NTT DOCOMO

Technical Journal

Vol.17 Jan.2016 | No.3

DOCOMO Today

Technology Reports

Collaboration Projects

NTT docomo

Mobile Terminals: Advances to Date and Advances Going Forward

Norihito Tokuhiro

Managing Director of Communication Device Development Department

I joined NTT in 1987. A year later, in July, I became involved in the development of mobile phones. Since then I have continued to be engaged in its development.

The first project I joined was the development of the TZ-803BI mobile phone. At the time of its launch, it was considered revolutionary with specifications such as 400 cc volume, 640 g weight, 40 minutes of talk time, and 9 hours of standby time, although they seemed to be inferior to those of today's features. Mobile phones have been evolving since then, especially in the area of size reduction. In April 1991, a mobile phone branded "mova" was released. It had 150 cc volume, 230 g weight, 45 minutes of talk time, and 12 hours of standby time. Further developments have been made in size and weight reduction and in battery longevity.

The first mobile communication system was an analog-based system. In April 1995, however, a digital-based mobile phones system called "PDC" was launched. The mobile communication system next evolved to the W-CDMA system in October 2001, and then to LTE. Also, as radio communication technology progressed, data communication bandwidth drastically improved, from just 9.6 kbps at first to a maximum download speed of 225 Mbps at present. Meanwhile, in terms of services, prior to February 1999 mobile phones could handle only voice calls, and mobile data communication was possible only on PCs. After the launch of the i-mode service, however, users could enjoy email and Web browsing on mobile phones themselves. In terms of mobile phone development, the focus changed from making phones more compact and lighter to making phones thinner. With regard to displays on mobile phones, after color LCD was implemented in December 1999, the development trend shifted to a greater emphasis on enlarging screen size and improving qualities of display in order to display more rich and attractive content. Furthermore, after the introduction of smartphones, large touch-panel displays became dominant on mobile phones. In addition, application CPUs used in mobile phones have also advanced significantly, from 200 MHz single-core processors in 2005 to 2 GHz octa-core processors in 2015.

In summary, the evolution of mobile phones to date has focused on improving high-speed data communication, increasing system capacity, shortening latency, and boosting application CPU performance to enable more advanced services, as well as on evolution of displays for larger screens and higher resolution.

I believe that there are two major directions in the future mobile phones. The first is the further evolution of current smartphones. The other is development of data communication modules for the purpose of connecting not people but "things" to the network, known as the Internet of Things (IoT). Smart meters are a good example.

The evolution of smartphones entails, firstly, the provision of stress-free, convenient, and easy-to-use services at even faster data communication speeds, greater system capacity, and less latency, which will be realized by the further development of LTE (LTE-Advanced) and the commercialization of the new generation mobile communication system called 5G. Another important element in the evolution of smartphones is improvements in user experience (UX). The expected UX enables mobile phones to be used by wide range of users with more intuitive and naturally operable user interfaces. Because users have a variety of IT literacy, it is necessary to personalize the user interface and functions to meet each user's needs and preferences. Furthermore, more highly convenient UX can be provided by activity support functions. These functions enable the mobile phones to learn users' activities and operation and usage histories and also take into account the current time, place, and occasion, and then provide appropriate activity support to users by estimating their future behaviors based on learnt users' context. On the other hand, there is also a need to balance advancements in security functionality and ease of use on the mobile phones. Even though fingerprint and iris authentication have been implemented, more diverse and user-friendly biometric authentication, such as face authentication and voice print authentication, are expected to be implemented.

The above mentioned advanced UX and security features cannot be realized just on the smartphone itself; they must be realized by highly sophisticated interworking with the cloud. Regarding smartphone displays, we have dealt with advanced technologies (i.e. 3D displays). Going forward, we will continue to further develop higher resolution, larger displays and so on. In addition, we can provide added value by linking mobile phones with peripheral devices, such as display mirroring to TVs and displays on wearable devices like smart glasses.

As for the evolution of data communication modules, smaller and lower-cost devices, which are realized by applying a specialized standard focused on narrowband data communication, will enable solutions to suit various application areas. Furthermore, for example, battery-less data communication modules powered by solar battery and specialized compact wireless data communication with low power consumption will enable application in environments where provision of power supply is difficult.

Smartphones and data communication modules will surely play active roles in our daily lives to an even greater extent going forward. We will continue to develop mobile phones (devices) that will not only become even closer partners with customers, but also elicit exciting and attractive feelings about the future when customers hold them in their hands.

NTT DOCOMO Technical Journal

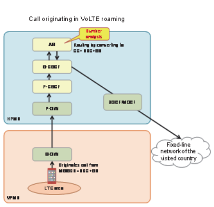
Vol.17 No.3 Jan. 2016

Contents

DOCOMO Today

Technology Reports

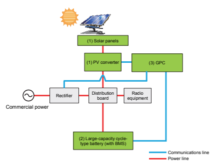
(P.4)



(P.13)

Collaboration Projects

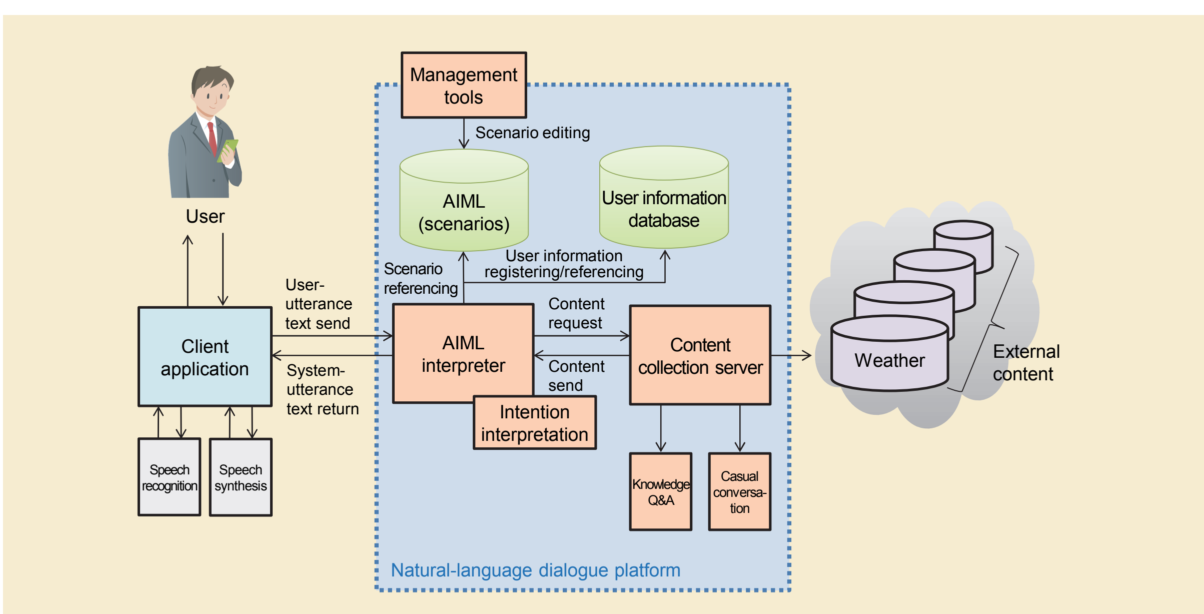
Topics



(P.30)

Activities

(P.38)



Technology Reports **Natural-language Dialogue Platform for Development of Voice-interactive Services (P.4)**

Configuration of natural-language dialogue platform

Natural-language Dialogue Platform | Voice Agent | AIML

Technology Reports

Natural-language Dialogue Platform for Development of Voice-interactive Services

A wide variety of devices are coming to be connected to the Internet, and voice input/output is becoming an important feature for devices with no screen and for situations when user's hands are full. NTT DOCOMO has developed a natural-language dialogue platform to simplify the provision of voice-interactive services. This platform enables third-party developers to develop voice-interactive services without specialized knowledge of natural-language processing technology. In this article, we present an overview of the natural-language dialogue platform and describe several application examples.

Service Innovation Department *Kanako Onishi*
Kosuke Kadono
Wataru Uchida†

1. Introduction

Various types of voice-interactive services can now be found on the market. NTT DOCOMO, for example, provides the Shabette Concier voice-agent service that interprets the intention of the user's utterance and performs a task such as executing a mail application (task) in response to the utterance "write mail" or responding to a question like "How high is Mt. Fuji?" Going forward, we can expect such voice-interactive services to increase in number and the need for them to grow. It is therefore desirable that just about anyone be capable of developing voice-interactive services in a prompt manner.

However, there are two main issues in developing such interactive services. One is that providers and designers of services using voice interaction are not necessarily familiar with technology for achieving natural-language dialogue. The other is the need for preparing a large number of scenarios for achieving natural-language dialogue. At NTT DOCOMO, we have developed a platform*1 that enables the creation of interactive services without having to be familiar with such technology and without having to create a large number of scenarios. This natural-language dialogue platform incorporates a mechanism for using a variety of functions and external content by simply adding several lines to a set of user-system response rules (hereinafter referred to as "scenario"). It also features a mechanism for flexibly matching actual utterances with scenario data thereby reducing the cost of creating scenarios. These features make it relatively easy for developers to develop voice-interactive services.

In this article, we present an overview of NTT DOCOMO's natural-language dialogue platform and describe examples of applications that we developed using the platform.

This platform is being provided as part of the "+d*2" initiative for creating new value by sharing NTT DOCOMO business assets with partner companies.

† Currently of Human Resources Management Department

*1 **Platform:** The basic software required to run applications.

*2 **+d:** Name of NTT DOCOMO initiative for creating new value together with partner companies.

2. Overview of Natural-language Dialogue Platform

Developers developing voice services and products capable of conversing with human beings can customize NTT DOCOMO's natural-language dialogue platform as needed and incorporate it in those services and products. This feature means that a desired voice agent can be easily developed by freely combining components (such as Knowledge Q&A [1]) deemed useful for developing the target voice-interactive system. The configuration of this platform is shown in **Figure 1**.

2.1 Function Overview

This platform controls dialogue with the user through a "scenario dialogue" function that enables a conversation consisting of a sequence of utterances and replies to be held between a person and computer and an "intention interpretation" function that classifies a user utterance into a task such as "write mail" or "check the weather." In the scenario dialogue function, the method for describing user utterances and system-response rules was designed with reference to Artificial Intelligence Markup Language (AIML)*3. Actual dialogue with the user is controlled through an AIML interpreter.

(1) AIML interpreter

The AIML interpreter analyzes the user-utterance text, references scenarios, determines the system-utterance text, and returns a reply to the user. Scenarios referenced by the AIML interpreter can be edited with management tools having a graphical user interface (GUI)*4 similar to standard text-editing tools and can be created by developers having no specialized knowledge of technology for achieving natural-language dialogue. The AIML interpreter can also extract user-related information such as interests or hobbies from user utterances based on the current scenario and can store that information in a user information database. User information extracted in this way can be used for conditional items within a scenario and incorporated in system utterances.

(2) Content collection server

The content collection server functions as a link to various types of content. It accesses external content such as weather information

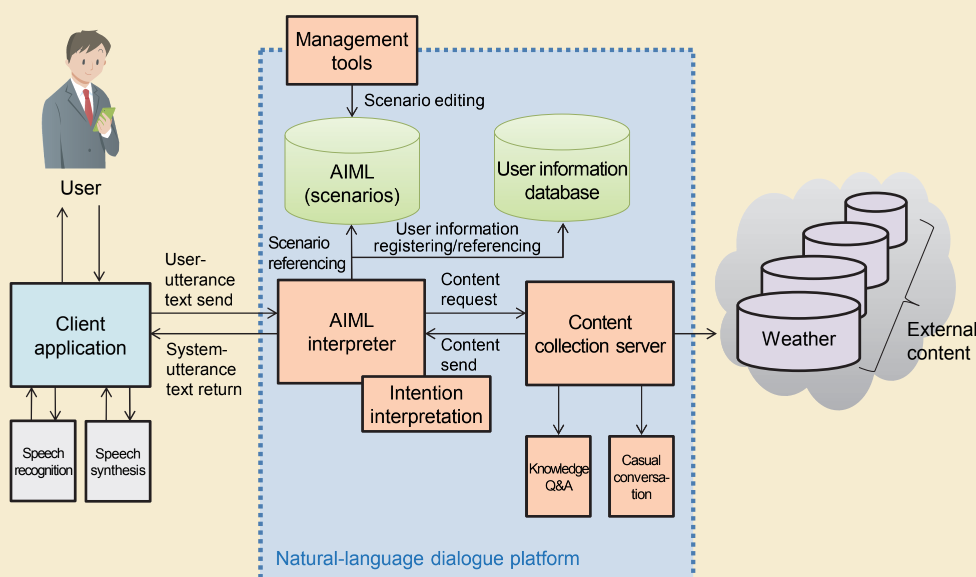


Figure 1 Configuration of natural-language dialogue platform

*3 **AIML:** A description technique for constructing an interactive agent.

*4 **GUI:** An interface enabling intuitive operations.

and news and collects whatever information is needed. It can also use the Knowledge Q&A function to respond to a wide range of user questions and the casual conversation [2] function to provide a reply not described in a scenario or to respond to questions that cannot be answered by Knowledge Q&A. The server sends collected information back to the AIML interpreter so that it can be used within a scenario. Instructions for collection of external content and its insertion in system responses can be described in a few lines within a scenario. This makes for a very simple design applicable to even developers with no specialized knowledge of natural-language processing technology.

2.2 Elemental Technologies

At NTT DOCOMO, we developed an expression-normalization function [3] for the AIML interpreter to handle diverse Japanese expressions as an elemental technology of the natural-language dialogue platform. Furthermore, for casual conversation, we developed two key functions separate from the AIML interpreter. The first of these is a user-information automatic extraction function [4] [5] for automatically extracting interests, preferences, and other user information from a dialogue. The other is a personality-oriented utterance conversion function [6] for converting a sentence written in an ordinary style to one that a certain type of personality or animated character might speak in. The above technologies make it unnecessary to describe a large number of scenarios, which means that the cost of creating scenarios can be reduced. These functions—expression-normalization, user-information automatic extraction, and personality-oriented utterance conversion—were developed at NTT DOCOMO with technical support and research results provided by NTT Media Intelligence Laboratories.

(1) Expression-normalization function

This function consolidates various types of expressions having the same meaning such as "Do you like ice cream?" and "Do you enjoy ice cream?" and "Ice cream, OK?" into a single expression. This makes it unnecessary for a developer to write up a large number of scenarios for dealing with various types of wording and enables the same effect to be obtained by simply writing a representative scenario.

(2) User-information automatic extraction function

Given a user utterance such as "I like reading," this function would automatically extract "reading" as a user interest. In this way, there is no need for a developer to describe in a scenario a procedure for extracting user information.

(3) Personality-oriented utterance conversion function

This function automatically extracts conversion rules from previously prepared sentences having the personality, for example, of an animated character and uses such utterance-generation rules to convert a dry utterance like "Today is cold, so warm clothes are recommended." to an utterance with more personality such as "Hey, it's freezing outside—wear something warm!" In this way, a developer can reuse general-purpose scenarios when creating multiple characters with various personalities and can have expressions with such personalities automatically generated.

2.3 Dialogue Example

An example of a dialogue generated by the system that we developed using the natural-language dialogue platform is shown in **Figure 2**. In this example, the system controls the flow of a narrative conversation using the scenario dialogue function as described below.

