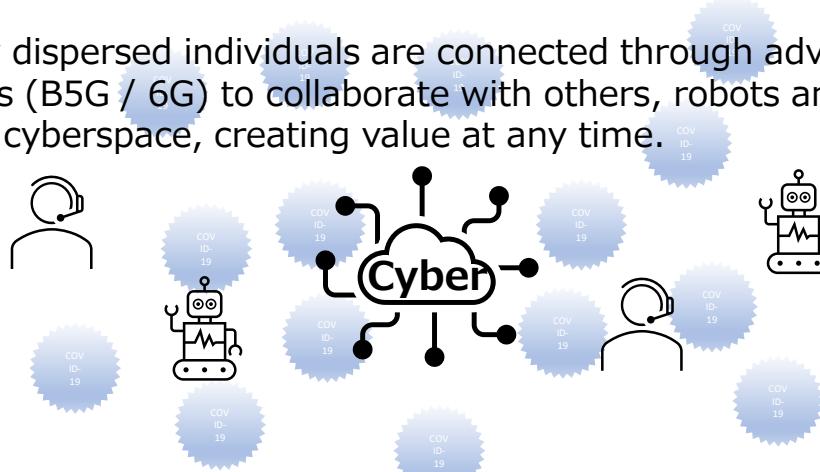


# Technology Vision for Beyond 5G / 6G

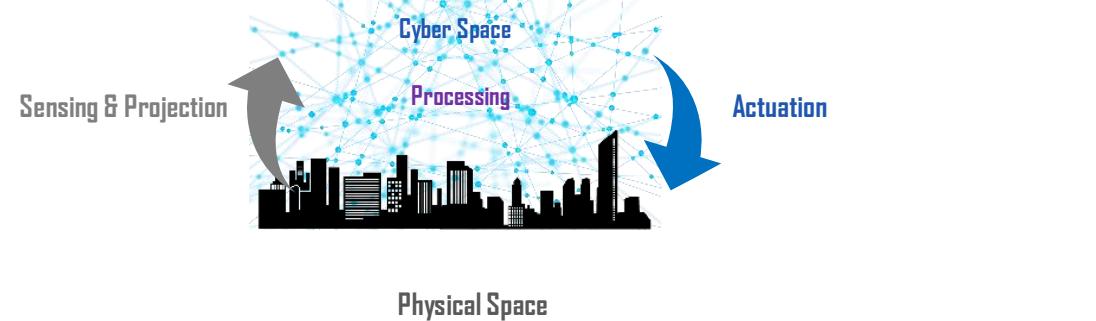
**Urgent issues: Economic growth under the new-normal → Non-contact society by utilizing ICT  
~ "Society 5.0"**

**Keys are the development of the Beyond 5G / 6G, together with the realization of the Cyber-Physical System (CPS)**

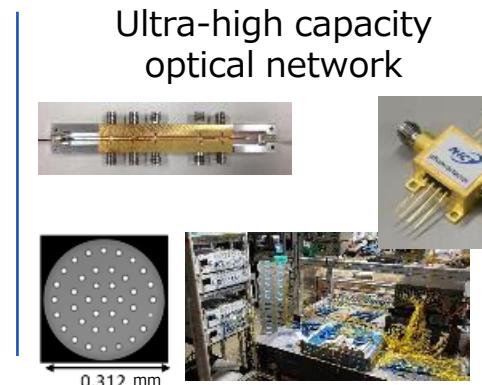
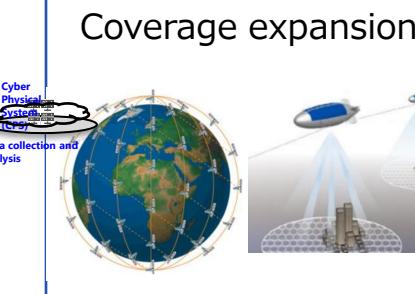
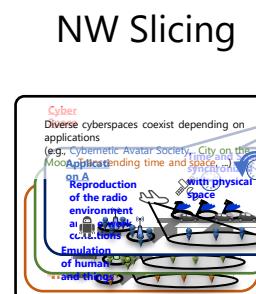
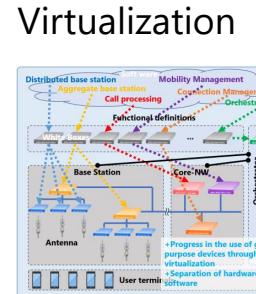
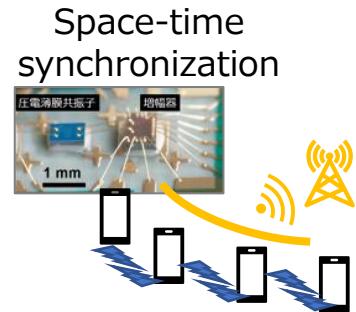
Spatially dispersed individuals are connected through advanced networks (B5G / 6G) to collaborate with others, robots and avatars through cyberspace, creating value at any time.



