White Paper

6G Network and Technologies

Introduction

More than a year has elapsed since the launch of 5G, and we are gradually reaping the benefits. While general consumers are enjoying high-speed services via the 5G infrastructure, industries are beginning to deploy private 5G networks to enterprises.

The trend toward virtualization and openness in IT over the past decade is gradually penetrating the field of networking. The openness and virtualization of networks is now making it easier than ever before for companies and individuals to build networks. In future, they will not only have the use of wide-area networks provided by communications service providers, but will probably also be able to use virtualization technology to build their own networks, and then implement various services using those networks.

What future networks will look like beyond 5G, what kind of performance they will deliver, and what functions they will be able to provide are very interesting topics for enterprises and individuals. This white paper summarizes how networks will evolve toward the 6G era, how they will contribute to solving future social problems and creating a more prosperous society, and what kind of research and development Fujitsu will conduct to achieve this.

Society and the countdown to 2030

Social problems and IT services

The 17 Sustainable Development Goals (SDGs) with 169 targets adopted at the UN Summit in 2015 are international goals for a sustainable and better world. These goals are related to various fields surrounding us all, including social infrastructure, healthcare, education, and agriculture. With ICT technology crucial to solving problems in these fields, many kinds of ICT solutions are now being provided as services. Some of these solutions can of course only be implemented in certain fields, while others that are not always fully effective on their own in certain fields can solve more complex problems when linked with other solutions across multiple fields.

Digital transformation is about achieving change by integrating digital technology into the core processes of society, but for companies, it is not only about transforming internal business processes through automation, but also about providing higher value-added services to solve social problems.

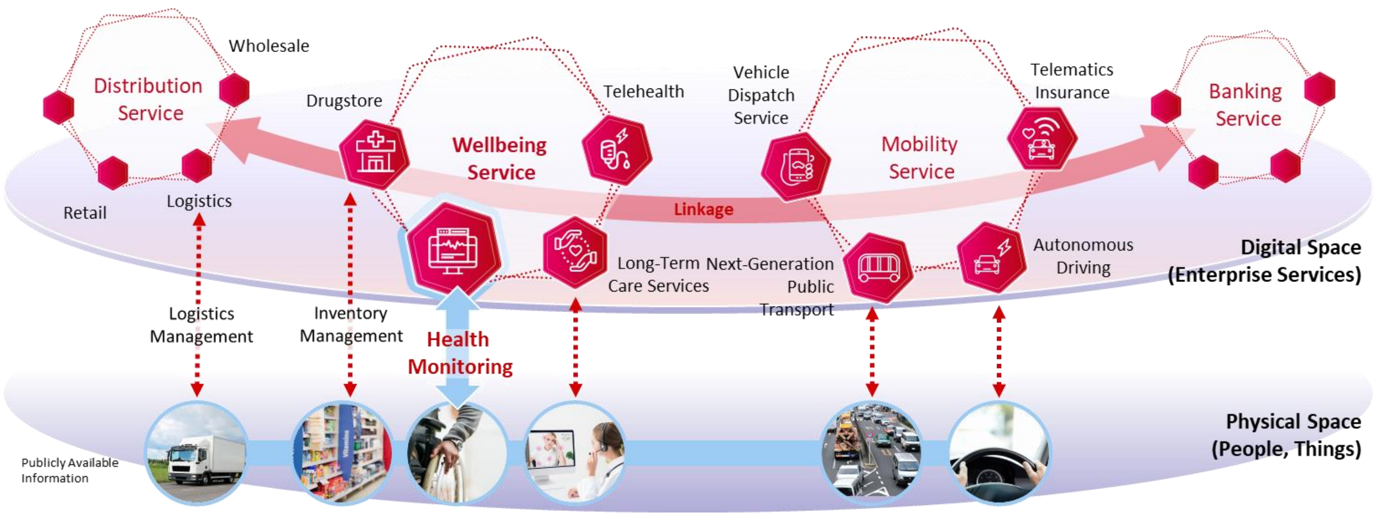

Figure 1 - Cross-industry service collaboration

In particular, companies are not only expected to solve increasingly complex problems by themselves, but in collaboration with other companies and industries as well. As an example, Figure 1 shows a wellbeing service that employed digital technology to solve a social problem. Its health monitoring service digitizes a person's condition and activities via health devices. Sharing the digital data among various services opens up a world that offers systems for automatically scheduling telehealth appointments and automatically delivering clinical results and prescriptions. In the event that a visit to hospital or long-term care is required, the digital space will enable cross-industry collaboration to provide higher value-added services such as staff deployments and vehicle dispatch.

What the future holds for society

Meanwhile, the closer we get to 2030, the more the real physical space of people and things will evolve. Human augmentation technologies such as holography and extended reality (XR) will conceivably become more accessible. For example, holographic technology can be used to reproduce digitized space as real-time images, however we hope that it will also be possible to apply it to remote projection of things in industry, spatial projection of human images in medicine, and presence in personal communication and teleconferencing. The number of things such as sensors, robots, and cameras that can be connected by IoT will continue to increase, allowing a range of sensed data and video information to become available for use.

It will also be possible to connect with objects such as unmanned aerial vehicles (UAVs) and flying cars in places where connection was previously impossible, permitting optimal communication anywhere and everywhere. Linking this evolving physical space with services in the digital space will develop and expand society to deliver extremely rich user experiences. The evolution of physical space and the increasing sophistication of services across industries will help solve social problems, enhance the user experience, and lead to a more prosperous society.

