Fujitsu's Approach to IoT Business and its Related Technologies

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The Internet of Things (IoT) is now in the spotlight. It is not an exaggeration to say that not a day passes without it being mentioned by the media. An analysis of IoT-related projects has shown that, in addition to the conventional emphasis on return on investment, enterprises are creating new value by giving people new products and raising their awareness of previously unrealized value. Fujitsu has established the concept of "Human Centric IoT" and is moving forward with various activities to realize a world where the IoT has people at the core. For example, we have developed IoT implementation models that clarify the values that can be realized by combining IoT-related products, and we use these models as the basis for co-creating business with customers and forming an ecosystem with business partners. The scope of the technologies to be covered by a system to realize this world is very wide. There are requirements specific to IoT systems that differ from those for conventional information and communications technology (ICT) systems. Therefore, Fujitsu is working on new research and development with the focus on the characteristics of IoT. This paper describes Fujitsu's approach to IoT and the related technologies it is developing.

1. Introduction

The Internet of Things (IoT) has moved into the spotlight in all sorts of media, which suggests that society has finally come to embrace it. When the expression "Internet of Things" first came into use, it was often used in a literal sense, that is, as a "network of things." Recently, however, it has come to be defined as "innovation that can provide users with new value through the mutual connection of all kinds of objects, people, and places."

Why, then, has IoT been thrown into the spotlight? The reason is thought to be the emergence of two major trends in the business environment. The first trend is *commoditization*, in which products become common and general-purpose in nature to the point that they are difficult to differentiate at the unit level. To cope with this trend, companies are working to expand their product range from things (products) to services and attempting to apply the technologies that they have so far developed and enhanced to other fields. The second trend is *borderless business*, in which a strong player in another line of business to which no thought had previously been given suddenly enters one's own market as a competitor. Examples of this trend include Apple Watch[1] by Apple and Nest Learning Thermostat[2] by Nest Labs, a subsidiary of Google's parent company, Alphabet.

In such a severe business environment, what can an enterprise do? It should identify those things on which its end users place value, find out what they would pay for those things, and give those things a concrete form as a product,. How best, then, to identify those things? The conventional approach has been to perform market surveys or administer questionnaires, but in today's environment in which end-user values can easily change, such conventional techniques are not necessarily effective. Instead, the enterprise must forge stronger ties with end users to create a new relationship within which end-user activities can be detected by using sensing techniques and analyzed to extract information of value.

Fujitsu calls this creation of a new relationship between an enterprise and its end users "virtual relationship building." It is important that the information obtained through the resulting relationship be used to create a cycle that includes a real response such as the actual selling of things and provision of services (**Figure 1**). This virtual-and-real cycle holds not only for the relationship between a company and its end users but also for the one between a public institution and the community it serves.

A promising way to create this cycle is to use IoT and big data. This is due to technical innovations including the diversification of sensors and their decreasing cost, the development of faster and cheaper networks for collecting sensor data, and the provision of analysis tools and business applications in the cloud to process and use the data collected.

2. New trends in IoT business

In this section, we describe Fujitsu's approach to creating a virtual-and-real cycle.

In November 2014, Fujitsu announced the launch of the "Human Centric IoT" concept (**Figure 2**). In this announcement, Fujitsu declared that it would provide products, technologies, and services to achieve a cycle

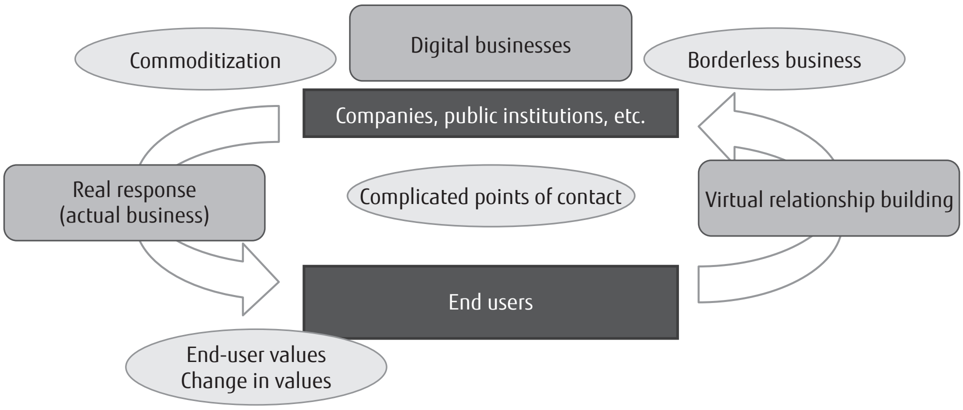


Figure 1
Virtual-and-real cycle.

