NTT DOCOMO

Technical Journal

vol.18 No.4 | Apr.2017

NTT docomo

Creating a New Network from a Clean Slate

Wataru Takita

General Manager of Research Laboratories

"Next generation" and "new generation" are well-known expressions used to indicate the stepwise evolution of network technology, but they can also be found in discussions of other established technologies. However, the word "generation" is not used to describe research on something totally new—when "first generation" technology is under study, no one calls it "first generation." "Next generation" and "new generation" usually indicate relatively major advancements from current technical achievements, so their use requires long-term and continuous evolution with a good technical foundation. Mature technology with a solid foundation has many widely accepted results, so subsequent developments, which often bear the label "next generation" or "new generation," must consider many compatibility issues and migration requirements that hinder the creation of disruptive new technologies. In the 2000s, internet technology, which had rapidly evolved in the 1990s, faced similar difficulty—it had matured and discussions on its development had become stagnant. To break the status quo, a new research movement was started to create a new network technology for the Internet from a "clean slate" without the burden of compatibility issues and migration requirements. This movement began around 2005 in the United States as a major research project of the National Science Foundation (NSF)*1, an advocate of the clean-slate approach. It has since expanded throughout the world.

The challenge of creating new technology from a clean slate may look very attractive to a researcher, but it is not easy to study something without any requirements. In the early stage of the clean-slate project, researchers struggled with this difficulty. In the first five years or so, researchers were exploring various technical possibilities without a clear view of what the new network technology should be. In looking for direction, many of them focused on problems with existing technology as a basis for establishing requirements. Regrettably, these requirements were neither requested by actual users nor helpful in determining a direction for their research. Then, around 2010, cloud computing systems brought about a significant change in network research, enabling researchers to determine what problems truly needed to be solved. The cloud, which is a large network of cooperating computers, was expanding dramatically at that time and was on its way to becoming a massive system on an unprecedented scale. At the same time, cloud operators were eager for more efficient operations to deal with such a massive system since network equipment, e.g. routers, in the cloud still concealed functions not controllable from the outside. Operators felt frustrated at this lack of full control and were looking for a solution to this problem. Thankfully, Software-Defined Networking (SDN)*2, which provided better programmable network control decoupled from data forwarding functions, offered the right solution at the right time. Studies on SDN in conjunction with the cloud began to take shape and accelerate, and network equipment vendors including startups and telecommunications carriers began to climb aboard one after another. It took only a few years for SDN to became a major trend in network technology, and in 2012, the standardization of Network Functions Virtualisation (NFV)*3 covering the virtualization of the network nodal system began at the European Telecommunications Standards Institute (ETSI)*4. NTT DOCOMO has been deeply engaged in these ongoing studies and activities and has made many contributions to NFV standardization. These efforts led to NTT DOCOMO's commercial launch of an NFV-compliant network nodal system in March 2016.

At present, most people think of 5G (5th Generation) as the promised new and advanced network technology. Originally, 5G referred to the evolution of radio access technology, but nowadays, it appears to cover network evolution on the whole. Some studies on this new network that have chosen the clean slate approach present a variety of possibilities, but they have yet to find a proper research direction. Fortunately, changes in the end system are taking place thanks to rapid progress in the development of the Internet of Things (IoT)*5 and Artificial Intelligence (AI) applications. We can expect these changes to show the way for new network studies in much the same way that the cloud opened the way for SDN. Aiming for a commercial service launch of 5G in 2020, NTT DOCOMO is committed to driving major trends in new network technology in conjunction with the evolution of IoT and AI.

---

*1 **NSF:** A United States government agency that grants research funds in a wide range of science and engineering fields for the advancement of science and technology in the United States. NSF supports many innovative research projects.

*2 **SDN:** A new approach to network technology that decouples network control from data forwarding functions and performs network control by software.

*3 **NFV:** A technology that allows implementing communication processing functions with hardware-independent software and enables dynamic reconfiguration of those functions and flexible resource allocation by use of virtualization technology.

*4 **ETSI:** A European standardization body engaged in the development of international telecommunications standards.

*5 **IoT:** General term for the paradigm of collecting real-world information and controlling real-world entities via networks and connected devices ("things").

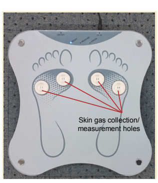
NTT DOCOMO
Technical Journal

Vol.18 No.4 Apr. 2017

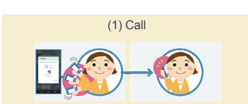
Contents

DOCOMO Today

Technology Reports



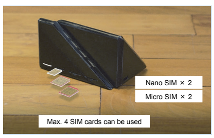
(P.4)



(P.12)

Collaboration Projects

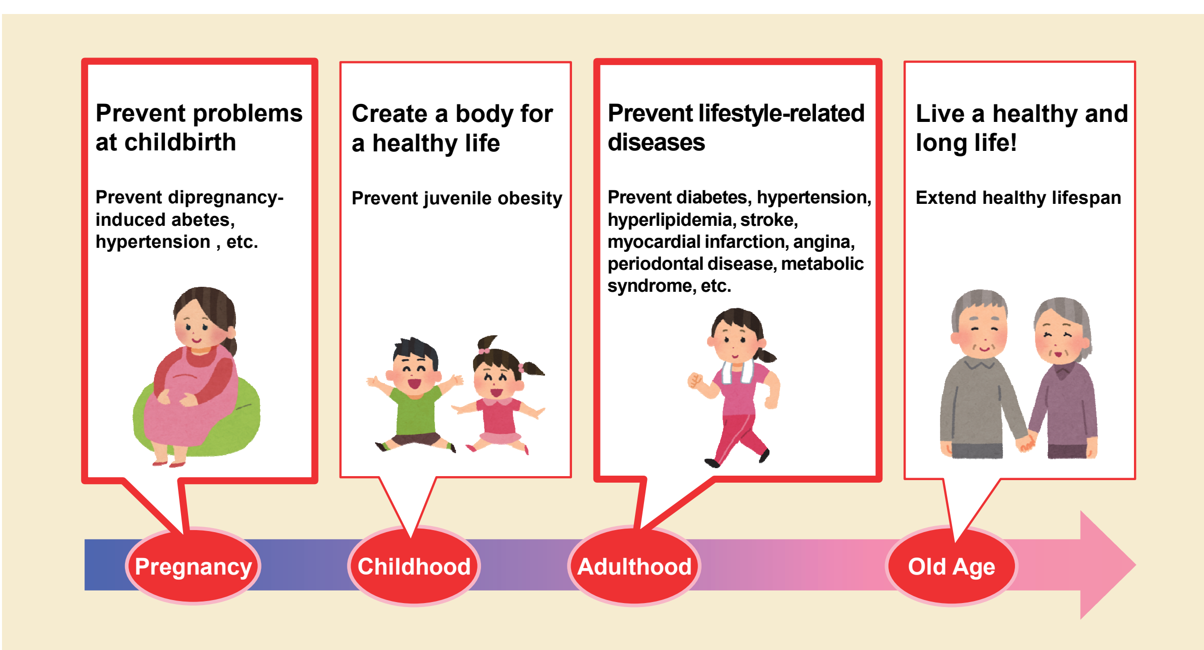
Topics



(P.30)

News

(P.35)



Technology Reports　Application of Biological Gas Analysis toward Self-health Management (P.4)

NTT DOCOMO’s medium-term vision in health and medical care fields

Self-health Management | Breath Analyzer | Foot-sole Skin Gas Analyzer

Technology Reports

Application of Biological Gas Analysis toward Self-health Management

Research Laboratories *Yuki Yamada*
Satoshi Hiyama

NTT DOCOMO is researching and developing self-health management using biological data in the heath and medical care fields as part of its Smart Life vision. Many types of biological data reflecting individual differences can be obtained from biological gas contained in human breath and emitted from the skin's surface without the pain of drawing blood, and that data can be applied to self-health management through multi-item analysis. We have developed devices that measure a variety of biological gas components contained in breath or emitted from the skin's surface on the sole of the foot for use as markers of fat metabolism, alcohol intoxication, and other conditions. These easy-to-use devices are expected to be useful in maintaining and improving one's health and in the prevention and early detection of disease.

1. Introduction

In April 2015, NTT DOCOMO announced "New Initiatives toward Delivery of Medium-term Targets" with a focus on value generation through co-creation with diverse partners and solutions to social issues through services [1]. These social issues include those in the health and medical care fields, so R&D at NTT DOCOMO aims to solve issues arising in the various stages of life such as lifestyle-related diseases and to contribute to healthy and long lives. Important issues here include the prevention of diabetes, hypertension syndrome, and other conditions occurring during pregnancy and the alleviation and prevention of lifestyle-related diseases in adulthood (**Figure 1**).

With respect to the former, NTT DOCOMO is conducting joint research with Tohoku University with the aim of establishing methods for the prevention and early detection of pregnancy-related diseases through information analysis. In addition to the use of genome information*1, this research will combine data related to periodically obtained biological substances from blood samples, etc. and healthcare data obtained daily using a healthcare data collection platform*2 [2] [3].

With respect to the latter, NTT DOCOMO has undertaken the visualization of fat metabolism with the aim of alleviating and preventing obesity, which can lead to all sorts of diseases and raise the risk of acquiring lifestyle-related diseases. Specifically, we have come to develop

*1 **Genome information:** Information related to the various types of genes possessed by living organisms.

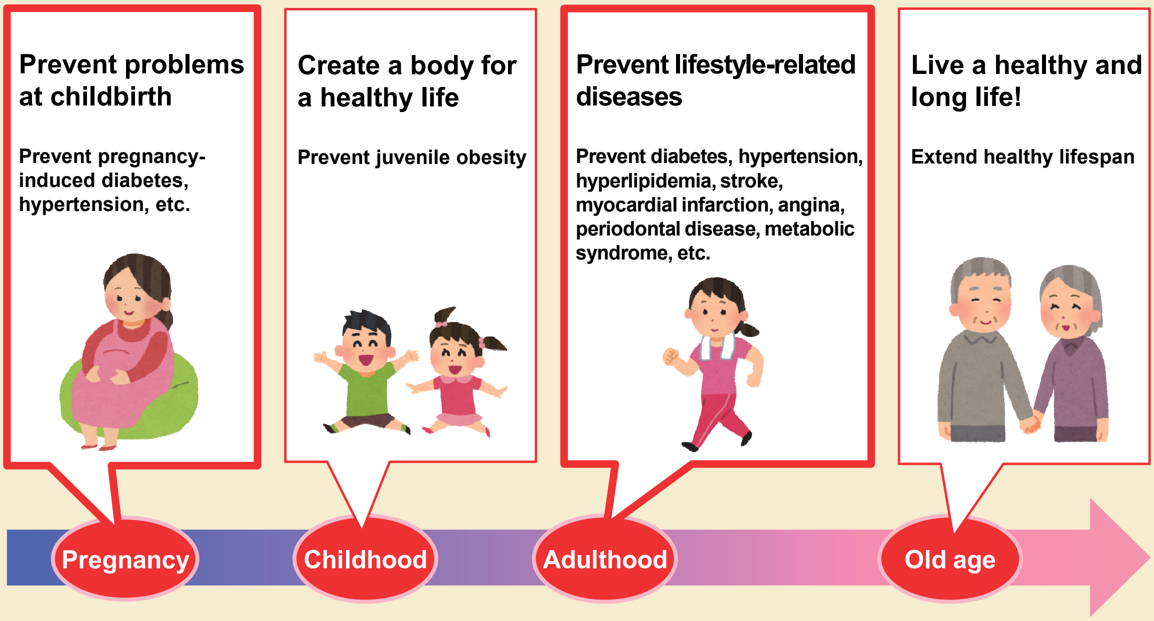


Figure 1 NTT DOCOMO's medium-term vision in health and medical care fields

breath analyzers [4] [5] and arm-wearable monitors [6] [7] for measuring acetone*3, a marker of fat metabolism. Biological gases*4 like acetone contained in breath or emitted from the skin's surface can provide abundant biological data on metabolic processes reflecting individual differences without the pain of drawing blood, and the use of such devices requires no special qualifications in collecting or analyzing samples. There are therefore high expectations for applying biological gases to self-health management through trouble-free multi-item analysis that can be performed inside or outside the home.