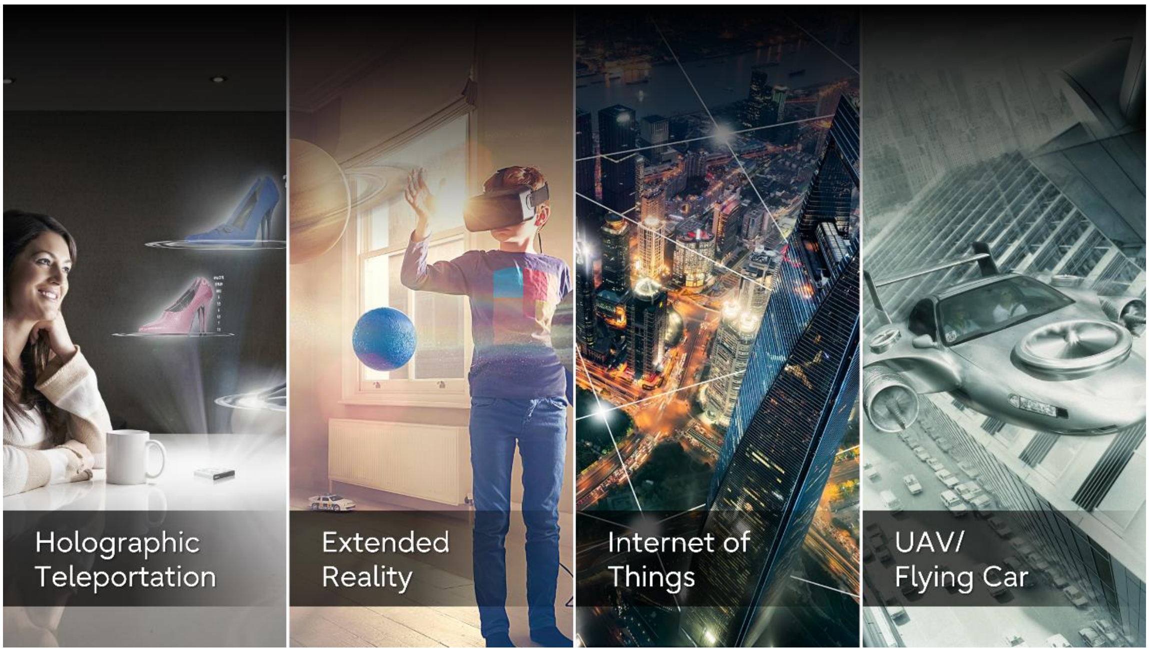

Figure 2 - Evolution of physical space

Figure 3 - What the future holds for society

Evolving network architectures

The role of networks

Networks, especially wireless networks, were originally used for voice communication between people, over such devices as telephones. However, as the Internet evolved and wireless access facilitated the transfer of ever larger amounts of data, the sharing of data and information such as text and images through web access from smartphones and tablets became the norm.

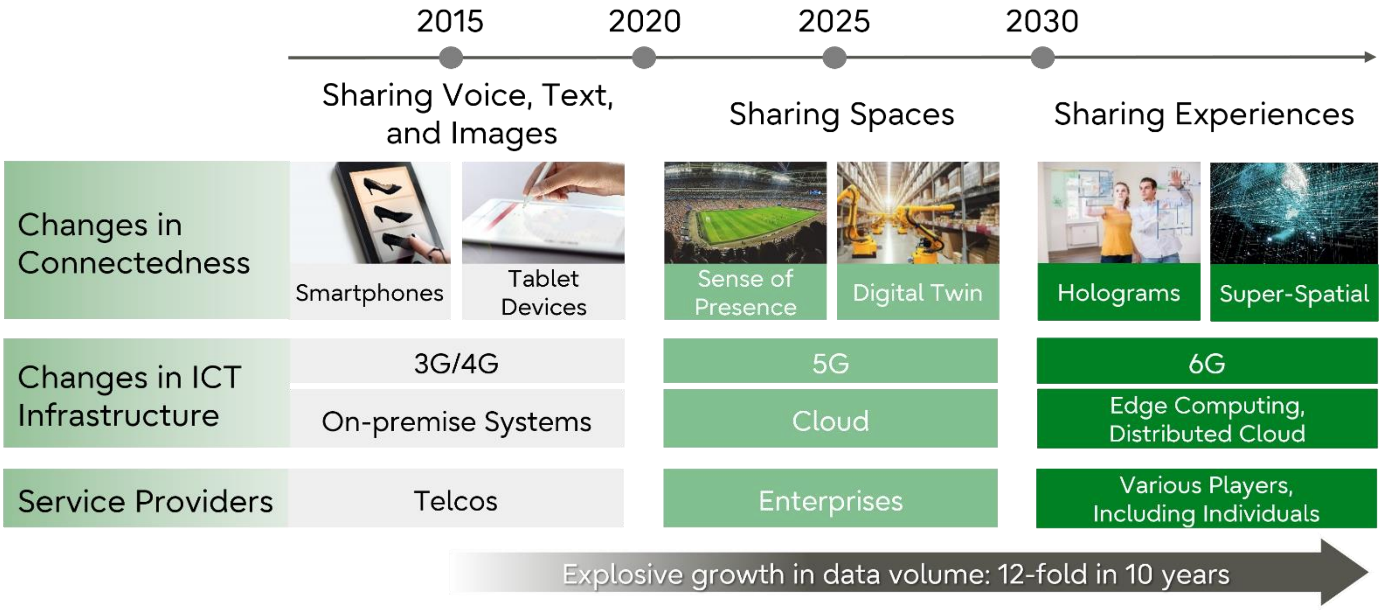

Figure 4 - The role of networks

Wireless access is now gradually extending its reach beyond phones and smartphones, to IoT devices. The global rollout of 5G services started in about 2020, and wireless networks that leverage 5G features such as multi-connectivity and low latency are now being used effectively in various industries to provide new services. By mapping and simulating the real world in the digital space, users can sense and control the real space in the digital space. In future, the physical space will be further enriched by the holographic and XR technologies mentioned in the previous section, while the digital space will evolve towards more complex services. In this way, we will be able to share different spaces as well as different experiences.

One example of how networks are used in industry involves cyber physical systems (CPSs), where a range of data collected from sensors in the physical space is analyzed using AI and other technologies. The results are then either tagged or converted to valuable information, which is used to provide new services to solve problems in industry. The network in a CPS functions exactly as a bridge between the physical space and the digital space. For the physical space to become richer and the digital space more complex in the ways previously mentioned, there will be new demands on the network that bridges the two, generating the need for a network architecture better suited to these requirements.

