Technology Reports

IoT | Smart Home | Web API

Special Articles on Making Life More Convenient and Seamless—toward Future Lifestyles

"IoT Smart Home" Supporting Daily Life Activities

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IoT is attracting much interest in diverse fields. It is seen as promising technology for creating value in various ways such as the remote control of devices and the analysis of collected data. As part of this trend, NTT DOCOMO is focusing on the "home" as the center of life and is constructing an IoT Smart Home®*1 that installs IoT devices throughout the home. The IoT Smart Home performs integrated management of home IoT devices through an IoT access control engine and achieves information sensing and device control within the home. NTT DOCOMO has conducted a demonstration experiment using this IoT Smart Home with the aim of achieving a home that can support a person's daily life.

1. Introduction

The Internet of Things (IoT) is becoming increasingly known and accepted in society. In the beginning, the targets of IoT were mainly fields such as factory automation and productivity improvement, but more recently, attention has been focusing on use cases more familiar to the general public such as integrated control of home appliances and home security.

Nevertheless, IoT is surrounded by a variety of technical issues such as data volume, communication networks, security, data analysis techniques, and cost [1]. At NTT DOCOMO, we have been promoting research and development in this area focusing particularly on the problem of interconnectivity.

*1 IoT Smart Home®: A trademark or registered trademark of NTT DOCOMO, INC.

At the same time, diverse social issues are making their appearance as a result of Japan's aging society such as an increase in elderly single-person households [2], increase in the population of elderly requiring nursing care [3], and rising healthcare costs [4]. In fact, the difference between average lifespan and healthy lifespan in Japan is widening, which suggests that these social problems will become increasingly severe in the years to come. In the light of the above, NTT DOCOMO is constructing an IoT Smart Home to support people's lives from various perspectives including comfort and health by applying the company's expertise and know-how in IoT technology to the "home" as the center of life.

In the past, the "smart home" was often talked about in terms of power management and energy efficiency using such keywords as Net Zero Energy House (ZEH)*2, Home Energy Management System (HEMS)*3, smart meter*4, and demand response*5.

In contrast, NTT DOCOMO's IoT Smart Home has been constructed based on the concept that the home can support its occupants from the viewpoints of comfort, health, peace of mind, safety, and beauty. The IoT Smart Home features a mechanism that collects and analyzes everyday life-related data of its occupants through IoT devices in the home and that provides them with an appropriate living space again through IoT devices based on analysis results. The aim here is to achieve a home that supports daily life through this mechanism.

To provide an IoT system that can achieve the IoT Smart Home, we have constructed an IoT access control engine*6 as a cloud-based platform that can coordinate diverse IoT devices in an integrated manner and have developed a variety of applications. This article describes the IoT Smart Home and the technical features of the IoT access control engine, presents the results of a demonstration experiment using the IoT Smart Home, and touches upon future developments.

2. Configuration of IoT Smart Home

2.1 Overview of IoT Smart Home

NTT DOCOMO has constructed an IoT Smart Home to achieve a home that supports daily life. Exterior and interior views of the IoT Smart Home are shown in **Figure 1**. This IoT Smart Home was implemented as a mobile home that could be towed and moved as desired. As shown in **Figure 2**, the IoT Smart Home embeds a variety of IoT devices that are managed and controlled by NTT DOCOMO's IoT access control engine to create a comfortable and healthy living space.

2.2 System Configuration of IoT Smart Home

The system configuration of the IoT Smart Home

Figure 1 Exterior and interior views of IoT Smart Home

*2 ZEH: According to the Ministry of Economy, Trade and Industry (METI), a house that can simultaneously achieve a "comfortable indoor environment" and "net energy consumption of zero or less on an annual basis."

*3 HEMS: A system for visualizing and managing the amount of electric power, gas, and other forms of energy used by home appliances and household equipment through monitors, etc.

*4 Smart meter: A power meter equipped with a communications function.

