Hyperconnected Cloud to Embrace Megatrends in ICT

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With significant changes occurring on a daily basis, the information and communications technology (ICT) industry is coming to a major turning point, potentially facing an imminent paradigm shift, or business revolution. Fujitsu is dedicated to embracing new trends while maintaining its previous system integrator (SI) business models. As the Group's R&D center, Fujitsu Laboratories plays an increasingly significant role in group-wide activities. In this paper, we present an overview of recent ICT megatrends and future prospects from a technological perspective. We then describe our R&D strategy for achieving the "hyperconnected cloud" of the future.

1. Introduction

The rapid development of information and communications technology (ICT) is bringing about a major revolution in the way people live and businesses operate. In particular, the proliferation of mobile computing combining smartphones and cloud services is driving major changes in the way people come into contact with ICT. The emphasis is shifting from a physical orientation centered around servers, terminals, and networks to a functional orientation centered around services, data, and user interfaces. Furthermore, the Internet, which began simply as interconnections among host computers, is now expanding into an Internet of Things (IoT) that can interact directly with devices without human intervention. It is expected that mobile computing and the IoT will eventually be provided as cloud services.

In short, there is a growing demand for functionalization and abstraction from the user's point of view; however, at the same time, the supporting infrastructure is becoming increasingly diverse and complex. As a result, ensuring continuous system operation while maintaining compatibility between services and the infrastructure is becoming increasingly difficult. In addition, security tends to degrade as system convenience increases, so ensuring system security and robustness while maintaining convenience is becoming a major issue.

In this paper, we first examine these ICT megatrends in more detail and present the direction of research and development at Fujitsu Laboratories in the face of these trends. Then we consider where ICT should be strengthened and where it should be transformed.

2. Megatrends in ICT and hyperconnected cloud

Megatrends in ICT can be organized along three technology axes. As shown in **Figure 1**, the evolution of technology can be represented as flows from a center starting point. At this starting point, systems have been constructed through the interconnection of terminals, servers, and storage equipment via a network. Now, as a result of technological innovations along the three axes, systems are evolving into a form consisting of mobile/IoT, cloud, and big data. Looking forward, we can expect virtualization to progress so that the physical borders between these axes disappear and technologies that have so far been developed individually converge at the service level. For this reason, it is becoming especially important to develop technologies in a composite domain enclosed by these three axes and to enhance the corresponding business domain.

At Fujitsu Laboratories, we expect that the continuing expansion of the cloud will lead to convergence of the digital world and real world and that this massive

space will become the business platform of the future hyperconnected world. We therefore express the future direction of research and development at Fujitsu Laboratories in terms of a "hyperconnected cloud." As schematically represented in **Figure 2**, technology is evolving from a format in which clients remotely access services provided through consolidated servers forming a data center cloud to one in which they access services provided through transformed real-world spaces forming a hyperconnected cloud. The aim is to construct a world in which the Web space expands from a hypertext to a hyper-service format in which services can be used from anywhere as needed.

In the following, we discuss in more detail research and development at Fujitsu Laboratories along each of these technology-domain axes.

3. Research and development for embracing ICT megatrends

1) Mobile/IoT axis

The mobile/IoT axis is clearly the driver of the hyperconnected world, and the most important technical innovation accelerating this movement is network virtualization, including wireless networks. The network evolution from an all-Internet protocol (IP) network to an all-Web network is shown in **Figure 3**. In the past, practically all applications were constructed on TCP/IP, the standard protocol supporting networks. At present, however, the trend is toward applications created with Web technology placed above TCP/IP. It is therefore thought that the existence of the IP network itself will eventually be concealed and that the network on the whole will evolve to a point at which programs that