Against the above background, NTT DOCOMO has installed a breath analyzer in a health kiosk developed as an application of self-health examinations outside the home and developed a skin gas*5 analyzer targeting gas emitted from the sole of the foot as an application of self-health management in the home. These user-friendly devices are expected to be useful in maintaining and improving one's health and in the prevention and early detection of disease. This article provides an overview of these newly developed devices.

2. Installation of Breath Analyzer in Health Kiosk

2.1 Overview of Health Kiosk

A "health kiosk" is a piece of equipment that enables the user to check for health problems by activating a variety of sensors and health management devices installed in the kiosk while following directions on a screen. This kiosk, which was developed and manufactured by Smart Service Technologies Co., Ltd. under the guidance of the Experimental Center for Social System Technologies (Fukuoka Industry, Science & Technology Foundation) and System LSI Research Center, Kyushu University, is capable of performing more than 21 types of self-health examinations including height, weight, blood pressure, body fat percentage, body temperature, pulse, visual acuity, hearing acuity, lung capacity, glaucoma, cataracts, electrocardiogram, mental health,

---

*2 **Healthcare data collection platform:** A platform designed for collecting routinely measured healthcare data such as blood pressure and amount of physical activity and for determining some of that person's lifestyle practices with high accuracy and high frequency.

*3 **Acetone:** A highly volatile organic compound—chemical formula: C_3H_6O.

*4 **Biological gases:** Gases contained in breath or emitted from the surface of the skin.

*5 **Skin gas:** Biological gas emitted from the surface of the skin.

and dementia (**Figure 2**). After a personal authentication process by smart card, the kiosk displays the results of each examination on the screen for the user to view while also storing them on a network server. The user can review these stored results later on a personal computer or mobile terminal.

2.2 Installation of Breath Analyzer

Human breath includes several hundred types of gas components in addition to acetone, and some of those components can give rise to errors in acetone measurement. For this reason, conventional gas analyzers separate gas components before performing measurements, but this scheme tends to enlarge the size of the equipment. To resolve this issue, the breath analyzer developed by NTT DOCOMO incorporates two types of semiconductor-type gas sensors having different sensitivity characteristics. For the first gas sensor, we selected tungsten oxide as the main sensor material because of its exceptionally high sensitivity to acetone. Then, for the second sensor, we selected tin oxide as a main sensor material because of its sensitivity to acetone and gas components that give rise to errors in acetone measurement. Next, we performed beforehand a sensitivity-characteristic evaluation of these semiconductor gas sensors with respect to acetone and gas components that give rise to errors in acetone measurement and determined a calibration curve*6 for each of the results obtained. Finally, we recorded these curves in the developed breath analyzer making it possible to calculate the concentration of acetone

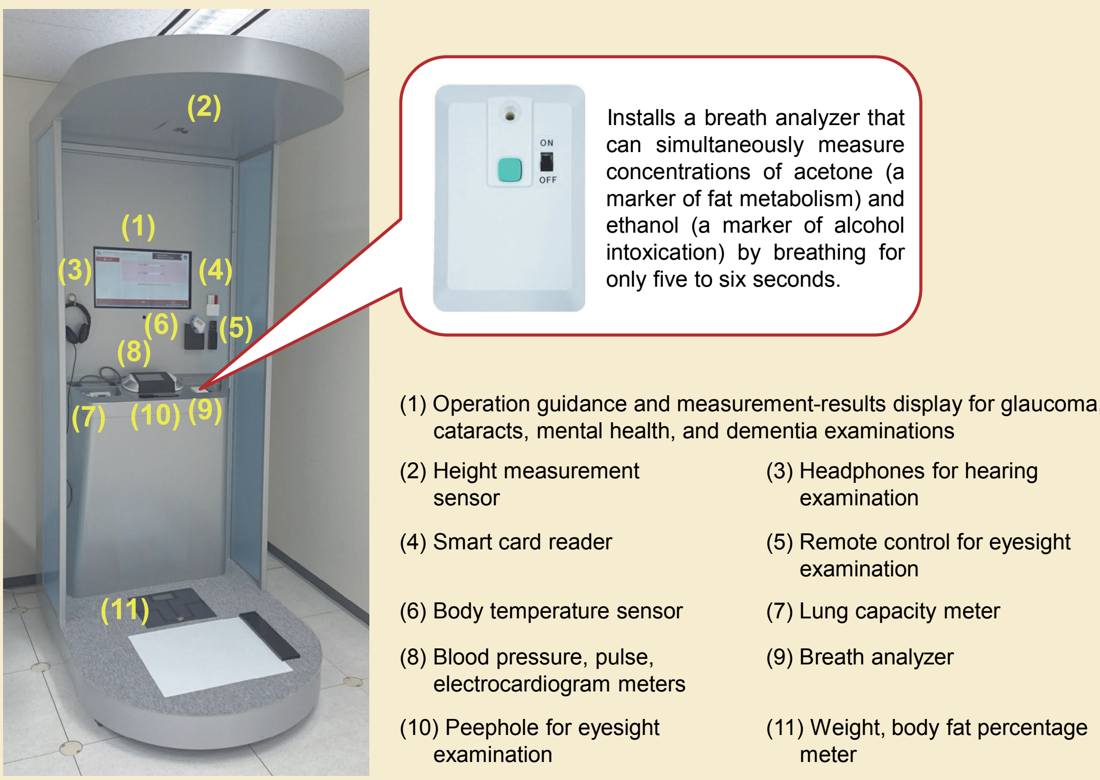


Figure 2 Health kiosk installing a breath analyzer

*6 **Calibration curve:** A curve that shows the relationship between standardized substances whose amounts and concentrations are known and measured data.

in breath with good accuracy without having to separate gas components. As a result, we succeeded in developing a compact and light breath analyzer with dimensions of 65 × 100 × 25 mm and a weight of 125 g, which is approximately 1/100 the volume and 1/50 the weight of conventional breath analyzers that perform rigorous gas analysis by separating gas components.

In addition to having a compact and light configuration, NTT DOCOMO's breath analyzer is also easy to operate. These features make for easy installation in a health kiosk enabling the provision of a function for examining fat metabolism. The addition of this breath analyzer has made this health kiosk the world's most advanced self-health examination device for determining the presence of metabolic disorders brought on by diabetes, eating disorders, and excessive diets.

This health kiosk is expected to be useful in determining the need for consultation at a clinic or hospital, for improving one's health, and for early detection of disease, and it should be particularly useful in regions having a shortage of physicians, on remote islands, etc. Going forward, the plan is to conduct usage experiments both inside and outside Japan targeting the residents of such areas with the aim of assessing the effectiveness of this health kiosk. We would also like to see this health kiosk installed in public facilities, drug stores, and other establishments outside the home to make it easy for people to perform self-health examinations.

3. Development of Foot-sole Skin Gas Analyzer

3.1 Overview of Analyzer

Daily measuring of one's weight has become a widespread practice for managing weight and dieting and has therefore become an important means of alleviating and preventing obesity. The functional performance of weight scales and body composition analyzers has been advancing in recent years, and devices that can measure not only weight and body fat percentage but also muscle mass, bone mass, and other physical characteristics have become commercially available. It would be no exaggeration to say that at least one weight scale or body composition analyzer can now be found in each home. In short, the weight scale or body composition analyzer is a typical healthcare device that has gained widespread acceptance in society.

Biological gas components such as acetone, ethanol*7, and water vapor that act as markers of fat metabolism, alcohol intoxication, and dehydration, respectively, are not only contained in human breath but also emitted from the surface of the skin. Consequently, if skin gas components like acetone can be measured at the same time as weight measurement, it should be possible to perform a multi-item health check in a hassle-free manner. To this end, NTT DOCOMO has developed the world's first "foot-sole skin gas analyzer" that can simultaneously measure the three gas components of acetone, ethanol, and water vapor by having the user simply stand on a device patterned on a weight scale (**Figure 3**) [8].

The developed device has dimensions of 30 × 30 × 3.5 cm and a weight of 1.7 kg, which is comparable in size and weight with popular weight scales and body composition analyzers. It features four holes for skin-gas collection and measurement, each of which is equipped with a gas sensor highly sensitive to acetone, a gas sensor highly sensitive to ethanol, and temperature/humidity sensors as well as a physical switch for determining that the user has stepped onto the device. Since the amounts of gas components emitted from the skin are much smaller than those of gas components contained in breath, measures were taken to enable the measurement of minute levels of skin gas components such as increasing the sensitivity of the gas sensors themselves and using appropriate methods for installing the gas sensors in the device. After the user steps onto the device, it takes approximately 20 seconds to simultaneously measure the acetone, ethanol, and water vapor emitted from the soles of the feet. In addition, while the molecules of biological gas components like acetone are about several angstroms (Å)*8 in size, the fiber of socks or stockings has a mesh

*7 **Ethanol:** A highly volatile organic compound and the main component of alcoholic beverages—chemical formula: C_2H_6O.

*8 **Å:** A unit of length equal to 10 billionth of a meter.

Figure 3 Foot-sole skin gas analyzer

approximately several hundred μm[*9] in size, which is large enough for those molecules to pass through. In other words, the device is capable of measuring biological gas components even if the user is wearing socks or stockings. Measurement results are transmitted to the user's smartphone or tablet by wireless transmission using Bluetooth®[*10].

An Android™[*11] application has been developed for installation in the user's smartphone or tablet. This application receives the measurement results transmitted by the device and visually represents the user's current level of fat metabolism, alcohol intoxication status, dehydration status, and health-related advice by a Graphical User Interface (GUI)[*12]. Typical screenshots of this application showing measurement results are shown in **Figure 4**.

3.2 Performance Evaluation Experiment

We conducted a performance evaluation experiment to assess measurement accuracy by the gas sensors installed in the developed device. Specifically, we measured acetone and ethanol emitted from the skin of several subjects using the developed device and conventional large-size gas measuring equipment (gas chromatography equipment[*13]) and compared the amounts of each gas component between both types of equipment. This experiment revealed that measurement results by the developed device and measurement results by conventional large-size equipment showed high positive correlation (acetone correlation coefficient[*14] $R = 0.87$, ethanol correlation coefficient $R = 0.99$) (**Figure 5**). These results show that the performance of the developed device is practical enough for determining one's health status at home in an easy-to-use manner. At present, the developed device can only measure three types of skin gas components, but the plan is to implement more functions for measuring body weight, etc.