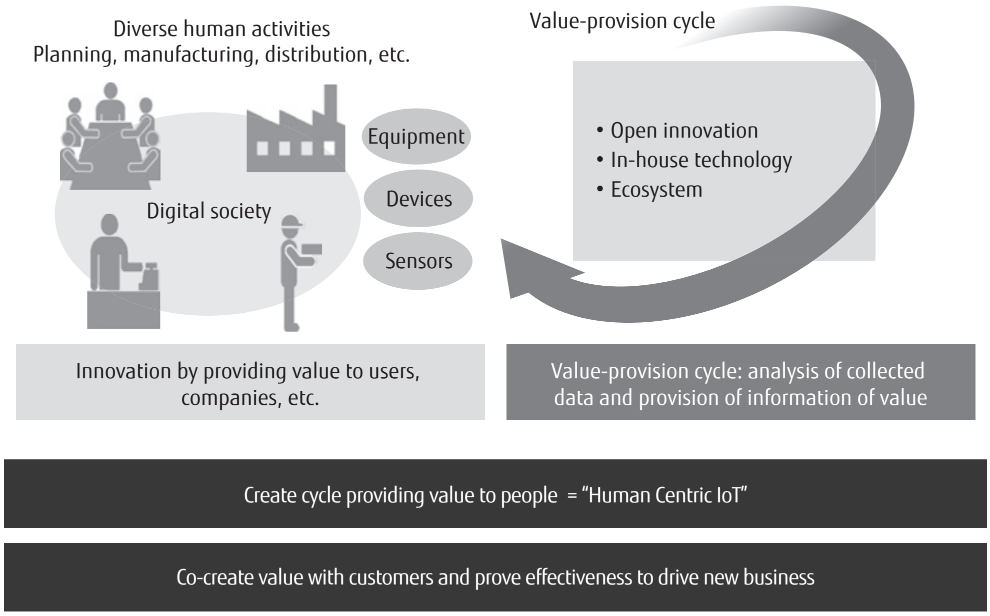


Figure 2
Human Centric IoT.

that converts human activities into new value and provides that value to people. Since then, Fujitsu has been conducting proof of business (PoB) demonstrations together with many customers. A PoB demonstration uses a small-start implementation to assess how IoT can specifically drive innovation toward achieving new value or solving social problems. It can also be used to collect the information needed to create a business budget and initiate actual business development.

These PoB demonstrations have brought several trends to light (**Figure 3**). First, machine-to-machine (M2M) technology—a precursor to IoT—has so far been introduced only in business fields in which the return on investment is clear [**Figure 3 a)**]. For example, using M2M technology to accurately replenish products in vending machines has had the effect of reducing labor costs, enabling the collection and analysis of truck driving conditions, and improving fuel efficiency by providing feedback to drivers. It has not been introduced in fields in which the return on investment is less than clear. Accordingly, the trend has been to divide M2M technology into two distinct fields: those in which its introduction is progressing and those in which it is not.

However, this trend has begun to split into three directions as the IoT concept penetrates society. The first direction is reflected by cases in which the range of obtaining a fixed return on investment is expanded to multiple businesses and/or organizations. One example [**Figure 3 b)**] is the expansion of a building energy management system (BEMS) originally used for individual buildings to the energy management of an entire city. In Germany, the Industrie 4.0 initiative promoted by industry, government, and academia can be applied in various ways, but an important theme of this initiative is thinking beyond one plant and interconnecting multiple plants, even ones used for different types of businesses. The aim is to achieve a cost structure that can support a new form of manufacturing called "mass customization."

The second direction is reflected by a need to create new value even if the effects of that value are not immediately felt. For example [**Figure 3 c)**], customers and company staff have expressed a desire for new value in the form of safety management and motivation enhancement for employees working at specific sites, inheritance of know-how from veteran employees, provision of new lifestyles, etc. Specific projects in this regard reflect a desire to check whether employees are working in a safe environment through the use of sensing technologies, a desire to motivate employees by visualizing the conditions of a plant manufacturing line and determining in real time the results of improvements made from the viewpoints of employees, on-site supervisors, and managers, and a desire to give the elderly peace of mind through a feeling of being cared for by collecting useful information from walking-support tools. In short, an attempt is being made to extract new value from the virtual relationship between a company and its employees or a company and elderly persons and from the real response to this relationship.