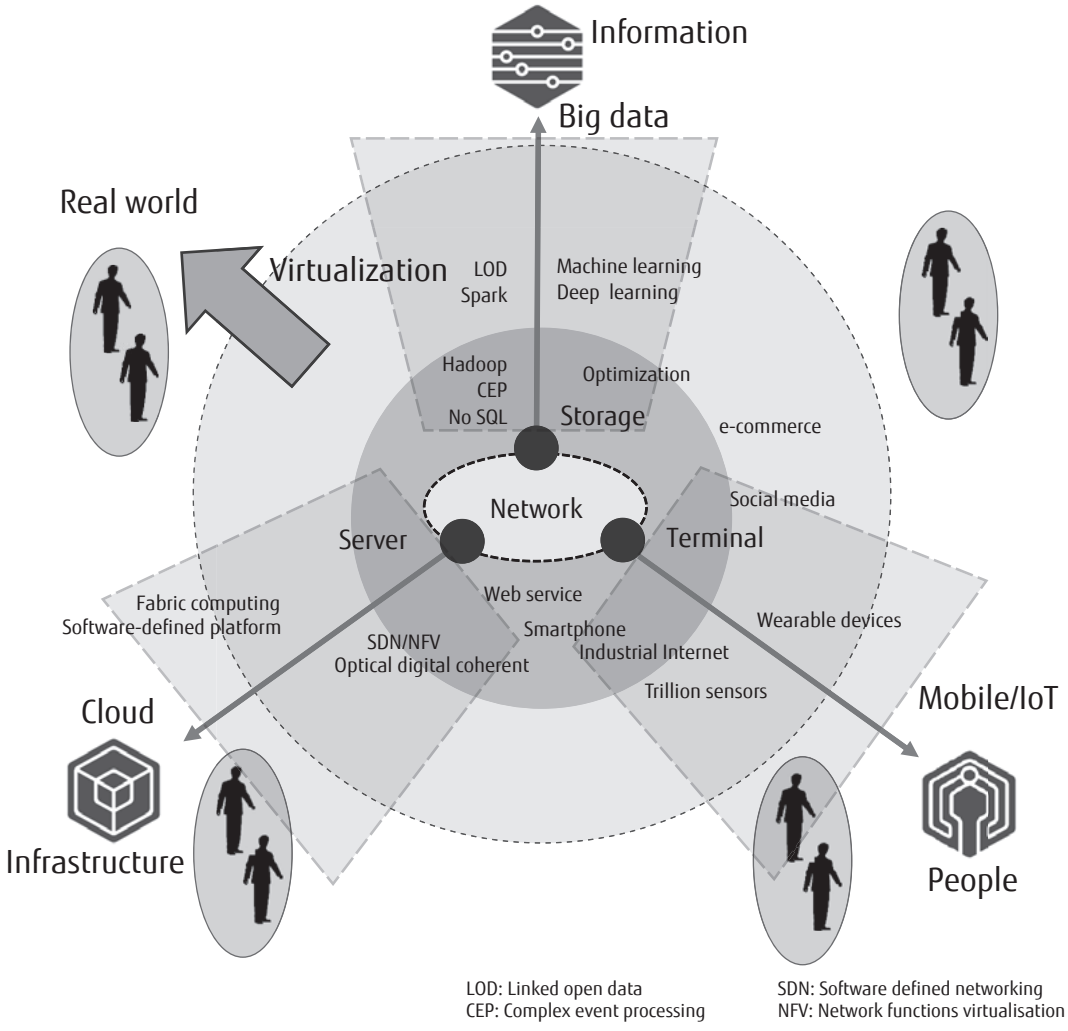

Figure 1
Megatrends in ICT.

incorporate Web application programming interfaces (APIs) simply combine services as needed. In addition, the appearance of the IoT stage will extend this evolutionary trend to the real world so that real-world non-IP networks that could not be interconnected in the past and small devices that could not process protocol termination will come to be integrated as a system. This calls for a radical change in network architectures—