3.3 Expected Effects

1) Dieting Support and Health Advice

Successful dieting requires a decrease not in water or muscle but in body fat, but measuring only body weight is not enough to determine whether that reduction in weight is in body fat or water/muscle. In contrast, acetone is a metabolic

---

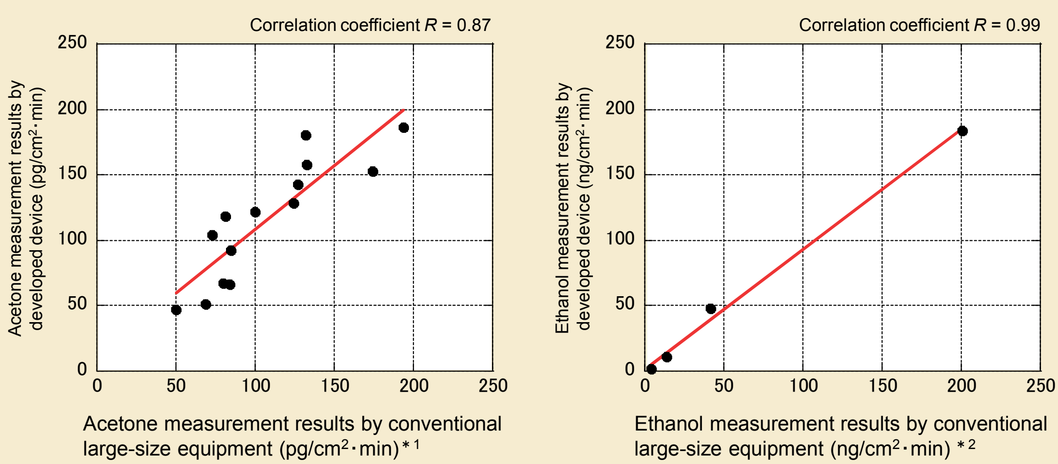
*9 **μm:** A unit of length equal to 1 millionth of a meter.

*10 **Bluetooth®:** A short-range wireless communication standard (IEEE 802.15.1) using the 2.4 GHz band and requiring no registration or licensing for use. A registered trademark of Bluetooth SIG, Inc. in the United States.

*11 **Android™:** A Linux-based open source platform developed by Google Inc. in the United States targeting mainly mobile information terminals. A trademark or registered trademark of Google Inc. in the United States.

*12 **GUI:** An interface that represents operations and objects graphically on a screen and that excels in intuitive operability and visibility.

Figure 4 Screenshots of measurement results



*1: Indicates the amount of acetone emitted per 1 cm^2 of skin per minute. 1 pg is equal to one trillionth of a gram.
*2: Indicates the amount of ethanol emitted per 1 cm^2 of skin per minute. 1 ng is equal to one billionth of a gram.

Figure 5 Comparison of acetone/ethanol measurement results

product emitted in conjunction with the decomposition and metabolism of body fat, so measuring it together with body weight makes it possible to determine whether any reduction in weight is due to a decrease in body fat. This scheme supports effective dieting. In addition, a body composition analyzer based on the impedance method*15 can suffer from

*13 **Gas chromatography equipment:** Micro-analysis equipment generally used for identifying and quantifying gas components by using a column to separate and measure them.

*14 **Correlation coefficient:** A statistical index indicating the degree of similarity between two variables. The closer to 1 this value is, the more similar the variables, while the closer to 0, the more dissimilar.

*15 **Impedance method:** A method for indirectly determining water volume, body fat percentage, and muscle mass by passing a weak current through the body and measuring electrical conductance.

large measurement error due to the effect that an increase or decrease in the amount of body water can have on the measurement of body fat, but that effect is not present in acetone measurements. In this regard, excessive dieting can lead to an inadequate intake of carbohydrates, which can produce excessive decomposition and metabolism of body fat and result in an abnormally large amount of emitted acetone. Calling attention to this condition can prevent harm to the user's health. For people interested in dieting, stepping on a weight scale is a daily activity, so evaluating fat metabolism by acetone measurement incurs no burden. Finally, the results of measuring ethanol and water vapor can be used to estimate lifestyle-related habits such as the frequency of drinking alcohol and offer health-related advice.

2) Early Detection of Ketoacidosis

Measuring acetone is expected to be useful in the early detection of a metabolic disorder (ketoacidosis) in diabetic patients and pregnant women. Ketoacidosis indicates a state in which the blood becomes acidic due to a buildup of ketone bodies*16. It is known to be a condition in which failure to receive appropriate and early treatment can lead to death. There is also the risk that symptoms can become even more serious in a state of dehydration. Since diabetic patients and pregnant women manage their weight on a daily basis, measuring skin gas components together with weight increases the possibility of detecting the onset of ketoacidosis early without having to perform any burdensome tasks.

4. Conclusion

In this article, we overviewed a health kiosk incorporating a breath analyzer as an application of self-health examinations outside the home and a skin gas analyzer targeting gas emitted from the sole of the foot as an application of self-health management at home. By making these devices easy to use on a routine basis, we expect them to be useful in maintaining and improving a person's health and in the prevention and early detection of disease.

In Japan, the difference between average lifespan and healthy lifespan*17 is 9.13 years for men and 12.68 years for women as of 2010, which indicates that there is an unhealthy period that limits everyday life lasting from about 9 to 13 years [9]. In addition, a comparison of data between 2001 and 2010 reveals that average lifespan in Japan increased by 1.48 years for men and 1.37 years for women while healthy lifespan increased by only 1.02 years for men and 0.97 years for women. That is to say, the increase in healthy lifespan was smaller than the increase in average lifespan [9]. Both of these differences are expected to escalate in the years to come, which means that the unhealthy period that consumes considerable healthcare and nursing-care benefits will be increasing. This is another reason why extending the healthy lifespan is necessary.

NTT DOCOMO seeks to contribute to solutions for social issues through various R&D initiatives in the health and medical care fields such as extending the healthy lifespan to shorten its difference with the average lifespan.

References

[1] NTT DOCOMO Press Release: "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] D. Ochi et al.: "Initiative toward Prevention and Early Detection of Disease Using Healthcare Data and Genome Analysis," NTT DOCOMO Technical Journal, Vol.17, No.3, pp.23-29, Jan. 2016.

[3] NTT DOCOMO Press Release: "Recruitment of Participants for Research toward Prevention of Diseases in Pregnant Women Completed—Launch of World's Largest Integrated Analysis of Lifelog Data and Biological Data—," Nov. 2016 (in Japanese).
https://www.nttdocomo.co.jp/info/news_release/notice/2016/11/15_00.html

[4] Y. Yamada et al.: "Breath Acetone Analyzer to Achieve 'Biochip Mobile Terminal'," NTT DOCOMO Technical Journal, Vol.14, No.1, pp.51-57, Jul. 2012.

[5] T. Toyooka, S. Hiyama and Y. Yamada: "A Prototype Portable Breath Acetone Analyzer for Monitoring Fat Loss," J. Breath Res., Vol.7, No.3, 036005, Jul. 2013.

[6] Y. Yamada et al.: "Wearable Skin Acetone Analyzer and its Applications in Health Management," NTT DOCOMO Technical Journal, Vol.17, No.2, pp.77-82, Oct. 2015.

[7] Y. Yamada, S. Hiyama, T. Toyooka, S. Takeuchi, K. Itabashi, T. Okubo and H.

*16 **Ketone bodies:** Generic name for acetone, acetoacetic acid, and beta-hydroxybutyrate.

*17 **Healthy lifespan:** The period in which a person can go about his or her daily life in a state with no health problems.

Tabata: "Ultratrace Measurement of Acetone from Skin Using Zeolite: Toward Development of a Wearable Monitor of Fat Metabolism," Anal. Chem., Vol.87, pp.7588-7594, Jul. 2015.

[8] NTT DOCOMO Press Release: "Health Management Device by Analysis of Skin Gas Emitted from Sole of the Foot." Jul. 2016 (in Japanese).
https://www.nttdocomo.co.jp/info/news_release/2016/07/20_00.html

[9] Ministry of Health, Labor and Welfare, Health Sciences Council, Subcommittee on Community Health and Nutrition and Health Promotion, Expert Committee for Framing the Next-term National Health Promotion Movement: "Reference Materials for Promotion of Health Japan 21 (the second term)," pp.24-27, Jul. 2012 (in Japanese).

Suguden | Sensor | Motion

Technology Reports

Tapless Phone Operations by Natural Actions! —Suguden Functions—

*NTT DOCOMO has developed "Suguden" functions that enable a user to operate a phone using only natural actions without having to touch the screen. This article describes the Suguden mechanism for determining user actions using only sensors that are typically installed in Android™ *1 smartphones. It also describes a method for achieving similar operability among different phone models despite sensor-dependent output values.*

Communication Device Development Department *Kiichi Ishibashi*
Shigeru Ochi
Product Department *Satoru Kawamura*
Shunsaku Yamazaki

1. Introduction

The proliferation of smartphones in recent years has made screen tapping a routine way of operating a phone. Nevertheless, there are still situations in which screen tapping is difficult or impossible to perform. Tapping operations are particularly inconvenient to users who want to answer an incoming call immediately but cannot tap the screen because their other hand is tied up with carrying a handbag or briefcase, their fingertips are wet, etc. In addition, making a call with a smartphone requires a greater number of taps compared with a feature phone, which can also be a source of inconvenience. NTT DOCOMO has responded to this issue by developing "Suguden" functions that enable a user to operate a phone using only natural actions without having to tap the screen. These original functions were first installed in the 2016 summer models of NTT DOCOMO smartphones.

In this article, we first explain the Suguden mechanism for determining user actions using only sensors that are typically installed in Android devices. We then describe a method for achieving similar operability despite differences in sensor output values that vary by phone model.

2. Overview of Suguden

Suguden enables the user to perform the following basic phone operations without having to tap the screen (**Figure 1**).

(1) Call: The user can make a call by simply shaking the phone and holding it up to an ear. One calling destination (person) may be registered for each left/right ear. First, shaking the phone one time displays a calling dialog (**Figure 2**). The previously set calling destinations are displayed at this time enabling the user to check what is currently registered for each ear and to make a call by holding the phone up to the appropriate ear (The 2016 winter models enable calling destinations to be set from the

*1 **Android™:** A Linux-based open source platform developed by Google Inc. in the United States targeting mainly mobile information terminals. A trademark or registered trademark of Google Inc. in the United States.