Finally, the third direction is toward the emergence of new changes even in fields in which the introduction of M2M technology is progressing. This reflects a move from the use of M2M technology that is limited to objectives with a clear return on investment to expanded use of M2M technology with the aim of creating new value [**Figure 3 d)**]. In this regard, efforts have begun toward the creation of new value related to safety and security. For example, in addition to improving fuel consumption in trucks, M2M technology can be used for detecting drowsiness in a truck driver and sounding an alarm.

3. Business co-creation with customers and ecosystem formation

At Fujitsu, we are preparing IoT implementation models (**Figure 4**) based on the knowledge gained from the PoB demonstrations described above. They are customized to match the target application and show the specific value that can be provided in combination with sensors and other IoT-related products, with devices and gateways that accommodate or connect those sensors, and with network services, cloud infrastructures, and analysis tools.

There are three main reasons for preparing these implementation models. The first is to promote business co-creation with customers. Although interest in IoT has been growing, only a few actual cases provide a clear picture of how IoT can be used. An implementation model makes it easy for customers to envision business scenarios using IoT and facilitates the drafting of specific business plans.

The second reason is to facilitate quick creation of

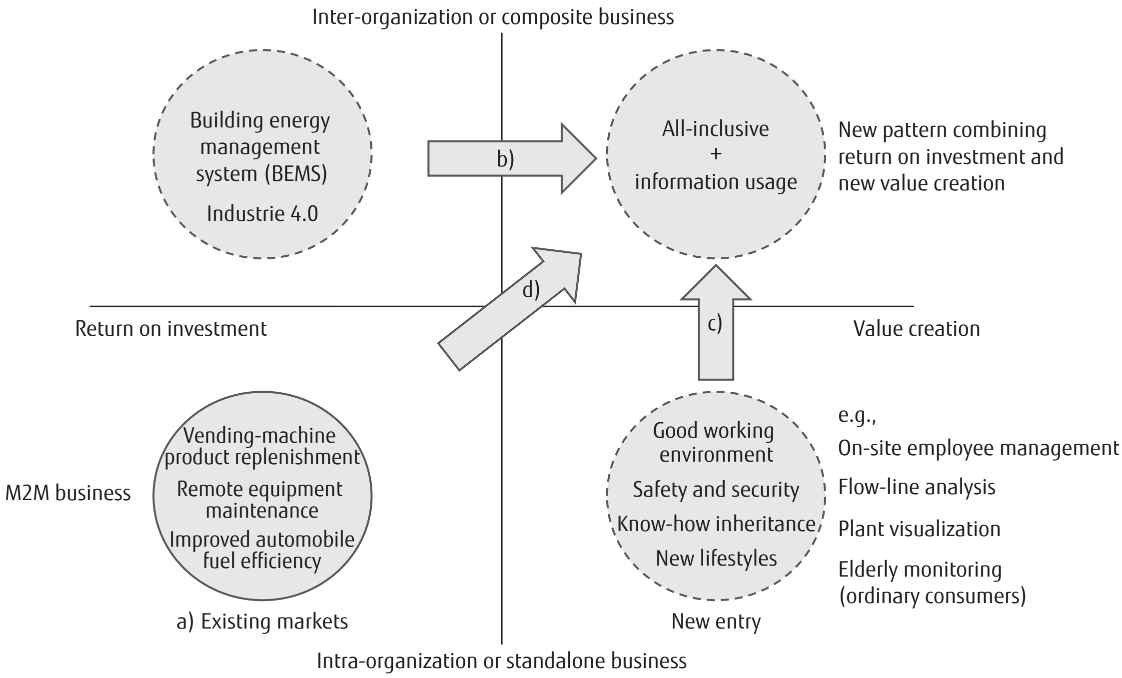
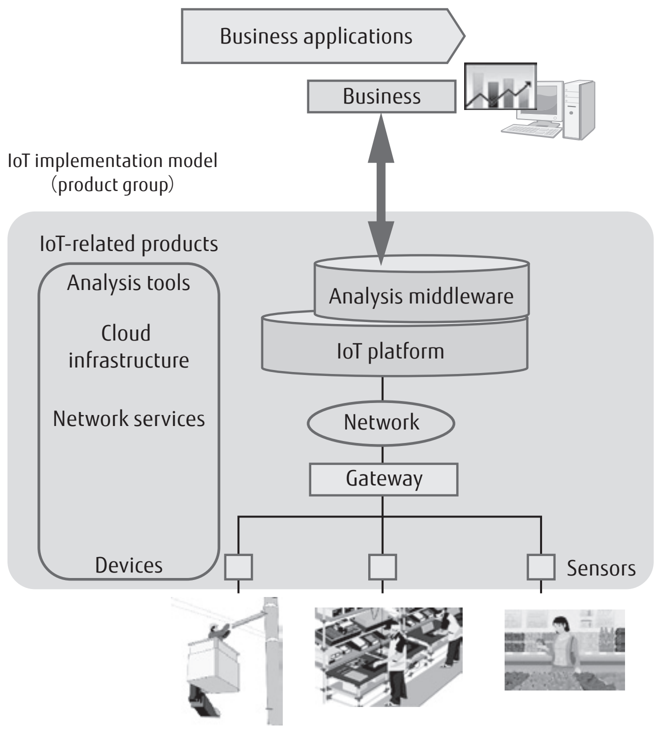