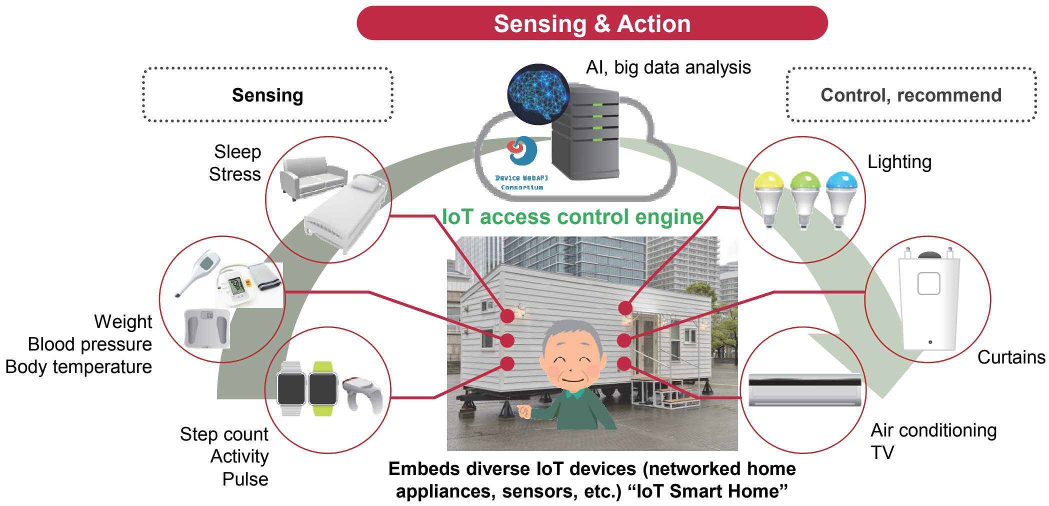

Figure 2 Overview of IoT Smart Home

is shown in **Figure 3**. The IoT Smart Home consists of four main elements: IoT devices, home gateway, IoT access control engine, and user application.

In this article, IoT devices refer to things targeted for control over the Internet and things that can collect information. IoT devices installed in the IoT Smart Home consist of commercially available products such as a body weight scale and lighting and custom-made products such as a smart mirror (a mirror with a head-up display). These IoT devices are managed and controlled by NTT DOCOMO's IoT access control engine. In this regard, many IoT devices perform communications based on Near-Field Communication (NFC) standards such as Bluetooth®*7 and Wi-Fi®*8, so communications between IoT devices in the IoT Smart Home and the cloud are performed via a home gateway installed in the home. The user application is implemented as a Web application that provides functions for controlling IoT devices and visualizing information through the IoT access control engine.

2.3 Connection of IoT Devices through IoT Access Control Engine

The IoT Smart Home currently installs about 20 types of IoT devices. The IoT access control engine developed by NTT DOCOMO manages and controls these IoT devices having different manufacturers and specifications. The IoT Smart Home achieves the five functions described below through use of the IoT access control engine.

1) Collection of Information from IoT Devices

The IoT access control engine can obtain life-related data collected from various types of IoT sensors via the home gateway equipment in the home. For example, an IoT sleep mat can be placed

