Research and Development Initiatives on the Internet of Things at NTT

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Abstract

The Internet of Things (IoT) holds great promise for creation of new value in society, and this age of utilizing IoT represents a third era, which could be called the *driving era*, with great changes in the role of telecommunication networks and their requirements. This article introduces network and information processing requirements for realizing this new IoT era and describes a reference architecture for this functionality. It also introduces IoT related initiatives at NTT.

Keywords: Internet of Things, sensing, data exchange, social prediction

1. Introduction

The term Internet of Things (IoT) has been appearing in the newspapers every day recently, and there is much anticipation of the value that it will bring society. Telecommunication networks have made great advances over the years. The first generation had the role of *connecting*, mainly providing communication between people, and the second generation had the role of *understanding*, which refers to gathering knowledge and information from around the world (**Fig. 1**).

In contrast, the idea of connecting *things* to the network and somehow controlling them has been around for a long time; examples include infrastructure monitoring using sensors, and home security technology. This basic concept is also represented in proposed developments such as ubiquitous computing. However, there are several reasons why IoT has become the large-scale initiative it is today. One is that the spread of networks and computing functionality has surpassed a threshold, and the number and types of things connected to networks is growing explosively [1]. Another is that in synergy with the rapid collection of knowledge brought by the second generation, the potential for new value is becoming apparent.

For example, through the development of low-power wide-area wireless technology able to send and receive information using extremely low energy, it is becoming possible for objects with minimal capabilities to connect to networks over long periods of time. Technologies to collect huge amounts of data on the cloud, and data analysis technologies such as machine learning and artificial intelligence (AI) to analyze it, are also being developed, and every day the knowledge available on the network is being consolidated further.

IoT is being used to visualize, optimize, and control the activities of physical things and society in this way; that is, it is *driving* them. Therefore, this third generation could be called the driving era, which involves great changes in the role of telecommunication networks. Second-generation communication has required the involvement of people, who also made all final decisions in most cases. In the IoT era, however, actions occur without human intervention, automatically and at very high speeds, and the real, physical world that we can touch is controlled by cyberspace, which is integrated with the real world. Thus, it is inevitable that the requirements for telecommunication networks will be different than they have been until now. The Feature Articles in this issue introduce key new technologies for realizing this IoT era, along with some of their applications in society.

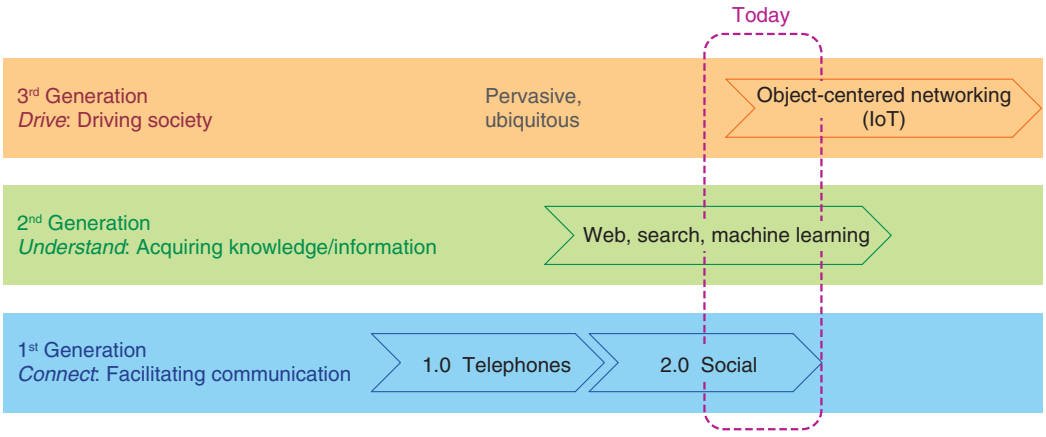

Fig. 1. Third-generation telecommunications: *driving* society.

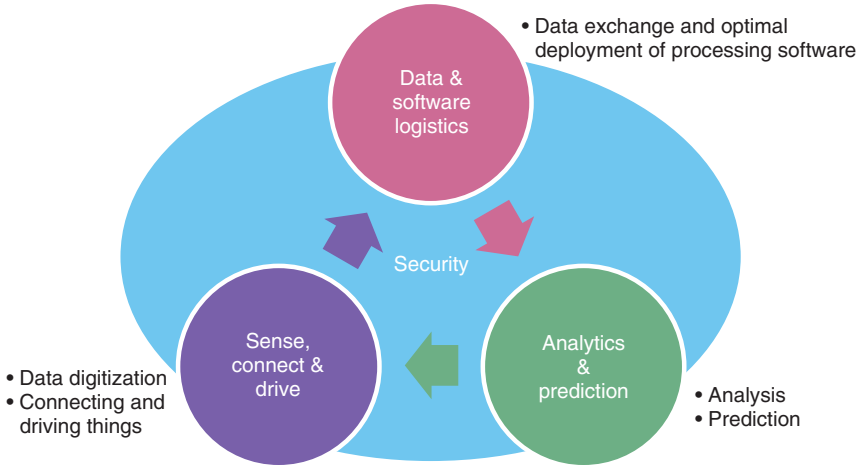

Fig. 2. Four roles and technologies in IoT.