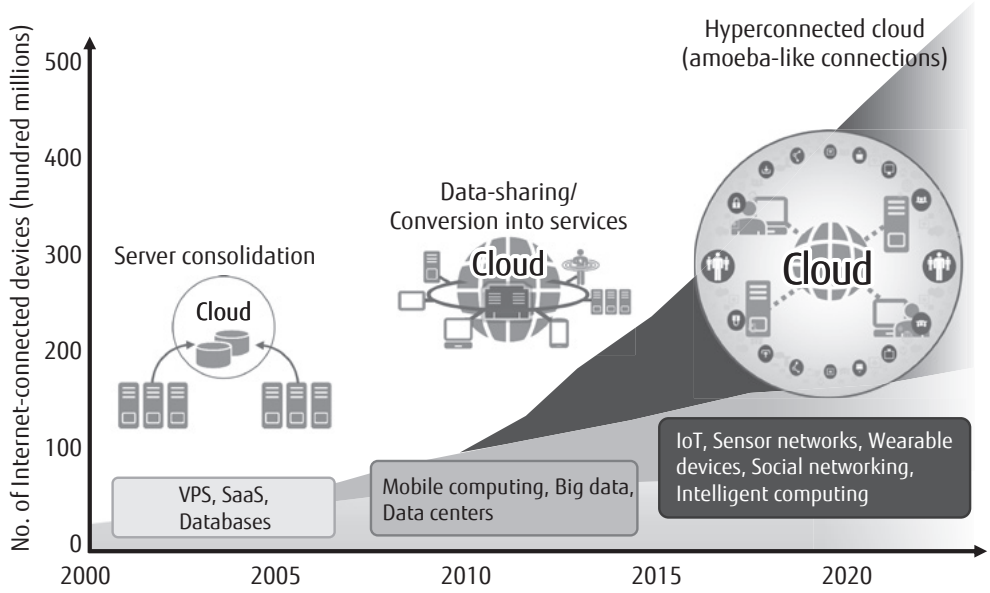

Figure 2
Hyperconnected cloud.

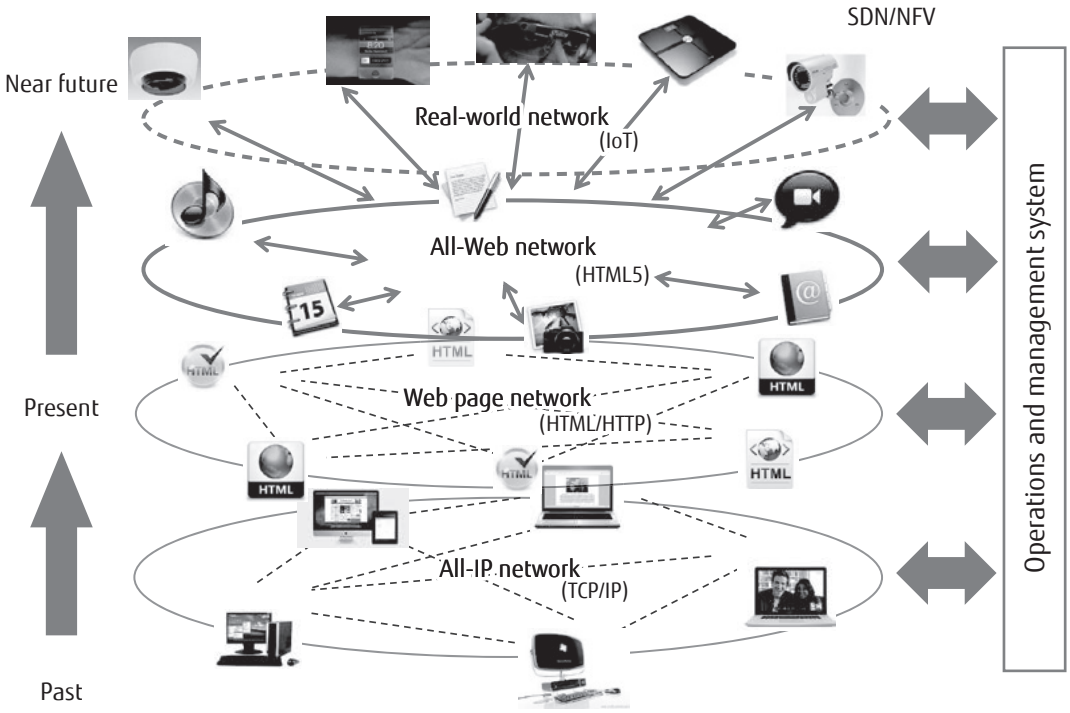

Figure 3
Progress in network virtualization.

network control must be closely linked with operations and management of the applications system.

