Information and Communication Management in the 5G Era for Connecting Cyberspace and Physical World

● Akiko Yamada ● Miyoshi Saito ● Jun Kakuta ● Tatsuro Matsumoto
● Kenichi Horio ● Kenji Hikichi

As the 5th Generation Mobile Communication System (5G) era approaches, various efforts are underway to realize cyber-physical systems (CPS) in which real world people/things and the cyber world come together. Fujitsu Laboratories conducts R&D on key technologies to facilitate the social implementation of diverse CPS services and enable experiences never before possible. The "field area management platform" makes possible control of various devices in the real world without having to develop separate technology for each device. The "real-world service platform" enables the efficient implementation, in line with real world states, of the combining and recombining of services that handle large amounts of data by mapping the real world as "virtual objects" into cyberspace. The "environmentally adaptive virtual networking technology" makes possible the construction and control of secure network environments based on the attributes of users and their purposes. This paper describes the two above-mentioned platform technologies, which are important for connecting the cyber and the physical worlds, and the networking technology to connect the real world and services in a timely and secure manner.

1. Introduction

According to an online survey conducted by Fujitsu in February 2017, 89% of business leaders are beginning to work on digital innovation.[1) In the age of digital innovation, realizing a cyber-physical system (CPS) that digitizes everything in the real world, maps it in cyberspace, and links it with various applications, to create a safer and more efficient society, is required.

Already, Uber replaces private cars, Airbnb hotel rooms, and crowdsourcing agents people's skills, with resources that can be found in cyberspace. And, by connecting these resources with people who need them, these companies are creating a new economic structure called the sharing economy that is in the process of replacing the existing industry structure.

In preparation for the 5th Generation Mobile Communication System (5G) era, Fujitsu Laboratories is conducting R&D of technologies that will dramatically expand the range of items that can be connected, such as people, things, data, and services, and lead to the realization of diverse CPS services. This further spurs the movement to replace the existing industry structure and enables various new types of experience.

This paper describes three technologies to connect cyberspace and the physical world in a timely and secure manner. The first one is the "field area management platform" for easily connecting people and things in the real world to CPS. The second is the "real world service platform," which allows applications in cyberspace to easily detect the state of people and things in the real world and provide services accordingly. The last is "environmentally adaptive virtual networking technology" for securely connecting the real world and cyberspace according to the use situation. Finally, the paper touches upon technologies that are advancing R&D to solve various other challenges.

2. Easily and safely connecting cyberspace and the physical world

Various challenges will have to be addressed to allow the connection of all kinds of things and accelerate the social implementation of CPS. Until now, complicated procedures were required before data such as the situations of people, things, and fields in the real world could be used from services. For example, one of the hurdles that hinder smooth implementation is the necessity of individual configuration and development for each service.

For this reason, Fujitsu Laboratories is developing technology that makes it possible to construct and use CPS easily and safely by endowing the space (interface) where the real world and cyberspace come together with functions (**Figure 1**).

As the interface on the real world side, we provide the "field area management platform," an operation platform capable of easily handling various devices through the Web of Things (WoT)[2] under standardization by the World Wide Web Consortium (W3C). WoT is a technology that allows any device to be handled by web technology. Through the provision of WoT APIs, the creation of new applications linking existing web services/business applications and devices can be accelerated. As the interface on the cyberspace side, we provide the "real world service platform," a platform that allows easy coordination with a large number of things in the real world when creating applications and services. With regards to networking, which is essential for CPS, our "environmentally adaptive virtual networking technology" allows easy connection and disconnection of things and services according to real world states.

These three technologies are described in greater detail in the following sections.

3. Field area management platform

Under the CPS scheme, devices are placed in the field (field area) and are connected to a network for the provision of services. The devices used in the field area are subject to various issues, such as the lack of a common interface, the need to use wireless communications in spite of stability issues, and limited availability of resources and functions. This makes it difficult to realize a safe and stable system that allows various devices to be used from a given service.

To overcome these hurdles, Fujitsu Laboratories has been developing field area operation and management platform technology. This section describes the technology for making devices easy to use from services.