(1) This scenario describes a sequence of actions as follows. First, the system asks the question "Where are you going tomorrow?" Next, the user responds with the name of a place. Then, on the basis of that information, the system makes a reply that includes information on a souvenir related to that place. Here, the AIML interpreter decides whether the user utterance includes a place name using a category dictionary and absorbs var-

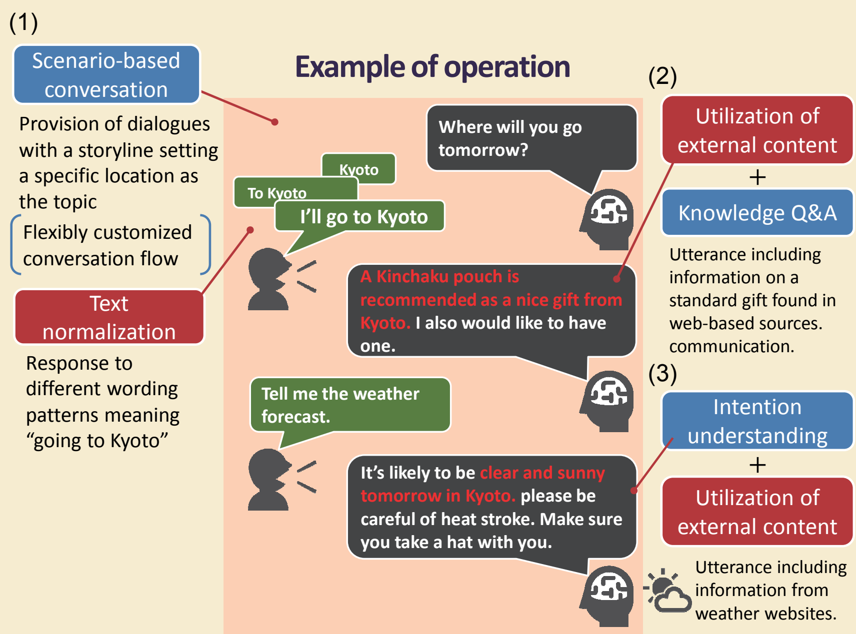


Figure 2 Dialogue example

iations in the user utterance using the expression-normalization function described above. In short, the system can recognize that the place where the user is going tomorrow is "Kyoto" from different wordings such as "Kyoto," "To Kyoto," and "I'm going to Kyoto" all having the same meaning.

(2) Next, given that the user's response to the system's question is a place name, the system generates a response that includes information on a souvenir related to that place using the Knowledge Q&A function. This process enables a response like "Speaking of Kyoto souvenirs, I like traditional drawstring pouches." In general, the word "Kyoto" in such an utterance would be the place recognized by the system as the one where the user will be going tomorrow and "traditional drawstring pouch" would be the name of a souvenir related to that place as obtained from the Knowledge Q&A.

(3) The final system response here is "It should be clear tomorrow in Kyoto. Be careful of heat stroke—wear a hat when going out." This is an example of a response that combines intention interpretation and external content related to the weather. The natural-language dialogue platform can generate natural conversations by combining various functions in this way.

3. Application Examples

The following introduces a "tablet agent," "automobile agent," and "talking toy" as application examples of NTT DOCOMO's natural-language dialogue platform.

3.1 Tablet Agent

1) Overview

As an application example of the natural-language dialogue platform for use in the home such as in the living room or bedroom, NTT DOCOMO has developed an agent system for demonstration purposes as a frontend application running on Android™*5 tablets. A screenshot of the tablet agent application is shown in **Figure 3**. This system enables a 3D computer-generated agent re-

*5 **Android™:** A software platform for smartphones and tablets consisting of an operating system, middleware and major applications. A trademark or registered trademark of Google Inc., in the United States.

siding on the screen to converse with the user by voice means using the natural-language dialogue platform.

2) Features

This system incorporates scenario-dialogue and casual-conversation functions and links with external content such as weather information and TV-program information. It also records user attributes and interests/preferences included in dialogues and uses that data to generate utterances that present information tailored to the individual. The emphasis here is on information useful in everyday life such as the weather, news, horoscope, and TV programming. The content collection server has the role of gathering this information.

3) Application State Transition

The application can be in one of three states: standby state, dialogue state, or notification state. A state transition occurs in the event of a user action or signal from the server. The state transition diagram is shown in **Figure 4**.

The application is in (a) standby state when no dialogue is taking place with the user or when there is no information to pass on to the user. However, on detecting an utterance of specific words or an action such as picking up the tablet (Fig. 4 (1)), the agent will move from the back of the screen to the front and enter into a state of dialogue with the user.

In the (b) dialogue state, the agent

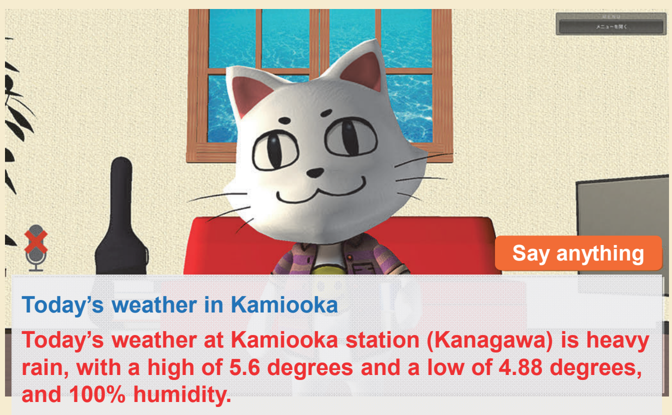


Figure 3　Screenshot of tablet agent (dialogue state)

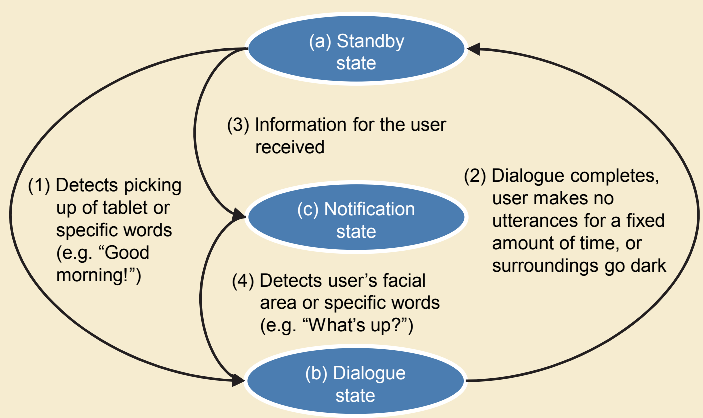


Figure 4　State transition diagram of tablet agent

is positioned at the front of the screen and carries on a dialogue with the user. At this time, the application sends speech data input through the microphone to the speech recognition server when not generating agent utterances. In this way, the application can always recognize user utterances. The application can also detect the user's facial area with the tablet's built-in camera and orient the agent in the direction of the user. Then, when inputting user utterances, the application can have the agent perform some kind of action, such as turning an ear toward the user, to give the dialogue a natural feel. In this state, the application can make a transition to the standby state and return the agent to the back of the screen if the dialogue completes, the user makes no utterances for a fixed amount of time, or surroundings go dark as detected by the tablet's illumination sensor (Fig. 4 (2)). Then, if information applicable to the user is received from the content collection server (Fig. 4 (3)), the application will make a transition from the standby state to the notification state.

In the (c) notification state, the application is in possession of information that needs to be passed on to the user. At this time, the agent moves to the front of the screen and performs some sort of action to get the user's attention. Then, on detecting the utterance of specific words or the user's facial area by the tablet's camera (Fig. 4 (4)), the application enters the dialogue state and presents that information to the user.

The above state-control scheme achieves an agent system that can provide support for everyday life in a natural way.

3.2 Automobile Agent

1) Overview

The automobile industry is one of several industries having high expectations for the industrial application of a voice agent system. Although functions for controlling on-board systems by voice have come to be provided, these functions generally accept only particular utterances such as "I'm returning home" or "I'd like to make a call." In response to this limitation, an "interactive automobile agent" was developed using the natural-language dialogue platform [7]. Assuming use by the automobile's driver or passengers, this automobile agent achieves natural-language dialogue in response to user utterances or events occurring on the automobile such as sudden braking.

2) Dialogue Example

An example of a dialogue between the user and automobile agent is shown in **Figure 5**. The interactive automobile agent detects engine startup as an event and begins to talk with the user (Fig. 5 (1)). Considering that it's the morning of a workday, the agent informs the user of weather conditions in the area of his or her workplace (Fig. 5 (2)). Then, on receiving a question about another place from the user, the agent replies based on the dialogue up to that point (Fig. 5 (3)) while also responding to an offhand utterance from the user expressing personal feelings (Fig. 5 (4)).

3) System Configuration

The system configuration of the interactive automobile agent and process flow are shown in **Figure 6**. The system links each server with a client application for use on Android smartphones and incorporates a voice-centric user interface based on a microphone and speaker mounted inside the automobile. In the system, a content-collection source such as the automobile generates event information that serves as an opportunity to initiate system-driven dialogue.

4) Features

The system links with the scenario-dialogue and casual-conversation functions and with weather information as external content. This enables the system to speak and converse with the user while including external information such as weather reports. In addition, linking with in-vehicle Controller Area Network (CAN) data*6 enables the system to generate dialogues corresponding to a variety of situations such as sudden breaking and car passing in relation to event information issued from the automobile.

3.3 Talking Toy

1) Overview

As an application example of the natural-language dialogue platform in

*6 **In-vehicle CAN data:** Information related to sudden braking, handling, etc. obtained using sensors mounted on the automobile.

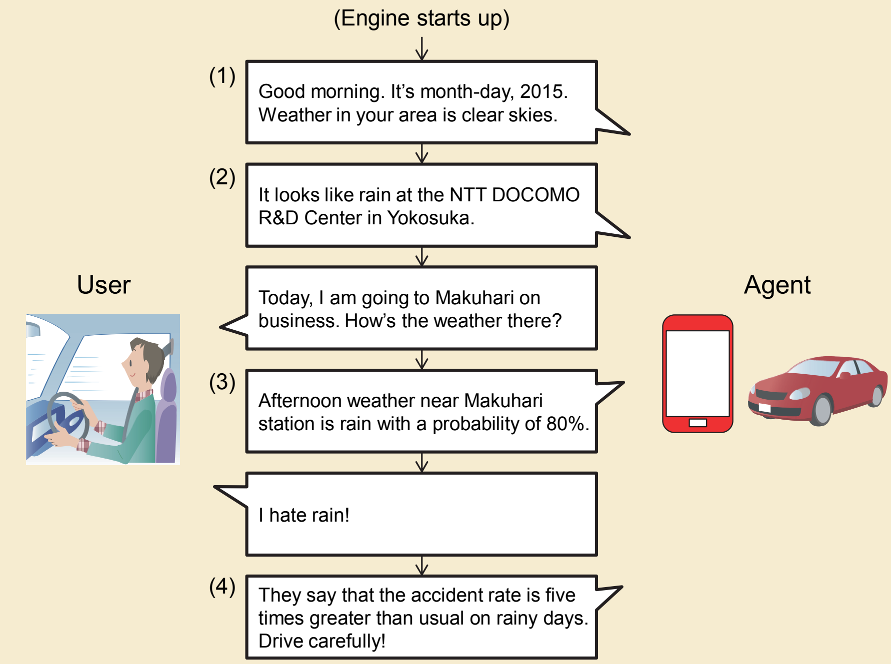


Figure 5　Example of a dialogue with the interactive automobile agent

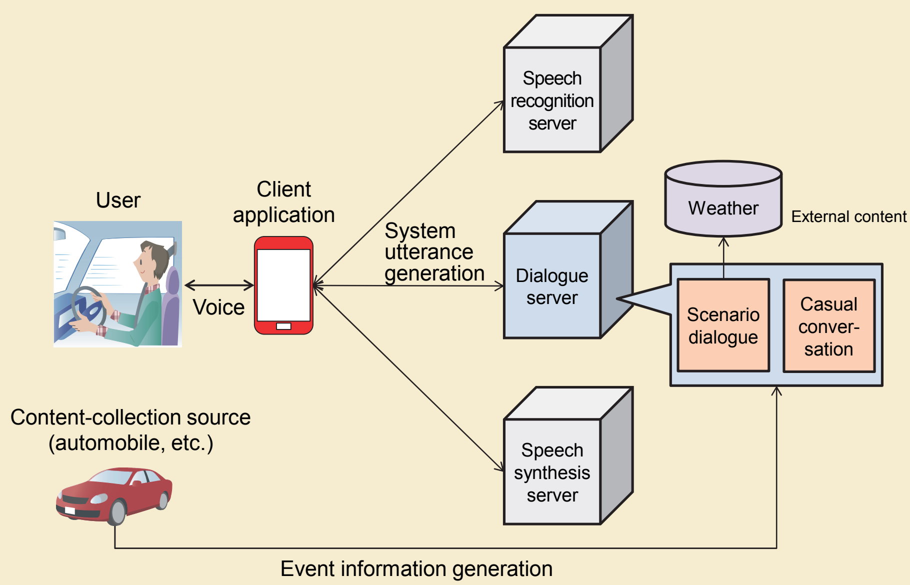


Figure 6　System configuration of interactive automobile agent

the toy industry targeting children and families, NTT DOCOMO and TOMY Company, Ltd. have jointly developed an interactive conversational toy named "OHaNAS®*7" that operates in conjunction with a smartphone or tablet [8].

*7 **OHaNAS®:** A registered trademark of TOMY Company, Ltd.

2) System Configuration

The system configuration of the talking toy is shown in **Figure 7**. To begin with, the user installs a specialized application in a smartphone or tablet to enable the system to connect to the natural-language dialogue platform. If the user now faces OHaNAS and makes an utterance, that speech will be connected to the terminal via Bluetooth®*8. The specialized application in the terminal then converts the speech to text using a speech recognition server and sends that text to NTT DOCOMO's natural-language dialogue platform, which returns a reply appropriate to the user's utterance. That reply is output from OHaNAS through speech synthesis. The user is able to have a natural conversation with OHaNAS in this way.

3) Features

This system links with the scenario-dialogue, casual-conversation, and Knowledge Q&A functions and with various types of external content such as weather reports and recipes. It is capable of three types of conversations between the user and toy from within the scenario dialogue function: (1) "useful conversation" in which the toy responds to the user's desire to know something, (2) "narrative conversation" in which the toy makes conversation with a storyline, and (3) "fun conversation" in which the toy becomes a playmate when the user is bored.

(1) Useful conversation

In a useful conversation, OHaNAS may reply to a user utterance such as "tell me some recipes using cabbage" or "cabbage is cheap" by saying: "I looked up some recipes using cabbage—I'll send you the information." This information would come from external content. In this example, OHaNAS provides information in response to a user request, but it may also provide the user with information directly on its own. OHaNAS does this by searching for external content based on certain rules and generating a reply even when no request is included in the last user utterance. In the above example, such a rule might be to search for and provide recipes that use an ingredient whose name was mentioned in a user utterance.

(2) Narrative conversation

A narrative conversation consists of a sequence of questions and replies that flow in a story-like manner. For example, the user may respond to the system question "Where are you going this weekend?" by saying "Nagoya," to which the system might say "Nagoya is famous for its Uiro steamed cakes." In this narrative conversation, the system proactively includes external content, which reflects the goal of achieving a toy that can be enjoyed without getting bored.

(3) Fun conversation

A fun conversation can be truly entertaining and recreational in the form of word games, riddles, quizzes, horoscopes, etc. Compared with application examples in other fields, OHaNAS includes many types of fun conversations.

Adding multiple types of conversation functions in the above way has achieved a toy with which children and families can enjoy natural-language conversation without getting bored.