Realization of a "cyber-physical system" that measures real-world phenomena (big data), projects them into cyber-space, finds solutions (optimal solutions), and actuate the real world.

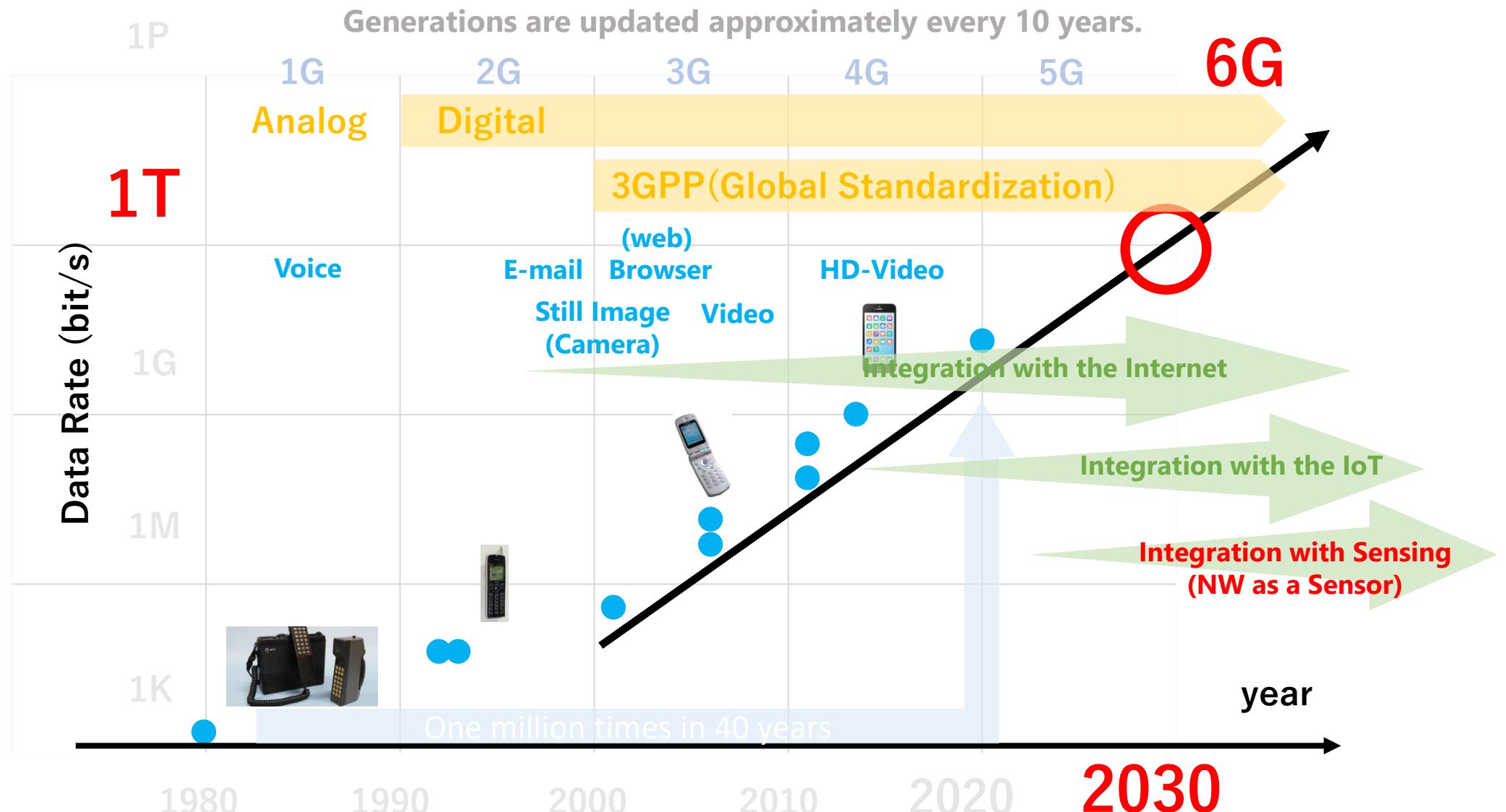


## Seeds of Techs @NICT



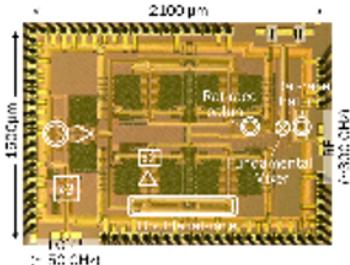
# Back-up Slides

# History & Future of Mobile Communication System



## Terahertz (Handle undeveloped frequencies as intended)

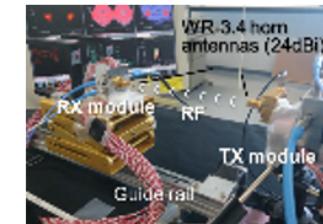
### ■ Development of THz band wireless transceiver using silicon CMOS integrated circuit



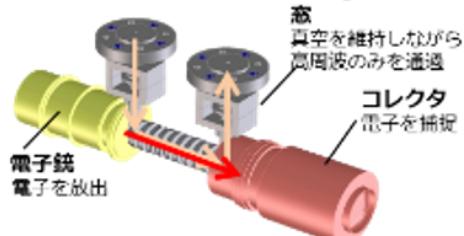
300GHz Silicon CMOS Receiver Chip

(Jointly developed with Hiroshima University and Panasonic Corporation)

**World's First Terahertz Communication  
Module Achieves 20 Gbps. → 100 Gbps**



### ■ THz Band Amplifier Technology

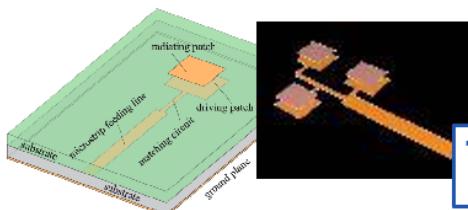


(Joint development with NEC Network Sensors, Ltd.)

THz band amplification technology using  
vacuum tube technology

**Aiming for 100 Gps even  
at a distance of 1 km  
with backhaul lines, etc.**

### ■ Compact and Wideband Antenna Technology for THz Band Wireless Comm.



Small antenna with impedance bandwidth of 70 GHz or more, antenna gain of 10 dBi or more, and gain bandwidth of 80 GHz or more

**Terahertz antennas can be mounted on cell phones and other devices**

# Ultra-high-capacity optical network

(To become a backbone network supporting B5G / 6G)



It is the basis of data communication not only in the real world, but also within and between cyberspace and the real world.