Figure 3
IoT business trends.



IoT implementation model	IoT-provided content
Remote maintenance M2M	Make networks and cloud platforms to collect and analyze device data on-site
Smart plant visualization	Interconnect device data, human-based work data (input by tablet), and production data
Flow-line analysis	Convert smartphone Wi-Fi access logs and image data into location/direction flow lines
Worker management	Provide worker location, vital signs, and environment and stress data (Stress data to be provided in near future.)
Next-generation street lighting	Provide ad hoc networks and cloud service for remote control of street lighting

Figure 4
Example IoT implementation models.

solutions using IoT. Since Fujitsu provides a wide range of essential components, from sensors to a cloud infrastructure and analysis tools, the customer need only add a business application to achieve a solution based on the information collected from sensors.

The third reason is to form an ecosystem based on an implementation model that combines Fujitsu original technologies with those of a business partner. Since the application range of IoT systems is extremely broad, it is difficult for the products and technologies of a single company to cover all requirements, so it is essential that tie-ups be formed with business partners. To this end, Fujitsu first determines what technologies are needed to apply a certain implementation model and then provides those technologies, with its proprietary technologies at the core and the technologies of business partners making up the rest in a complementary manner.

4. Development of IoT-supporting technologies

In this section, we introduce IoT-supporting technologies being developed by Fujitsu and Fujitsu Laboratories.

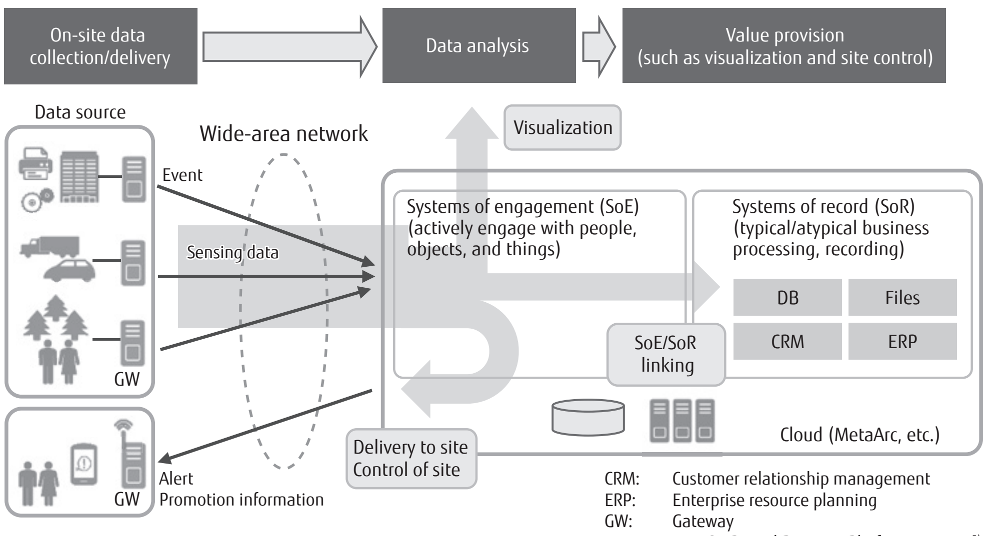
An IoT system has a three-part functional structure: collection and delivery of real-world data from the field, analysis of the data collected, and provision of value for field operations such as visualization of field conditions and site control (**Figure 5**). Since an IoT system targets locations from terminal sensors via networks to the cloud which are geographically separated, non-functional aspects such as security and stable operation must also be considered. An IoT system also consists of elemental technologies, constituent equipment, and application technologies in a supporting capacity, resulting in a highly diverse structure. With this in mind, we consider that the following five requirements must be satisfied to achieve an IoT system.