4. Conclusion

In this article, we presented an overview of a natural-language dialogue

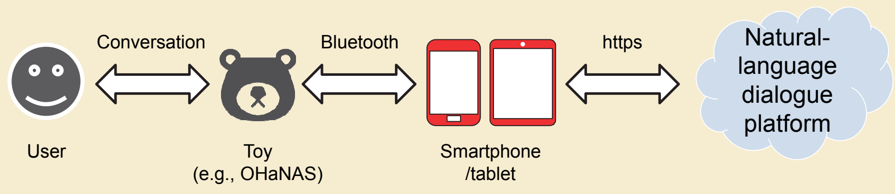


Figure 7 System configuration of talking toy

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

platform and described three application examples. A major feature of this platform is that whatever components are needed to develop a voice-interactive system can be combined freely, which significantly improves the ability of a developer to provide a customized service. This feature makes it easy to develop distinctive voice agents in a wide range of areas including home, in-vehicle, and entertainment.

Looking to the future, we plan to apply NTT DOCOMO's natural-language dialogue platform to even more products such as home appliances and game consoles and to provide multi-language support in addition to Japanese.

References

[1] W. Uchida et al.: "Knowledge Q&A: Direct Answers to Natural Questions," NTT DOCOMO Technical Journal, Vol.14, No.4, pp.4-9, Apr. 2013.

[2] K. Onishi et al.: "Casual Conversation Technology Achieving Natural Dialog with Computers," NTT DOCOMO Technical Journal, Vol.15, No.4, pp.16-21, Apr. 2014.

[3] T. Izumi, K. Imamura, T. Asami, K. Saito, G. Kikui and S. Sato: "Normalizing Complex Functional Expressions in Japanese Predicates: Linguistically-Directed Rule-Based Paraphrasing and Its Application," ACM Transactions on Asian Language Information Processing (TALIP), Volume 12, Issue 3, Article No.11, Aug. 2013.

[4] T. Hirano, N. Kobayashi, R. Higashinaka, T. Makino and Y. Matsuo: "Classification of Character Attributes from Self-disclosure Statements for Extracting User Information," Proc. of 21st Annual Meeting of the Association for Natural Language Processing, pp.273-276, Mar. 2015 (in Japanese).

[5] N. Kobayashi, T. Hirano, R. Higashinaka, T. Makino and Y. Matsuo: "Predicate Argument Structure Analysis of Question-Answer Pairs for User Information Extraction," 29th Annual Conference of the Japanese Society for Artificial Intelligence, 2L3-4, 2015 (in Japanese).

[6] C. Miyazaki, T. Hirano, R. Higashinaka, T. Makino and Y. Matsuo: "Automatic conversion of sentence-end expressions for characterization of dialogue system utterances," Proc. of the 68th SIG-SLUD-B301 (Special Interest Group on Spoken Language Understanding and Dialogue Processing) of the Japanese Society for Artificial Intelligence, pp.41-46, Sep. 2013 (in Japanese).

[7] W. Uchida, "Development of Voice Agent for Communicating with Automobiles," Automotive Engineering, Vol.69, No.3, Mar. 2015 (in Japanese).

[8] NTT DOCOMO Press Releases: "DOCOMO and TOMY Develop Interactive Conversational Toy," Jun. 2015.
https://www.nttdocomo.co.jp/english/info/media_center/pr/2015/0604_00.html

VoLTE Roaming | S8HR | IMS Platform

Technology Reports

VoLTE Roaming Service Using New VoLTE Roaming Architecture "S8HR"

NTT DOCOMO has been providing VoLTE services to domestic users in Japan since June 2014. Now, to make VoLTE services even more convenient for users, it has developed roaming-out and roaming-in functions to enable VoLTE to be used by NTT DOCOMO users on trips abroad and overseas users visiting Japan. For these functions, NTT DOCOMO has adopted the S8HR VoLTE roaming architecture that is now the focus of studies throughout the world.

This article describes the background to why NTT DOCOMO chose the development of VoLTE roaming using S8HR and overviews the functions added to the network and User Equipment (UE) of NTT DOCOMO for achieving VoLTE roaming.

Core Network Development Department *Mana Kaneko*
Shinichi Minamimoto
Zhen Miao †
Tomonori Kagi
Communication Device Development Department *Shinya Takeda*

1. Introduction

Voice over LTE (VoLTE) is a technology for providing voice services over Long Term Evolution (LTE). NTT DOCOMO has been providing VoLTE to domestic users in Japan since June 2014 in a form conforming to technologies specified by 3rd Generation Partnership Project (3GPP) and Global System for Mobile communications Association (GSMA)*1 [1] [2]. VoLTE services have also been launched in South Korea, the United States, and other countries—the number of operators providing VoLTE is increasing throughout the world.

At NTT DOCOMO, VoLTE-capable UE went on sale starting with the 2014 summer models. However, in the case of roaming, this UE, while being capable of data communications on LTE the same as conventional non-VoLTE-capable UE, could only achieve voice communications by making connections via 3G circuit switching [3]. To enable NTT DOCOMO users to use VoLTE when overseas, NTT DOCOMO has developed a VoLTE roaming function for its network and UE. Future NTT DOCOMO VoLTE-capable UE will progressively support VoLTE roaming. This will enable users to enjoy the distinctive features of VoLTE such as high-quality calls, quick call connections, high-speed multiple access*2, and video calls even when out of the country. In addition, users from other countries having a VoLTE-capable UE will also be able to use VoLTE services when camping on the NTT DOCOMO network. Moreover, since control of voice communications is achieved over LTE data roaming (data communications), it will now be possible to conclude an VoLTE roaming agreement even with non-W-CDMA providers with which a 3G roam-

† Currently DOCOMO Technology Inc., Packet Network Division

*1 **GSMA:** An association that supports and manages activities of the mobile industry, such as formulating roaming rules. The largest mobile communications industry association in the world, with members in related businesses including mobile communications providers, IPX operators, and UE, equipment and software vendors.

*2 **Multiple-access:** Accessing different bearers from a single UE (called Multi-Call in 3G).

ing agreement could not be concluded in the past due to differences in Radio Access Technologies (RAT)*3.

There are two major architectures for VoLTE roaming: Local Breakout architecture (hereinafter referred to as "LBO") and S8 Home Routed architecture (hereinafter referred to as "S8HR"). NTT DOCOMO is using S8HR that is now being studied throughout the world as one new type of architecture for VoLTE roaming. S8HR enables the provision of services not provided in the visited network and shortens the time-to-market of VoLTE roaming.

In this article, we describe the background to NTT DOCOMO's development of VoLTE roaming using S8HR and overview the functions added to the network and UE of NTT DOCOMO for achieving VoLTE roaming.

2. Background to Adoption of VoLTE Roaming with S8HR

2.1 Features of LBO and S8HR

As described above, the two major types of architecture for VoLTE roaming are LBO and S8HR. These are compared in **Figure 1**.

LBO implements Evolved Packet Core (EPC)*4 entities and Proxy-Call Session Control Function (P-CSCF)*5 in the Visited Public Mobile Network (VPMN) and Serving-Call Session Control Function (S-CSCF)*6, Application Server (AS)*7, Home Subscriber Server (HSS)*8, etc. in the Home Public Mobile Network (HPMN). The assumption here is that a voice connection (Session Initiation Protocol (SIP)*9/Real Time Protocol (RTP)*10 connection) will be made

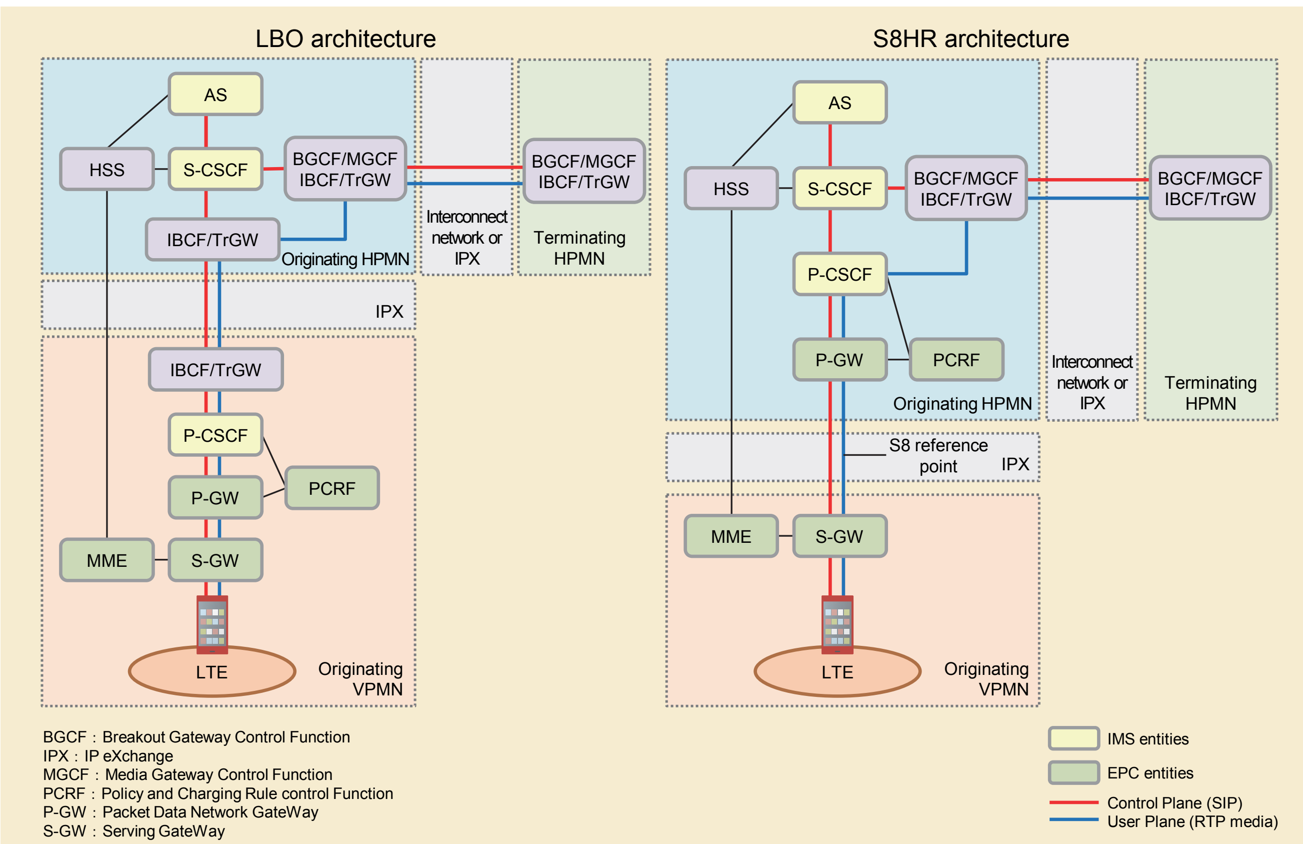


Figure 1　Comparison of LBO and S8HR methods

*3 **RAT:** A mobile communications circuit such as LTE and 3G (W-CDMA).

*4 **EPC:** A core network accommodating a radio access network such as LTE. It consists of MME, SGW, P-GW, and PCRF and provides functions such as authentication, mobility control, bearer management, and QoS control.

*5 **P-CSCF:** A function deployed at the connection point with EPC and at the connection point with S-CSCF and I-CSCF. It has the roles of linking with EPC to initiate QoS control and of relaying SIP signals between the mobile UE and S-CSCF and I-CSCF.

*6 **S-CSCF:** A SIP server performing UE session control and user authentication.

*7 **AS:** A server that executes an application to provide a service.

*8 **HSS:** A subscriber information database in a 3GPP mobile communications network managing authentication information and visited-network information.

*9 **SIP:** A call control protocol defined by the Internet Engineering Task Force (IETF) and used for IP telephony with VoIP, etc.

*10 **RTP:** A transmission protocol for streaming video and voice media. As a UDP type of protocol, no countermeasures to packet loss are performed. Generally used in combination with a communications status report provided by RTCP.

between the VPMN and HPMN via the Interconnection Border Control Function (IBCF)*11/Transition GateWay (TrGW)*12, which acts as a gateway node between IP Multimedia Subsystem (IMS)*13 networks [4]. In contrast, S8HR adopts an architecture based on LTE data roaming and utilizes the S8 reference point*14 that lies between the VPMN and HPMN. This means that all IMS entities such as the P-CSCF can be implemented on the HPMN side [5].

2.2 Advantages of S8HR

The advantages of S8HR in comparison with LBO are summarized below.

(1) Signaling on the IMS layer conducted by SIP protocol is performed directly between the UE and P-CSCF in the HPMN. This enables control by HPMN without having to rely on IMS entities in the VPMN. For example, when providing a video call service to a roaming-out user, LBO requires that video call functionalities be supported by P-CSCF/IBCF/TrGW in the VPMN, but S8HR has no need for such capabilities in the VPMN thereby simplifying the provision of services.

(2) Since the IMS entities do not span the HPMN and VPMN, gateway nodes (IBCF/TrGW) are not required between HPMN and VPMN.

(3) The P-CSCF in the HPMN is only accessed by UE that is deployed in the HPMN—it is not accessed by any other UE. This means that the IMS stack in the UE and P-CSCF connectivity for domestic VoLTE service can be directly used for VoLTE roaming.

To provide users with VoLTE roaming with high connectivity as soon as possible, NTT DOCOMO decided to develop VoLTE roaming and to launch services with S8HR having the advantages described above. NTT DOCOMO is also active in S8HR standardization activities in parallel with commercial launches—S8HR architecture was officially endorsed by GSMA as a VoLTE roaming architecture in May 2015.

3. Overview of VoLTE Roaming Functions

3.1 Conditions for Providing VoLTE Roaming

The architecture of VoLTE roaming using S8HR is based on LTE data roaming. The following conditions must therefore be met to provide VoLTE roaming to a user.

- HPMN and VPMN must have concluded an LTE data roaming agreement.
- HPMN and VPMN must have concluded an VoLTE roaming agreement with S8HR.
- The user must be using UE supporting VoLTE roaming.

If the above conditions are met, the user can use VoLTE services in the VPMN.

The following describes the distinctive features to be added to the UE and the network to achieve VoLTE roaming-out and roaming-in with S8HR. We note here that added functions mainly concern the roaming-out service since it is the HPMN that controls roaming-out users when using S8HR.

3.2 Overview of Roaming-out Functions

Since the UE cannot recognize whether the VoLTE roaming architecture between HPMN and VPMN is S8HR or LBO, the UE proceeds to operate without being aware of it.

1) Attach*15/IMS Registration*16 of Roaming-out User

Section 4 of Ref. [3] described UE operation according to the conditions of the VPMN in LTE roaming scenarios. In this article, we assume UE supporting VoLTE roaming and describe UE operations up to the point at which voice, data and SMS can be used after the UE has initiated the Attach procedure in various networks. Furthermore, while the article referenced above took up voice-centric, data-centric, and data as types of UE, we point out here that all

---

*11 **IBCF:** A function deployed on both sides of a network border for interconnecting IMS cores and networks. It serves to relay SIP signals and conceal the internal network.

*12 **TrGW:** A gateway controlled by IBCF performing media communication control (network-address/port conversion, IPv4/IPv6 protocol conversion, etc.).

*13 **IMS:** A call control procedure that realizes multimedia communications by consolidating 3GPP standardized communication services offered over fixed and mobile networks through the use of SIP, which is a protocol used on the Internet and in Internet phones.

*14 **S8 reference point:** An interface connecting P-GW and S-GW.

*15 **Attach:** The processing of registering a mobile UE with a network when UE power is turned on, or the state of being registered.