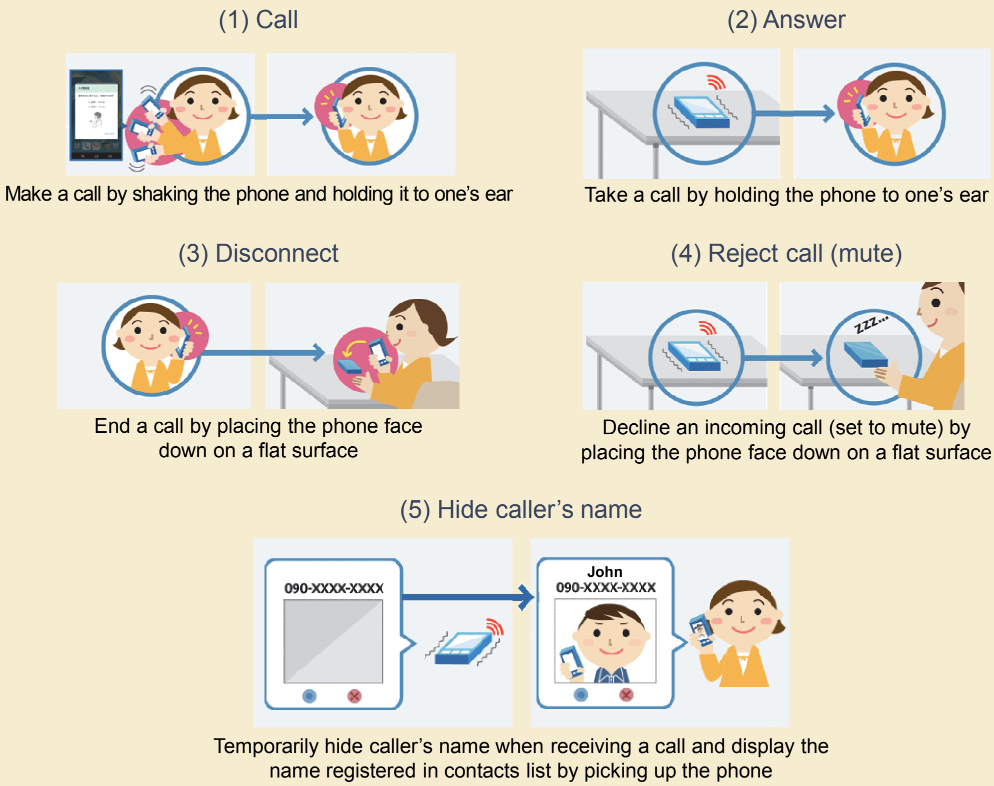


Figure 1 Overview of Suguden functions

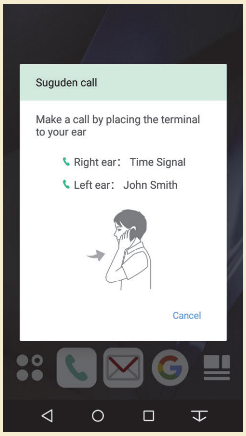


Figure 2 Calling dialog

user's call history).

(2) Answer: The user can answer an incoming call by simply holding the phone up to an ear.

(3) Disconnect: The user can end a call by placing the phone facedown

on a desk or shaking it twice (supported from 2016 winter models).

(4) Reject call (mute): The user can decline an incoming call by placing the phone facedown on a desk or shaking it twice (supported from 2016 winter models). The specific type of reject-call operation to be performed at this time may be selected from "mute," "reject," and "reject and send SMS."

(5) Hide caller's name: There are times when the user does not wish surrounding people to see the name of the caller at the time of an incoming call such as when the phone is sitting on a table in full view during a meeting. Envisioning such a scenario, this function disables display of the caller's name from the user's contacts list at the time of an incoming voice or video call. The user can then display the name by picking up the phone or simply moving it.

3. Suguden Algorithm

A conceptual diagram of Suguden operations is shown in **Figure 3**. The Suguden application, which is separate from the phone application, receives notifications on call state from the phone application and initiates/terminates motion*2 detection. Suguden motion detection is accomplished by combining data from a proximity sensor*3, acceleration sensor*4, and gyro sensor*5. Here, a standard Android Application Programming Interface (API)*6 is used to obtain sensor data, which makes any revisions to Android itself unnecessary and enables the Suguden application to be used in nearly all Android smartphones. In addition, we observed a variety of user behavioral cases with the aim of using natural actions to perform phone operations such as call, answer, disconnect, and reject call. Furthermore, given that handset shape, sensor-installation position, sensor specifications, etc. can differ between smartphone models, motion-detection thresholds are adjusted for each model and stored as a parameter file to enable uniform detection of each type of motion. This parameter file is supported from the 2016 summer models on.

The following describes the detection algorithm for each type of motion.

3.1 Phone-to-ear Motion (Call/answer Operations)

We examined the actions of actual users in studying an appropriate algorithm to adopt. In the call operation, it was often observed that the user would bring the phone up to the chest after shaking it to check the calling dialog on the screen. In the answer operation as well, there were many cases in which the user would bring the phone up to the chest at the time of an incoming call to check the identity of the caller.

For the above reasons, it was decided to detect the action (motion) of bringing the phone up to the ear using the

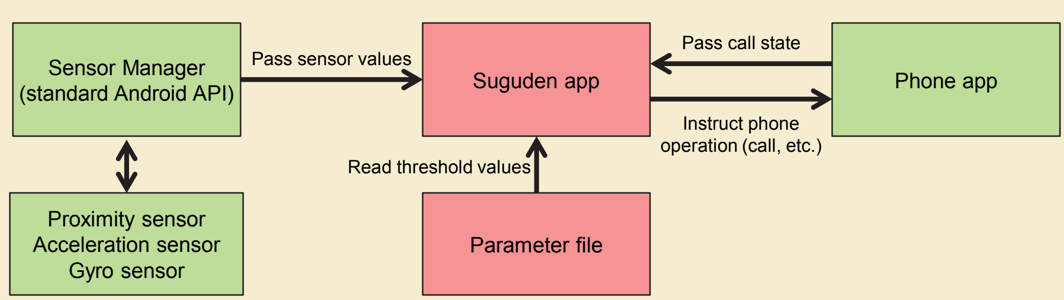


Figure 3　Conceptual diagram of Suguden operation

*2 **Motion:** Action associated with a user terminal operation.

*3 **Proximity sensor:** A sensor that detects contact with or closeness to an object.

*4 **Acceleration sensor:** A sensor that measures changes in speed. Equipping a mobile terminal with an accelerometer allows it to sense orientation and motion.

*5 **Gyro sensor:** A sensor that measures angular velocity. Installing a gyro sensor in a mobile terminal enables change in velocity in the rotational direction to be measured.

*6 **API:** An interface that makes the functions provided by the OS, middleware and other such software available to upper-level software.

position of the chest as base point. Furthermore, to enable the selection of not one but two calling destinations by allowing the user to hold the phone up to the left or right ear, it was decided to detect which ear the user was using to make a call.

Based on the above user actions, each type of motion is detected by determining phone movements as described below.

The sequence for detecting the motion of bringing the phone up to an ear is shown in **Figure 4** (a) and the definition of the phone's coordinate axes for use as reference is shown in **Figure 5**.

(1) After recognizing an opportunity to initiate motion detection (call: at time of calling dialog display; answer: at time of incoming voice call), the Suguden application activates the gyro, acceleration, and proximity sensors.

(2) Suguden uses the gyro sensor to detect the user action of holding the phone up to an ear. First, motion is detected in step (2)–1, and next, the locus of the phone approaching an ear is measured in step (2)–2 to detect that the phone has been brought next to that ear.

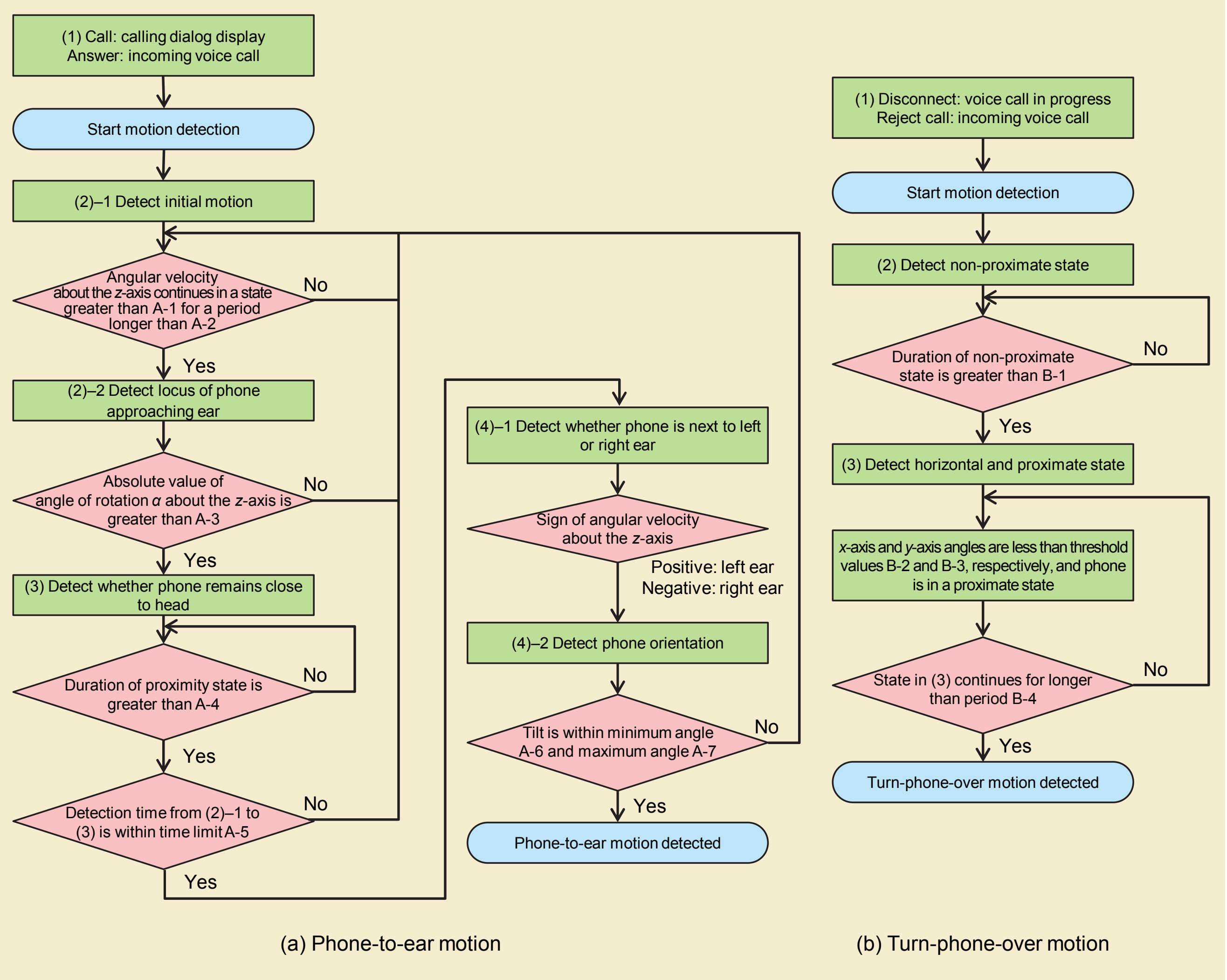


Figure 4 Motion sequence

(2)–1: Detect initial motion of phone

In the event that the *x*–*y* surface is rotated about the origin (phone center), this step uses the gyro sensor to determine whether an angular velocity greater than threshold A-1 continues for longer than period A-2. Furthermore, to exclude phone movement within a handbag, briefcase, etc. the proximity sensor is used to check whether the phone is in a non-proximate state during period A-2.

(2)–2: Detect movement from initial motion to holding phone up to ear

This step calculates the absolute value of angle of rotation α about the *z*-axis from detection time (2)–1 by taking the time integral of the angular velocity obtained from the gyro sensor and checks whether that value is greater than threshold A-3. If below the threshold, the flow returns to decision (2)–1 above. (**Figure 6** (a)).