The wireless standards and protocols of the various devices used in the field area often differ among devices. Thus, an issue was the need for individual development of interface software on the cloud and gateways for each device to allow its use from a service,

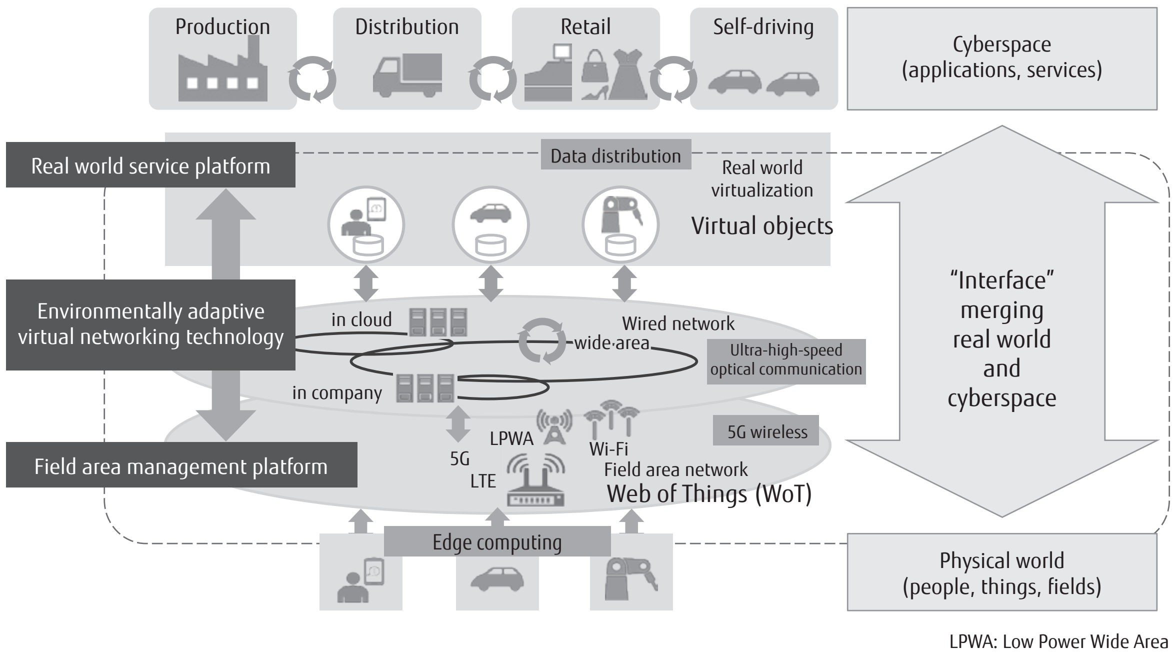

Figure 1
R&D activities for social implementation of CPS.

resulting in high development and deployment costs (**Figure 2**, left).

To overcome this problem, we developed a device virtualization method that manages any device as a common type of device (virtual device) having a common interface including application programming interfaces (APIs) and data model.[3] In this method, the functions of the device are modeled as operations for the properties defined for each type of the device. As a result, various device functions can be controlled by invoking one of four types of operations for device properties, namely *get* (device data and status acquisition), *set* (control of device functions), *subscribe* (device data and status change notification request), and *notify* (device data and status change notification).

This method is based on two major technological elements, namely device adaptation technology to terminate protocol processing for each device, and device management APIs for operating virtual devices from applications (Figure 2, right).

1) Device adaptation technology

Processing of the various protocols of different devices is handled by combining adapters that perform Internet Protocol (IP) and other communication processing, and adapters that perform data processing such as ECHONET (a communication standard for home appliances),[4] unit system conversion, and the like. In the past, all required software for application and device processing was developed when new devices were connected, but by using this technology, only the required adapters that are not available need be developed. It was confirmed that the amount of development required when connecting a new device can be reduced to 1/2 or even 1/3 by dividing the conventional processing of devices into communication processing and data processing.