*16 **Registration:** In IMS, mobile UE register current location data in HSS with SIP.

VoLTE-capable UE are voice-centric. Additionally, considering the possibility of using the Circuit Switched FallBack (CSFB)*17 procedure when camping on a non-VoLTE-capable network or when VoLTE is temporarily unavailable, current UE will send an Attach Request for both the Packet Switched (PS) and Circuit Switched (CS) domains. Operation of a VoLTE-capable UE that does not support the CS domain will be taken up as a future topic of study.

The procedure up to the point at which VoLTE with S8HR can be used is described in Ref. [5]. However, when the UE attempts to initiate VoLTE roaming, it can be assumed that the VPMN response to an Attach Request will differ depending on the type of VoLTE and RAT support provided by the VPMN, whether a VoLTE roaming agreement has been concluded, etc. The operations performed by the UE for various types of network responses to Attach Request are summarized in **Figures 2** and **3** and explained below. Operation by UE not supporting VoLTE roaming is also shown for reference.

In relation to the above, an IMS Voice over PS session indicator (hereinafter referred to as "IMS VoPS") has been specified by 3GPP [6]. IMS VoPS indicates whether or not the VPMN supports VoLTE per user. This value is set according to the VoLTE roaming agreement between HPMN and VPMN. The UE can check IMS VoPS to decide whether to provide voice calls in the PS domain or in the CS domain [7].

(a) Attach successful for both CS/PS domains and VoLTE can be used

In the event that the VPMN provides not only LTE but also W-CDMA/GSM, that is, RAT having a CS domain, the network will respond to a Combined Attach Request from the UE with a message indicating that Attach was successful for both the PS and CS domains. In addition, if VoLTE is supported and a VoLTE roaming agreement has been con-

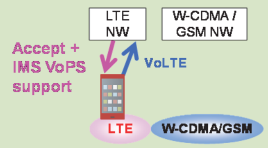
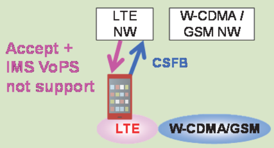
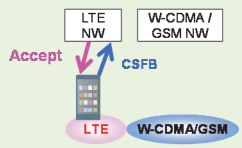
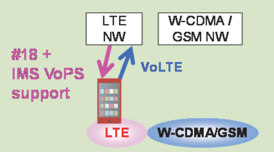
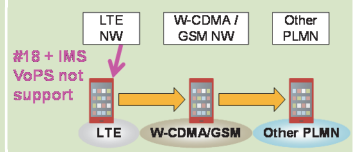
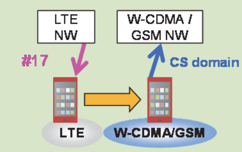
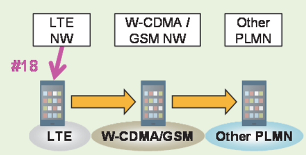
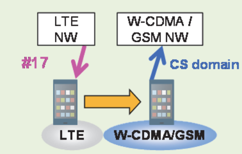
UE Type	Response from the VPMN	
	PS/CS domains successful	
	(a) VoLTE can be used (IMS VoPS support)	(b) VoLTE cannot be used (IMS VoPS not support)
Voice-centric, VoLTE-roaming capable	Camps on LTE, performs IMS Registration	Camps on LTE, performs IMS Registration
	Voice: can be used via VoLTE Data: can be used via LTE SMS: can be used via SMS over IP	Voice: can be used via CSFB Data: can be used via LTE SMS: can be used via SMS over IP or SMS over SGs
		
Voice-centric, non-VoLTE-roaming capable	Camps on LTE	
	Voice: can be used via CSFB; Data: can be used via LTE; SMS: can be used via SMS over SGs	
		

Figure 2 UE operation when Attach succeeds

*17 **CSFB:** A procedure for switching to a radio access system having a CS domain, when a UE sends/receives a circuit switched communication such as voice while camped on an LTE network.

UE Type	Response from the VPMN		
	Only PS domain succeeds (e.g., receives #18 (CS domain not available))		(e) PS/CS domains both fail (e.g., receives #17 (Network failure))
	(c) VoLTE can be used (IMS VoPS support)	(d) VoLTE cannot be used (IMS VoPS not support)	
Voice-centric, VoLTE-roaming capable	Camps on LTE, performs IMS Registration	Disables LTE and selects another operator if W-CDMA/GSM is unavailable	After 5 Attach attempts, disables LTE and moves to W-CDMA/GSM
	Voice: can be used via VoLTE Data: can be used via LTE SMS: can be used via SMS over IP	Voice, data, SMS: can be used via W-CDMA/GSM (or another operator)	Voice, data, SMS: can be used via W-CDMA/GSM
			
Voice-centric, non-VoLTE-roaming capable	Disables LTE and selects another operator if W-CDMA/GSM is unavailable		After 5 Attach attempts, disables LTE and moves to W-CDMA/GSM
	Voice, data, SMS: can be used via W-CDMA/GSM (or another operator)		Voice, data, SMS: can be used via W-CDMA/GSM
			

PLMN : Public Land Mobile Network

Figure 3 UE operation when Attach fails

cluded, IMS VoPS will be set to "supported" in the Attach Accept [8]. If the UE supporting VoLTE roaming camps on such a network and its voice domain preference [6] is set to "IMS PS voice preferred, CS Voice as secondary," a Packet Data Network (PDN) connection for IMS will be established and IMS Registration will be completed according the procedure in Ref. [5]. At this point, VoLTE will be prioritized for voice [7] and SMS over IP*18 will be prioritized for SMS.

(b) Attach successful for both CS/PS domains but VoLTE cannot be used

When in an LTE area, UE supporting VoLTE roaming will attempt to establish a PDN connection for IMS and perform IMS Registration. If the Attach has been initiated in the VPMN that provides CSFB but no VoLTE or the VPMN has not concluded a VoLTE roaming agreement, the UE will receive IMS VoPS set to "not supported" [8] while the Attach procedure succeeds in both CS/PS domains. In this case, the UE supporting VoLTE roaming will determine that VoLTE cannot be used even if a PDN connection for IMS has been established and IMS Registration has been completed and that the CS domain must instead be used for voice via CSFB.

Moreover, while IMS VoPS indicates whether the VPMN is VoLTE capable or not, using the indicator to determine whether SMS should be used via SMS over IP or SMS over SGs*19 has not yet been specified in 3GPP. Current NTT DOCOMO UE uses SMS over IP if a PDN connection for IMS has been established

*18 **SMS over IP:** SMS that sends/receives messages using SIP protocol.

*19 **SMS over SGs:** SMS via a SGs interface connecting MSC and MME. Non-VoLTE-capable UE sends/receives SMS messages via SMS over SGs when camped on an LTE network.

and SIP Registration has been completed.

(c) Attach successful for only PS domain and VoLTE can be used

Some networks do not provide a CS domain (W-CDMA). Combined Attach Request will be accepted for PS domain only with cause value #18 (CS domain not available) by such a network. In the case of UE not supporting VoLTE roaming, it is assumed that the UE will disable the LTE capability and make a transition to another VPMN that provides a CS domain in which voice can be used. However, in the case of UEs supporting VoLTE roaming that receives IMS VoPS set to "supported," the UE will perform IMS Registration after establishing a PDN connection for IMS without disabling LTE and proceed to use VoLTE. These procedures achieve VoLTE roaming with VPMNs not providing W-CDMA. Here, SMS over IP will be used for SMS.

(d) Attach successful for only PS domain but VoLTE cannot be used

If no W-CDMA is provided by an operator that does not provide VoLTE or has not concluded a VoLTE roaming agreement, IMS VoPS received by the UE will be set to "not supported" and the Combined Attach Request will be accepted for PS domain only with cause value #18 (CS domain not available). In this case, VoLTE roaming cannot be used and neither can voice in the CS domain, so only data roaming can be used.

UE camped on such a network must perform some type of operation to use voice, so it is assumed that the UE will disable LTE and move to another VPMN that provides voice services.

(e) Attach fails for both domains

In the case that Attach procedure fails for both PS and CS domains owing, for example, to no LTE data roaming agreement, no services at all including voice can be used even if camped on an LTE network. The UE can therefore disable the LTE capability and move to a W-CDMA network to enable the use of voice, data, and SMS services. This operation is the same for UE not supporting VoLTE roaming.

2) Voice Originating/Terminating

In 1) above, we described the procedures of UE supporting VoLTE roaming for making voice calls and sending SMS messages when camped on various VPMNs. In the following, we describe network procedures.

Since call processing for originating/terminating voice calls in VoLTE roaming-out uses IMS entities in the HPMN, the sequence is the same as that of non-roaming calls [2]. The key changes in a network for originating/terminating voice calls in VoLTE roaming-out are summarized below.

(a) Determining existence of VoLTE roaming agreement

When the UE is camped on a VPMN having no VoLTE roaming agreement but having a LTE data roaming agreement, it is assumed that the Mobility Management Entity (MME)*20 in the VPMN will return the IMS VoPS indicator set to "not supported" and that the UE will perform conventional CSFB calling based on that information. However, if MME in the VPMN should return IMS VoPS set to "supported" at this time, IMS Registration can proceed, which means that the UE may attempt to originate a VoLTE call. For this reason, the AS in the HPMN is equipped with a function for prohibiting VoLTE originating/terminating calls from a VPMN with no VoLTE roaming agreement. This function is achieved by having the AS determine whether the VPMN has a VoLTE roaming agreement at the time of voice originating/terminating calls based on VPMN information obtained from the HSS.

(b) User dialing operation

With user convenience in mind, the aim was to make the VoLTE roaming-out user dialing operation

*20 **MME:** A logical node accommodating a base station (eNB) and providing mobility management and other functions.

the same as that of 3G roaming-out, so call-originating and call-terminating functions were added as described below.

(1) Call-originating function

The comparison of call originating for 3G roaming-out and VoLTE roaming-out is shown in **Figure 4**.

For 3G roaming-out, number analysis when the roaming-out user is originating a voice call has been performed at an entity in the VPMN. For example, if the roaming-out user makes a call to a fixed-line number in the VPMN, routing can be performed by dialing the number starting with the area code without affixing the plus key (+) and Country Code (CC).

For VoLTE roaming, however, number analysis is performed at AS in the HPMN, so the AS is equipped with a function for translating the number dialed by the user and converting it to a routable number. For example, in the event that a roaming-out user originates a call to a fixed-line number in the VPMN, the AS in the HPMN will connect the call to the VPMN by deriving the country of the visited operator and adding the CC of that country to the dialed number.

(2) Call-terminating function

Given a call made from a domestic user to a roaming-out user, this function affixes a CC to the originating number at the AS server as part of the call-termination process. This is done considering the possibility that a call to that number will be returned to HPMN from the roam-

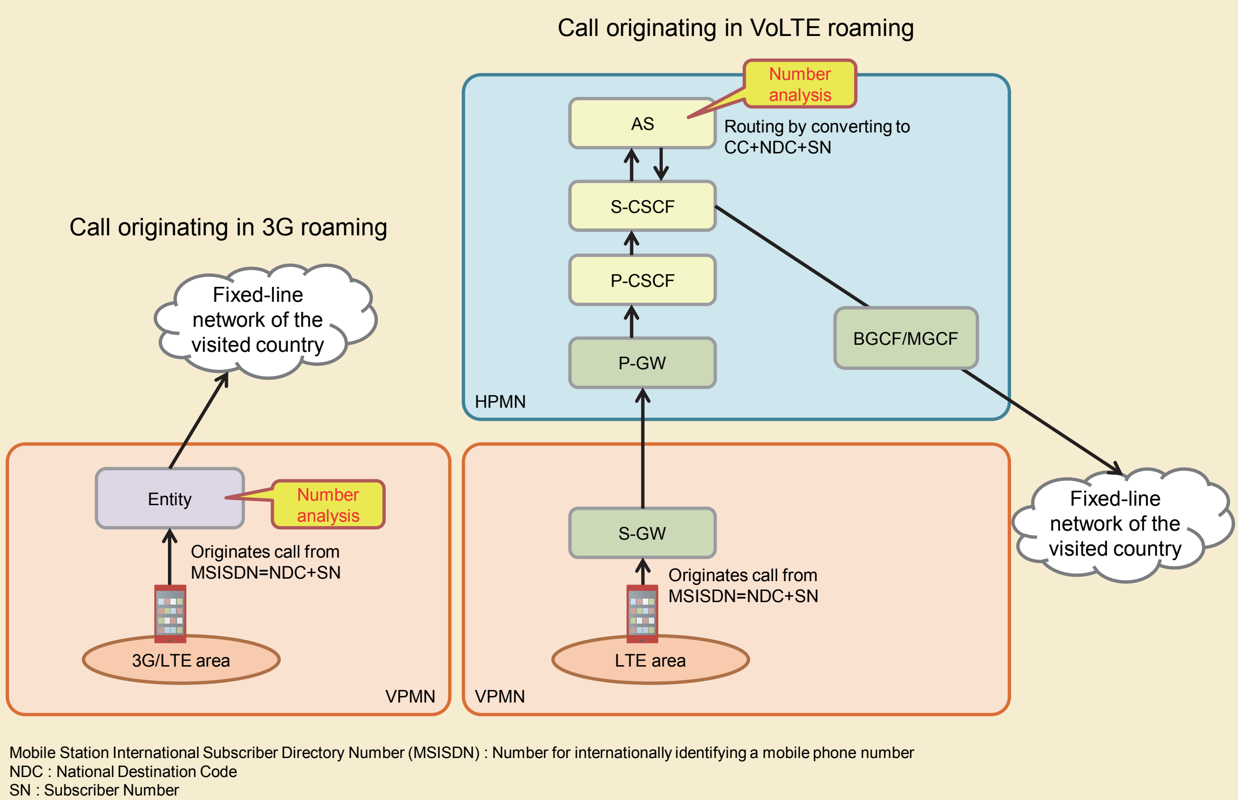


Figure 4 Call originating compared between 3G roaming-out and VoLTE roaming-out

ing-out user. In other words, this function converts the originating number to a format that enables a return call to be correctly connected from the VPMN.

(c) Domain selection at call termination

Similar to domestic VoLTE, there are times when it is unclear at HSS whether the user is camped on 3G or LTE. In such a case, HSS will execute the Terminating Access Domain Selection (T-ADS)*21 function to identify the RAT in which the call is terminated. The T-ADS process flow is shown in **Figure 5**.

To begin with, the terminating AS determines whether the VPMN has a VoLTE roaming agreement based on VPMN information obtained from HSS. At this time, AS selects 3G termination if there is no agreement and initiates T-ADS if there is an agreement. For the latter case, HSS on receiving the T-ADS initiation request from the AS sends an inquiry to both the MME and Serving General packet radio service Support Node (SGSN)*22 to retrieve the time of the last location registration request from the UE. It then compares those two time stamps and informs AS of the RAT corresponding to the most recent time stamp so that call termination can be performed in the appropriate domain.

It is generally considered that the VPMN's MME and SGSN will support the T-ADS function if there is a roaming agreement between the HPMN and VPMN, but NTT DOCOMO adopts the following policy considering that T-ADS support may not yet be provided.