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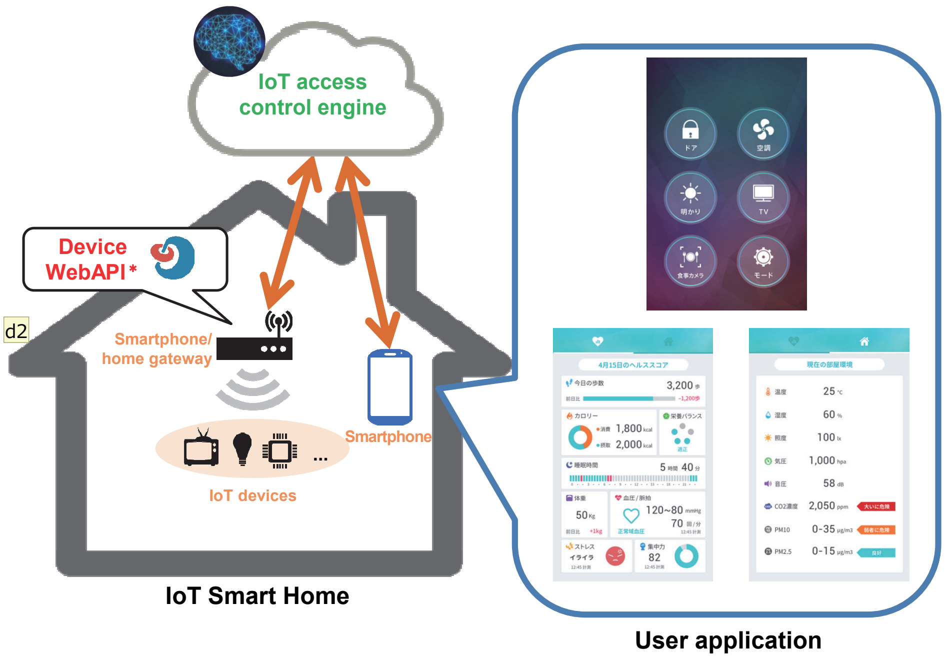
*5 Demand response: According to the Ministry of Economy, Trade and Industry (METI), the adjustment of power demand patterns by holders of consumer energy resources or third parties by controlling those energy resources.

*6 IoT access control engine: A cloud platform developed by NTT DOCOMO for controlling and managing various type of IoT devices.

*7 Bluetooth®: A short-range wireless communication standard for interconnecting mobile terminals such as mobile phones and notebook computers. A registered trademark of Bluetooth SIG Inc. in the United States.



*Device WebAPI: Generic name for Web-based APIs used within the API framework GotAPI standardized by Open Mobile Alliance (OMA), an international standardization organization.

Figure 3 System configuration of IoT Smart Home

under bedding to collect data on an occupant's sleep patterns such as the quality of sleep, breathing rate, and frequency of tossing and turning in sleep. In addition, a body weight scale can be imbedded in the floor in front of a washbasin to collect biological data such as weight in a natural, unencumbered manner.

2) Control of IoT Devices

The IoT access control engine enables all sorts of home devices to be controlled. For example, it enables the front door to be locked and unlocked through a smart digital key and infrared-controllable curtains to be opened and closed. Home appliances such as air conditioners and televisions can also be controlled. Furthermore, such IoT devices can not only be individually controlled but also controlled in groups such as by turning off power, shutting down air conditioners, and locking doors before going to bed.

3) Remote Management

Constructed as a cloud system, the IoT access control engine can collect information from IoT devices and control them from remote locations. This makes possible a variety of functions, such as setting the air conditioning system before returning home and checking home conditions from a remote location.

4) Device Extendibility

The IoT access control engine enables supported IoT devices to be added simply by adding plug-in software to the home gateway. This ease of extendibility means that devices within the IoT Smart

*8 Wi-Fi®: The name used for devices that interconnect on a wireless LAN using the IEEE802.11 standard specifications, as recognized by the Wi-Fi Alliance. A registered trademark of the Wi-Fi Alliance.

Home can be extended and modified as needed.

5) Diverse Access Rights Management

The IoT access control engine enables a variety of access rights management functions to be achieved in terms of users, time periods, and functions. In the demonstration experiment that we conducted using the IoT Smart Home, a different subject lives in the house for one week during which time the subject's account is given the right to use IoT devices while the manager is given the right to view IoT device status. In this way, only the subject and manager can access the functions required for the IoT Smart Home.

6) Accumulation of Life Data

All operation history and data logs of IoT devices in the IoT Smart Home are stored in a database within the IoT access control engine. This scheme enables the huge amount of daily life-related data to be automatically accumulated and diverse types of data to be analyzed resulting in value-added data. The aim here is to automatically create a comfortable and healthy living space for the occupant of the IoT Smart Home by analyzing the data collected from IoT devices on the cloud and controlling those devices based on analysis results.