2. The four roles and technologies of IoT

Four essential roles and technologies for the development of IoT are shown in **Fig. 2**.

2.1 Sense, connect & drive

Sense, connect & drive refers to the processes of digitizing the information of physical things into a form that computing devices can handle and connecting them to a network through some type of access method. In other words, it is the interface function between the real world and cyberspace. The number and variety of connected things is directly related to the value produced with IoT, so this role is extremely important. In order to drive society, communication requirements such as reliability and real-time performance must also be satisfied, more than ever before.

2.2 Data & software logistics

Data & software logistics refers to moving the data from connected things to a location suitable for processing and utilizing the data, and to deployment of the software that will perform this processing and utilization. IoT holds promise for creating new value by combining diverse data spanning different types of industries. However, development has advanced independently in the past, in different industries and different regions around the world, and this has resulted in a flood of different data models and protocols in the market and made interoperability among

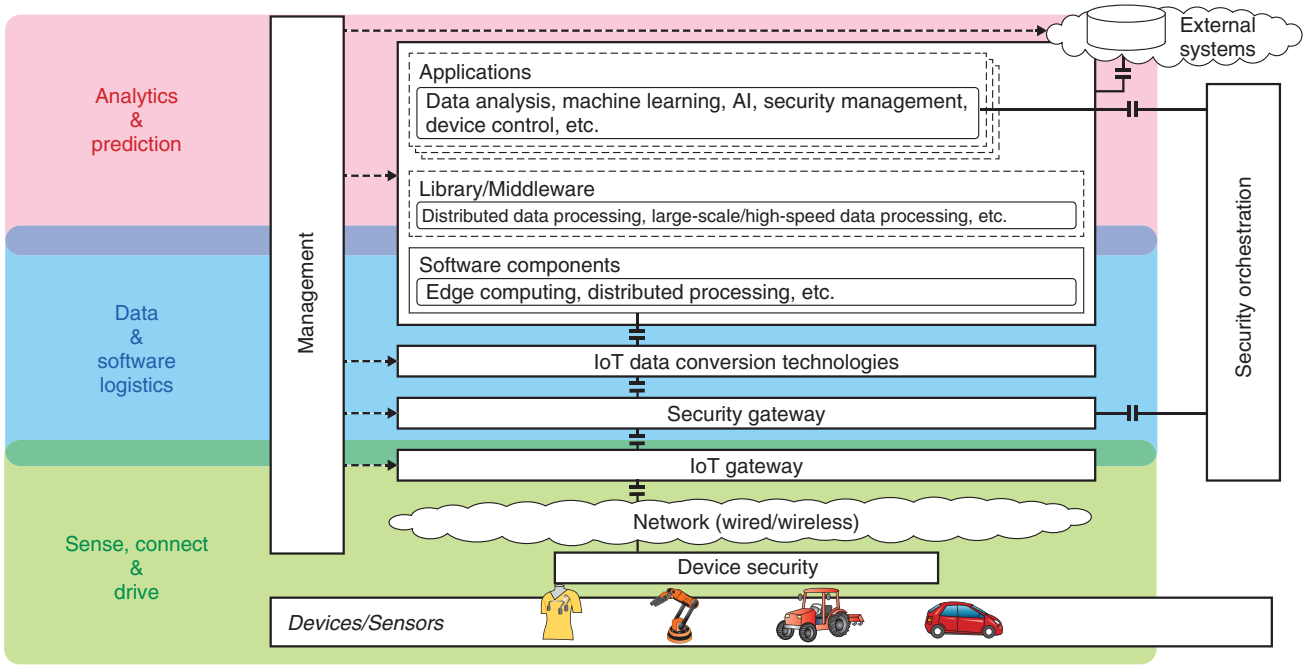

Fig. 3. Reference architecture.

them very difficult in their current condition.

For example, field networks for production management in factories, networks for building management, and networks for device control in automobiles each have their own de facto standards and regulations in their respective industries.