(1) Since a VPMN supporting T-ADS can be expected to notify HSS of "T-ADS capability" from MME and SGSN at the time of

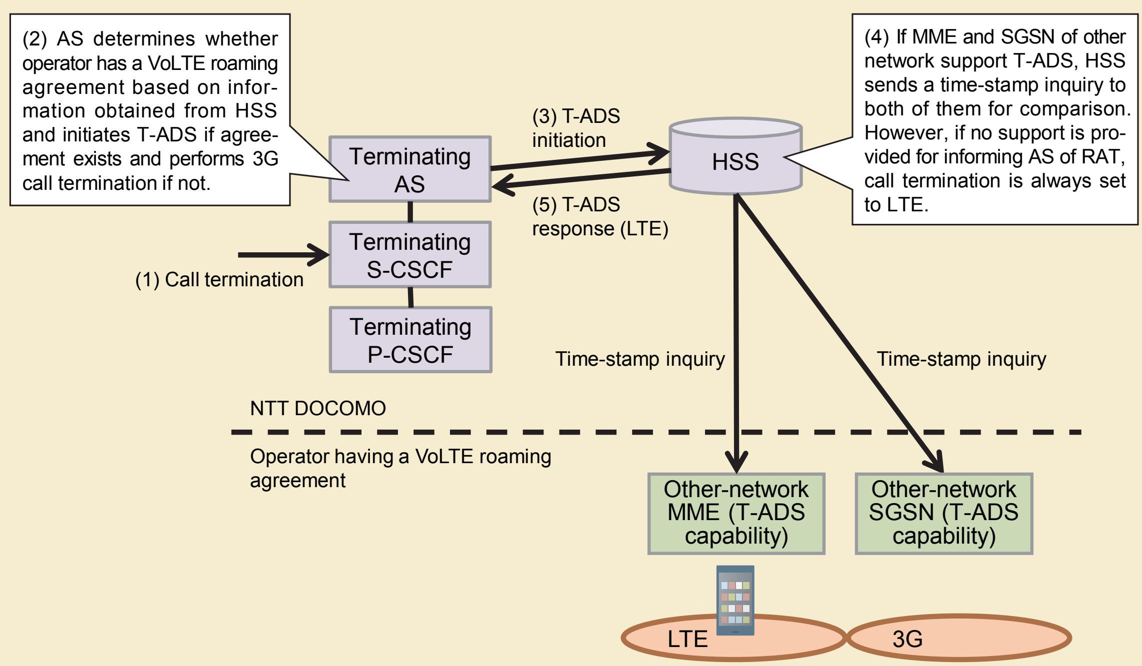


Figure 5 T-ADS process flow

*21 **T-ADS:** A function that specifies the access network in which the UE is currently camped.

*22 **SGSN:** A logical node in 3GPP standard specifications providing functions such as mobility management for a mobile UE performing packet switching and packet communications.

UE location registration, T-ADS will always be initiated in the event that HSS is notified of that parameter.

(2) If HSS is not notified of T-ADS capability, the RAT of the terminating call must be determined without initiating T-ADS. Thus, taking into account the fact that some operators provide only LTE, all call terminations will be of the VoLTE type if no notification of T-ADS capability is received.

3) Supplementary Services

In 3G roaming-out, the architecture is such that call control is performed at entities in the VPMN. This makes it difficult to provide an operator's unique services (such as Melody Call and call recording which are provided by NTT DOCOMO). In contrast, the architecture for VoLTE roaming-out enables call control to be performed using IMS entities in the HPMN, which enables the HPMN to provide the same unique services to both roaming and non-roaming users.

3.3 Overview of Roaming-in Functions

The launching of a VoLTE roaming-in service means that roaming-in users with VoLTE-capable UE will be camped on networks other than their HPMN. These users, however, will be a mixture of those having and not having a VoLTE roaming agreement. For this reason, NTT DOCOMO has configured their network entities according to 3GPP TS23.401 [8]. Here, if the roaming-in user belongs to a HPMN that has concluded a VoLTE roaming agreement, the NTT DOCOMO MME returns IMS VoPS set to "supported" to the UE upon the Attach Accept and proceeds to provide VoLTE functions. However, if the roaming-in user belongs to a HPMN that has not concluded a VoLTE roaming agreement, MME returns IMS VoPS set to "not supported" to the UE and disables VoLTE functions. Consequently, if the roaming-in user attempts to originate a voice call, it will likely be handled via the CS domain.

Furthermore, as shown in Fig. 4, the network that performs number analysis differs between 3G roaming and VoLTE roaming, so in the event that the user originates a call to an emergency number that cannot be recognized as such by the UE, that call would have to be determined to be an emergency call by the AS in the HPMN, which would make it necessary to manage emergency-call numbers of the VPMN on the HPMN side. To prevent this, the NTT DOCOMO MME is being equipped with a function for providing the roaming-in UE with an Emergency Numbers List as specified by 3GPP TS 24.301 [6] at the time of a location-registration response. With this information, the UE is made aware of emergency-call numbers. Thus, if the roaming-in user needs to make an emergency call (110, 118, or 119), the UE itself will be able to recognize the number as an emergency call with no need for a function to do that on the HPMN side under the NTT DOCOMO network. This capability enables the appropriate domain to be selected and an emergency call to be connected.

4. Conclusion

In this article, we described the background to why NTT DOCOMO chose the development of VoLTE roaming with S8HR architecture and overviewed the functions added to the network entities/UE of NTT DOCOMO for achieving VoLTE roaming-out and roaming-in services. This development/deployment will unleash the VoLTE user experience that was originally limited to Japan to roaming users visiting operators abroad that have concluded a VoLTE roaming agreement with NTT DOCOMO. With the aim of further expanding VoLTE coverage in the future, NTT DOCOMO plans to make even more contributions to standardization activities and to promote studies with operators/vendors.

References

[1] I. Tanaka et al.: "Overview of GSMA VoLTE Profile," NTT DOCOMO Technical Journal, Vol.13, No.4, pp.45–51, Mar. 2012.

[2] K. Tokunaga et al.: "VoLTE for En-

hancing Voice Services,” NTT DOCOMO Technical Journal, Vol.16, No.2, pp.4-22, Oct. 2014.
[3] H. Inaba et al.: “Implementing LTE International Data Roaming-out,” NTT DOCOMO Technical Journal, Vol.16, No.3, pp.16-26, Jan. 2015.
[4] I. Tanaka: “VoLTE Roaming and Interconnection Standard Technology,” NTT DOCOMO Technical Journal, Vol.15, No.2, pp.37-41, Oct. 2013.
[5] M. Abe et al.: “Standardization of New VoLTE Roaming Architecture,” NTT DOCOMO Technical Journal, Vol.17, No.1, pp.37-40, Jul. 2015.
[6] 3GPP TS24.301 V13.0.0: “Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3,” Dec. 2014.
[7] 3GPP TS23.221 V13.0.0: “Architectural requirements,” Jun. 2014.
[8] 3GPP TS23.401 V13.0.0: “General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access,” Sep. 2014.

Mobile Healthcare | Maternity Log | Preventive Medicine

Collaboration Projects

Initiative toward Prevention and Early Detection of Disease Using Healthcare Data and Genome Analysis

Research Laboratories
Daisuke Ochi†
Takafumi Yamauchi†
Satoshi Hiyama

With the aim of achieving the "ultimate smart life" that can prevent the onset and progression of disease, NTT DOCOMO has begun joint research focusing on diseases and changes in physical condition related to pregnancy as an initial target. This research will analyze information that combines the three elements of genome information, biological substances in blood, and daily healthcare data on a scale of several hundred pregnant women. Through this initiative, NTT DOCOMO expects to establish the world's first methods for the prevention and early detection of diseases that many pregnant women experience but whose causes has so far been unclear. This research is being conducted jointly with the Tohoku Medical Megabank Organization of Tohoku University (Executive Director Masayuki Yamamoto, Professor Masao Nagasaki, and others).

1. Introduction

As declared in "New Initiatives toward Delivery of Medium-term Targets" announced in April 2015, NTT DOCOMO plans to collaborate with new partners for the creation of value including solutions to social issues such as health and medical care [1]. To this end, NTT DOCOMO is promoting research and development toward the "ultimate smart life" that can prevent the onset and progression of diseases affecting many people.

Disease is thought to develop as a complex intertwining of genetic factors that an individual is born with and acquired environmental factors such as lifestyle and living environment. Since 2003 when the entire human genome*1 was first sequenced [2], great strides have been made in the analysis of genetic factors owing to advances in genome analysis technology. In contrast, environmental factors have traditionally been analyzed on the basis of questionnaires targeting a person's lifestyle, so accuracy and frequency of administering these questionnaires have been issues of concern. Against this background, the NTT DOCOMO Group has constructed and deployed a healthcare data collection platform that can determine an individual's lifestyle practices in part with high accuracy and high frequency. This is accomplished by leveraging NTT DOCOMO's core competence in mobile terminals and network operation to enable the daily measurement of healthcare data such as blood pressure and physical activity. We expect the use of this platform to enhance the analysis of environmental factors.

† Currently on loan to Tohoku University

*1 **Genome:** All genetic information associated with the entire base sequence of DNA (see *2 below) making up an organism's chromosomes.

A major issue in modern medicine is that fundamental methods for preventing and treating many diseases related to pregnancy have not yet been found. NTT DOCOMO has therefore set pregnancy-related diseases as its first research target with the aim of establishing disease-prevention and early-detection methods for diseases related to pregnancy. It plans to accomplish this by being the first in the world to perform integrated analysis that combines genome information with biological substances in blood obtained by periodic blood sampling and daily healthcare data obtained using the healthcare data collection platform.

In this article, we explain disease factors, precision medicine and prevention and NTT DOCOMO's approach, the method of joint research targeting pregnancy-related diseases, and expected results from this research.

This joint-research initiative commenced in November 2014 in partnership with the Tohoku Medical Megabank Organization (ToMMo) of Tohoku University, a leading genome analysis center in Japan [3].

2. Background to Research: Disease Risk Factors

As stated above, the aim of this research is to establish methods for prevention and early detection of diseases, but we first examine the causes of disease to provide some background. Many diseases are thought to develop through an intertwining of genetic factors and environmental factors. It is therefore essential that both types of factors be analyzed in detail to prevent the onset and progression of those diseases (**Figure 1**).

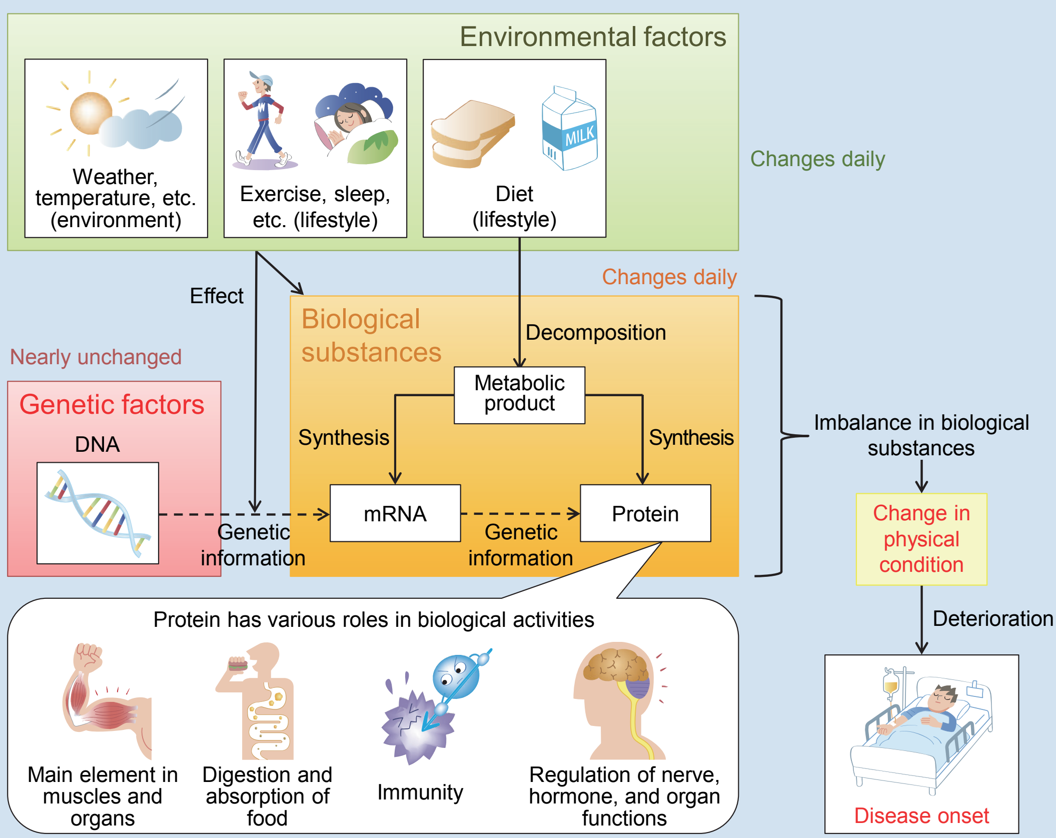


Figure 1　Connection among health, genes, and environment

2.1 Genetic Factors

Among the causes of disease, genetic factors originate in inherent genetic information passed from parent to child. This information is determined by the sequencing of a substance called DeoxyriboNucleic Acid (DNA)*2 found in human cells. Human DNA consists of four types of bases in a double helix structure—there are approximately 3 billion base pairs in DNA.

The arrangement of bases (base sequence) in DNA includes information that acts as a template for biological substances in blood such as protein. Part of this base sequence is copied as messenger RNA (mRNA)*3 that preserves this information and serves as a basis for synthesizing protein and other important biological substances. Protein can provide key functions for maintaining biological activities. These include a function for generating muscles and internal organs, a function for digesting and absorbing food, an immune function, and a function for regulating organ functions. The base sequence in DNA differs in part from person to person and the functions of protein generated from this base sequence likewise depend on the individual. As a result, protein that does not function normally can be generated depending on the person and it is that protein that can trigger disease. For example, a specific biological substance is needed to stabilize blood pressure, but if an abnormality exists in the base sequence of the protein involved in the generation of that biological substance, the quantity of that biological substance cannot be correctly controlled. This turns out to be a genetic factor for a disease like high blood pressure.

2.2 Environmental Factors

The body contains a wide variety of substances such as protein and metabolic products, the latter of which includes lipids and amino acids that are generated by chemical reactions in the production and consumption of energy. It is said that several thousand types of metabolic products exist within the body.

Such metabolic products appear and disappear daily in the body, but their concentrations are controlled within a certain range so as not to hinder biological activities. At the same time, the types and concentrations of these biological substances can vary according to environmental factors. A good example of such an environmental factor is an individual's lifestyle including diet, exercise, and sleep, which, if erratic and disordered, can cause the balance among biological substances to collapse. This condition can lead to a change in physical condition and eventually to disease. The natural environment in which one lives including weather and temperature is likewise an environmental factor that can induce changes in one's physical condition. For example, it is known that blood pressure during pregnancy can vary according to the expected date of delivery [4].

In the above way, our biological activities are governed not just by genetic factors but also by a variety of environmental factors. These two types of factors make their contribution in a complex manner. They bring about changes in the functions, types, and concentrations of biological substances such as protein and can induce changes in a person's physical condition. Such small changes that are out of the ordinary can be an "omen," and if they worsen, they can eventually lead to disease. A correct assessment of these factors that differ from person to person should help promote the development of precision medicine and prevention tailored to one's own physical constitution.

3. Precision Medicine and Prevention and NTT DOCOMO's Approach

The analysis of genetic factors has made great progress thanks to advances in genome analysis. However, the analysis of environmental factors has so far been mostly based on a self-reporting system consisting of lifestyle questionnaires administered once or twice a year. This format has raised issues with respect to analysis accuracy and frequency.

NTT DOCOMO can determine some of an individual's lifestyle practices with high accuracy and high frequency by using its healthcare data collection platform via mobile terminals and the network to measure and acquire healthcare

*2 **DNA:** A substance carrying genetic information in an organism and consisting of four types of nucleobases: adenine, guanine, cytosine, and thymine.