2.4 Installed Devices

The devices currently installed in the IoT Smart Home are listed in **Table 1**.

2.5 Functions

The IoT Smart Home is currently made up of six main functions as summarized below.

1) Visualization of Healthcare Information

Healthcare information collected by various healthcare devices in the IoT Smart Home can be visualized on the occupant's smartphone. In this way, the occupant can view comprehensive healthcare information that combines the data of multiple devices instead of viewing information from individual devices separately.

2) Environment Monitoring

This function provides real-time visualization of indoor/outdoor environment information such as dust concentrations (PM10, PM2.5), temperature/humidity, CO_2 concentrations, and wind direction/speed, plus open/closed status of each door in the home and locations where someone is present. It can be used to watch over family members living separately and to view indoor/outdoor environment information invisible to the naked eye.

3) Smart Mirror

The IoT Smart Home adopts a smart mirror for the washbasin. This mirror can display various types of information for the occupant such as yesterday's and today's body weight, one week's worth of sleep data, and today's weather. A body weight scale is also imbedded in the floor in front of the washbasin. This type of natural information collection and display brings health matters to the attention of the occupant in a casual, trouble-free manner.

4) Meal Analysis

This function can determine the content of a meal and calculate calories and nutritional balance by having the occupant take a photo of the meal with a smartphone camera. It can also offer advice on meals based on the content of one day's worth of meals.

5) Remote Control

IoT devices within the IoT Smart Home can be controlled by smartphone. This function enables

Table 1 Devices installed in IoT Smart Home

IoT device	Communication scheme	Function
Blood pressure monitor	BLE	Measure blood pressure
Body weight scale	BLE	Measure body weight
Sleep meter	Wi-Fi	Measure sleep status
Human sensor	EnOcean	Detects human presence (bedroom, front door, bathroom, sofa)
Door open/closed sensor	EnOcean	Detects whether a door is open or closed (refrigerator, freezer, microwave oven, closet, front door)
Smart wristband	BLE	Measures number of steps, burned calories, etc.
Meal camera (smartphone)	LTE	Estimates meal content, calories, nutritional elements
Dust sensor	BLE	Measures PM10, PM2.5
Light	Wi-Fi	Turns light ON/OFF, change color
Infrared learning remote control	Wi-Fi	Controls air purifier, aroma diffuser, air conditioning, TV, curtains, skylight curtains
CO_2 sensor	EnOcean	Measures CO_2 concentration
Smart lock	BLE	Gets locked/unlocked status and performs locking/unlocking
Power distribution board	Wired LAN (ECHONET Lite)	Measures power
Smart mirror	Wi-Fi	Displays information such as sleep data, body weight, weather, time, etc.
Position detecting floor	BLE	Extracts position of occupant
Shutter	Wi-Fi (ECHONET Lite)	Opens/closes shutter, adjusts angle
Indoor/outdoor environment sensor	Wired LAN	Measures NO, NO_2, SMP, PM2.5, wind direction/ speed, temperature/humidity, HCHO, VOC, CO_2
Health advisor	–	Not yet connected to IoT access control engine
Cosmetic dispenser	–	Not yet connected to IoT access control engine

BLE (Bluetooth® Low Energy): Extended specification of Bluetooth near-field communication standard, added to Bluetooth ver. 4.0. Features low-power communications. Bluetooth is a registered trademark of Bluetooth SIG Inc.
ECHONET® Lite: A communication protocol specified by the ECHONET Consortium mainly for home systems. ECHONET is a registered trademark of ECHONET Consortium.
EnOcean®: A wireless communication technology using the sub-gigahertz band featuring self-powered, battery-free data communications. EnOcean is a registered trademark of EnOcean GmbH.

IoT devices to be controlled separately as well as in groups according to various life scenarios such as when returning home. This capability eliminates the bother of operating the remote control unit for each IoT device.

6) Chatbot Conversation

IoT devices can be controlled and information visualized via a chat-oriented User Interface (UI). This function also supports conversation on other than IoT-related matters, which makes it appear as if the home has a personality of its own.