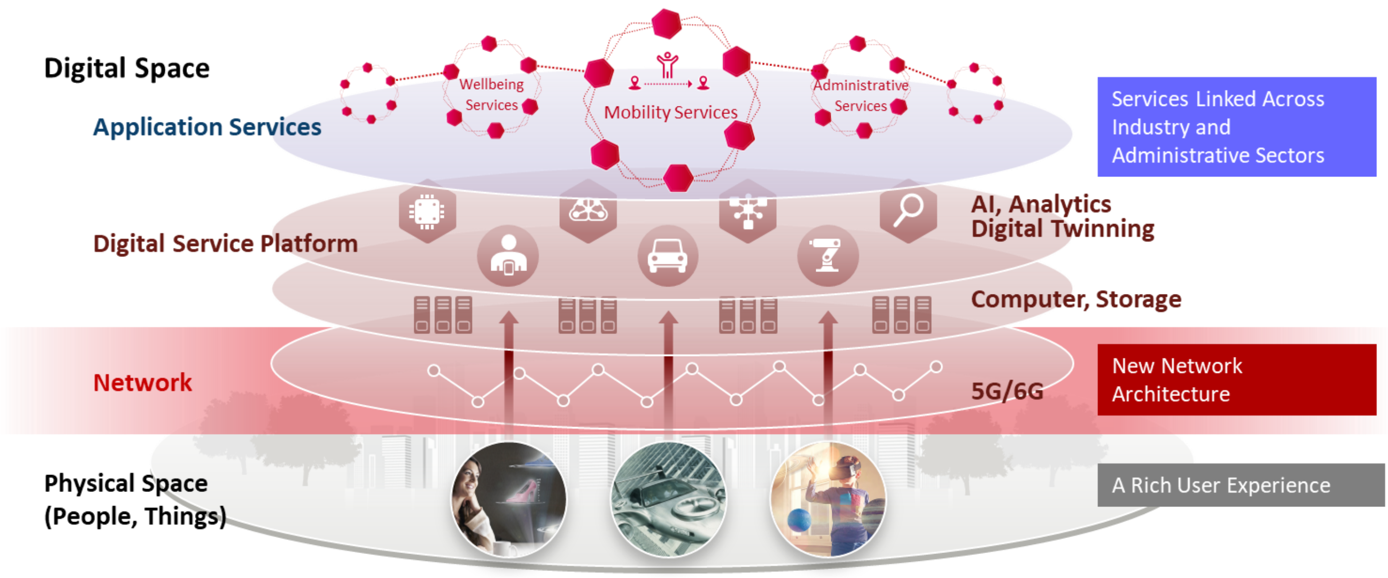

Figure 5 Evolution of cyber physical systems

Requirements of the network

What, then, will be the requirements of the network? There are two main areas on which we need to focus. The first is to improve the network infrastructure to support feature-rich devices. This will require greater performance from the features ascribed to 5G (high-speed, high-capacity, low-latency, massive connectivity), as well as the ability to provide these requirements under low power consumption. In addition, it will be necessary to support the diversification of connected devices, including everything from smartphones and computers to various IoT devices and software (AI and programs).

Table 1 - Future requirements of the network

Item	Description
High-capacity, low-latency, massive connectivity	Keeping up with advances in holography and XR technology in the physical space calls for a high-capacity, low-latency network. With the use of networks (CPS/IoT) in industry, the number of connected devices per unit space also needs to be improved.
Low power consumption	It is essential for networks to be energy efficient, without the power consumed by network devices and systems increasing whenever network capacity increases or massive connectivity is provided.
Diverse topologies	There is a need for connectivity not only to smartphones and tablet devices, but also to IoT devices, between devices, and between AI and AI.
Easy-to-use networks	Networks used in industrial applications need to be easy for people who are not network engineers to build. Networks must also be autonomous, so that they can be monitored and controlled with as little human intervention as possible during operation.
Collaboration between networks and IT applications	It is advisable to provide value that leads to the advancement of services, such as providing data held by the network (e.g., traffic flow rate, device distribution, etc.) to applications, or converting user bit data in the network into meaningful data and providing it to applications.

The second is to expand the functions provided by the network. The implementation of networks in industry demands ease of use, including easy connection and operation with as little human intervention as possible. Such autonomous networks must also be inexpensive to build and operate. Coupled with this, services will be greatly expanded once the network has the capacity to not only carry bits, but also convert the bit data into meaningful data within the network and provide it to applications and services.

Holographic communication is one example of a use case we can expect to see in the 6G era. In holographic communication, it is said that reproducing space in real time at the receiving end requires transmitting light-field data at a bandwidth of 1 Tbps.[1] A delay in the order of milliseconds is also required to avoid irritating the user's senses (sight, hearing, and in some cases, touch). Sending point cloud data rather than light-field data reduces the amount of data transmitted to a level of around 0.5 to 2 Gbps, however this necessitates a massive amount of computing power at the receiving end to reproduce theprecise holographic images from less data, and hence the total transmission and processing time must be constrained to the equivalent delay. Thus, the requirements for holographic communication must not only take network capabilities into consideration, but also the performance of the end devices and the performance of the computer on which the application will be deployed.

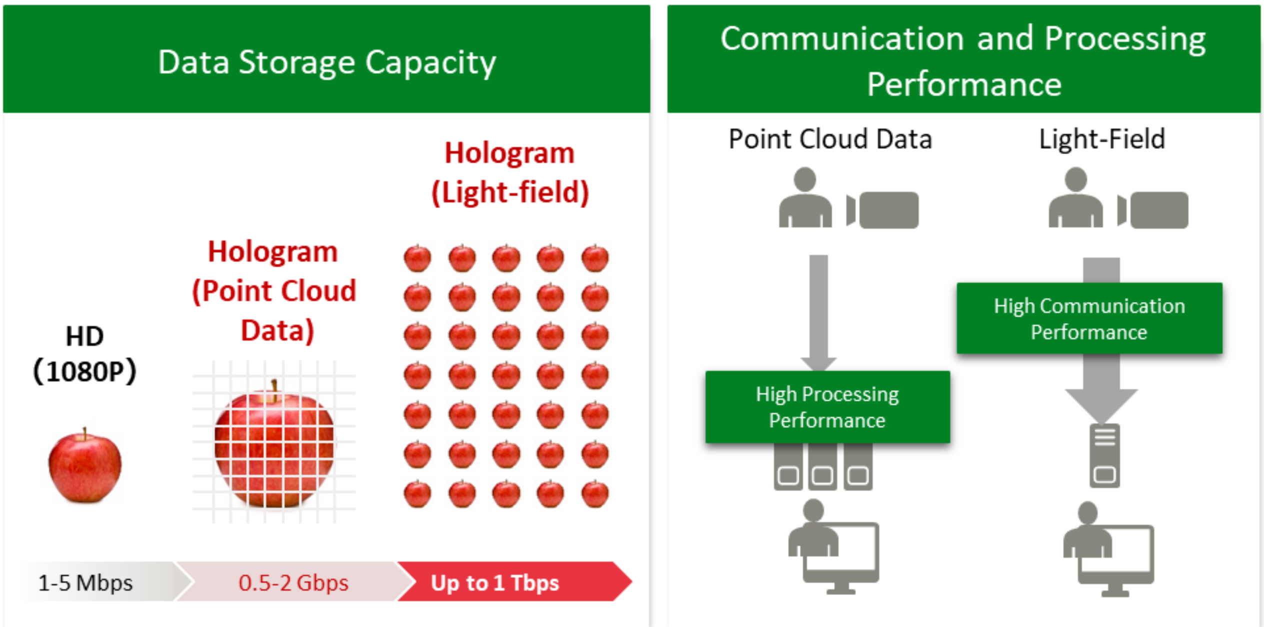

Figure 6 - Requirements for holographic communication

Changes in network architecture

How will network architectures evolve to meet these diverse requirements? Until now, network products such as wireless base stations, switches, and routers have mainly been provided as box-type, that is, dedicated hardware appliances. However, advances in network virtualization now enable software-defined network functions to be deployed as applications on general-purpose computers. Disaggregation, whereby the network is decomposed into its functional components and then reconfigured into a combination of the requisite components, is also becoming more and more common. For example, in the 5G mobile core network, the mobile core is decomposed into various network functions, and each function can be used as a microservice. This kind of network virtualization architecture has a high

[1] ITU-T FG NET-2030. "New Services and Capabilities for Network 2030: Description, Technical Gap and Performance Target Analysis" (October 2019)

affinity with IT services deployed in the cloud. We therefore believe that in the future, there will be more integration of architectures, not only in networks but also in the IT area.