2) Device management APIs

The device management APIs used in the developed technology to manipulate virtual devices were configured so that they can be easily used from multiple systems by switching software modules that realize the aforementioned four kinds of operations. On the other hand, the need to change software modules for each application can be avoided through the provision

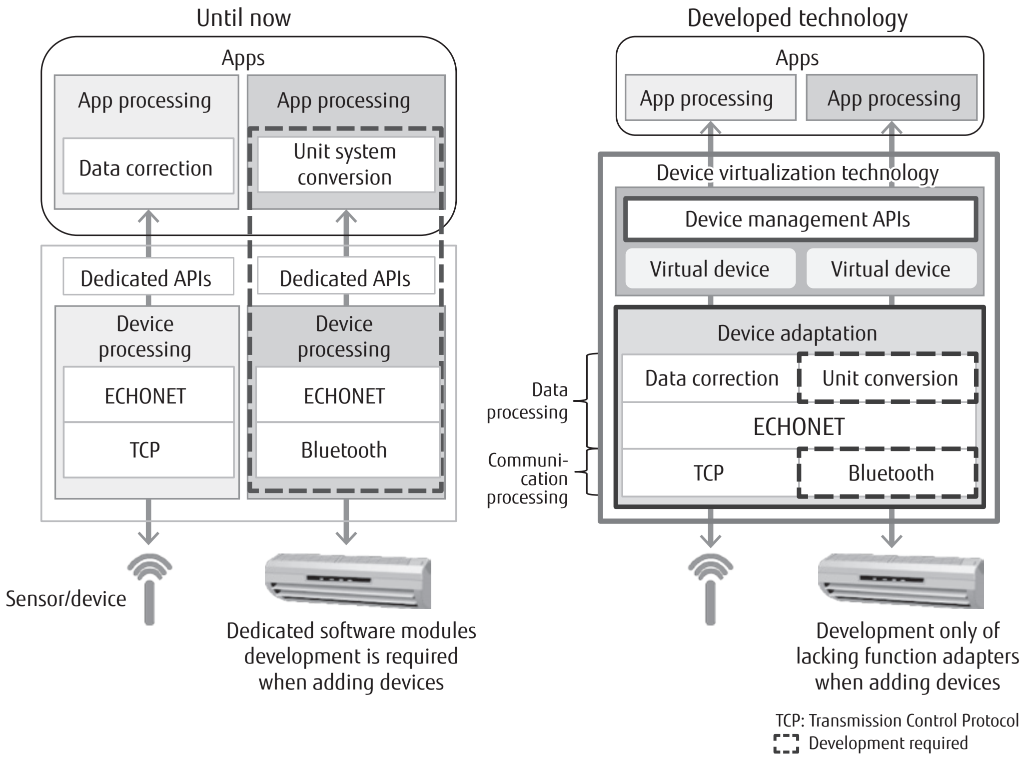

Figure 2
Device virtualization technology.

of widely used standard device management APIs. Thus, for default device management APIs, Fujitsu Laboratories is currently working on the standardization of the WoT standard, along with compliance with WoT Thing Description in WoT, and the draft version of the WoT Protocol Binding Templates.

4. Real world service platform

In the CPS era, services that meet real world states will be provided by connecting people and things in the real world to networks, and by linking them with services in the cloud.

Fujitsu Laboratories has been promoting the development of a real world service platform. This platform realizes more efficient development of services that provide optimal information and applications according to real world states. It places data synchronized with the real world states of people and things (hereafter, virtual objects) on the cloud and achieves simple handling of real world objects from the cloud.

This section introduces the basic concept of the real world service platform, issues regarding the implementation of this platform, developed technologies, and application examples.

4.1 Concept of real world service platform

So far, CPS has been expected to solve particular problems by grasping detailed and accurate information of specific sites. Recently, expectations have expanded to include wide-area optimization and the creation of new services that span multiple sites, tasks, and industries. Wide-area optimization through the coordination of multiple services, and support of changes in service behavior according to on-site states, are difficult to achieve if attempted through the conventional development of vertically integrated services that are closely linked to devices and services. Therefore, assembly-type development that allows developing and changing services in an evolutional manner by flexibly combining specific functional units is required.

To facilitate such assembly-type development, we proceeded with the development of the real world service platform based on the basic concept of translating real world people and things into web APIs allowing flexible combination and coordination with services.

4.2 Challenges

Based on the above-mentioned concept, the challenges to be overcome in developing and operating services linked with the real world are described below.

1) Challenges in service development

- Challenge 1

Countless IoT devices such as sensors and devices are connected to networks, but they all differ in terms of interfaces and functions. Therefore, unless one is familiar with the specifications of each IoT device, it is difficult to develop services that utilize such devices.