3. Life Monitoring Demonstration Experiment Using the IoT Smart Home

3.1 Overview of Demonstration Experiment

We conducted a demonstration experiment using the IoT Smart Home to determine whether a home could provide its occupant with a comfortable and healthy space using IoT and AI technologies.

In the experiment, each subject spent one week living in the IoT Smart Home, and at the end of this week, we performed an evaluation to check for any before-and-after changes in the condition, awareness, and behavior of the subject. Other than living in the IoT Smart Home, each subject went about daily life as usual such as going to work or working from home. This experiment has so far been conducted two times at different locations with a total of 20 subjects, each of whom were asked to spend one week living in the IoT Smart Home. **Table 2** provides an overview of this life monitoring experiment.

3.2 Experimental Results (Questionnaire)

We administered a questionnaire to the 20 subjects. The replies from each subject were obtained from a website on the last day of living in the IoT Smart Home for one week. The response rate was 100% (20 out of 20 subjects). Results are shown in **Figure 4**.

As a result of living in the IoT Smart Home, it was found that 75% of responders reported a rise in health awareness and that 65% noticed something about their own state of health. It was also found that living in the IoT Smart Home resulted not only in a change in awareness but also in specific behavioral changes such as greater concern about meals and proactive use of stairs as reflected by statements in the comment field of the questionnaire.

3.3 Experimental Results (Data)

Among the data obtained from the experiment, the human-sensor values for the time that two subjects lived in the IoT Smart Home are visualized

Table 2 Overview of life monitoring experiment

	Time period	Experiment location	No. of subjects
1st session	2017. 12～2018. 02	Sotetsu Rosen Mini Sachigaoka store, parking lot (near Futamatagawa Station)	6
2nd session	2018. 06～2018. 09	Sotetsu Bunka Kaikan, parking lot (near Ryokuen-toshi Station)	14

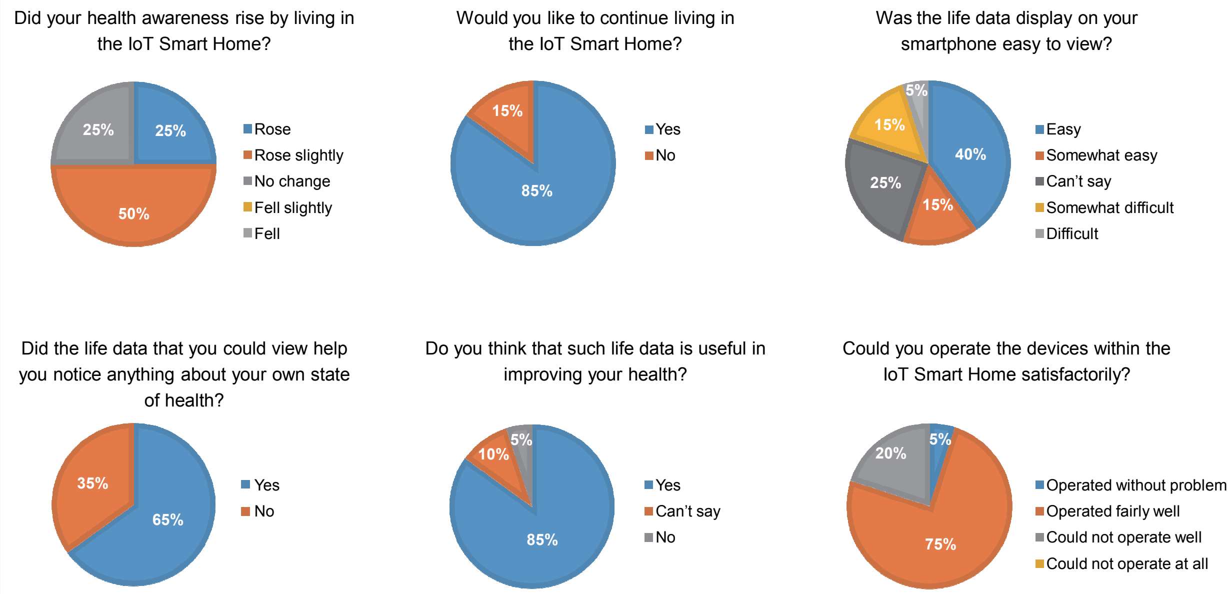


Figure 4　Results of questionnaire

in **Figure 5**. The following three functions can be considered from this data.