(3) Suguden uses the proximity sensor to check whether the phone brought near an ear remains close to the user's head. If the proximity state continues for period

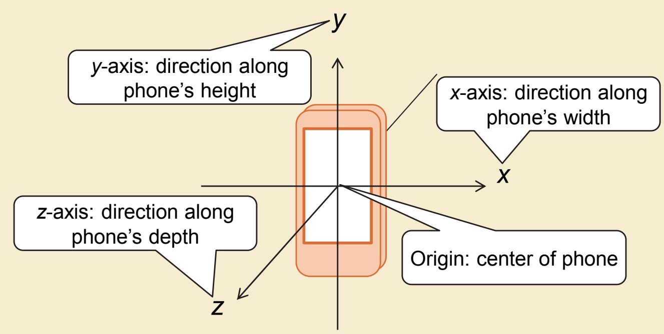


Figure 5 Reference coordinate axes

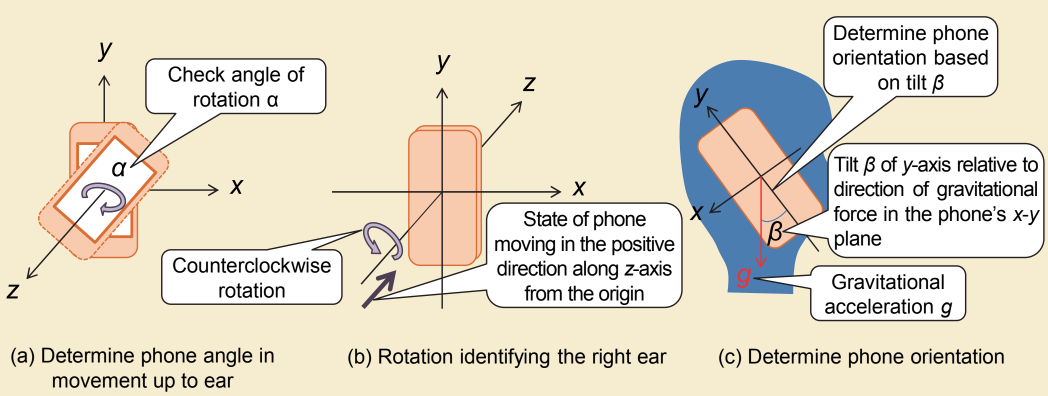


Figure 6 Detection of phone-to-ear motion

A-4, the flow advances to decision (4). If detection time from (2)–1 to (3) is longer than time limit A-5, the flow returns to decision (2)–1 above.

(4) Suguden uses the acceleration sensor to determine whether the phone has been brought close to the left or right ear and checks whether the final orientation of the phone is appropriate in terms of its tilt angle when held up against the ear.

(4)–1: This step determines whether the phone has been brought up to the left or right ear based on the direction of its rotation (clockwise/counterclockwise) when in a state moving in a positive direction from the origin along the *z*-axis at decision time.

Condition for right ear (Fig. 6 (b)): rotation about the *z*-axis is counterclockwise, that is, angular velocity about the *z*-axis < 0

Condition for left ear: rotation about the *z*-axis is clockwise, that is, angular velocity about the *z*-axis > 0

(4)–2: This step determines the orientation of the phone with respect to the ear (left or right) determined in step (4)–1 (Fig. 6 (c)).

Tilt of *y*-axis in the phone's *x*-*y* relative to gravitational acceleration g is taken to be β. This step checks whether β lies within a range of threshold values (minimum angle A-6, maximum angle A-7). Since the phone's sensor cannot detect β directly, this check compares g_x, g_y calculated by the following expressions based on threshold values with g_x, g_y detected from the phone's sensor (g_x, g_y are the *x*-axis and *y*-axis components of gravitational acceleration g).

Right ear:

$g_x = g \cdot \sin \beta$,

$g_y = g \cdot \cos \beta$

Left ear:

$g_x = g \cdot \sin (-\beta)$,

$g_y = g \cdot \cos (-\beta)$

If the above matches the conditions up to step (4)–2, that action is considered to be a motion that brings the phone up to the left or right ear.

3.2 Turn-phone-over Motion (Disconnect/reject-call Operations)

It often happens in a disconnect operation that the user moves the phone away from the ear and places it on a desk, table, or some kind of surface. In such a case, proximate and non-proximate operations in the form of proximate (next-to-ear state), non-proximate (away-from-ear state), and proximate (on-surface state) are repeated in a short time period, so we here designed the algorithm so that the phone state at this time could be correctly detected using the proximity sensor.

Meanwhile, in a reject-call operation, it often happens that the user first brings the phone in front of the chest to check the identity of the caller and then places the phone on a desk, table, or some kind of surface. For this reason, we designed the algorithm so that the motion of placing the phone on a surface could be detected using the non-proximate state as base point.

The sequence for detecting the turn-phone-over motion is shown in Fig. 4 (b).

(1) After recognizing an opportunity to initiate motion detection (disconnect: at time of voice call; reject call: at time of incoming voice call), the Suguden application activates the acceleration and proximity sensors.

(2) Using the proximity sensor, Suguden checks whether the phone is in a state away from the user's head or a surface. If a non-proximate state continues for longer than period B-1, the flow continues to decision (3). Since the phone can momentarily enter a non-proximate state due to user movements, we adjusted period B-1 so that such a case would not be judged to be a non-proximate state.

(3) Using the acceleration and prox-

imity sensors, Suguden checks whether the phone has been placed on a surface in a horizontal and faced-down state.

(3)–1: This step uses the acceleration sensor to check whether the phone is in a horizontal state.

Specifically, the method used here detects a horizontal state by using the absolute value of gravitational acceleration obtained from the acceleration sensor. If the gravitational acceleration of the *x*-axis and *y*-axis are each zero, the phone is considered to be in a horizontal state. However, in actual situations, the desk or table on which the phone is placed may not be strictly horizontal, so we established thresholds for angles θ_x and θ_y of the *x* and *y* axes (*x*-axis threshold B-2, *y*-axis threshold B-3) and use the absolute value of gravitational acceleration to check whether these angles are less than those thresholds (**Figure 7**).

(3)–2: This step uses the proximity sensor to check whether the phone is near an object. If the phone is in a proximate state, it is considered to be resting on a desk, table, or other kind of surface.

Finally, if the state that simultaneously satisfies the conditions in steps (3)–1 and (3)–2 continues for period B-4, the motion-detection conditions are satisfied. Otherwise, the detection flow starts again from step (3).

3.3 Shake-twice Motion (Disconnect/reject-call Operations)

In a disconnect operation, when the user moves the phone away from the ear and shakes it, the shaking position differs among users.

Furthermore, in a reject-call operation at the time of an incoming voice call, the user brings the phone up to the chest to check the identity of the caller, but the shaking position likewise differs among users.

For this reason, we designed the algorithm to detect whether the user has explicitly shaken the phone regardless of the phone's position or state at that time. We also incorporated control measures to prevent a reaction to oscillations that occur in normal use of a smartphone such as when walking.

The method used for detecting the shake-twice motion is shown in **Figure 8**.

(1) After recognizing an opportunity to initiate motion detection, the Suguden application activates the acceleration and proximity sensors.

(2) Suguden confirms that the phone has been stationary for period E-1 (has not exceeded threshold E-2) and begins decision (3). If E-2 is exceeded within E-1, decision (2) is repeated using the time at which E-2 was exceeded as the start point.

(3) Suguden confirms that the phone

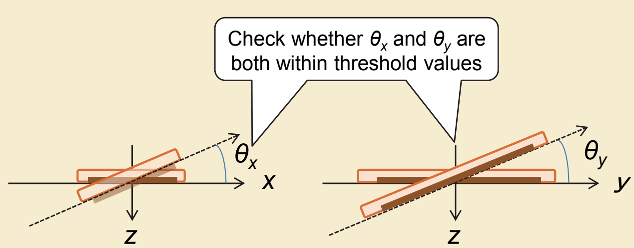


Figure 7 Horizontal state detection

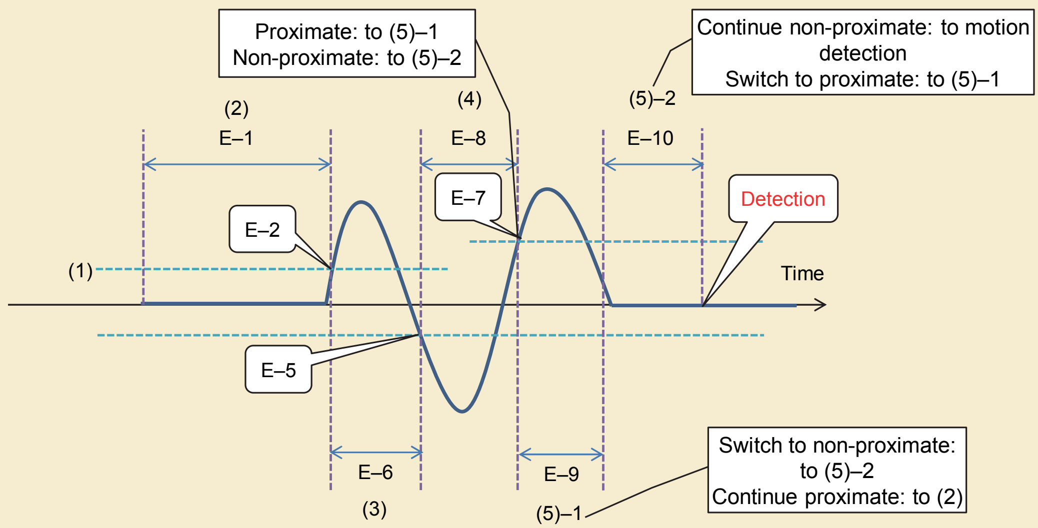


Figure 8 Shake-twice motion detection

has exceeded threshold E-5, the inverse of E-2, during period E-6 and begins decision (4). If acceleration exceeding E-5 is not detected within E-6, the flow returns to decision (2).

(4) Suguden confirms that the phone has exceeded threshold E-7, the inverse of E-5, during period E-8. If acceleration exceeding E-7 is not detected within E-8, the flow returns to decision (2).

Now, if the proximity sensor detects a proximate state at the point at which threshold E-7 is exceeded, the user may have performed an unintended operation such as holding the phone up to the ear, so a transition is made to decision (5)–1. However, if the proximity sensor detects a non-proximate state at the point at which threshold E-7 is exceeded, a transition is made to decision (5)–2.

(5)–1: If the proximity sensor switches to a non-proximate state during period E-9, a transition is made to decision (5)–2. If the proximity sensor continues in a non-proximate state for period E-9, Suguden decides that the user has performed an unintended operation and returns to decision (2).

(5)–2: If the proximity sensor continues in a non-proximate state for period E-10, Suguden detects that a shake-twice motion (disconnect/reject-call operations) has occurred. If the proximity sensor switches to a proximate state during period E-10, Suguden decides that the user has performed an unintended operation and makes a transition to decision (5)–1.

3.4 Move-phone Motion (Hide Caller's Name Operation)

Users have stated that there are times when they do not wish surrounding people to see the name of the caller of an incoming call when placing their phone on a table during a meeting. In response to this need, we have made it possible to disable display of the caller's name at the time of an incoming voice or video call and to then display the name by having the user intentionally pick up the phone or slide it back and forth on the table.

(1) After recognizing an opportunity to initiate motion detection, the Suguden application activates the acceleration sensor.

(2) Suguden obtains phone motion from the change in gravitational acceleration using the acceleration sensor.

The method used for detecting the move-phone motion is shown in **Figure 9**.

(2)–1: Get maximum and minimum values over a fixed period of time for gravitational acceleration in each of the *x*, *y*, and *z* directions.

(2)–2: Calculate difference *Δ* between those maximum and minimum values obtained for gravitational acceleration in each of the *x*, *y*, and *z* directions.