The conventional client/server model treats the server that provides services and the client that uses those services as basic units. These units were implemented as separate pieces of hardware, and the boundary between the network and applications was fixed, which facilitated development and continuity in the computing model. The client/server model has been preserved even with the coming of the Web-browser-based 3-tier Web model. The appearance of smartphones has triggered the spread of Web API development tools and HTML5. As a result, distributed Web-OS technology is coming to permeate frontend systems. At the same time, it is becoming necessary for service functions to run not only on servers but also on terminals, and conversely, for client functions to run on the server side as well. In addition, the appearance of the IoT is accelerating horizontal linking between terminals, and in the case of machine-to-machine (M2M) communications and big data applications, the direction of data flow between clients and servers is frequently becoming reversed. In this way, the functional role of services, the physical location of service execution, and the direction of information transfer are becoming independent of hardware, and the network architecture is becoming software defined. This is having a major effect on development and operations-and-management methodologies.

This new frontend-based computing model is shown in **Figure 4**. The basic idea of this model is that a client application (written in a scripting language) calls cloud services in the digital world and device-access services in the real world via a Web API in accordance with the current location and context. This model includes a mechanism that dynamically maps these processes to a physical execution location in accordance with the present circumstances, as shown on the right of the figure.

This is the true meaning of the hyperconnected cloud promoted by Fujitsu Laboratories. Although business systems have been somewhat behind consumer systems in the support and penetration of service modularization, it is thought that they are now moving in this direction despite many twists and turns.

2) Cloud axis

The basic concept of cloud computing is to provide ICT core functions via the network as software services in comparison to the conventional method of providing them via servers and databases. In addition, design work in system construction is migrating from a method that sequentially implements a function from required specifications to a standard method that combines ready-made service components in accordance with requirements. It is therefore likely that the methods used for testing, maintaining, and updating will fundamentally change, making it necessary to revise the operations and management system.

The logical configuration of the hyperconnected cloud is redrawn in **Figure 5** from the viewpoint of network operations and management. Thanks to software-defined networking (SDN)/network functions virtualisation (NFV), progress has been made in network virtualization and unified management. We can therefore expect increasing use of a format that links multiple clouds and that dynamically links conventional frontend systems with cloud services as opposed to a use of individual clouds. The issue of concern will thus become how to achieve a mechanism that can standardize—at the network level—the infrastructures constructed for each cloud and dynamically provide services within a cloud, between clouds, and between a cloud and terminal. In other words, importance will be attached to 1) a mechanism equivalent to a software bus that can make the differences in network protocol invisible to an upper-layer application and 2) an arbitration function that can dynamically provide only necessary services. In particular, there will likely be an increasing number of opportunities for providing solutions that combine open cloud services with private spaces centered around corporate intranets and personal terminals. Constructing such a platform with SDN/NFV technologies and operating it as a "coordination cloud" will enable the achievement of a mechanism that can respond flexibly to a wide variety of customer requests.

3) Big data axis

In the hyperconnected cloud, data that up to now has been consolidated in data centers will come to be dispersed and deployed in all sorts of places. This new regime will require the way in which we handle and process data to be radically revised. The current database system achieves a balance between the speed of information generation and that of information storage