- Challenge 2

With services that use IoT devices, the format and reception timing of data obtained from IoT devices all differ according to the service content. If format conversion and timing adjustment are implemented in a service, modification of the service is required when different IoT devices are used.

2) Challenges in service operation

- Challenge 3

To grasp real world states in real time and stably provide services accordingly, it is necessary to process real world data obtained from a large number of IoT devices in real time. Furthermore, when a system failure occurs, quick recovery without data loss and time sequence inconsistencies is required.

- Challenge 4

Since it is difficult to prepare real world data and conduct detail verifications using it in advance, it is not easy to fix specifications before service operation. Therefore, after a service is launched, it is necessary to continuously change its specifications according to real world data while maintaining continuous service.

4.3 Developed technology

To solve the challenges mentioned in the previous section, we developed the following technologies and constructed the real world service platform.

1) Real world virtualization platform technology

To overcome challenges 1 and 2, we developed the real world virtualization platform[5] shown in **Figure 3**. On this platform, objects are placed and virtualized in the cloud in units of people and things synchronized with real world event data. Objects have an internal state that reflects in real time the real world states of the corresponding people and things.

The following two types of objects can be used.

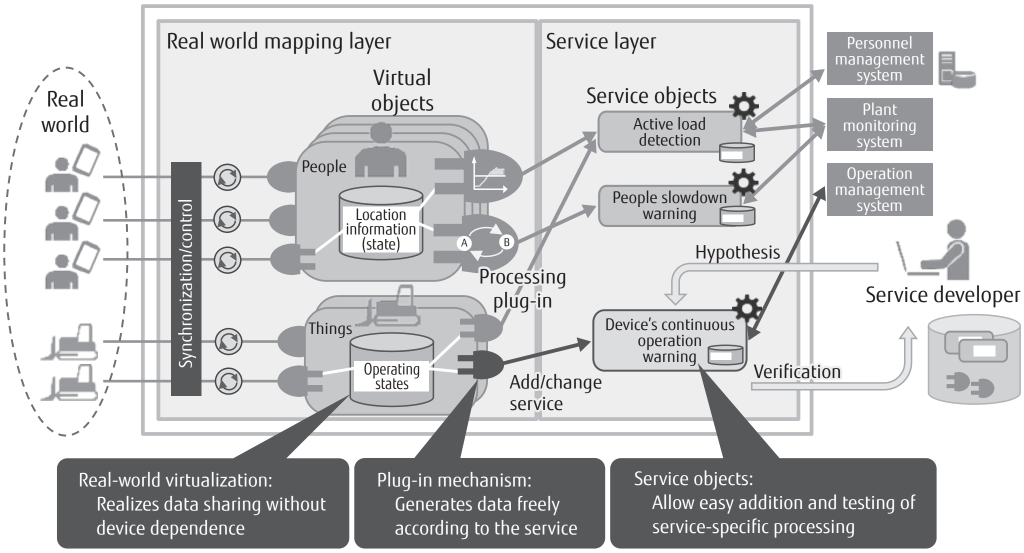

Figure 3
Real world virtualization platform technology.

- Virtual objects

The latest states of people and things in the real world (location of people, motions of machines, and so on) are held as states.

- Service objects

Upon reception of an event from a virtual object, service specific processing (detection of loads of activities from changes in people's location information, warnings of abnormal continuous operation from operating states of machines, and so on) is performed, and the results are output as states of the objects in question.

Furthermore, the platform has a plug-in mechanism that allows the addition of data processing. The specific states of an object are monitored, any state change is treated as an event that activates the plug-in, and the results of the processing done (data abstraction level control, data format or type conversion, new data generation combining multiple data, and so on) are output as another state.

2) Distributed event data processing platform technology[6]

Figure 4 shows the distributed event data processing platform for overcoming challenges 3 and 4, and the functions of that platform are described below.

- Distributed event data processing

To process event data in real time with high throughput, we adopted Apache Flink,[7] which is open source software (OSS). Apache Flink can hold arbitrary states in distributed nodes. For this reason, it is suitable for applications that provide services according to the past event history and the resulting current state. Plug-ins of objects defined by real world virtualization are deployed on distributed nodes as tasks on Apache Flink, and event data processing is performed accordingly.