(2)–3: Using the total value of the absolute values of difference *Δ* as a criterion, determine that the phone has moved (motion detection) if that criterion is greater than a certain value and display the caller's name.

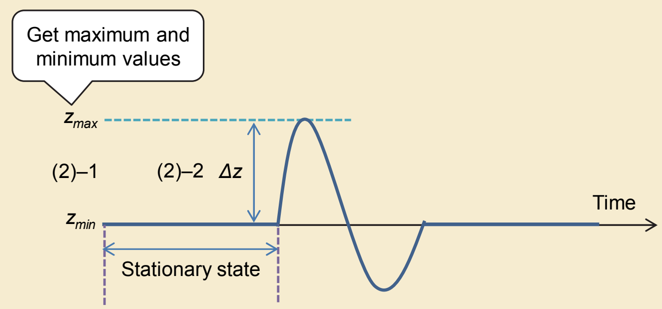


Figure 9 Detection of move-phone motion (for phone movement in the *z*-axis direction)

4. Conclusion

"Suguden" enables a user to operate a phone using natural actions like bringing the phone up to one's ear without having to perform tapping operations that have so far been the norm. Going forward, we will focus on many natural actions performed by users in daily life and incorporate a variety of them in Suguden. Our goal is to facilitate the further evolution and spread of Suguden functions so that they become a part of everyone's lifestyle. We also plan to add enhancements to the Suguden algorithm to further improve its accuracy.

OS Upgrade | Test Coverage | Black-box Test

Collaboration Projects

Efficient Application Testing for OS Upgrades

Application development accompanied by OS upgrades for smartphones requires the use of many test items to detect bugs that cannot be predicted solely on the basis of technical information released by the OS provider. This requirement drives up costs in application development, so to keep costs in check, we propose a method for extracting test items affected by OS code differences between the old and new versions of the OS before and after an upgrade. In this method, we first make an association between the application code affected by the upgrade and the target test process and then use test coverage information of affected application code for each test item. This proposal was developed and implemented in a tool through a joint-research partnership formed with Systems Engineering Consultants Co., Ltd. in January 2015.

Communication Device Development Department

Koichi Asano
Shinya Masuda
Mitsuhiro Ogata
Kazumasa Kobayashi

1. Introduction

In application development accompanied by OS*1 upgrades for smartphones, many test items must be used to deal with bugs that cannot be predicted solely on the basis of technical information released by the OS provider. This large number of test items has become a factor in increasing the cost of application development. In addition, the time period from the announcement of an OS upgrade to its market release tends to be short, so it has become very difficult to release an application supporting the post-upgrade OS (hereinafter referred to as "new OS") soon after the release of the new OS. Consequently, when working to keep up with OS upgrades, it is important that so-called upgrade development that deals with new functions provided by the new OS and changes to Application Programming Interface (API)*2 specifications be completed in a short time. This is essential to maintaining market competitiveness.

The production process of coding/compiling*3 in upgrade development involves editing work such as the addition of source code (hereinafter referred to as "code") to support new functions and the revision of code for existing functions affected by the upgrade. This work is performed based on technical information/materials [1] released by the OS provider and is followed by a testing process that may begin after compiling. At this time, actual execution of the application under the new OS may still

*1 **OS:** Software for managing an entire system by incorporating functions for basic management and control of a device and basic functions used in common by many software applications.

*2 **API:** A set of instructions, conventions, functions, etc. for use during programming.

uncover some bugs. One reason for this is that changes to operation specifications that actually exist may not be included in the technical information/materials. The fact is, totally unforeseen bugs may suddenly appear. Consequently, if the range of items targeted for testing cannot be specified, that range will inevitably broaden. That is, the number of test items subjected to a black-box test*4 tends to increase, which has been a factor in extending application development time and increasing development costs.

In this article, we focus on test items subjected to black-box tests and propose a method for specifying the range of testing and extracting test items. We then describe the implementation of a prototype system for Android™*5 applications to assess the usefulness of the method including its ability to reduce the number of test items. Finally, we present experimental results.

This proposal was developed and implemented in a tool through a joint-research partnership formed with Systems Engineering Consultants Co., Ltd. in January 2015.

2. Proposed Method

In this research, Step 1 obtains test coverage information [2] by associating the total application test table with the source code of the application (hereinafter referred to as "application code"). Next, Step 2 compares the application code with difference information between the old and new versions of OS code to extract all application code affected by the OS upgrade. Finally, Step 3 proposes a method for associating the extracted application code with the test process. Here, the test process may be joint/integration testing in application development or even acceptance testing performed on the side ordering the application development. The procedure for creating an application test table (extracted version) from the total application test table using the proposed method (steps 1 - 3 above) is shown in **Figure 1** and explained below.

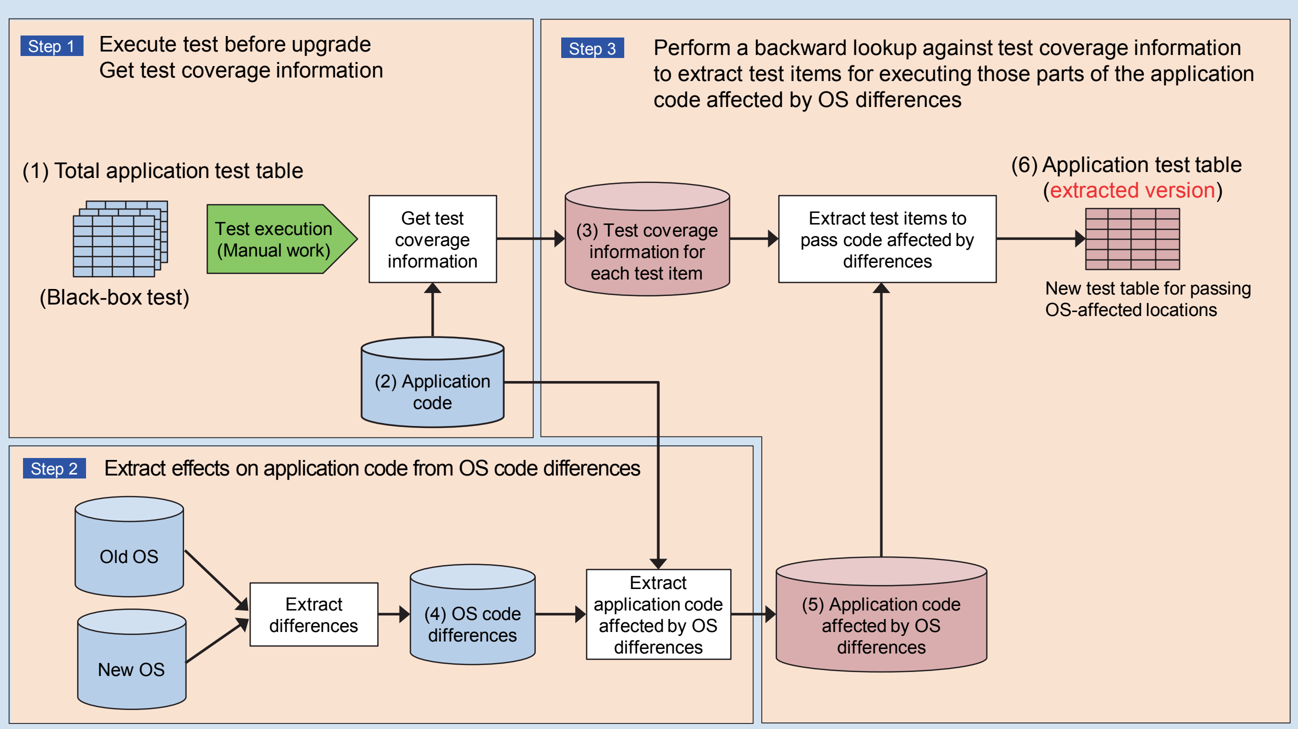


Figure 1 Extraction of test items affected by OS difference using test coverage information

*3 **Compiling:** The process of converting source code written in a programming language into an executable form after attaching a header, checking grammar, etc.

*4 **Black-box test:** An evaluation of a function seen as a unit from the outside without regard to its internal structure. Often used for joint testing, integration testing, and acceptance testing.

*5 **Android™:** A Linux-based open source platform developed by Google Inc. in the United States targeting mainly mobile information terminals. A trademark or registered trademark of Google Inc. in the United States.

2.1 Step 1: Get Test Coverage Information

Prior to the OS upgrade, the total application test table (Fig. 1 (1)) of the implemented test process is associated with the application code (Fig. 1 (2)). This work of associating the two is performed by the following procedure. First, when running the application to execute the test items in the total application test table, which lines of the application code are actually ran are recorded in units of line numbers. The content recorded here is called test coverage information for each test item (Fig. 1 (3)), which can be represented as shown in **Table 1**. It can be seen from this table that test item number 100 is appropriate when it is desired to run the 20th line of source code a.java®*6.

2.2 Step 2: Extract Effects of OS Differences

Extraction of differences between the old and new versions of the OS code can be represented as shown in **Table 2**. This is called OS code differences (Fig. 1 (4)). For example, it can be seen for OS code DEF.java that API internal processing changed after the upgrade, which means that a difference in operation may occur when called by the application. The effects of such OS differences on the application can be extracted by comparing OS code differences with the application code. Given application code as shown in **Table 3**, the application code affected by OS differences (Fig. 1 (5)) can be represented as shown in **Table 4**. It can be seen here that the OS upgrade affects the 20th line of application code a.java.

2.3 Step 3: Extract Test Items

The application test table (extracted version) (Fig. 1 (6)) can be extracted by comparing the application code affected by OS differences (Fig. 1 (5)) extracted in Step 2 with the test coverage information for each test item (Fig. 1 (3)) recorded in Step 1. **Table 5** is obtained from Table 1 and Table 4. It can be seen here that executing test item number 100 from among the test items

Table 1 Test coverage information for each test item (example)

Test item no.	Source code	Executed line number (test coverage information)
100	a.java	20
200	b.java	30

Table 2 OS code differences (example)

File name	Before change (Ver. 5.0)	After change (Ver. 6.0)	Difference
ABC.java	int ABC(a, b, c){	int ABC(a, b, c, d){	Add parameter
DEF.java	g = defexec();	g = def2exec();	Change internal processing

Table 3 Application code (example)

File name	Line no.	Source code statement
a.java	10	int r = 0;
	20	ret = DEF();
b.java	150	log(ABC(a, b, c));

Table 4 Application code affected by OS differences

File name	Line no.	Type	Description
a.java	20	Warning	Internal processing of called function DEF has changed
b.java	150	Fatal	Number of parameters of API ABC has increased

*6 **Java®:** An object-oriented programming language. Applications implemented in Java execute on a virtual machine, so they can operate on different platforms. Oracle and Java are registered trademarks of Oracle Corporation, its subsidiaries, and affiliates in the United States and other countries. Company and product names appearing in the text are trademarks or registered trademarks of each company.

in the total application test table is sufficient for testing the application code affected by the OS upgrade, and that test item number 200 need not be executed for this OS upgrade.