*3 **mRNA:** A substance generated from part of the DNA base sequence for synthesizing protein.

data on a daily basis. These data include blood pressure and ambient temperature, weight, body temperature, active mass, quality of sleep, etc. For example, a person making measurements with a weight and body composition analyzer need only touch the analyzer with his or her smartphone to register the measurement data on the healthcare data collection platform through Near Field Communication (NFC)*4. This enables centralized management of the user's healthcare data on a daily basis. In short, NTT DOCOMO's approach makes it possible to determine a user's biological information and lifestyle behavior day in and day out, which has been difficult to do by conventional approaches.

Information obtained via the healthcare data collection platform can be analyzed in a comprehensive manner with information on biological substances obtained by periodic blood sampling and genetic information obtained by genome analysis. We expect such comprehensive analysis to bring about new discoveries in relation to disease prevention and early detection.

4. Research Target

While there are countless diseases in the world, there are those that, while accounting for many patients, have not yet been fully explained owing to the difficulty of analyzing the environmental factors affecting each patient. These include diseases related to pregnant women such as pregnancy-induced hypertension syndrome, diabetes, and premature delivery. Approximately 200,000 out of one million pregnant women suffer from these diseases each year in Japan. However, due in part to limitations applied to medication and examinations so as not to affect the unborn child, little progress is being made in explaining the causes of these diseases or developing fundamental methods of treatment. Yet, it is known that health conditions during pregnancy can have a profound effect on the future health of the mother and child. For example, it is known that maternal obesity during pregnancy magnifies the risk of premature mortality in adult offspring [5].

NTT DOCOMO aims to establish methods for the prevention and early detection of pregnancy-induced diseases as its initial research target. It will adopt an integrated approach to information analysis that targets not only genome information but also biological substances obtained by periodic blood sampling and daily healthcare data.

5. Joint Research

To resolve the issues described above in relation to pregnancy-induced diseases, NTT DOCOMO commenced a joint research project with ToMMo in November 2014. This project is scheduled to run approximately four and a half years.

5.1 ToMMo

ToMMo was founded to establish advanced forms of medical care and support reconstruction in the wake of the Great East Japan Earthquake. It is a leading genome analysis center in Japan having biobank facilities for collecting and storing genome information on a scale of 150,000 individuals. It also features Japan's largest genome-analysis facility using cutting-edge genome-analysis techniques. ToMMo is conducting a large-scale survey called a "three-generation cohort study*5" [6] of mainly healthy pregnant women but also targeting the child to be born and the child's father, siblings, and grandparents. The study will analyze genetic factors and environmental factors through blood sampling and questionnaires.

5.2 Overview of Joint Research

This joint research aims to enhance the comprehensive analysis of genetic factors and environmental factors by combining ToMMo's genome analysis facility and NTT DOCOMO's mobile healthcare data collection platform. The ultimate goal is to establish new methods of prevention and early detection of diseases and to contribute to the health of the mother and child and the development of advanced medical care. NTT DOCOMO has also obtained approval from the ethics review committee established by Tohoku University School of Medicine to perform a "maternity log study" as an addition to the three-generation cohort study. This study will target pregnant women receiving

*4 **NFC:** A short-range wireless communication technology including FeliCa and other systems.

*5 **Cohort study:** Research that examines health changes in a group of people and studies the relation between body conditions, lifestyle, etc. and the onset of diseases.

obstetric care at Tohoku University Hospital. It will include blood sampling as a supplement to the blood sampling conducted under the three-generation cohort study and daily measurement of healthcare data. The plan is to target several hundred pregnant women for this study and to have them participate from the first stage of pregnancy to approximately one month after giving birth.

In the study, the subjects will use specific devices to make daily measurements of blood pressure and ambient temperature, weight, body temperature, amount of physical activity, etc. and will register measured values with NTT DOCOMO's healthcare data collection platform using smartphones (**Figure 2**). They will also be asked to give blood samples several times during the course of their participation.

Data obtained from blood samples and other healthcare data constitute sensitive information for the pregnant women participating in this study. In this joint research, we are setting up a security system based on ToMMo security guidelines and managing personal information with strict controls. Blood-sample data and other healthcare data are immediately turned into anonymous data at ToMMo so that study participants cannot be identified in the analysis process.

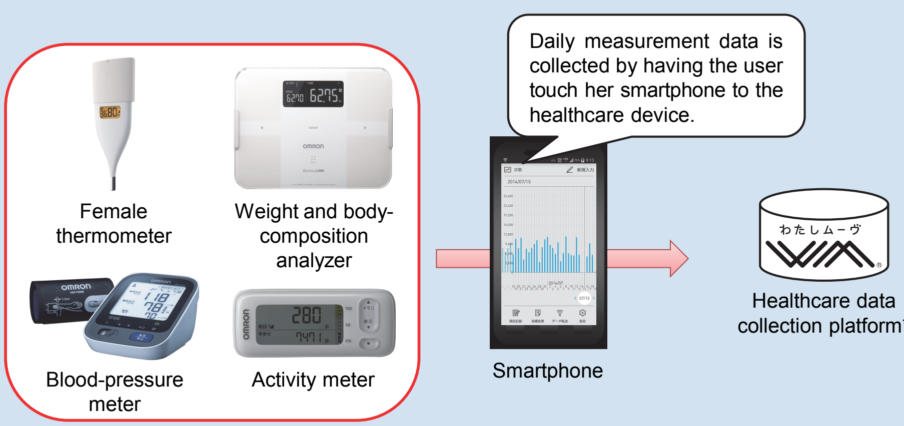
5.3 Challenges in Joint Research

Observational studies that target people involve many concerned parties starting with the subjects and medical practitioners. It is essential in studies of this type to design and share detailed research procedures, test them in advance, and construct a support system for the subjects.

Moreover, considering that the pregnant women acting as subjects in our research will be asked to measure and register healthcare data regularly over a long period of approximately 10 months, maintaining a subject's motivation to register that data is also a challenge. It is important that some means be developed to encourage a subject to take interest in the growth of her unborn child and in the change of her own physical condition. One way would be to develop a smartphone application especially for joint research and incorporate game-like elements according to the rate of data registration.

5.4 Expected Results

There have been past studies targeting pregnant women and analyzing metabolic products [7], but the joint research introduced in this article is the world's



*Healthcare platform "WM (Watashi Move)" provided by docomo Healthcare, Inc.
"WM (Watashi Move)" is a registered trademark of docomo Healthcare, Inc.

Figure 2 Devices used in study

first comprehensive analysis combining daily healthcare data with periodic blood sampling, genome information, biological substances, etc. The plan here is to observe how biological substances such as protein and metabolic products change over time and to clarify how that change relates to daily healthcare data, the onset of disease, and genome information. We also aim to shed light on the causal relationship between lifestyle and physical changes, between physical changes and blood pressure, etc. and to establish methods for prevention and early detection of diseases related to pregnant women.

Prevention and early detection of diseases affecting pregnant women can bring about positive effects not only during pregnancy, at childbirth, and after childbirth, but also in the pre-pregnancy and child-development periods (**Figure 3**). It has been pointed out that health management before pregnancy can have an effect on the health of the mother and unborn child during pregnancy. It is therefore expected that the development of a pre-pregnancy health management method tailored to the individual should reduce the risk of pregnancy-related diseases and promote a healthy pregnancy. Likewise, the development of health-management and disease-prevention methods to be applied during pregnancy should lead to childbirth without incident and increase the number of mothers that can maintain their health after giving birth. For example, it is known that the occurrence of pregnancy-induced hypertension syndrome and diabetes can increase the risk of high blood pressure and diabetes after childbirth. The disease attack rate after childbirth can therefore be expected to drop by controlling the onset of such diseases during pregnancy. In addition, improving conditions in the womb should make for healthy development of the unborn child and have a positive effect not only on the mother but also on the child's development after birth. In this way, establishing technology for the prevention and early detection of diseases particular to pregnant women can protect the health of the mother and child over a broad range of time from the pre-pregnancy stage to the child development period.

6. Conclusion

This article described factors contributing to disease, issues in precision medicine and prevention, NTT DOCOMO's research target, the method adopted for

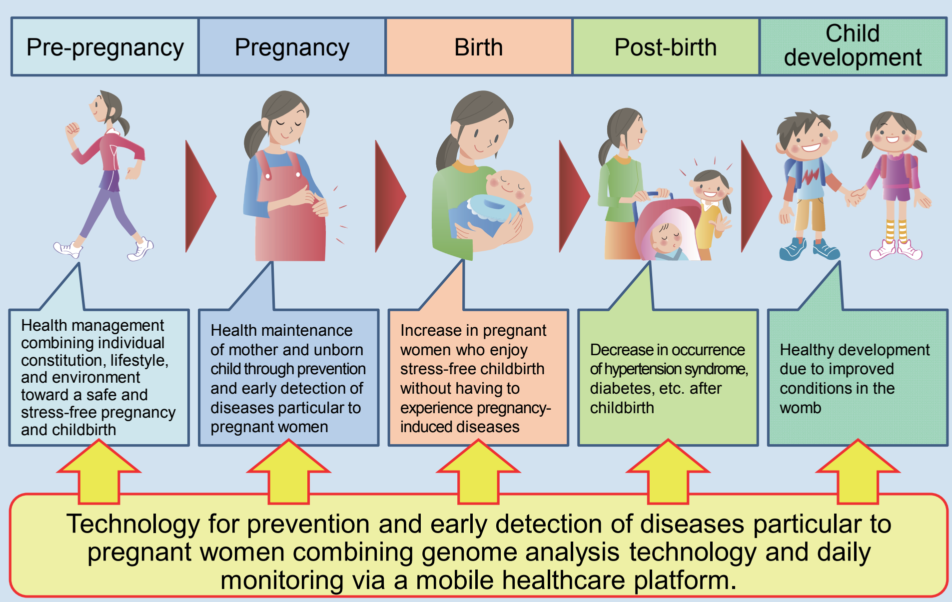


Figure 3 Expected social values

joint research, and expected results. Going forward, we expect to apply the knowledge gained from this exploratory research on diseases targeting pregnant women and their prevention and early detection to prevention of diseases in other target groups. NTT DOCOMO wants to contribute its expertise to achieving a healthy long life for everyone.

References

[1] NTT DOCOMO Press Releases: "DOCOMO Announces New Initiatives toward Delivery of Medium-term Targets," Apr. 2015.
https://www.nttdocomo.co.jp/english/info/media_center/pr/2015/0428_00.html

[2] HGP: "Human Genome Project Information," 2003.
http://www.ornl.gov/sci/techresources/Human_Genome/home.shtml

[3] NTT DOCOMO Press Releases: "DOCOMO and ToMMo to Jointly Research Pregnancy Disease Prevention & Early Detection," Nov. 2014.
https://www.nttdocomo.co.jp/english/info/media_center/pr/2014/1119_00.html

[4] H. Metoki, T. Ohkubo, Y. Watanabe, M. Nishimura, Y. Sato, M. Kawaguchi, A. Hara, T. Hirose, T. Obara, K. Asayama, M. Kikuya, K. Yagihashi, Y. Matsubara, K. Okamura, S. Mori, M. Suzuki, Y. Imai and the BOSHI Study Group: "Seasonal trends of blood pressure during pregnancy in Japan: the babies and their parents longitudinal observation in Suzuki memorial hospital in intrauterine period study," J. Hypertens, Vol.26, Issue 12, pp.2406-2413, 2008.

[5] R. M. Reynolds, K. M. Allan, E. A. Raja, S. Bhattacharya, G. McNeill, P. C. Hannaford, N. Sarwar, A. J. Lee, S. Bhattacharya and J. E. Norman: "Maternal obesity during pregnancy and premature mortality from cardiovascular event in adult offspring: follow-up of 1 323 275 person years," Br Med J, 347 (2013), p. f4539, 2013.

[6] Tohoku Medical Megabank Organization: "Three-generation Cohort Study, Tohoku Medical Megabank Project," (in Japanese).
http://www.megabank.tohoku.ac.jp/3gen/

[7] L. Maitre, E. Fthenou, T. Athersuch, M. Coen, M. B. Toledano, E. Holmes, M. Kogevinas, L. Chatzi and H. C. Keun: "Urinary metabolic profiles in early pregnancy are associated with preterm birth and fetal growth restriction in the Rhea mother - child cohort study," BMC Medicine, 2014; 12:110, 2014.

Establishment of Optimal Equipment Design and Nationwide Monitoring for Environmentally Friendly, Disaster Resilient Green Base Stations

Research Laboratories
Kazuhiro Komiya
Takashi Furutani†
Masaki Nakamura
Yurie Mura
Takayuki Tamura

1. Introduction

While establishing environmentally friendly and self-sufficient renewable energy sources (mainly Photovoltaic (PV)), NTT DOCOMO continues to research green base stations to achieve long-lasting backup power supplies and visualized PV power generation data*1 enabled by large-capacity cycle-type*2 batteries and Green Power Controllers (GPC). Since determining commercial green base station viability through verification of their operation in the R&D Center [1] and at ten field trial stations in the Kanto Koshinetsu region [2], NTT DOCOMO set up commercial green base stations in 11 locations from Hokkaido to Kyushu in FY 2014, to bring the total to 21 stations, which began operations in April of 2015.

This article describes the basic structure of green base stations set up for the field trials and optimal design patterns for commercial green base station installation (power-receiving stations, and solar-powered stations). Also, the article describes the monitoring methods using an integrated monitoring system that enables visualization of PV power generation data, and example data acquisition.

2. Green Base Station Power Supply Structures

2.1 Field Trial Stations

Figure 1 shows the basic structures of the green base stations set up for field trials. While using commercially available power from a utility, these green base stations have been configured by adding (1) PV, (2) large-capacity cycle-type batteries, and (3) GPC.

The following describes these added components and facilities:

(1) PV: Equipment consisting of solar panels and PV converters. The number of solar panels installed must meet a rated power generation capacity larger than the power consumed the communications load. When there is sufficient sunlight striking the surface of the solar panels, the base station can run on PV alone, while the surplus power generated, i.e. power not consumed by radio equipment (the load), is used to charge in large-capacity cycle-type batteries. PV converters in these stations have functions to measure the

† Currently Nippon Telegraph and Telephone Corporation

*1 **PV power generation data:** In this article, PV power generation data refers to both the power being generated by PV (kW), and overall amount of PV generation (kWh).

*2 **Cycle-type:** A battery system involving cyclic charging and discharging.

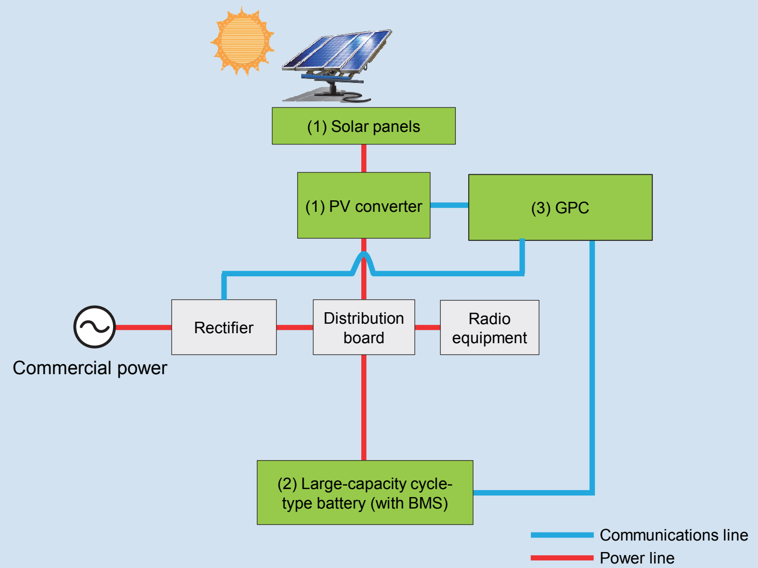


Figure 1 Green base station basic structure

amount of power generated by the solar panels and communicate it to GPC, as well as DC*3-DC voltage conversion functions to convert the direct current from the solar panels to the 48 V direct current required by the communications systems. By connecting solar panels to the direct current communications power supply in this way, base stations can operate on PV alone, which means mobile communications during the day can be secured even if the commercial power supply (alternating current) is cut off during a disaster.