- Plug-in updates

After sequentially distributing the plug-in to be updated to the distributed nodes, switching plug-ins in synchronization with the time stamp of the event data is performed. This makes it possible to update the plug-in while maintaining process consistency without temporarily stopping event data processing. Which of the plug-ins registered to the distributed nodes is to be used to process the event data is decided by using the valid period information set for each plug-in.

4.4 Application example

This platform can process large amounts of information obtained from people and things in real time. As a result, it can be expected to be applied to various services such as car insurance and operation support that utilize the data of connected cars, monitoring of elderly people and tourist guidance through the use of human data, among other things.

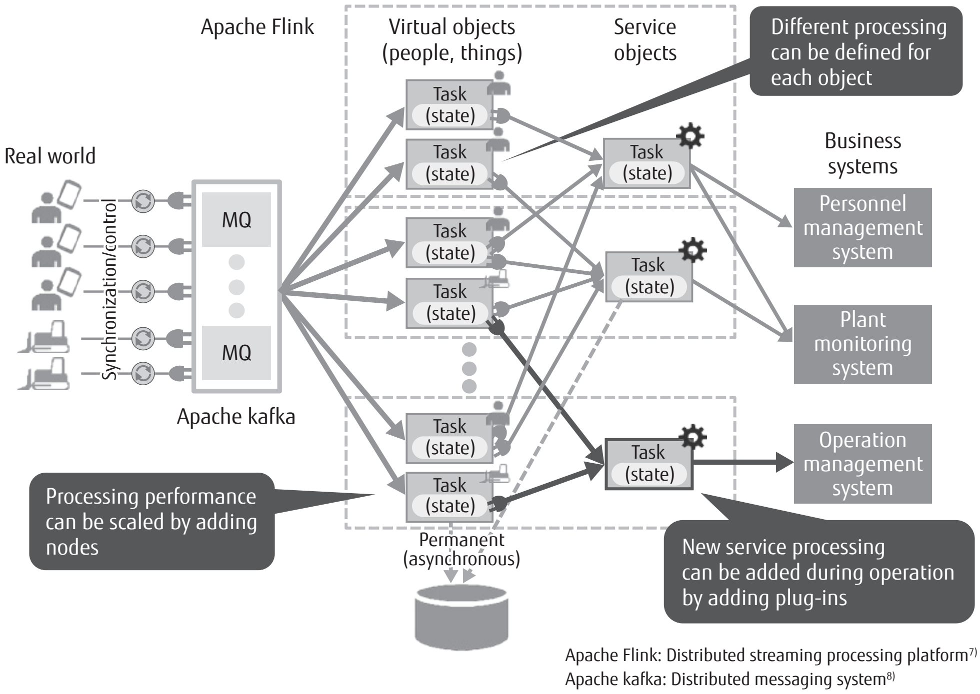

Figure 4
Distributed event data processing platform technology.

5. Environmentally adaptive virtual networking technology

In CPS, various things and services are connected by a network, thereby merging cyberspace and physical space. However, how things and services should be connected depends on the user's location, purpose, and intended use. For example, in the case of a co-working space where employees of different companies share a work place, there is a desire to realize a work environment where it is easy and safe to utilize internal services of each company. In other words, what is desired, as long as employees use the on-site facilities, is for employees to be able to safely connect to the in-house network so that only necessary information flows to and fro.

5.1 Challenges

Meeting such demands necessitates global control of the site and the company's services/network, and so on, according to the authentication results for things and people. However, if authentication methods, services, and networks are set up according to the individual requirements of each company, this raises the problem of very high operational costs. This is because it is necessary to find out the purpose and intended use from each user in the co-working space to make individual settings accordingly.

5.2 Developed technology

To solve this problem, Fujitsu Laboratories is developing "environmentally adaptive networking technology" that, even for shared places and things, makes it possible to dynamically construct and control at low cost "virtual network environments according to the people who will use them and their purposes" (hereafter, service spaces). **Figure 5** shows the system configuration for a co-working space to which this technology is applied, and **Figure 6** shows an example of the screen.