1) Extraction of Living Patterns

For subject A, the living pattern that could be observed from one week of data was one of going back and forth between the sofa and front door before sleeping and after getting out of bed. The data for subject B, meanwhile, revealed a pattern of spending some time on the sofa before sleeping but going back and forth between the sofa and front door after getting out of bed similar to subject A. These results suggest the possibility of classifying a person's daily life in terms of a certain pattern based solely on data obtained from human sensors. In this way, it should be possible to propose control schemes for IoT devices or provide optimal home-automation functions that take daily living patterns into account.

2) Detection of Abnormal Condition

As described in 1) above, the possibility exists that an occupant's living pattern can be extracted, but conversely, the possibility also exists of detecting movements out of the ordinary, that is, of detecting an abnormal condition. This is a capability that could be applied to keeping watch of family members living separately.

3) Distinguishing Occupants

If we assume that the daily living pattern of an occupant can be extracted as described in 1), it should also be possible to distinguish one occupant from another in the case of a home with multiple occupants. This suggests the technical feasibility

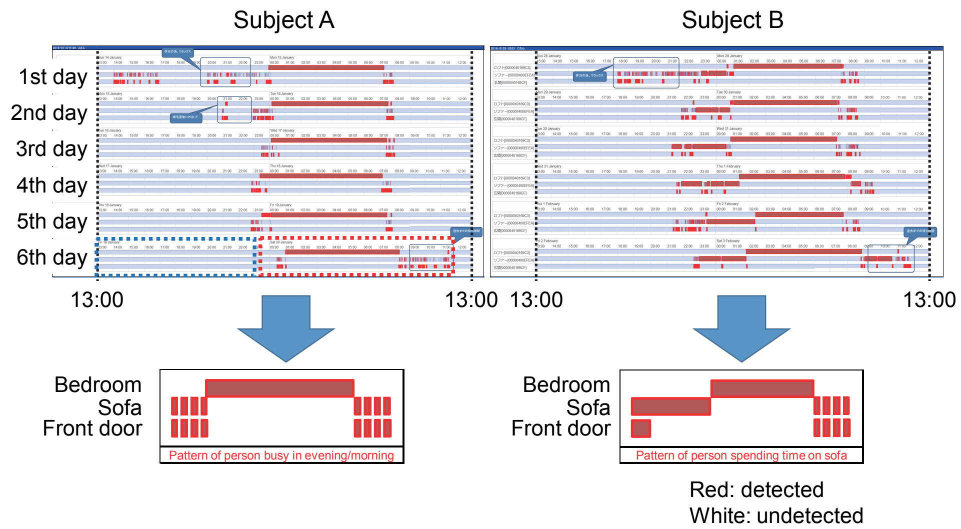


Figure 5　Visualization of human-sensor values

of applying this feature not only to single-person households but also to general households, communal homes, etc.

4. Conclusion

This article described a life-monitoring demonstration experiment using NTT DOCOMO's IoT Smart Home. This experiment demonstrated the possibility of managing a wide variety of IoT devices in an integrated manner through the use of an IoT access control engine and of creating a comfortable and healthy living space for the home's occupant. Next, to prove these hypotheses, we plan to perform data testing using combinations of IoT devices and conduct more demonstration experiments with a greater number of subjects. Finally, we aim to contribute to the solving of diverse social problems in the aging society by constructing a "home that supports daily life," that is, a home that takes on a personality of its own and automatically creates a comfortable and healthy living space by understanding the home's occupants.

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