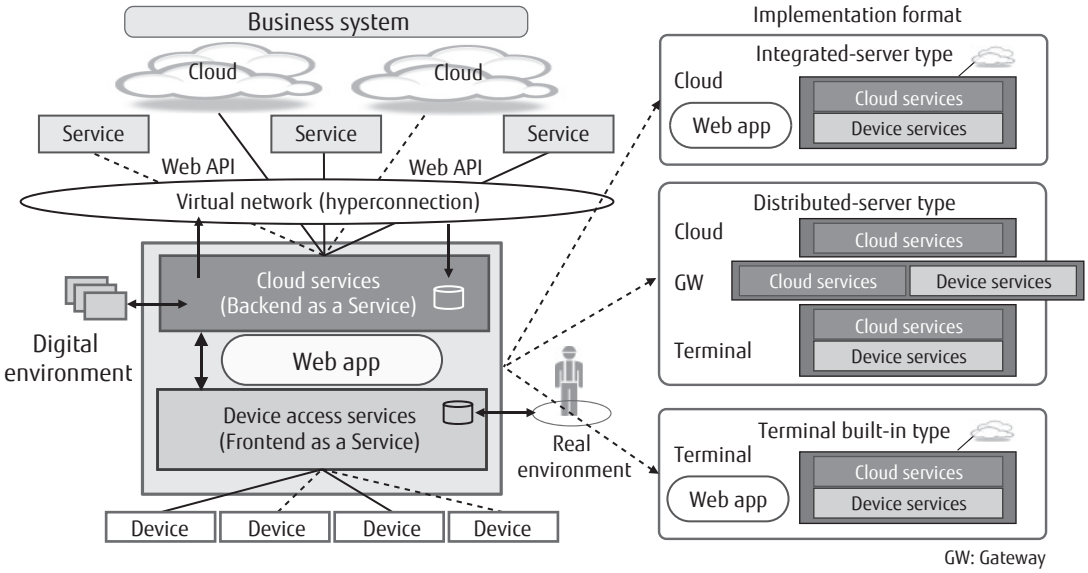

Figure 4
New computing model.

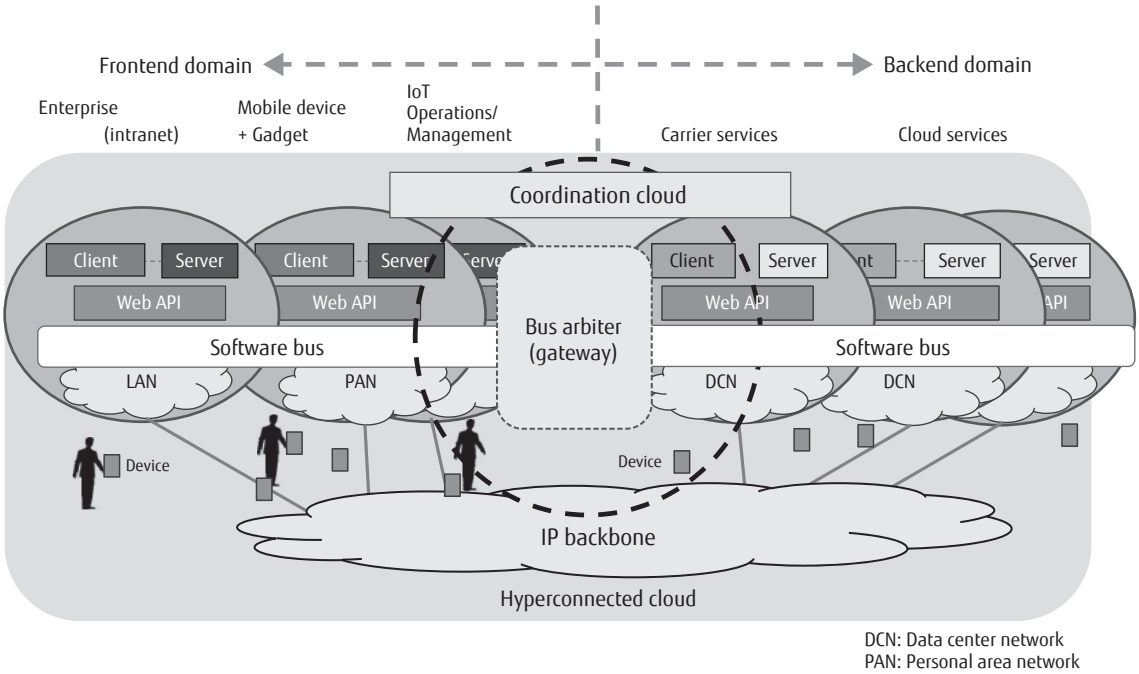

Figure 5
Logical configuration of hyperconnected cloud.

and processing, so conversion processing between the storage phase and the usage phase for each application may be done in a batch manner without problem. In the IoT era, however, the speed of data generation and the amount of information will increase by an order of magnitude. There will therefore be a need for a mechanism that can perform sequential high-speed processing in such a way that data can be organized by purpose while being collected. From here on, this trend looks to accelerate if the unstructured and non-text type of information from sensors or devices comes to be collected in large volumes over the network. In