In other words, we believe that these architectures will aggregate and evolve into two platforms: a hardware platform to deliver high performance and a software platform to deliver a variety of functions. The aim of the hardware platform will be to achieve high performance using computers (general-purpose computers or computers dedicated to specific applications) and the wireless access and optical transport that connect them, while the software platform is to provide various network functions (e.g., base stations, switches and routers, security, etc.) as well as service platform functions such as data processing from IoT devices. This type of integrated IT and network architecture will allow network and IT functions to be delivered in a way that maximizes hardware performance.

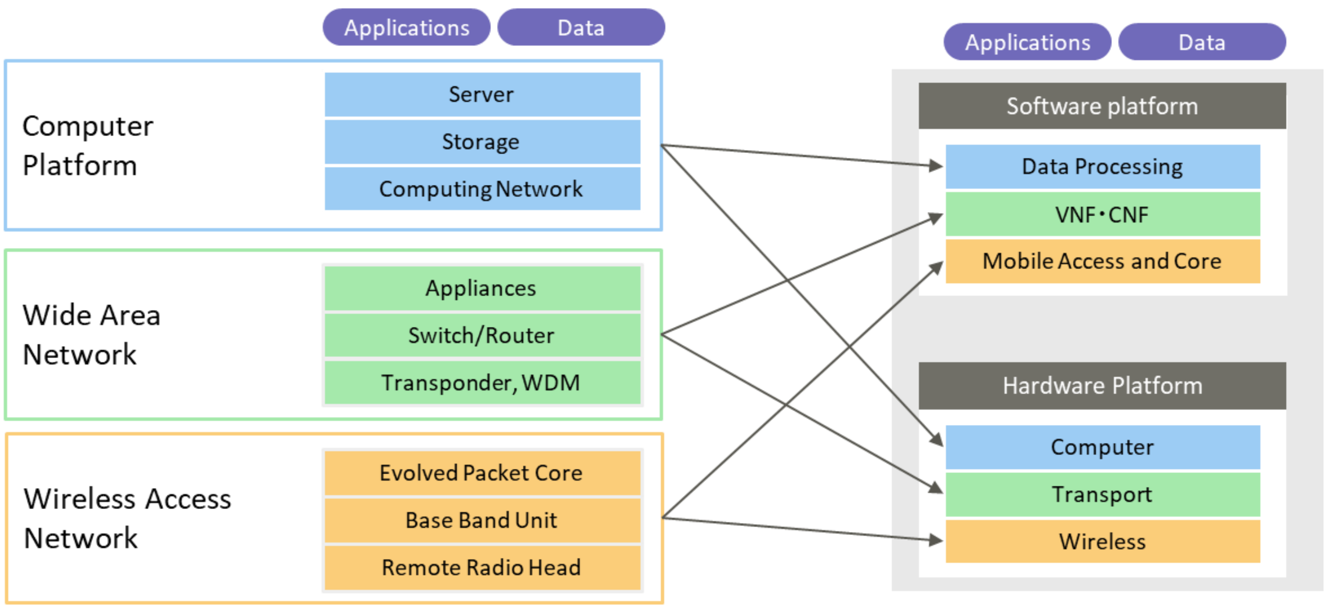

Figure 7 - Changes in network architecture

End-to-end cloud-native networks

Network function disaggregation, virtualization, and use of microservices frees the network from hardware location (site) constraints. Computer and network hardware infrastructure is distributed network-wide, including to enterprise and consumer sites and on-premise locations, telco edge clouds, and public cloud data centers via the Internet. Judicious linkage and use of these geographically distributed computing and network resources improves quality and reduces system costs.

For example, by dynamically deploying (orchestrating) network functions on general-purpose hardware according to the requirements (throughput, latency, number of connections, etc.) of the service to be implemented, it is possible to optimize the use of hardware resources while still meeting the service's network requirements. This enables flexible deployment of networks in an end-to-end, virtualized, cloud-native network like the one shown below.

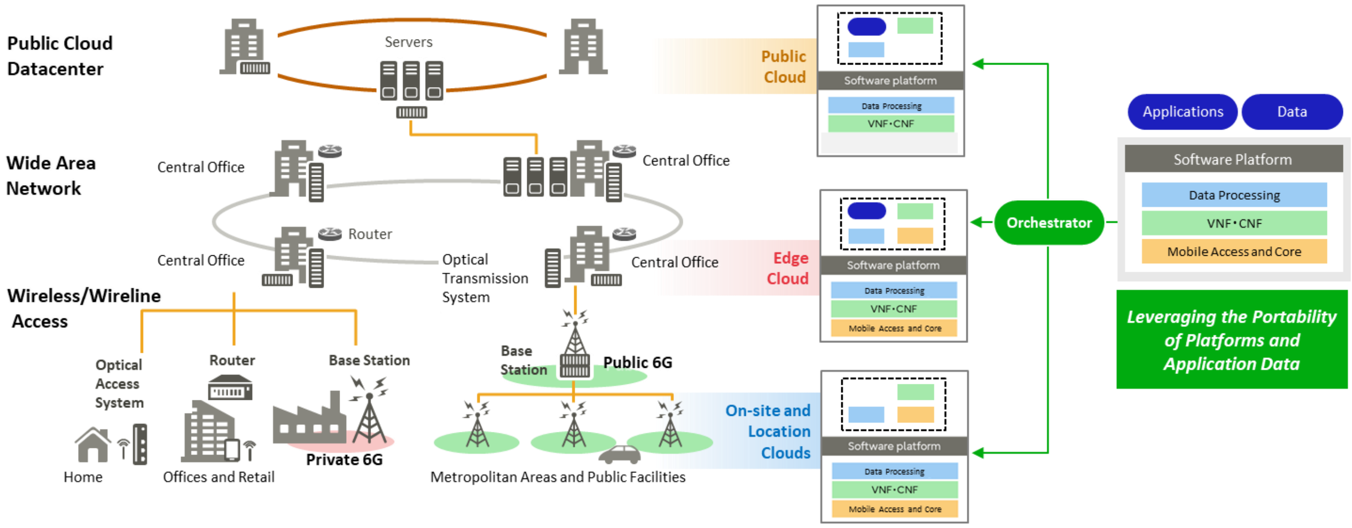

Figure 8 - End-to-end cloud-native network

Underlying Network Technologies

This section focuses on the configuration of the hardware and software platforms shown in the network architecture, and the underlying functions and core technologies that will make up those platforms.

Network platforms

Figure 9 shows where the hardware platform and software platform sit in the network architecture. The hardware platform consists of network hardware such as wireless and optical transport hardware, and computer hardware such as servers and storage. The computer hardware also comprises general-purpose computers and dedicated computers. While general-purpose computers can perform a wide range of functions, dedicated computers focus on the performance of specific applications such as image processing, digital signal processing, and optimization processing, rather than functional versatility. It will be important to vary the use of network functions on the hardware platform according to whether the computer is general-purpose or dedicated. As networks become progressively more advanced, this hardware platform is an area we will continue to develop.