(2) Large-capacity cycle-type battery: Compared to conventional float type*4 lead-acid batteries*5, these large-capacity cycle-type batteries (nickel-hydride*6 or lithium-ion*7 types) have approximately twice the battery capacity*8, and can provide 14 to 16 hours of backup power to base stations while only taking up a small amount of space. Also, the use of large-capacity cycle-type batteries with Battery Management Systems (BMS)*9 that can communicate with GPC enables flexible charge and discharge control.

(3) GPC: This enables remote control of the combination of three power supplies used by base stations (commercial power, PV, batteries), and enables "power visualization" of PV power generation data and battery charge levels etc. As an example of controlling power with this equipment, NTT DOCOMO has successfully demonstrated a system called "double power control*10" [3].

2.2 Commercial Green Base Stations

1) Power-receiving Stations

Figure 2 describes the configuration of commercial green base stations. The pattern shown at Fig. 2 (a) describes a power receiving station that operates continually using the existing rectifiers*11 and lead-acid batteries, and is converted to a green base station by adding (1) solar panels, a PV con-

*3 **DC:** The direct current component of electricity (frequency of 0 Hz).

*4 **Float-type:** A type of battery that charges as power is supplied to the load, and discharges during a power outage.

*5 **Lead-acid battery:** A battery that uses lead materials for its electrodes. These are inexpensive compared to other types of battery, but are large and heavy.

*6 **Nickel-hydride battery:** A battery that uses nickel and a hydrogen storing alloy (a metal that can take up hydrogen) for its electrodes. These batteries are very safe because the electrolyte and electrodes are non-flammable.

*7 **Lithium-ion battery:** A type of storage battery in which lithium ions in the electrolyte move during charging and discharging. These batteries are characterized by their high energy density and low self-discharge rate.

*8 **Battery capacity:** The total electrical capacity that can actually be discharged from a battery pack.

*9 **BMS:** A control system that enables monitoring and controlling of battery voltage, input and output current, charge level and temperature, etc.

*10 **Double power control:** Technology to store low environmental load electricity in lithium-ion batteries from daytime surplus PV power generation and from off-peak power at night. Battery power is used from the evening when PV generation stops until 11 at night when off-peak power becomes available.

*11 **Rectifier:** A device for converting AC power to DC power.

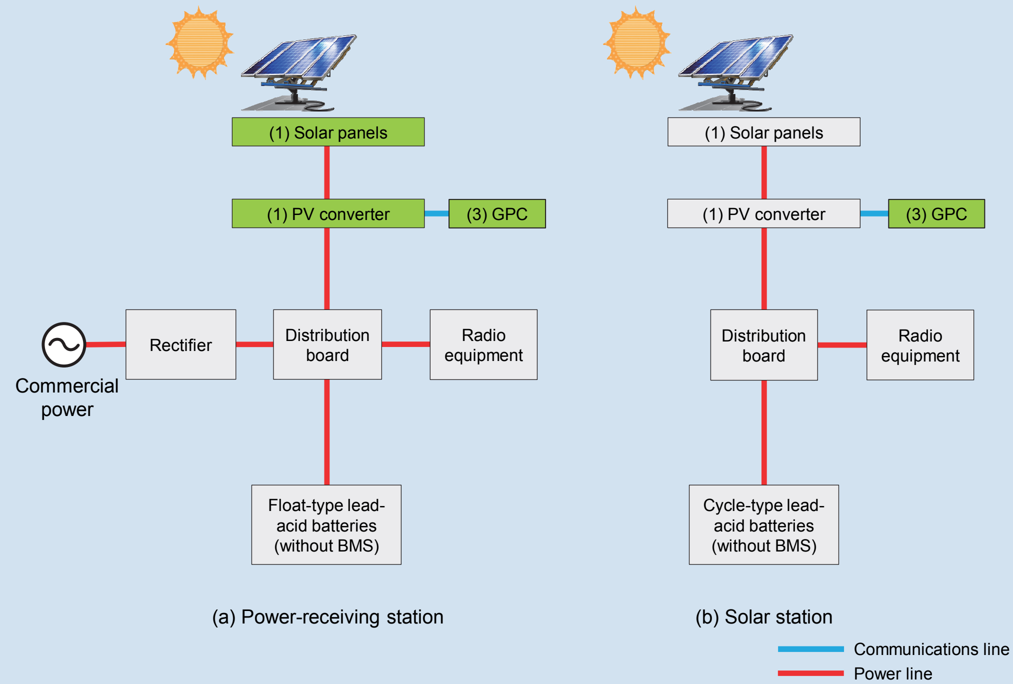


Figure 2 Commercial green base station configuration

verter and (3) GPC. In this case, because the existing lead-acid batteries do not have a BMS, it is not possible to control charging and discharging with GPC, although GPC is installed so that PV power generation data can be collected and sent to the monitoring system (described later) for power visualization.

2) Solar Stations

In general, commercial base stations are the "power-receiving" type that operate using commercially available power. However, in mountainous or remote locations where commercial power is not available, "solar stations" have existed for some time, and can be converted to green base stations as described by the pattern shown at Fig. 2 (b). Solar stations include enough solar panels to satisfy power generation rated higher than the power consumed by the load. In these stations, the surplus power generated that is not consumed by the load is used to charge lead-acid cycle-type batteries. The power supplies in these stations are designed so that stations can continue to operate even after several continuous days of insufficient sunshine. Since solar stations have PV and cycle-type batteries in common with green base station power supplies, the addition of GPC monitoring equipment enables visualization of PV power generation and enables solar stations to be converted to green base stations. To date, solar stations have featured a battery low voltage alarm to provide an alert if there is insufficient sunlight. However, because conversion to a green base station entails real-time acquisition of PV power generation data, conditions of insufficient sunlight can be detected earlier which means these systems offer better prospects for maintenance and support.

The power supply configurations described above are summarized in **Table 1**. In future, commercial green base stations can be expanded by adding monitoring and control equipment or modifying the equipment as required for the basic green base station structure.

3. Visualization through the Integrated Monitoring System

By installing monitoring equipment in the green base stations in various locations, we have built an integrated system to collect and monitor green base station power data. **Figure 3** describes the structure of this system. This system consists of (1) monitor-

Table 1 Comparison of green base station power supply systems

	Green base station system (field trial stations)	Commercial green base stations	
		Power-receiving stations	Solar stations
Receives commercial power	Y	Y	N
Rectifier	Y *1	Y *1	N
Solar panels	Y	Y	Y
PV converter	Y	Y	Y *1
Battery type	Cycle-type *2	Float-type (lead-acid)	Cycle-type (lead-acid)
Power generation monitoring equipment	GPC, data logger	GPC, data logger	GPC or data logger *1
Equipment monitored	PV converter, rectifier, distribution board, cycle-type batteries	PV converter, rectifier, distribution board	PV converter

*1 If the equipment does not support GPC, power data is acquired through the data logger.
*2 Must have a BMS that can communicate with GPC.

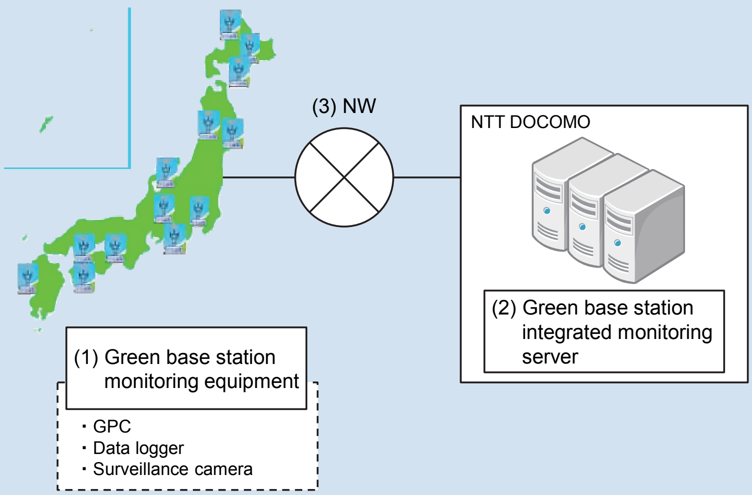


Figure 3 Structure of green base station integrated monitoring system

ing equipment, (2) an integrated monitoring server, and (3) the NetWork (NW).

(1) Monitoring equipment: This consists of GPC, a data logger and a surveillance camera, which provide PV power generation data/battery charge level, power consumption by the load, and an outdoor image of the solar panels respectively. The surveillance camera is included so that the relationship between PV power generation and weather or shade conditions and the conditions of solar panels can be monitored. In selecting equipment, minimizing power consumption increases due to the addition of extra devices and the wide range of operational temperatures around Japan must be carefully considered. For these reasons, we tested and verified equipment operation in the R&D Center before deployment in the base stations.

Figure 4 describes the configuration of monitoring equipment in green base stations. Fig. 4 (a) describes the structure of equipment in power-receiving stations (including field trial stations). As well as GPC, data loggers and surveillance cameras, we also installed Power over Ethernet (PoE)*12 hubs to connect this equipment to the NW, FOMA ubiquitous modules to send data to the integrated monitoring server, and a monitoring equipment power supply to supply power to these devices. In power-receiving stations, mon-

*12 **PoE:** Technology to transmit electrical power to other LAN devices using LAN cables in Category 5 or above (Unshielded Twist Pair (UTP) cables). Standardized in IEEE802.3ef.

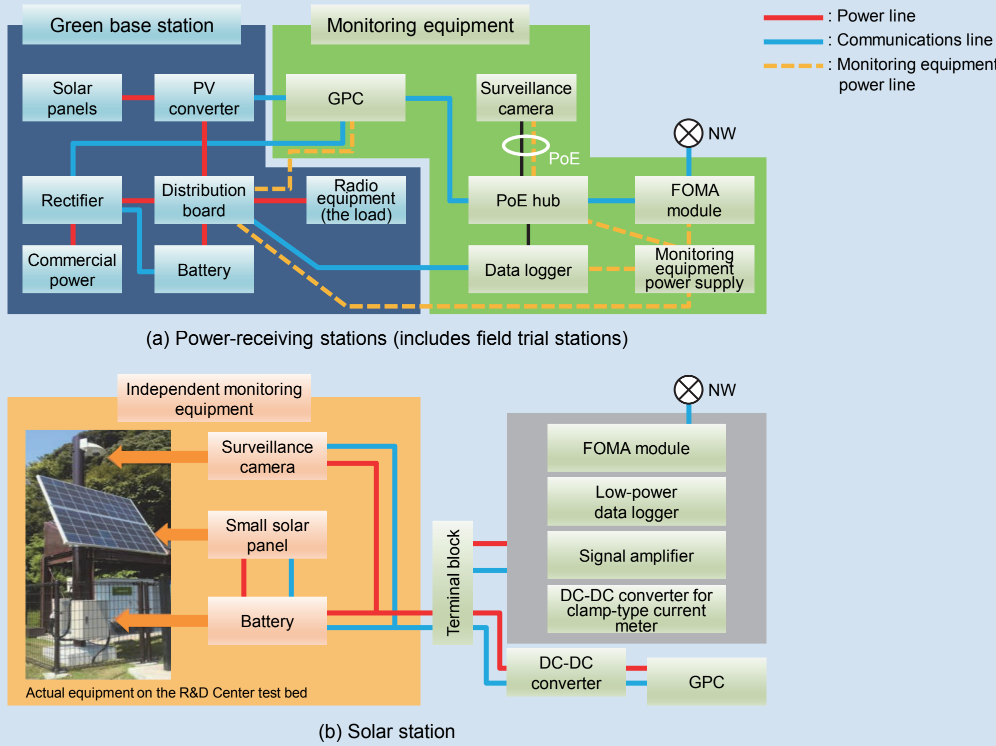


Figure 4　Configuration of monitoring equipment in green base stations

itoring equipment is powered by the commercial supply, whereas in solar stations, small solar panels and batteries are used to supply monitoring equipment with power because changing the design of the communications power supply in a solar station might cause the station to go off the air. Thus, with the addition of the surveillance camera, we have created monitoring equipment that operates independently (Fig. 4 (b)). We selected low-power data loggers and low-power surveillance cameras for use in these configurations.

(2) Integrated monitoring server: This equipment receives data from monitoring equipment via a closed NW, and has functions to record, manage and visualize the data. Data is stored for at least one year so that seasonal comparisons can be made. Also, visualized data can be viewed over the Web by accessing the integrated monitoring server from a terminal connected to the DOCOMO internal network.

(3) NW structure: All monitoring equipment connects to the closed NW via FOMA ubiquitous modules, while the integrated monitoring server connects to it via optical lines. Periodically, monitoring equipment automatically sends data to the integrated monitoring server. The integrated monitoring server identifies each green base station by its unique IP address. Also, for security, monitoring equipment can only communicate with the integrated monitoring server.

Figure 5 shows an example of the integrated monitoring screen for the green base stations. The screen displays PV power generation data by region for each of the ten field trial stations and the 11 commercial green base stations, for a total of 21 stations. In the pie charts for each region, the upper value shows the current power being generated (at the time of access), while the lower value indicates the rated power generation for the solar panels. The graph shows this proportion. If there is more than one green base station in one region, the total for the region is displayed, and the total for the whole country is displayed on the left of the screen.

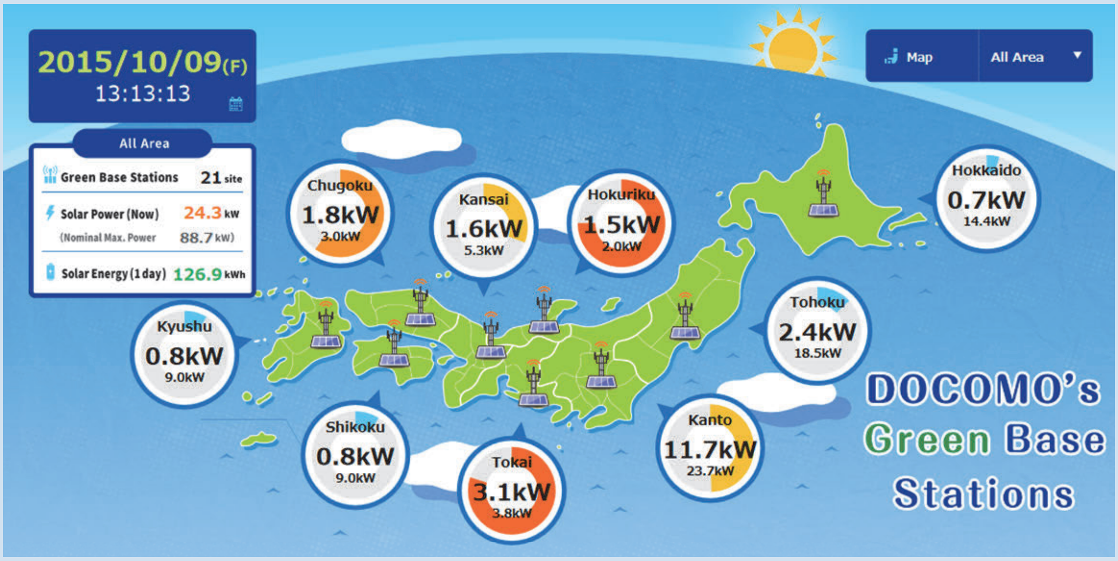


Figure 5　Example of a screen for monitoring green base stations

4. Nationwide Green Base Stations Deployment and Data Collection Examples

Figure 6 shows the locations of green base stations. The red circle shows the ten field trial stations in the Kanto Koshinetsu area, while the green circle shows the 11 commercial green base stations. Station locations are selected and facilities are designed to configure mobile telephone coverage areas, which means that in selecting stations to be converted to green base stations, facilities such as solar panels must be added in consideration of the constraints of those stations. With power-receiving stations, solar panels and PV converters must be installed anew, which means there must be some leeway in the station space to accommodate these additions, and there must be no obstacles casting shadows on the panels. This means there are cases that are less than ideal due to the influence of antenna towers and surrounding structures. For these reasons, solar panels are installed spatially separate, and cabling aligned so that the adverse effects of shadows on power generation are kept to a minimum. In contrast, solar stations, which are usually in mountainous or remote areas, have favorable installation space and surrounding environments, and are designed with solar panels on bigger scale than the power consumed by the load to enable power supply resilient to periods of low sunlight.