■ Fiber optic radio (RoF\*)  
1.5 Gbps communication has already been established with trains running at high speed in the 90 GHz band. Further upgrading will support B5G.

※ RoF (Radio on Fiber)

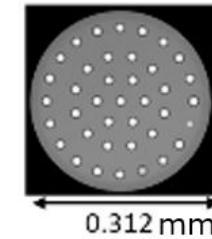


Optical Modulator



Photoelectric converter

■ multicore optical fiber  
Achieves 38-core 10P (peta) bps capacity with a single optical fiber. We also achieved 1Pbps switching with 22-core optical fiber. We are aiming for further advancement.



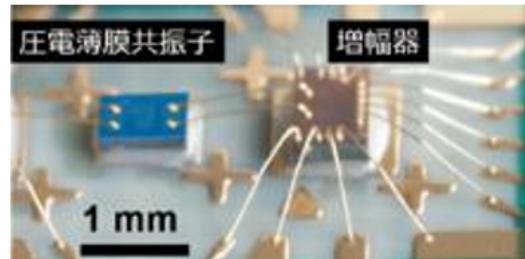
0.312 mm



(Reference) 1 Pbps is equivalent to 10 million channels of 8K broadcasting

## Space-time synchronization (To a base of non-GPS location)

(Joint development with Tohoku University and Tokyo Institute of Technology)



- Using Mechanical Vibrations of Piezoelectric Thin Films to Make Atomic Clocks Small Enough to Be Installed in Smartphones  
→A Major Step Toward Chip Technology

### Inter terminal coordination

Multiple terminals behave as if they were one terminal



Ultra-short range is linked by millimeter and terahertz waves

### Non-GPS location

- Accurate location services even in areas where signals from global positioning system (e.g., GPS) satellites with atomic clocks cannot reach (e.g., underground, indoors, in buildings, etc.)
- Continuity of service even in the event of system anomalies (solar flares, ionospheric anomalies, conflicts)

### Remote synchronization

Synchronized operation as if there was no propagation delay



High-resolution image synch.