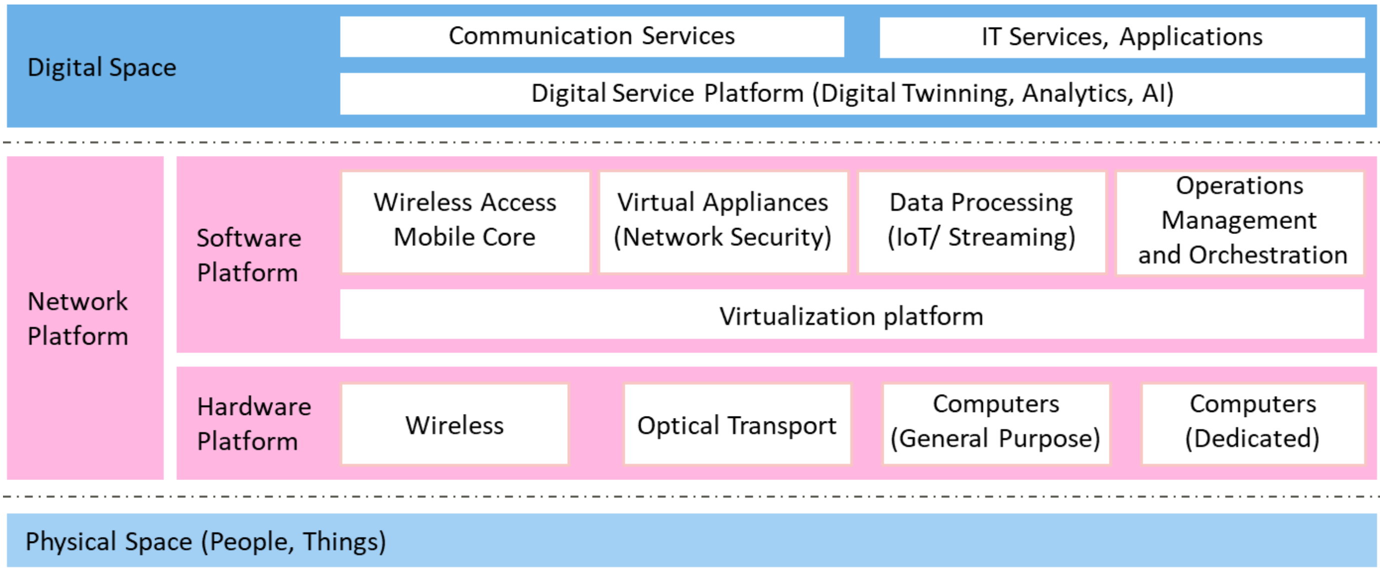

Figure 9 – Network platform

The software platform comprises a virtualization platform layer and network function software. The virtualization platform layer is the layer that will conceal the hardware and contain the operating system, etc., to run the virtualized software. The network function software provides mobile network functions (such as wireless access and the mobile core) and virtual network appliance functions (such as security) on the virtualization platform.

In addition, with the spread of edge computing, there will be cases where sensor data and video data will also be handled within the network. Functions for collecting and processing IoT data and providing it to applications, as well as networking between different types of data, will grow in importance in the future. In the area of operations management and orchestration, network maintenance and operation together with optimization functions such as dynamic configuration will be provided in conjunction with applications.

Network technology trends

The three core technologies required to implement end-to-end cloud-native networks are open networks, intelligent network orchestration, and green technology. Firstly, to ensure that disaggregated network functions can be optimally prepared end-to-end to meet requirements, the interfaces must be open, and the internal configuration of individual functions must be available to anyone in the network. Secondly, intelligent orchestration will be critical to reconfiguring functions to meet the requirements of clouds (edge clouds, public clouds, etc.) distributed across the network, and to making the network safe, secure, and easy to operate. Lastly, the network must be environmentally friendly, compact, and energy efficient, while still providing performance and quality. Given that 6G will involve faster and larger data transmission than 5G, it will require a substantial amount of energy under the current technology. It will therefore be crucial to leverage technological innovation to significantly curb the power consumption of the entire infrastructure.

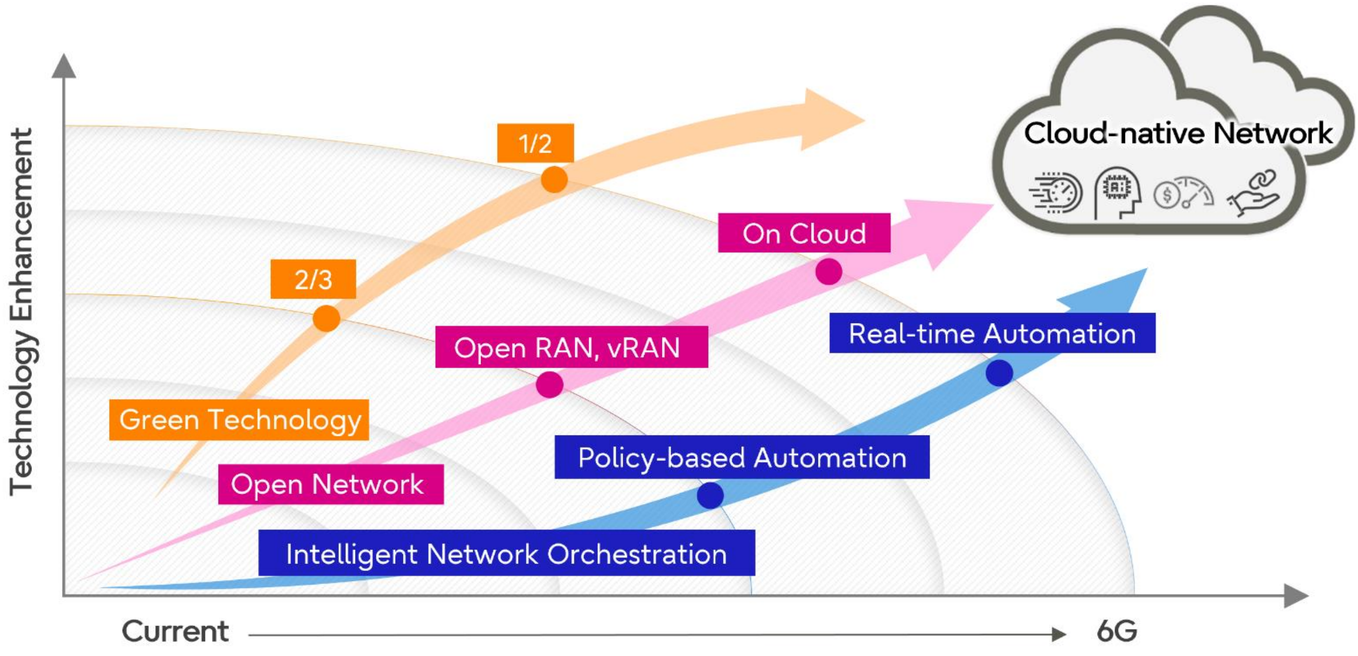

Figure 10 - Network technology development trends

Open networks

There are two points to note regarding network openness. The first is that the interfaces between disaggregated functions must be open, to ensure connectivity between functions provided by different vendors. The second is that all functions must be implemented by software, making it easy to carry out software-based addition, update, or deletion of functions.