3. Implementation Method

3.1 Acquisition Environment for Test Coverage Information and Information Formatting

1) Acquisition Environment

Test coverage information is obtained using Java Code Coverage Library (JaCoCo)*7 [3] incorporated in Android Studio*8 [4]. This information can be obtained at test execution time through the Instrumentation Test*9 [5] in Android Studio, but this requires a continuous connection by Android Debug Bridge (ADB)*10 [6] between the PC used for operations during test execution and the Android terminal. As a result, power will still be supplied to the terminal when executing test items that require a low battery state thereby hindering the execution of some test items. To resolve this problem, we added a function to the Instrumentation Test that enables reset*11 and dump*12 operations against test coverage information whenever desired. In this way, we were able to avoid connection by ADB at test execution time. The constructed environment and actual procedure are shown in **Figure 2**. Before executing the test procedure, the tester performs a reset to delete test coverage information collected by JaCoCo. Then, during execution of the test procedure, test coverage information is collected by JaCoCo in memory and dumped to storage later.

2) Formatting of Acquired Information

Test coverage information is obtained as a list of application code executed when executing test items. This test coverage information for all test items is then merged using application-code line numbers as keys to obtain a

Table 5 Application test table (extracted version) (example)

Test item no.
100

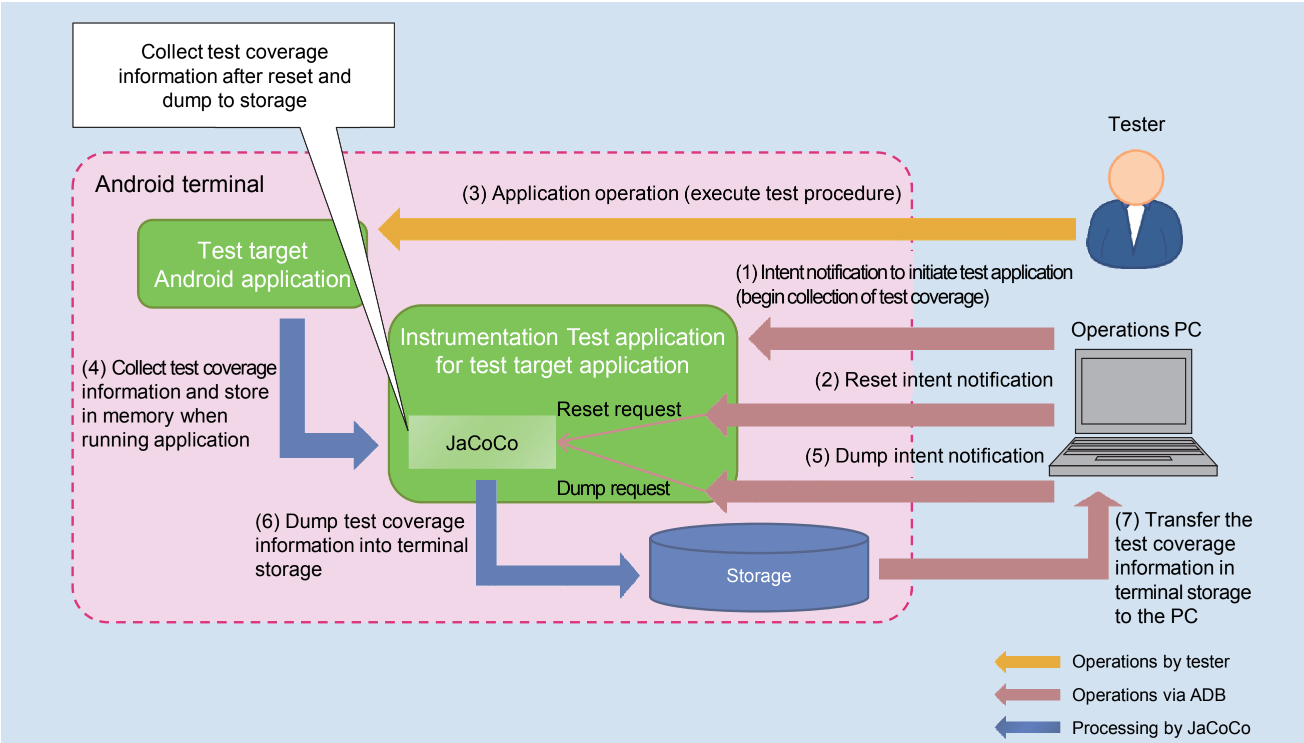


Figure 2 Environment and procedure for acquiring test coverage information at test execution

*7 **JaCoCo:** A library for obtaining test coverage of Java source code.

*8 **Android Studio:** An integrated development tool for Android applications.

*9 **Instrumentation Test:** A mechanism for performing automatic testing of Android applications.

*10 **ADB:** A tool included in the Android SDK capable of executing shell commands, performing file transfers, etc.

*11 **Reset:** An operation that deletes test coverage information saved in storage. Performed to prevent a mix-up with test coverage information recorded for other test items.

*12 **Dump:** An operation that saves test coverage information in storage. Used to record test coverage information for each test item.

list of application code passed at the time of test item execution (**Table 6**).

3.2 Procedures for Extracting OS Code Differences and Application Code Affected by Those Differences

Following the flow shown in **Figure 3**, OS code differences are extracted from OS source code before and after the OS upgrade as a list of classes*13 and methods*14 affected by classes and methods with differences.

Now, the portions of application code using OS code differences (classes and methods) are extracted to obtain a list of application code affected by OS code differences (**Table 7**).

3.3 Procedure for Extracting Test Items Affected by OS Code Differences

Finally, the lists obtained in Table 6 and Table 7 are merged with application code numbers as keys to extract

Table 6 List of application code to be passed at time of test item execution (example)

Application code		Test item no.1	Test item no.2	…	Test item no.X
Source file name	Line no.				
AAAAAA.java	10	○			○
	20	○	○		
	100		○		
BBBBBB.java	5		○		○
	15	○			○
	25	○			
⋮					

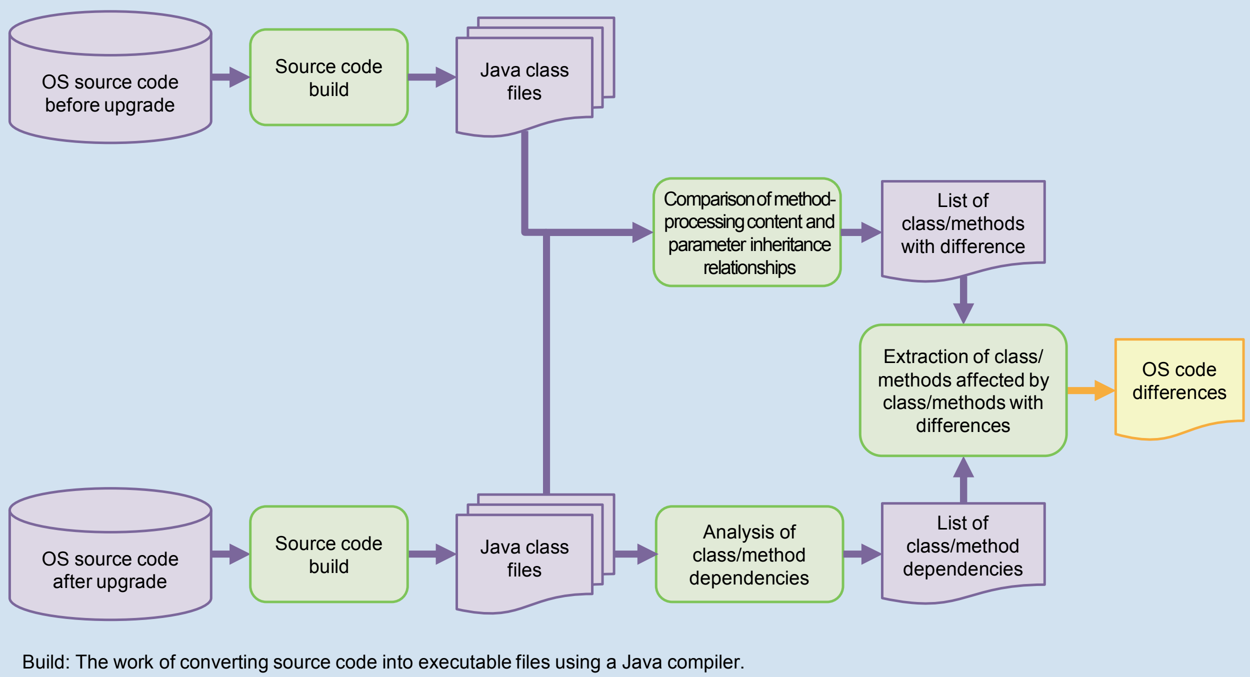


Figure 3 Flow of extracting OS code differences

*13 **Class:** Specified group of objects having similar states and behaviors in object-oriented programming.

*14 **Method:** Behavior of objects in object-oriented programming.

those test items affected by OS code differences (**Table 8**).

4. Experiment

We applied the procedure of this research to various Android applications at the time of the OS upgrade from 5.1.1 to 6.0.0 and measured whether the range of testing was specified, and if so, the extent to which the number of test items to be executed were decreased.

4.1 Experiment Results

The results of extracting application code and test items affected by OS code differences using the procedure of this research are listed in **Table 9**.

The test items extracted in this experiment indicate that extraction can be performed with equivalent accuracy as existing methods and that testing range can be specified by the proposed method without missing items that lead to the detection of bugs. On the other hand, results for two out of the four applications showed a reduction in number of test items of zero while the other two applications showed a reduction of 2 - 4 items (reduction effect of 2 - 4%). In short, we were not able to obtain the reduction effect in test range that we originally expected.

This can be explained by noting that source code lines for initialization processing, screen-related base class processing, etc. would be passed when executing any test item and that such lines are affected by the OS. As a result, nearly all test items came to be misjudged as "affected by OS differences."

4.2 Response to Issue

To resolve this issue, we assume that the following relationships exist between application code and test items.

- Assumption 1: For a line of application code passed when executing many test items, only the

Table 7 List of application code affected by OS code differences (example)

Application code		Level of OS-difference effect	Description
Source file name	Line no.		
AAAAAA.java	10	3	Class implementation change in API return value
	100	5	API parameter change
BBBBBB.java	15	4	API internal logic change
	50	3	Constructor logic change
	100	4	Addition of API throws specification
⋮			

Table 8 List of test items affected by OS code differences (example)

Application code		OS difference effect?	Test item no.1	Test item no.2	…	Test item no.X
Source file name	Line no.					
AAAAAA.java	10	Yes	○			○
	20		○	○		
	100	Yes		○		
BBBBBB.java	5			○		○
	15	Yes	○			○
	25		○			
⋮						

intended operation of that line when executing one of those test items need be verified.

- Assumption 2: For a line of application code passed only when executing a specific test item, the intended operation of that line when executing that test item must be verified.

An abbreviated example of a procedure based on the above assumptions for reducing the number of test items that must be executed is shown in **Table 10**. A red frame marks a line of application code executed by only one test item.

The results of applying this procedure to the results of the above experiment to reduce test items to only those for which execution is absolutely necessary are shown in **Table 11**. A red frame encloses the number of test items after this reduction process for each of the applications in the experiment.