As an example of commercial green base station data acquisition, **Table 2** shows the amount of PV power generated and the self-sufficiency rate. The self-sufficiency rate is a value defined as the ratio of the amount of PV power generated to the amount of power consumed by the load, and is an index that describes the level of power secured independently by PV. Here, we defined the average values of self-sufficiency rate, from daily PV power generation measured from the stations from June 1-10, 2015. When measurement began at the solar stations, the battery capacity was not considered, but because the power used for charging during the period of measurement comes from PV (PV surplus power), it is used to calculate the PV power generation for that day. If there is insufficient sunlight on the day, the self-sufficiency rate is low because charging with power from PV does not take place. However, stations are designed to operate using power stored on previous days when necessary. Table 2 shows how we have been able to visualize the self-sufficiency rate using power data collected by the integrated monitoring system.

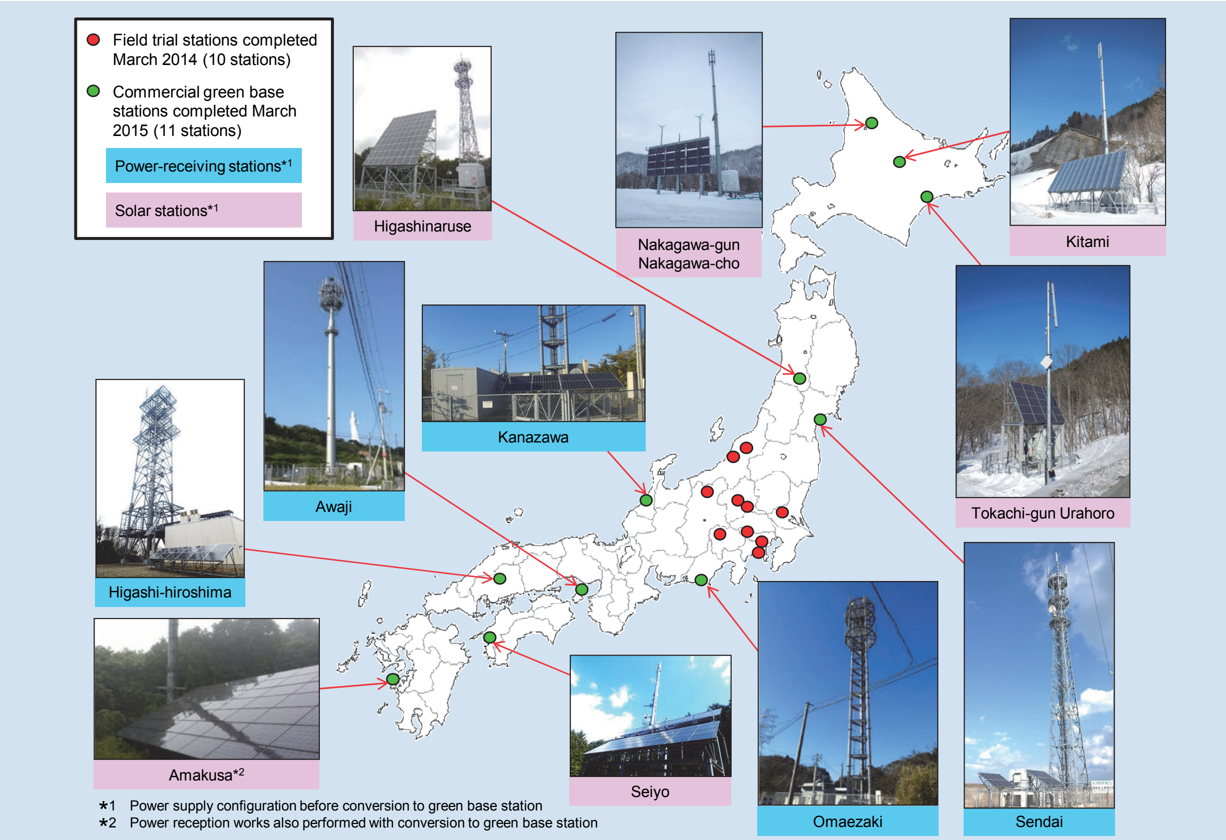


Figure 6 Green base station locations

Table 2 Example of data collection from commercial green base stations (averages for June 1-10, 2015)

Branch	Area	Daily amount of power generated by PV (kWh)	Power consumed by load (kW)	Self-sufficiency rate (%)
Hokkaido	Kitami	1.3	0.3	18.1
	Tokachi-gun Urahoro	4.2	0.3	58.9
	Nakagawa-gun Nakagawa-cho	0.7	0.1	30.5
Tohoku	Sendai	13.2	2.4	23.0
	Higashinaruse	11.8	0.5	98.2
Hokuriku	Kanazawa	5.41	4.3	5.3
Tokai	Omaezaki	10.22	8.2	5.2
Kansai	Awaji	13.44	2.2	25.5
Chugoku	Higashi-hiroshima	8.39	1.7	20.6
Shikoku	Seiyo	10.6	0.7	63.3
Kyushu	Amakusa	5.49	0.7	32.7

Blue: Power-receiving stations * Pink: Solar stations *

*Power supply configuration before conversion to green base station

5. Conclusion

This article has described the basic structure of green base stations set up for field trials, optimal design patterns for commercial green base station installation (for stations receiving power, and solar-powered stations), monitoring methods using an integrated monitoring system that enables visualization of PV power generation data, and examples of data acquisition. Remote monitoring and control of power is possible with green base stations, and they also provide better environmental and disaster-resilient functions. We have also established optimized design methods for selecting and installing additional components, and wiring in facilities etc. for each pattern of green base station installation. By deploying these advanced technologies throughout Japan, we have contributed to the progress of ecological management business. NTT DOCOMO will continues to convert its nationwide commercial base stations to green base stations while bringing down costs of parts, construction and operations.

References

[1] K. Komiya et al.: "Environmentally-Friendly, Disaster-Resistant Green Base Station Test Systems," NTT DOCOMO Technical Journal, Vol.15, No.1, pp.35-41, Jul. 2013.

[2] K. Komiya et al.: "Field Test of "Green Base Station" Designed for Environmental Friendliness and Reliability during Disasters," NTT DOCOMO Technical Journal, Vol.16, No.1, pp.48-52, Jul. 2014.

[3] NTT DOCOMO Press Release: "DOCOMO's Prototype Base Station Operates on 95% Reduced-impact Electricity - Dual power-source control technology used in eco-friendly base stations -," Mar. 2015.
https://www.nttdocomo.co.jp/english/info/media_center/pr/2015/0306_01.html

Activities

5G Tokyo Bay Summit 2015

On the 22 and 23 of July 2015, the 2-day event "5G Tokyo Bay Summit 2015" [1] was held in the DOCOMO R&D center in Yokosuka, Kanagawa prefecture. This was an open event presented by NTT DOCOMO on the 5th generation of mobile communications systems (hereinafter referred to as "5G"), and was attended by representatives of businesses, universities and media organization, both from within Japan and overseas.

To make 5G a reality, NTT DOCOMO has been researching radio communications technologies in consideration of the various frequency bands anticipated for future use, and by May of 2014 had agreed to perform experiments in partnership with six major Japanese and global vendors [2]. NTT DOCOMO added a further two partner vendors in March of 2015 [3], and has been continuing a range of laboratory and field experiments. This event brought together major global vendors under one roof, and presented details of 5G technologies and the latest experimental results. The event was held with the aim of actively promoting further research into 5G technologies and various 5G initiatives through discussions and information exchange among industry insiders.

The 2-day event featured 24 talks and 26 exhibits and demonstrations [1]. These talks and exhibits were enacted through the participation of NTT DOCOMO, and five more companies who agreed to cooperate in experimen-

Outdoor banners


Exhibit/demonstration corner (NTT DOCOMO)


Exhibit/demonstration corner (experiment partners)

Lecture venue (main venue)


Lecture venue (broadcast venue)

tation in addition to the eight partners mentioned above, bringing the total number of companies partnering with NTT DOCOMO to 13. Announcements were made on the first day of the event [4].

Lectures on the first day included a special talk presented by Mr. Junya Inoue, Senior Director of ICT Solutions, the Tokyo Organising Committee of the Olympic and Paralympic Games, who spoke of the importance of the communications platform required for the Olympics. Following, a lecture was given by Mr. Seizo Onoe, Managing Director of R&D Innovation Division, NTT DOCOMO, who discussed policies for commercialization of 5G by 2020. After that, key persons from major Japanese and global vendors delivered introductory talks, which were followed by an enthusiastic panel discussion on the world of networking and its expectations for 5G. The second day presentations featured a panel session and a technical lecture session called “5G technology workshop.” The panel session was chaired by Professor Fumiyuki Adachi of Tohoku University, and featured panelists from the Ministry of Internal Affairs and Communications, universities and leading vendors discussing the role of Japan in realizing 5G. The technical lecture session included introductions by each of the global vendors partnering with NTT DOCOMO in these ongoing 5G experiments. These sessions were well attended.

Under the theme of partnering for experimentation, the exhibits and demonstrations introduced 5G signal waveform design, 5G large-scale radio technology testing, ultra-high-density distributed antenna coordinated control tech-

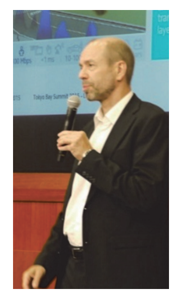
Special Lecture
Tokyo Organising Committee of the Olympic and Paralympic Games
Mr. Inoue

Keynote lecture
NTT DOCOMO
Mr. Onoe

Invited lecturer
Ericsson
Dr. Dahlman

Invited lecturer
Huawei
Mr. Wang

Invited lecturer
NEC
Mr. Hashimoto



Invited lecturer
Nokia
Mr. Oksanen

Invited lecturer
Qualcomm
Dr. Tiedemann

Panel discussion (first day)

Panel discussion (second day)

Invited lecturer
Tohoku University
Prof. Adachi

Invited lecturer
Ministry of Internal Affairs and Communications
Mr. Fuseda

Invited lecturer
University of Tokyo
Prof. Morikawa

Invited lecturer
Osaka University
Prof. Sampei

Invited lecturer
Fujitsu
Mr. Nakamura

Invited lecturer
NEC
Mr. Tanoue

Lecture
NTT DOCOMO
Mr. Nakamura

nology*1, 5 GHz band Massive MIMO*2, a 15 GHz band radio access transmission experiment, ultra wide-band mobile communications using the 28 GHz band, 44 GHz band ultra large-capacity Massive MIMO transmission, and ultra-wide band millimeter-wave radio communication*3. NTT DOCOMO presented a 5G real-time simulator, a 5G service image, a Non-Orthogonal Multiple Access (NOMA)*4 transmission experiment, the future core network, ultra-thin front-end and 5G radio wave propagation technologies etc.

Drawing on the momentum of this event to further accelerate joint experimentation and research into key 5G technologies in partnership with major Japanese and global vendors, the results of which will be discussed in international conferences and organizations involved in 5G research, and used in 5G standardization discussions due to commence in the Fall of 2015, NTT DOCOMO intends to continue its research initiatives to bring about the cutting-edge, 5G communications network.

References

[1] NTT DOCOMO: "5G Tokyo Bay Summit 2015," (in Japanese). http://5gs.idc.nttdocomo.co.jp/

[2] NTT DOCOMO Press Release: "DOCOMO to Conduct 5G Experimental Trials with World-leading Mobile Technology Vendors," May 2014. https://www.nttdocomo.co.jp/english/info/media_center/pr/2014/0508_00.html

[3] NTT DOCOMO Press Release: "DOCOMO's 5G Outdoor Trial Achieves 4.5Gbps Ultra-high-speed Transmission - Aiming at 5G launch by Tokyo 2020 Olympic and Paralympic Games -," Mar. 2015. https://www.nttdocomo.co.jp/english/info/media_center/pr/2015/0302_03.html

[4] NTT DOCOMO Press Release: "DOCOMO to Collaborate on 5G with Five Additional Vendors - Expands 5G collaborations to 13 world-leading vendors -," Jul. 2015. https://www.nttdocomo.co.jp/english/info/media_center/pr/2015/0722_00.html

*1 **Ultra-high-density distributed antenna coordinated control technology:** Technology that entails setting up many compact antenna units (base stations) in extra-high density in areas where high traffic volume can occur so that base stations can be configured flexibly by combining multiple antenna units to suit the radio propagation environment. Then, by coordinating between base stations in different areas, the areas covered by the base stations (virtual cells) can be dynamically changed so communications environments that are comfortable to use can be constantly provided.

*2 **Massive MIMO:** In Multiple-Input Multiple-Output (MIMO) systems that transmit radio signals overlapping in space by using multiple antenna elements for transmission and reception, these Massive MIMO systems aim to achieve high-speed data communications with greater numbers of simultaneous streaming transmissions while securing service areas by using antenna elements consisting of super multi-element arrays to create sharply formed radio beams to compensate for the radio propagation losses that accompany high-frequency band usage.

*3 **Ultra-wide band millimeter-wave radio communications:** Called "millimeter-wave" because the wavelengths of the Extra High Frequency (EHF) (30-300 GHz) band are between 1-10 millimeters. Using these higher frequencies than those used with conventional cellular systems enables ultra-wide bandwidth in the several hundred MHz to 1 GHz range, and thus enables super-high-speed data communications in the Gbps class.

*4 **NOMA:** When a base station connects to multiple users (multiple access), these systems adjust user radio signal transmission power to suit the size of the propagation loss, and transmit signals at the same time and frequency (i.e. non-orthogonally). These differences in power between user signals are used for reception to cancel interference and separate individual user signals.

NTT DOCOMO
Technical Journal Vol.17 No.3

Editorship and Publication
NTT DOCOMO Technical Journal is a quarterly journal edited by NTT DOCOMO, INC. and published by The Telecommunications Association.

Editorial Correspondence
NTT DOCOMO Technical Journal Editorial Office
R&D Strategy Department
NTT DOCOMO, INC.
Sanno Park Tower
2-11-1, Nagata-cho, Chiyoda-ku, Tokyo 100-6150, Japan
e-mail: dtj@nttdocomo.com