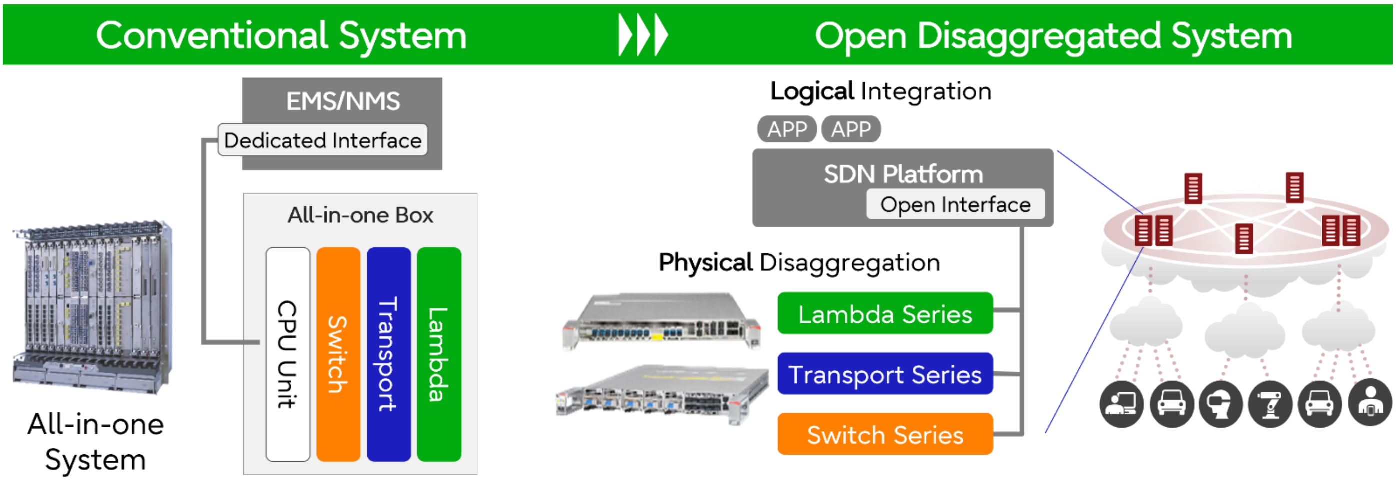

Figure 11 - Network openness (Optical transport system)

Figure 11 represents the approach to network openness in the field of optical transport. Conventional optical transport systems consist of all-in-one box type devices that integrate the switch, transmission, and optical components. However, disaggregating those functional components, creating an open interface between functions, and opening the monitoring and control interfaces will make it possible to flexibly build functions from various vendors in accordance with system requirements.

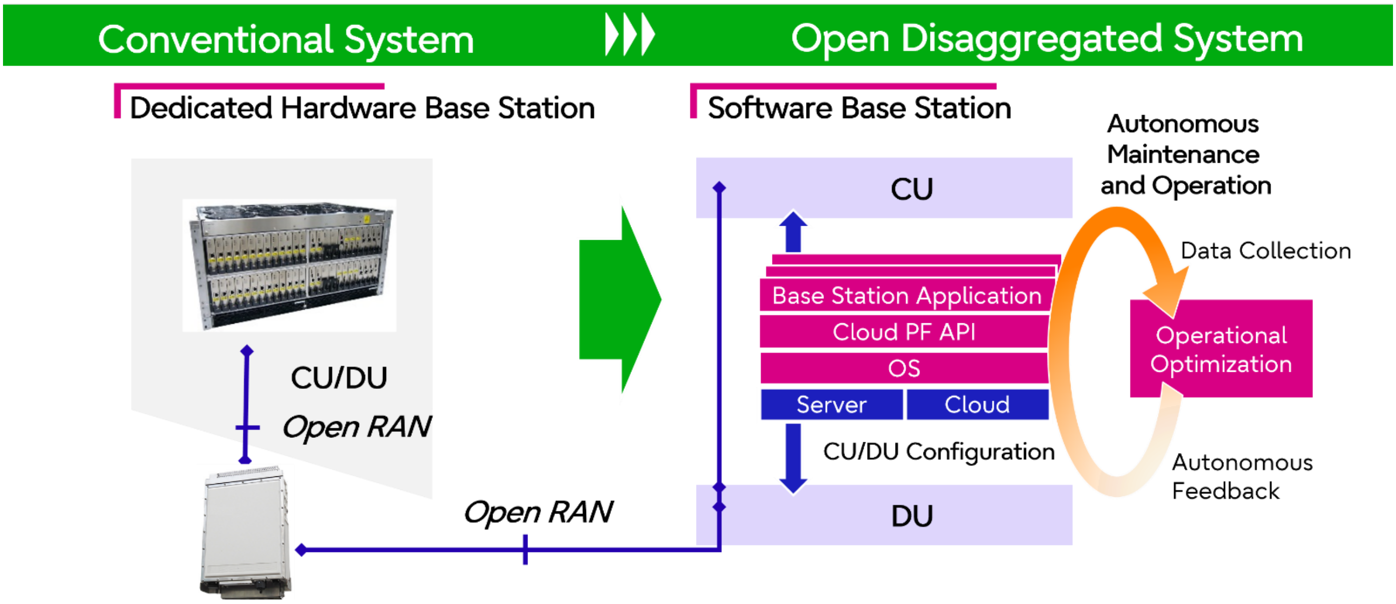

Figure 12 - Network openness (Base station)

Figure 12 shows the configuration of the software-defined base station that Fujitsu is currently working on. Connectivity between vendors is achieved by opening the interface between the Radio Unit (RU), which processes analog radio signals, and the Central Unit and Distributed Unit (CU/DU), which perform digital processing. In addition, a flexible network can be built by using software to configure the digital processing unit.

In preparation for 6G, Fujitsu will provide a compact, high-performance, highly flexible network for an open network configuration like this by combining open networks with green technology (mentioned below).

Intelligent orchestration

The quality of the network utilized by users depends on the performance of individual devices and the usage of transmission lines. It will therefore be important to integrate the monitoring and control of the network and IT devices used from the devices to the cloud. In a network that uses a combination of proprietary systems from different vendors, integrated operation and management of the entire network is exceedingly complicated.

Open and standardized monitoring and control interfaces for the systems and functions of each vendor will facilitate operations management across different vendors and layers. In addition, by collecting data on the status of networks that could impact service quality or affect the usage of resources of individual devices, and then using AI to analyze that data, it will be possible to automate operation to do things such as changing device settings in real time. Furthermore, by disclosing network status and other information through APIs, it will be possible to use the data to deliver new services.