This technology is characterized by the fact that edge switch control is performed by a software-defined networking (SDN) controller and/or virtual network function (VNF) deployment manager in coordination with a data layer such as an authentication function, using the service space control manager in Figure 5. This makes it possible to dynamically and quickly construct and control a secure network environment

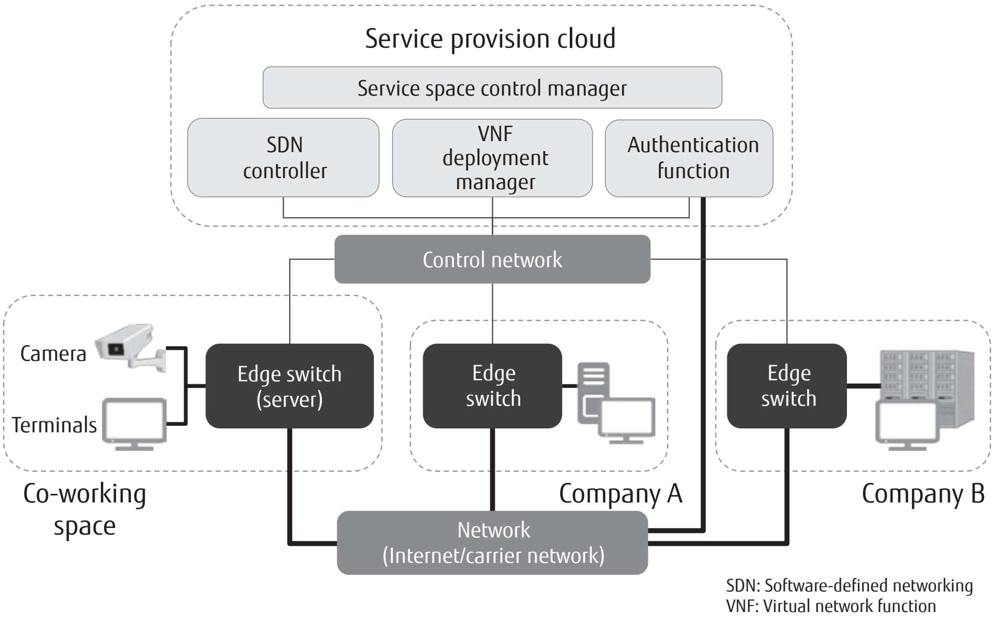

Figure 5
System configuration for a co-working space.

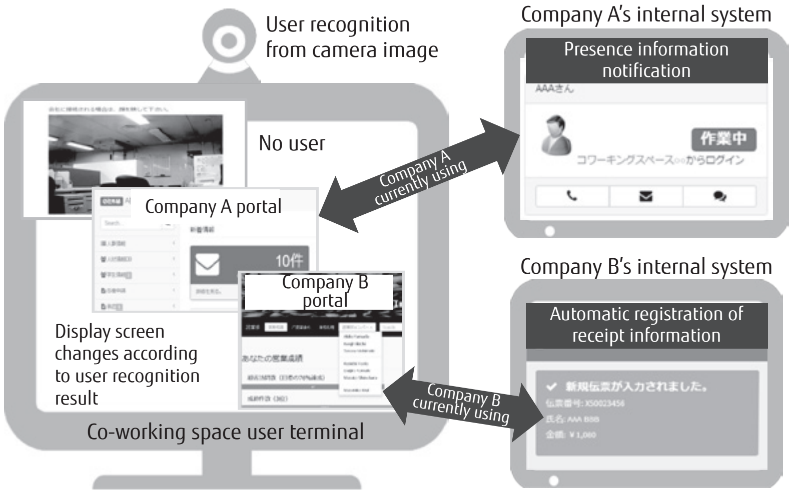

Figure 6
Example screens of co-working space user terminal, and user company's internal systems.

according to the users and their purposes. Furthermore, simply by describing the service design for each user, it is possible to create service spaces according to various uses at low cost. This service design consists of events that serve as a trigger for the utilization of the service space and actions that indicate concrete control.

5.3 Application examples and assessment

The operation of this system is explained below by taking the aforementioned co-working space as an example. As a premise, various equipment (terminals, cameras, etc.) are made available for use in the co-working space. Further, the network cameras installed in front of the terminals are linked with an authentication function as shown in Figure 5. Using face

Table 1
Examples of actions in co-working space.