1) Detection of diverse targets using various types of sensors

Since the detection targets are many and varied (people, things, environmental conditions, etc.), various types of sensors must be used to collect the corresponding data. In fact, various types may be used for the same target to enable assessment using images, to enable detection of certain characteristics, etc. The sensors to be used depend on the target environment.

2) Support for site evolution

Detection targets and their configuration can change with the movement of people and things, on-site changes, etc., so applications that aim to extract value must be able to evolve as well. There is therefore a need for IoT systems that can adapt to changes in the field in contrast to conventional information and communications technology (ICT) systems.



CRM: Customer relationship management
ERP: Enterprise resource planning
GW: Gateway
MetaArc: FUJITSU Digital Business Platform MetaArc[3)]

Figure 5
IoT system overview.

3) Handling of redundant, non-uniform data

The data obtained for diverse targets using various types of sensors as described above are also diverse in nature. This means that it is difficult to apply a uniform format to the data collected. Moreover, related information may be added at various points along the data-collection path. The system must thus be able to handle data with different formats that may include redundant information and to efficiently extract information of value from that data.

4) Extraction and use of information and management of device-related tasks

In addition to extracting information of value for a closed site such as a plant, the system must be able to extract information of value from widely dispersed locations and various types of devices. It must also be able to share information between remote plants, to monitor highly mobile devices and vehicles, and to monitor social infrastructures such as river systems. In addition, since such devices often need to be controlled or their settings updated all at one time, the system should be able to effectively manage such tasks.

5) Robust and economical operation in harsh environments

Since the target environment is often outside and thus subject to harsh conditions, the system must be able to detect power loss, moisture, etc. It must also be resistant to dust, temperature fluctuations, shock, and explosions. Moreover, it should be highly cost-efficient, particularly in regards to maintenance.

Fujitsu aims to provide flexible and optimally stable IoT systems tailored to conditions in the field. To this end, we are researching and developing IoT technologies to meet the above requirements from the following three perspectives.

4.1 Dynamic: Technologies for optimally adapting to changes in the field

These technologies will provide flexible tracking of a wide-area system with respect to various types of daily changes unique to an IoT system. These might be changes in equipment configuration, service content, and maintenance methods in the field and changes in the content of collected data. Examples include dynamic resource controller technology for optimal data processing not only in the cloud but also at gateways and elsewhere and power-saving communications technology for transmitting information only when necessary in accordance with the values of the sensed data.

4.2 Knowledge: Technologies for accumulating and applying IoT knowledge

These technologies will store the core similarities or essence of various types of cases and will create value by putting new knowledge to work without human labor. Examples include streaming analysis technology such as anonymous detection and image detection technology using cameras.

4.3 Engineering: Technologies for optimally combining diverse components and performing system tuning in accordance with objectives

These technologies will construct high-reliability systems with power-saving and resource-saving features by combining sensors, power supplies, CPUs, wireless resources, etc. to fit conditions in the field and meet service requirements. Examples include sensor-engineering technologies such as battery-less technology, power-saving technology, and near-field-communications operation and management technology, IoT security technology such as secure data collection and delivery and device authentication, and service-development support technology for combining various types of model-based data analysis and processing.

Details on the above technologies can be found in other articles in this special issue. In the following, we introduce advanced technologies and case studies not included in those articles.

4.4 Technologies for detecting signs of sewer system overflows[4),5)]

As sewer system overflows become a serious problem in many cities, these technologies aim to detect early signs of an overflow to enable rapid response. Fujitsu has been conducting operational trials with these technologies, which include some of the Knowledge and Engineering technologies described above. The Knowledge technologies will enable the visualization of internal conditions in a sewer system by continuously sensing water levels, which was technically difficult in the past. Fujitsu is also developing technologies for predicting when sluice gates should be opened or drain pumps activated using information for predicting changes in water levels on the basis of data obtained from the operational trials.