One important aspect of this function is to absorb these differences in a practical way to enable exchange and interoperability of data. Another function is related to how the physical location where data are processed is increasingly significant with IoT. A major recent development is that most data processing applications operate in two locations: the *cloud*, where servers are located, and the *end device*, but IoT is expected to bring great changes in this state of affairs. Due to the local nature of IoT data, the need for real-time control, and the large amounts of data produced by the many devices such as high-definition cameras, it is more appropriate to perform processing closer to the objects—at the network edge—rather than at a distant location on the cloud in an increasing number of cases. Since data processing locations are dispersing in this way, functions to select appropriate processing locations and to deploy processing algorithms are becoming increasingly important.

2.3 Analytics & prediction

Analytics & prediction refers to the creation of value from data. Big data analysis technologies such as machine learning and AI, which have grown rapidly in recent years, are used to create value by processing the IoT data being collected and circulated, understanding conditions, and predicting faults and other events that could happen in the future.

2.4 Security

The last element is security. With IoT driving real society, security risks such as cyber-attacks are a greater concern than ever [2]. There is also a greater range of IoT devices and the types of software used with them than with personal computers and smartphones, so safety must be maintained using different principles than have been used thus far.

To build IoT systems using these four functions, we have created the reference architecture shown in **Fig. 3**. The devices and data in the lower layers are gathered and circulated for higher layers, and applications in the top layer analyze the data and create value, and the results are fed back to control devices and to drive society.

3. IoT initiatives at NTT

We introduce in this issue recent IoT initiatives at NTT, namely the following.

3.1 Promoting partnerships to create new business

NTT's management strategy is focused on a B2B2X (business-to-business-to-X) business model, and business in the IoT domain is a typical example. In the third generation of telecommunication networks, we are aiming for an approach that expands collaboration with the owners of objects and information and the various stakeholders that derive value from them. With this in mind, the NTT Group is building partnerships from the early stages of developing technologies and working to create value through IoT. In the article "NTT Group Initiatives to Create New Internet of Things Business" [3] in this issue, we introduce some of the many initiatives already started, which are undergoing field trials and demonstrations or that are in technical development in collaboration with partners, as well as efforts to promote these initiatives.

3.2 New initiatives in sensing and its applications

One promising IoT initiative is creating value in healthcare using data from the human body. Devices such as smart watches are being used as sensors, but devices that can be used as sensors by simply wearing them like clothing, without any other special implements, are also coming into use. The NTT Group, in collaboration with Toray Industries, Inc., has developed a functional material called "hitoe" and is working on sensing applications for industries and uses not possible earlier. The article "Natural Sensing with 'hitoe' Functional Material and Initiatives towards Its Applications" [4] introduces the use of "hitoe" in the medical and safety management fields and the development of middleware technology that will expand the range of possible applications.

3.3 Initiatives promoting data exchange in society

As explained earlier, data models and their protocols have been developed within their business and/or regional domains (referred to as *silos*), which becomes a significant barrier of data exchange among various domains. However, to further increase the value created through IoT, it is essential to combine and use diverse data, and the promise of achieving IoT data exchanges in society so that data that span services can be circulated and utilized, is increasing. Industry 4.0 in Germany is an example of this. The article, "Data Exchange Technology Providing Real-time Data Processing and Scalability" [5] introduces NTT Group initiatives to promote this sort of IoT data exchange in society, including IoT data exchange technologies that deliver data reliably from devices to applications, and edge computing technology that realizes real-time performance by processing the IoT data being exchanged at an optimal location in the network.

3.4 Initiatives to make predictions in society using data

The NTT laboratories are advancing research and development (R&D) on spatio-temporal multidimensional collective data analysis technology able to model spatial and temporal relationships among the broad and diverse data and predict the place and time frame when phenomena will occur [6]. This is one technology able to create value from the large amount of diverse data being gathered and stored, from the real world and cyberspace, using sensing technology and data exchange.

We have recently developed this technology further using data on the flow of people and vehicles in urban areas to predict the immediate congestion risk, and we are conducting R&D on technology to give optimized guidance to groups in advance to avoid that congestion. The article, "Optimal Crowd Navigation via Spatio-temporal Multidimensional Collective Data Analysis" [7] introduces R&D initiatives on technology combining machine learning and simulation that is derived from optimized group guidance.

4. Future prospects

The number of *things* connected to networks is expected to continue to increase, so we hope to support society by further expanding and developing our range of IoT applications in order to promote development of a society where there is cooperation among people and things. The NTT Group will continue to collaborate with our partners in diverse fields and to promote R&D that creates new value.

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