Tenant ID	Event	Action
Company A	Employee detection	1) Build a closed network with the servers of the Human Resources Department 2) Provide a presence detection function on edge
Company B	Employee detection	1) Build a closed network with the Accounting System 2) Provide a receipt reading function on edge

recognition, they automatically detect who is using a terminal. Moreover, the service space was designed so that when employee detection is set as an event, action is taken according to the face recognition result. **Table 1** lists examples of actions in the co-working space. This service design is applied to the service space control manager in Figure 5.

For example, when an employee of the Human Resources Department of Company A sits in front of a terminal in the co-working space, that employee is recognized as an employee of Company A. Then the terminal quickly connects to the server of the Human Resources Department of Company A via virtually closed network. Furthermore, the presence detection function is deployed in the edge switch within the co-working space, and the presence status of personnel of the Human Resources Department is transmitted to that department's manager at Company A.

On the other hand, when a sales staff of Company B sits in front of a terminal in the co-working space, the system connects to the accounting system of Company B, and a receipt scanning function is deployed. This function scans receipts using a camera, converting them into text that is then transmitted to the accounting system.

Such functions are micro services that filter and convert camera images in the network. Through the deployment of such functions, advanced functions such as presence verification and image recognition, which are not implemented inside cameras, can be used. In other words, it is possible to customize the space in which a user is located into a more convenient service space, as well as prevent unneeded information contained in images from flowing into the network. By doing so, the same system can be used for various applications by changing the deployed functions and equipment. Moreover, upon camera detection of users leaving their seats, their respective terminals and cameras in the co-working space can be quickly disconnected from the respective networks of their companies to prevent unauthorized access.

We were able to confirm that service spaces can be smoothly formed, switched, and discarded by connecting things and services with this technology, yielding at low cost safety and convenience according to the intended application.

6. Toward the realization of CPS

For the realization of CPS, Fujitsu Laboratories conducts research and development in various fields besides the technologies introduced in this paper.

For example, in the area of field area networks, we have highly reliable 5G millimeter wave radio technology[9] that allows mobile devices to connect with large capacity and low latency even in crowded areas that contain many devices. We also have field engineering technology[10] allowing easy construction of wireless systems while taking care to prevent problems such as interference. Further, in the area of wired networks, we have next-generation ultra-high-speed optical communication technology[11] that supports communications of increasing capacity as CPS implementation progresses.

In the area of real world virtualization, we are developing Virtual Private digital eXchange (VPX),[9] a secure data distribution platform that data holders can use with confidence. Further, we have realized optimal distributed processing considering both the real world and cyberspace, and we are developing wide area distribution execution control technology supporting smooth data distribution (Dynamic Resource Controller: DRC).[9]

7. Conclusion

This paper introduced field area management platform technology, real world service platform technology, and environmentally adaptive networking technology to securely connect the real world and cyberspace—all fundamental technologies developed by Fujitsu Laboratories to allow easy CPS use. These technologies not only allow easy linking of all sorts of things, but also realize reconfigurable service development tailored to the real world states and the creation of environments that can be tailored to specific purposes. As such, they are important technologies for the effective promotion and realization of CPS ensuring safety and convenience.

The social implementation of CPS is expected to accelerate with the introduction of 5G in 2020. In preparation, besides the technologies presented in this paper, we will also enhance technology to promote data distribution, technology for efficient process execution and control, and technology for optical/wireless communication. Furthermore, we will make the necessary technology widely available through cloud services and the like to make it possible to all kinds of things in the real world to connect with cyberspace and thereby contribute to the realization of powerful CPS services.

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Akiko Yamada
Fujitsu Laboratories Ltd.
Ms. Yamada is currently engaged in digital business creation activities aimed at spreading 5G networks.

Miyoshi Saito
Fujitsu Laboratories Ltd.
Mr. Saito is currently engaged in research and development of IoT/cyber-physical systems.

Jun Kakuta
Fujitsu Laboratories Ltd.
Mr. Kakuta is currently engaged in research and development on operation management technology for field area networks.

Tatsuro Matsumoto
Fujitsu Laboratories Ltd.
Mr. Matsumoto is currently engaged in the development of the real world service platform.

Kenichi Horio
Fujitsu Laboratories Ltd.
Mr. Horio is currently engaged in digital service development and research and development to make the execution of digital services easier and more secure.

Kenji Hikichi
Fujitsu Laboratories Ltd.
Dr. Hikichi is currently engaged in research and development of advanced network operation management.