The Engineering technologies, in turn, are being used to develop sensors for installation in access holes. The operational requirements of such sensors include operation without a conventional power supply, wireless data transmission to nearby gateways, and installation in a harsh sewer environment. To make troublesome battery replacement unnecessary and achieve long-term operation, Fujitsu combines technologies matched to on-site installation and operating conditions. These technologies include energy harvesting, which enables devices to generate power by using solar light or the difference between the interior and exterior temperatures, and power saving, which enables devices to use less power by using water-level sensing and wireless communication.

4.5 Technologies for monitoring slope conditions[6)]

A basic technology is used for monitoring slope conditions to detect early signs of a landslide brought on by torrential rains or other conditions, which has been a growing problem in recent years. It features solar-powered sensors to detect slope conditions such as moisture content and movement and environmental conditions such as temperature and humidity. These sensors use multihop communications to relay detected data to each other wirelessly, which is enabled by simply planting the sensors on the slope at appropriate intervals. However, power supply can differ among sensors due to differences in the amount of solar power generated and the amount of sensing and multihop communications performed, so a sensor may run out of power and become nonfunctional. For this reason, dynamic control technology was developed to maintain stable operation across the entire system. This technology changes the multihop path configuration and balances the load across the sensors in accordance with the amount of power available to each sensor.

Knowledge-based data supplementation technology was also developed to deal with an unpowered or failed sensor. This technology uses the surrounding sensors to compensate for the lost data collection ability so that complete slope conditions can still be detected. Fujitsu tested a slope-monitoring system using these technologies through a proof of concept (PoC) field trial held in Taiwan. The system operated for one year without interruption, demonstrating that IoT can be applied to environmental monitoring to detect signs of a landslide.

The above introduced IoT-supporting technologies together with case studies. Fujitsu is formulating and applying an IoT architecture as an overall blueprint to give these technologies and the products and services that deploy them a unified direction and to provide systems that can easily connect these products in accordance with requirements. Going forward, Fujitsu plans to apply these technologies and products to various types of sites and to carry out PoC and PoB field trials jointly with customers to achieve early provision of services.

5. IoT standardization activities

Achieving an IoT ecosystem incorporating everything from devices to analysis functions and services requires the standardization of interfaces and data models between those elements. In the field of IoT, a variety of activities are taking place in each application and technology domain. As described below, these activities are dominated by conventional de jure standardization and forum-based standardization as well as by open ecosystem standardization that aims to construct new working systems. The aim of the open ecosystem method is to construct an ecosystem on a testbed as an actual working system using existing specifications or other specifications targeted for standardization as a specification framework. The importance of this type of standardization is expected to increase from here on.

The following describes Fujitsu's approach to and efforts in these different types of standardization.

5.1 De jure standardization

Centered about telecommunications, this type of standardization aims to ensure interconnectivity by implementing specifications through consensus. Key standardization organizations of this type include the International Telecommunication Union Telecommunication Standardization Sector (ITU-T), 3rd Generation Partnership Project (3GPP), and Institute of Electrical and Electronics Engineers (IEEE). There are also many cases in which 3GPP and IEEE have been classified as forum-type standardization, but such organizations have recently been moving toward de jure standardization, so they are classified as such in this paper.

Fujitsu participated in the formulation of IoT architecture toward smart homes in ITU-T Study Group 13 (SG13: a research committee in charge of studying network technology requirements and architecture). The idea behind this architecture is to enable sensors and devices such as home appliances connected to the home network to be accessed from the cloud. Fujitsu played a leading role in SG13 discussions that produced Recommendation Y.2070. Fujitsu also made contributions to Study Group 20 (SG20: a research committee in charge of studying IoT and IoT applications including smart cities and smart communities) in the role of vice-chairman. In addition to the above, Fujitsu has been actively involved in standardization activities surrounding fifth generation mobile communications (5G) scheduled to be launched in 2020. These include standardization activities at 3GPP toward a wireless network that can accommodate a huge number of things and those at IEEE toward fault management using near-field communications such as Wi-Fi and Bluetooth.

5.2 Forum-type standardization

This type of standardization establishes multiple implementation specifications for upper-layer protocols and data models and promotes their adoption.