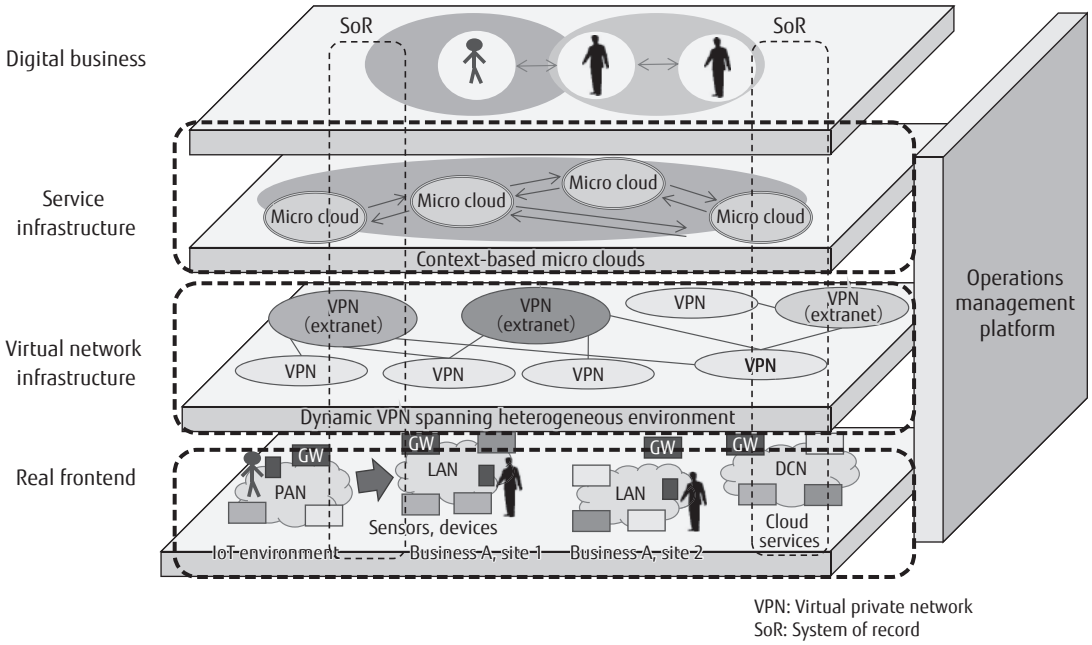

Figure 6
Hierarchical model of hyperconnected cloud.

fact, the database as an entity is likely to disappear under such conditions. Determining how to manage access to such distributed forms of data will become a major issue in terms of architecture. For example, new mechanisms such as those that integrate the data to be accessed with the access method itself will become increasingly important.

A hierarchical model of the hyperconnected cloud integrating the elemental technologies described above is shown in **Figure 6**. In the future, it will be necessary to provide solutions in diverse forms that integrate the digital service environment provided by the cloud and the frontend physical environment driven by people. It would be impractical to prepare each and every such solution as a vertically integrated system of record (SoR). It will therefore be important to provide a Systems of Engagement (SoE) mechanism as a total cloud system that can horizontally link these vertically directed systems in accordance with operating conditions. In the figure, the upper two layers represent a conventional data center cloud and the bottom layer represents the physical terminal/network configuration corresponding to the real frontend. These layers are dynamically linked by an intermediately positioned virtual network infrastructure. SoE operation can be enabled by dynamically controlling these layers via an operations and management platform, as shown in the figure.

4. Conclusion

In this paper, we organized ICT megatrends into specific categories and described the research and development at Fujitsu Laboratories directed toward achieving the "hyperconnected cloud" as the next mainstream paradigm. Today, there's no doubt that the world of ICT is moving in the direction of virtualization and super-distribution, which is making it easier to combine basic components to create and run a system and change functions without deep knowledge. At the same time, it is becoming increasingly difficult to continuously and consistently provide high performance, security, and robustness throughout the system. This is a field in which Fujitsu's role as an ICT integrator takes on particular importance.

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