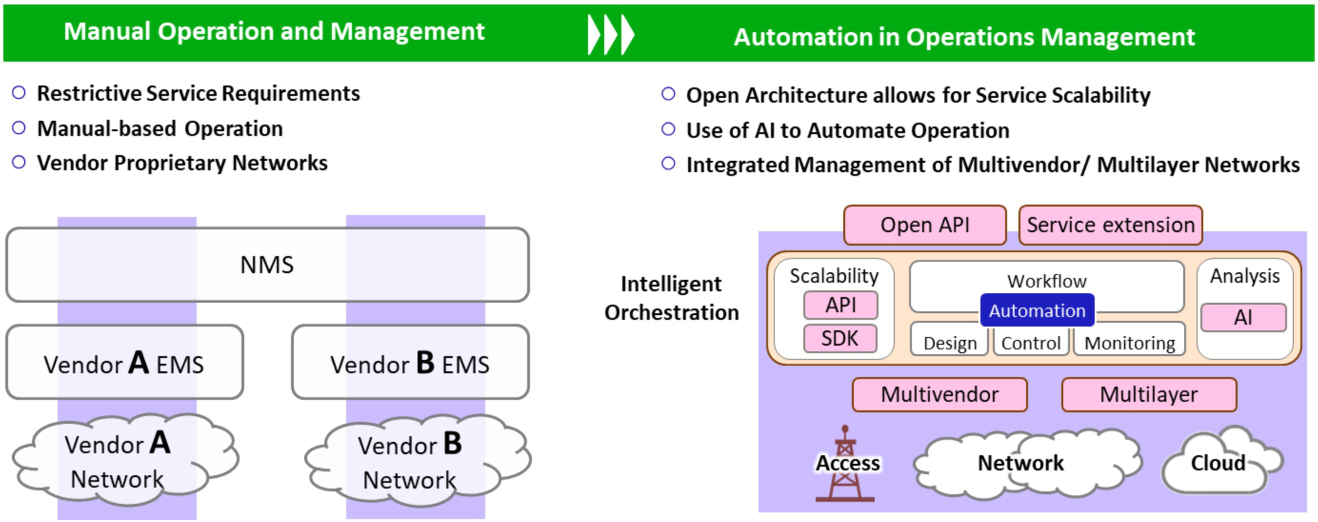

Figure 13 – Intelligent network orchestration

Green technology

In terms of green technology, we are working on achieving compactness and energy efficiency in the wireless and optical transport fields. We aim to use compound semiconductors such as gallium nitride and indium phosphide to deliver high-frequency RUs, with frequencies in the millimeter-wave and terahertz ranges that are higher than 5G to achieve high-speed, high-capacity transmission in compact, energy-efficient networks.

In addition, we will conduct research into network topologies such as mesh networks, focusing on how to economically construct networks to enable communication on land, underwater, and in the air, with low power consumption. Meanwhile, as the number of IoT and smart devices increases, the majority of data communication will evolve to be between devicesor between AI. We are working on low power consumption semiconductor devices that can be applied to such IoT and smart devices.

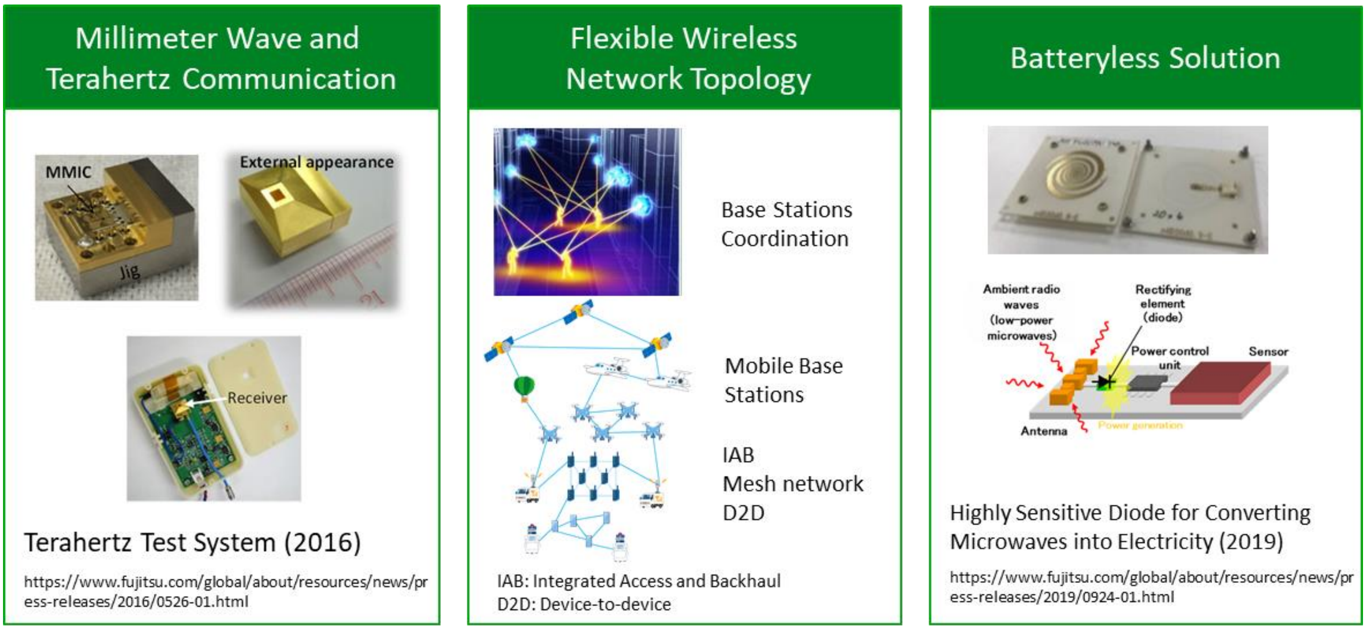

Figure 14 – Green technology (Wireless)

In the field of optical transport, we are working on photoelectric fusion technology to integrate electrical components (silicon) composed of discrete semiconductors and optical components (compound semiconductors) in the one semiconductor device. By taking the optical devices and optical subsystems that use this technology and applying them in optical transmission systems, we aim to develop an optical network that will be compact and energy efficient, yet be able to transmit large amounts of data.