Synch. of work equipment

## Space B5G (NTN) (Innovative expansion of coverage area)

### ■ Wireless network control and management technology

Inter-operator cooperation, multiple connections, low latency, propagation modeling in millimeter and THz bands

### ■ Wireless Network Reliability Technology

High reliability and expansion of communication environment, such as low latency radio for drone control and extreme environment radio for underwater and in-vivo communication

### ■ Wireless Network Adaptive Techs

Highly efficient data transfer technology, ultra power-saving operation technology, and modeling of wireless usage environment

### ■ Global Optical Satellite Communication Network

Optical communication technology to cope with the increasing capacity of satellite and ground station networking

### ■ Marine and Space Broadband Satellite

Provide broadband comms for maritime and air. Reducing the size and weight of comms equipment.

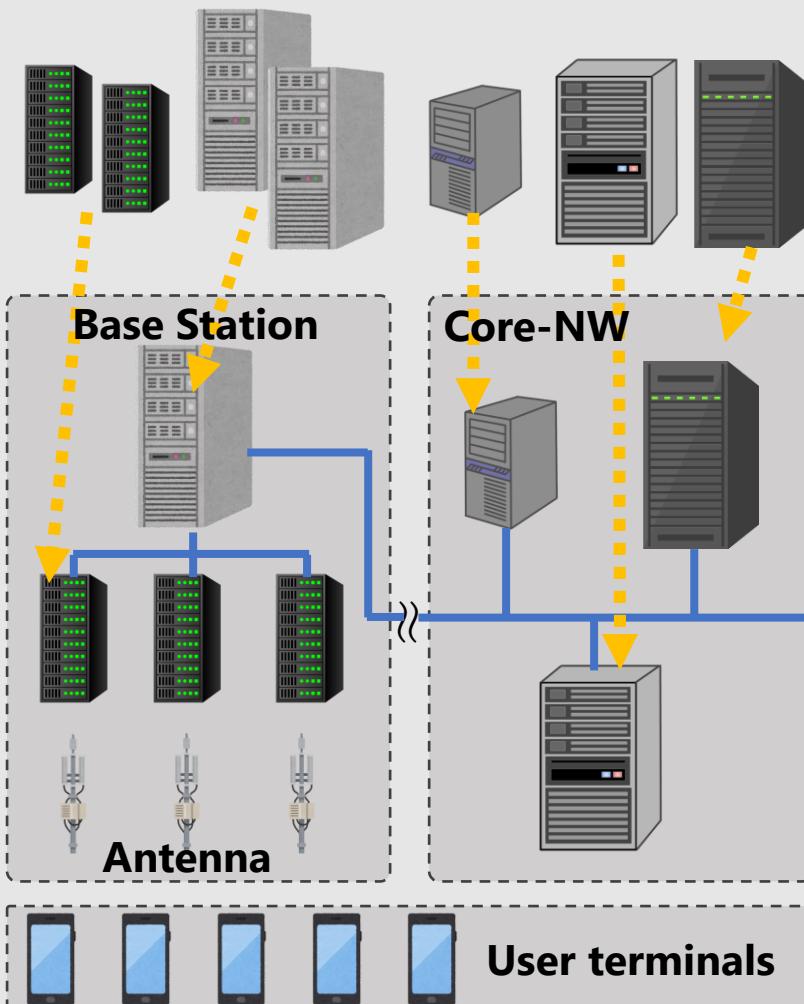


**Flexible, reliable, and fast connection without user awareness, at any time, at any place**

# Beyond 5G (6G)Related Technology Seeds

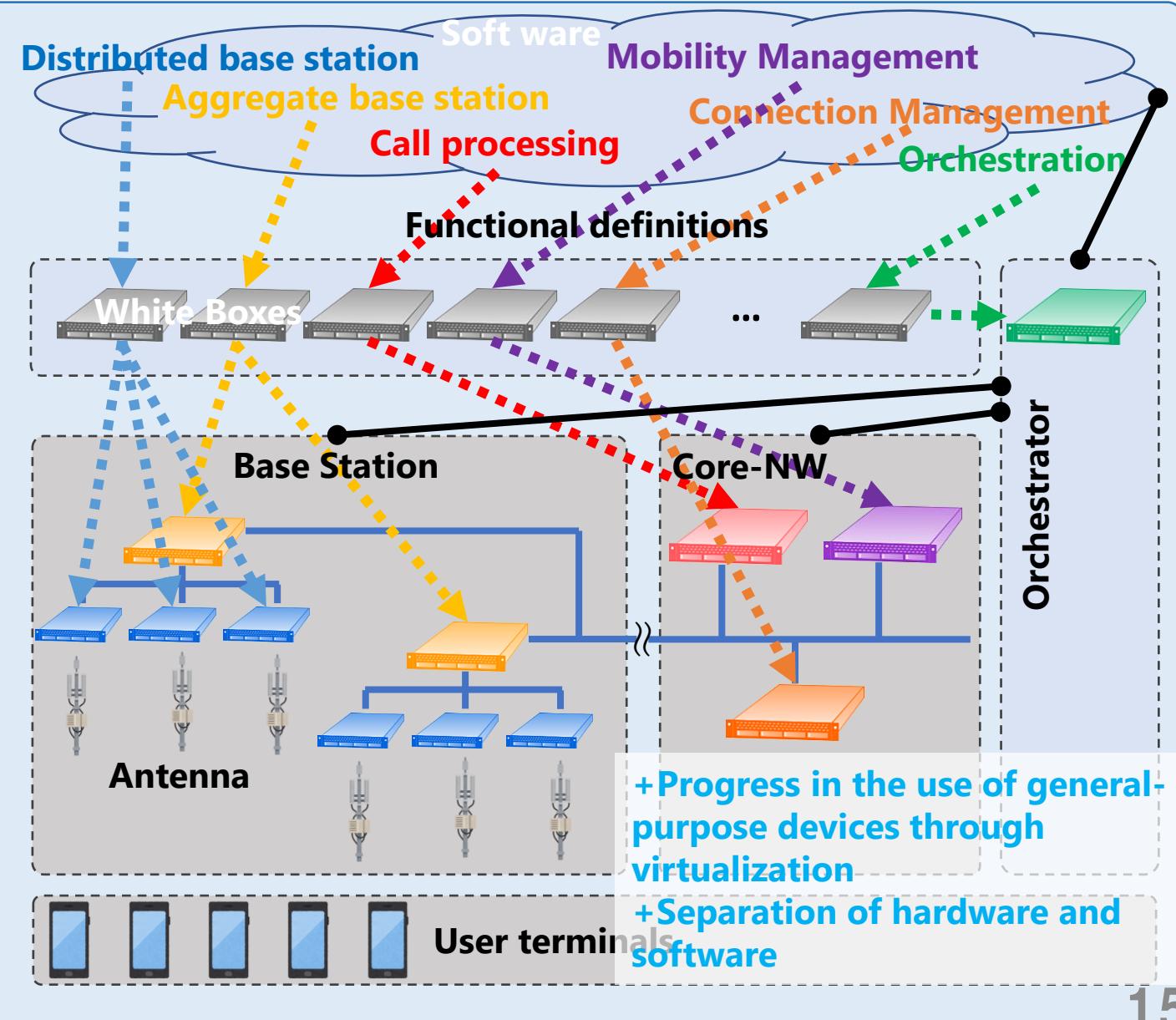
## Conventional networks

Individual dedicated devices for each of the various functions (Hundreds of types)



## Future Networks

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



# Beyond 5G Research and Development Promotion Project

With the aim of realising the next generation of wireless technology, Beyond 5G, which will be the foundation of society and various industries, the government is providing the National Institute of Information and Communications Technology (NICT) with the necessary shared research facilities and equipment, like testbeds, etc., in addition to providing funds for public R&D calls.

Revised budget for fiscal 2020: ¥49.97bil  
(Items : Competitive funds: ¥30bil、 ¥19.97bil)