The oneM2M standardization organization, for example, integrates eight standards bodies from around the world [including the Telecommunication Technology Committee (TTC) and Association of Radio Industries and Business (ARIB) in Japan] focused on IoT and M2M data communications. Fujitsu contributed to the formulation of the oneM2M Release 1 specifications[7)] published in January 2015 through its role as vice-chairman of the protocol-related working group (WG). Release 1 features the definition of 12 common functions in a uniform application program interface (RESTful API) to provide a platform that can simplify the construction and operation of an IoT system. These functions are centered about a device management function for collecting data from IoT devices in a stable manner and a data management function for storing and releasing the data collected. The plan going forward is to enhance the functions for accommodating IoT devices by using IoT-dedicated protocols formulated by other standardization organizations such as AllJoyn, Open Interconnect Consortium (OIC), and Open Mobile Alliance Lightweight M2M (OMA-LWM2M) while maintaining compatibility with the Release 1 basic functions.

Fujitsu is also contributing to the formulation and standardization of multihop data communication specifications of the Wireless Smart Utility Network (Wi-SUN) Alliance.

5.3 Open ecosystem-type standardization

This is a new movement that achieves early system implementation by collecting and assembling multiple technical specifications as a practical standard. Typical of this movement is the Industrial Internet Consortium (IIC), which was founded in March 2014 by General Electric, IBM, AT&T, Intel, and Cisco as an organization growing out of the Object Management Group (OMG: a non-profit standardization organization devoted to computer application architecture and technologies). The IIC formulates reference architectures and provides environments for developing and verifying testbeds to create ecosystems and demonstrate frameworks in application fields. Fujitsu has been participating in the IIC since its first meeting in June 2014 and became the first Japanese member of the steering committee in 2014. It has been active in proposing use cases, formulating security architecture, proposing and adopting the Factory Operations Visibility and Intelligence Testbed, and participating in other projects. The IIC plan for this testbed is to create an ecosystem composed of diverse partners toward the visualization and efficient operation of each process in a factory.

In the above ways, IoT-related standardization activities have been energetically moving forward in a variety of forms. Fujitsu is committed to supporting and participating in these activities toward the early creation of effective ecosystems.

6. Conclusion

In this paper, we analyzed the factors that have moved IoT into the spotlight, introduced Fujitsu's approach to providing total IoT solutions starting with PoB demonstrations, and described Fujitsu technologies and standardization activities for IoT.

IoT will enable things that have so far been unconnected to be connected and data that has so far been inaccessible to be accessible. It will enable new knowledge to be generated by analyzing that data and innovation to be driven by that knowledge. In this way, IoT has great potential for stimulating business innovation and social innovation in diverse ways. At the same time, measures must be taken to deal with new issues pertaining to security risk, data rights, privacy, etc. To this end, IoT will need to function as a single ecosystem that interconnects sensors, devices, networks, clouds, middleware, and applications.

As an IoT total-solutions vendor, Fujitsu aims to create a human centric society. To this end, Fujitsu is committed to co-creating business with its customers by harnessing the collective power of its IoT-promoting business departments, group companies, and Fujitsu Laboratories while forming alliances with business partners.

References

1) Apple: Apple Watch.
http://www.apple.com/watch/
2) Nest Labs: Nest Learning Thermostat.
https://nest.com/thermostat/meet-nest-thermostat/
3) Fujitsu: FUJITSU Digital Business Platform MetaArc.
http://www.fujitsu.com/global/solutions/cloud/metaarc/
4) Fujitsu Laboratories: Fujitsu Develops Technology for Low-Cost Detection of Potential Sewer System Overflows.
http://www.fujitsu.com/global/about/resources/news/press-releases/2015/0210-03.html
5) Fujitsu Laboratories: Fujitsu and the City of Koriyama Begin Operational Trials of Sensing System to Detect Signs of Sewer System Overflows.
http://www.fujitsu.com/global/about/resources/news/press-releases/2015/0723-01.html
6) Fujitsu Laboratories and Industrial Technology Research Institute: Fujitsu Laboratories and Taiwan's Industrial Technology Research Institute Team Up for Joint Development of Disaster-Prevention Technologies.
http://www.fujitsu.com/global/about/resources/news/press-releases/2014/0108-01.html
7) oneM2M: Published Specifications.
http://www.onem2m.org/technical/published-documents

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