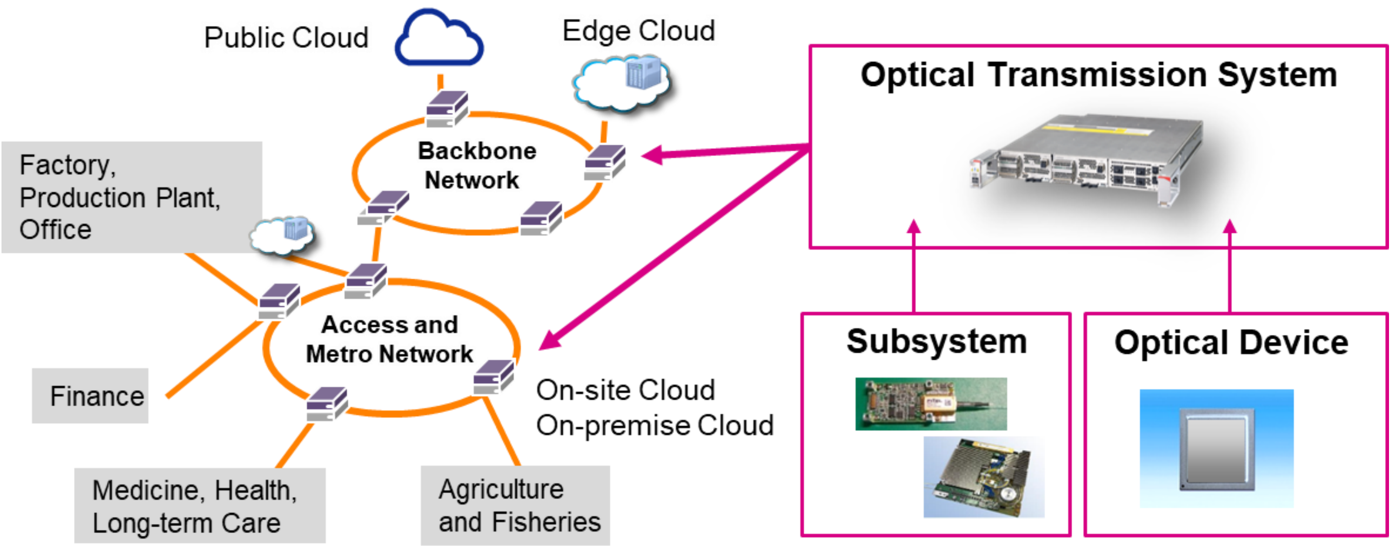

Figure 15 – Green technology (Optical network)

R&D roadmap

Figure 16 shows the R&D roadmap currently envisaged by Fujitsu. In terms of open networks, we are currently working on disaggregation and software development based on the current 5G architecture. Generally speaking, we will base 6G on this architecture, but we are also considering the possibility of discontinuous evolution

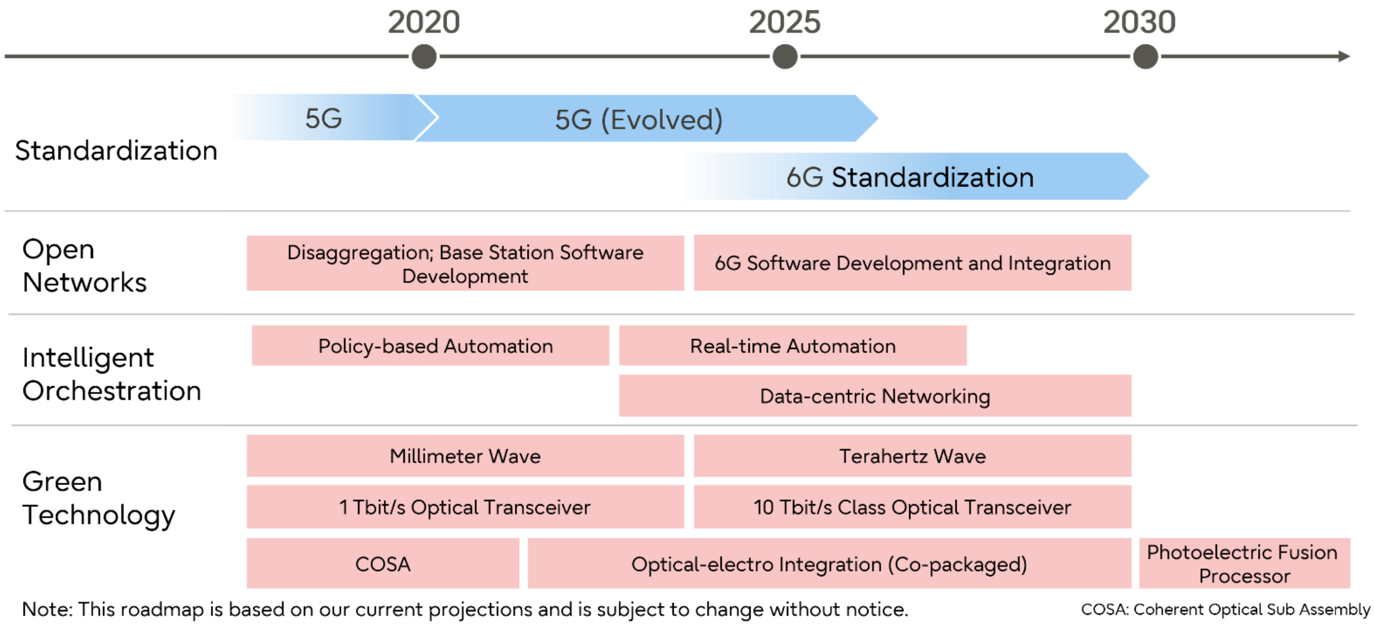

Figure 16 – R&D roadmap

In the field of intelligent orchestration, we will first automate multi-vendor and multi-layer operations based on rules and policies, and then use AI to extend this to real-time automation. We also plan to develop technologies related to data-centric networks to provide applications with data held by the network, or convert user bit data into meaningful data within the network and provide it to applications.

In terms of green technology, we will continue to develop millimeter-wave access systems and transmission systemsas enhancements to the current 5G, as well as hardware platforms such as higher-speed, higher-capacity devices and opto-electronic integrated devices for 6G. Lastly, we will continue to develop network platforms that include data processing and other processor operations.

In Conclusion

This white paper presents Fujitsu's perspective on society in 2030 and how networks and their underlying technologies will evolve. With the uptake of digital technology in industry and society, the future shape of society is growing ever clearer. The success of future societies relies on networks evolving, and technological innovation in hardware as well as software will play an integral role. Fujitsu will contribute to the development of society by delivering advanced network technologies to our customers around the world.

Acronyms

AI	Artificial Intelligence
API	Application Programming Interface
CNF	Cloud Native Network Function
CPS	Cyber Physical System
CU	Central Unit
D2D	Device-to-Device
DU	Distributed Unit
EMS	Element Management System
HD	High Definition
IAB	Integrated Access and Backhaul
ICT	Information & Communication Technology
IoT	Internet of Things
IT	Information Technology
NMS	Network Management System
OS	Operating System
PF	Platform
RAN	Radio Access Network
RU	Radio Unit
SDGs	Sustainable Development Goals
SDK	Software Development Kit
SDN	Software Defined Network
UAV	Unmanned Aerial Vehicle
VNF	Virtual Network Function
vRAN	virtual Radio Access Network
WDM	Wavelength Division Multiplexing
XR	eXtended Reality

About Fujitsu

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