Examining these results, it can be seen that the reduction rate for the "Schedule & Memo" application having a small number of test items overall is low. However, a reduction effect greater than 70% was obtained for each of the other three applications, which indicates that a sufficient effect was obtained in making testing at the time of an OS upgrade more efficient (by reducing the number of test items to be executed). Additionally, on comparing the results obtained by executing test items manually with results obtained by the proposed procedure, a test item for which bugs were discovered under manual execution was found to be absent in the set of test items after reduction. While

Table 9 Experiment results

Application name	No. of lines of code		No. of test items	
	Affected by OS differences	Total	Affected by OS differences	Total
Disaster Kit	1,676	7,964	28	28
Schedule & Memo	11,208	75,125	19	19
Hanashite Hon'yaku	8,548	41,844	165	169
Voice UI	1,025	4,323	47	49

Table 10 Overview of method for reducing test items (example)

Application code		Test item no.1	Test item no.2	Test item no.X
Source file name	Line no.			
AAAAAA.java	11	○		○
	12	○	○	
	13		○	
BBBBBB.java	21		○	○
	22	○		○
	23	○		
⋮				
Item reduction possible?		No Must be executed based on Assumption 2	No Must be executed based on Assumption 2	Yes Can be executed by another test item based on Assumption 1

Line of application code executed by only one test item

Line of application code executed by more than one test item the effect on testing quality of a reduced number of test items based on assumptions 1 and 2 has not yet been studied, application of the proposed procedure to the above four Android applications showed that the number of test items to be executed could be reduced while maintaining testing quality.

4.3 Future Outlook

On extracting a list of test items affected by OS code differences (Table 8), it became clear that application code that had not been tested before by existing methods despite being affected by an OS upgrade could also be extracted. The results of extracting untested application code from the results obtained in the above experiment are listed in **Table 12**. A red frame encloses the number of lines of untested application code despite being affected by OS differences for each of the Android applications in this experiment. Application of this method can detect a deficiency of test items in other applications too.

For the OS upgrade targeted by this experiment, no defects were released into the market even though we reduced the number of test items using the proposed method. However, with an eye to future OS upgrades, we plan to go in a direction somewhat opposite to test-item reduction and to add testing that would check an application for any room for making improvements to software quality.

5. Conclusion

This article proposed a method for extracting test items for applications affected by an OS upgrade and showed that application testing became more efficient when validating application operation with a prototype system incorporating that method.

Going forward, we plan to use the proposed method on the release of new OSs and apply it to more applications with the aim of decreasing the number of test items and preventing omissions in creating new items. We also plan to study ways of implementing the method for correct operation in many cases including automatic testing and thereby broaden the scope of its use.

References

[1] Android Developers website. https://developer.android.com/index.html

[2] K. Yasuda: "Concept and Practice of

Table 11 Experiment results after item reduction

Application name	No. of test items			Reduction rate
	No. of items requiring execution	Affected by OS differences	Total	
Disaster Kit	18	126	126	85.7 %
Schedule & Memo	16	19	19	15.8 %
Hanashite Hon'yaku	45	165	169	73.4 %
Voice UI	6	47	49	87.8 %

Table 12 Number of untested lines of application code affected by OS upgrade

Application name	No. of lines of code		
	Affected by OS differences		Total
	Untested	Tested	
Disaster Kit	790	886	7,964
Schedule & Memo	8,075	3,133	75,125
Hanashite Hon'yaku	5,503	3,045	41,844
Voice UI	0	1,025	4,323

Software Quality Assurance—Systematic Approach toward the Open Era—," JUSE Press, Ltd., 1995 (in Japanese).

[3] EclEmma: "JaCoCo Java Code Coverage Library."
http://www.eclemma.org/jacoco/

[4] Android Studio: "Android Studio Overview."
https://developer.android.com/studio/intro/index.html

[5] Android Studio: "Test Your App."
https://developer.android.com/studio/test/index.html

[6] Android Studio: "Android Debug Bridge."
https://developer.android.com/studio/command-line/adb.html

Packaged Portable SIM Technology “PSIM Suite” Licensing to Begin

Communication Device Development Department
Kazuma Nachi
Yuta Higuchi
Kazuoki Ichikawa

Portable SIM technology lets users use the Subscriber Identity Module (SIM)*1 card usually inserted in their mobile terminals (e.g. smartphone, tablet) for connecting to a mobile network as another device separated from the terminal. This technology enables the user to remove the SIM card from the terminal and insert it into another compact device for different purposes based on the concept of SIM card secure authentication and seamless telephone number switching [1].

In June 2014, NTT DOCOMO announced the world’s first Portable SIM concept and a prototype device, and has continued to engage in development of related technologies since then. In March 2015, NTT DOCOMO announced expanded functionality to enable sending and receiving of SIM data between smartphones, and then in August 2016 with the development of new technologies such as “psim proxy,” began licensing the “PSIM Suite,” which consists of the Portable SIM-related technologies (hereinafter referred to as “Portable SIM technology”).

1) Circumstances Surrounding Licensing

Conventionally, the use of a smartphone and SIM card entailed insertion of one SIM card into a smartphone, which meant if the user wanted to change lines (his or her telephone number or telecommunication carrier) due to a change in situation such as travel overseas, the user had to insert a different SIM card each time.

PSIM Suite enables sending data from a master device containing the SIM card to different devices, hence releasing the user from the one-to-one smartphone - SIM card relationship and enabling more flexible combinations.

The left of **Figure 1** shows an example of switching with one master device and several slave devices, and on the right, shows switching with several master devices and one slave device.

NTT DOCOMO has begun licensing PSIM Suite to enable various companies to use the features and technologies of the Portable SIM and drive development of devices and solutions with new concepts and value.

2) Elements of PSIM Suite

PSIM Suite basically consists of three parts - (1) a Portable SIM device technology, (2) psim proxy, and (3) Portable SIM software. **Figure 2** describes an overview of the system.

(1) Portable SIM device technology (Fig. 2 (1))

Technology to enable a master device (Portable

*1 **SIM:** An IC card which stores mobile phone subscriber information.

SIM device) to send data from an inserted SIM card to slave devices via Bluetooth®*2.

(2) psim proxy (Fig. 2 (2))

Technology to enable a terminal containing a SIM-sized card with Bluetooth functionality to connect to a Portable SIM device via Bluetooth and receive SIM data (the card is also referred to as a psim proxy). Simply inserting the card into the smartphone's SIM slot turns an existing smartphone into a Portable SIM slave device without the need for any modifications*.

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

* Requires installation of a dedicated app.

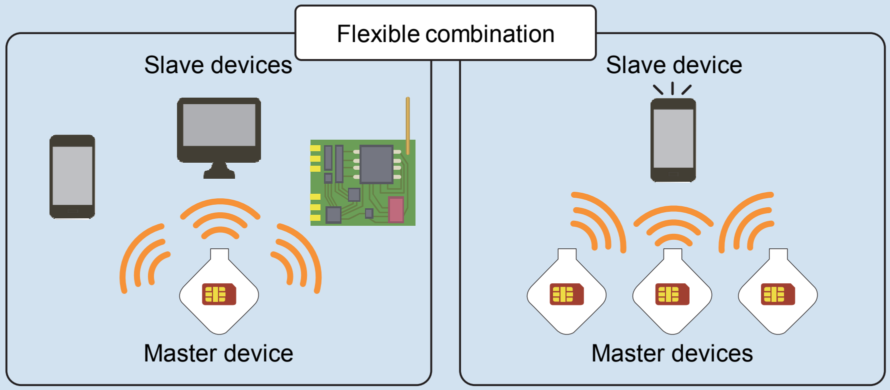


Figure 1 Example of flexible combination of master and slave devices with PSIM Suite

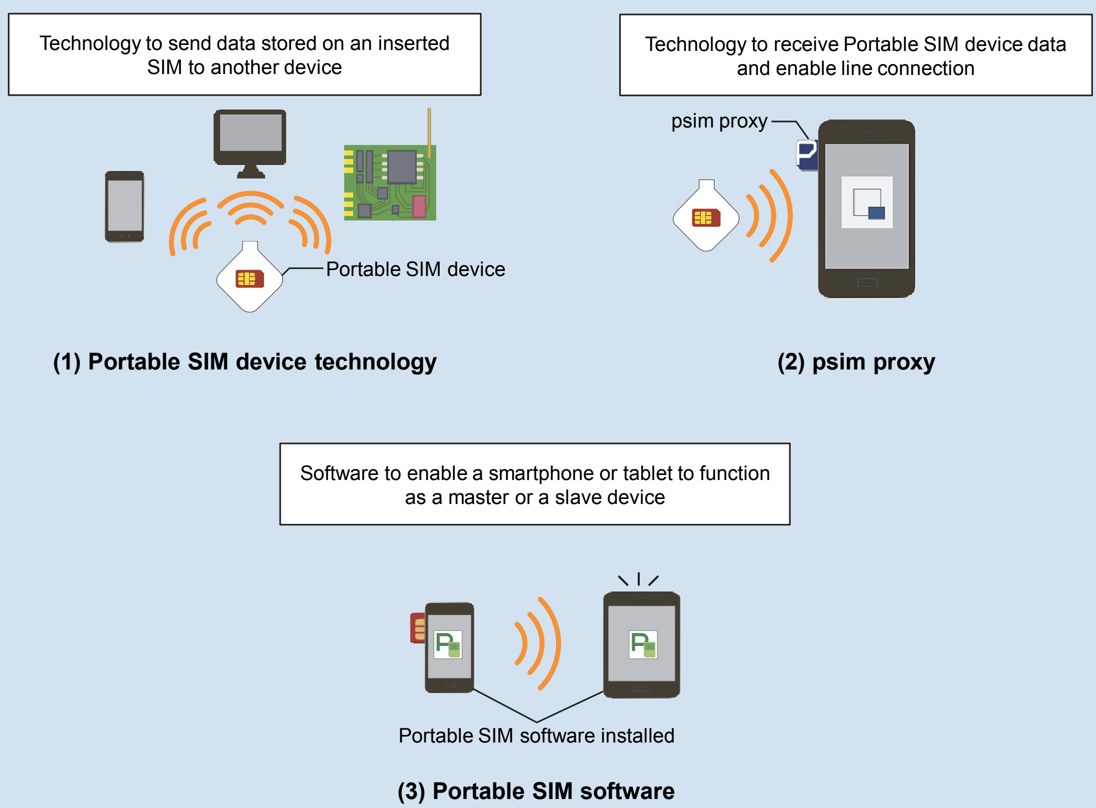


Figure 2 Elements of PSIM Suite

(3) Portable SIM software (Fig. 2 (3))

Software to enable a smartphone or tablet to function as either a master or a slave device.

Figure 3 shows a connection image of a Portable SIM device and psim proxy.

Table 1 describes the contents of this licensing in terms of the above elements. These three technological elements are not only licensed in a batch, but can also be licensed separately to suite the purposes of the licensee, making it more attractive to use.

3) PSIM Suite Licensing Example

The first round of PSIM Suite licensing was offered to a hardware startup company, Cerevo.

NTT DOCOMO has licensed the PSIM Suite to Cerevo, and Cerevo has developed "SIM CHANGER ⊿ (Sim changer delta) to enable communications with flexible SIM switching. On August 2, 2016, to confirm marketability, Cerevo started to collect funds through the "Makuake" crowdfunding website [2]. This crowdfunding project reached its funding target in 12 hours from commencement, enabling Cerevo to begin manufacture of the product [3].

SIM CHANGER⊿ developed by Cerevo is shown in **Photo 1**.

SIM CHANGER⊿ uses (1) Portable SIM device technology and (2) psim proxy from the PSIM Suite.

SIM CHANGER⊿ with the Portable SIM device technology enables up to four SIM cards to be inserted, while a "bridge card" with the psim proxy technology is inserted into a smartphone. Users can flexibly switch and use data from any of four SIM cards via a dedicated app running on the smartphone.

With this licensing, NTT DOCOMO is leveraging the strengths and specializations of its partnerships with its business partner Cerevo taking the

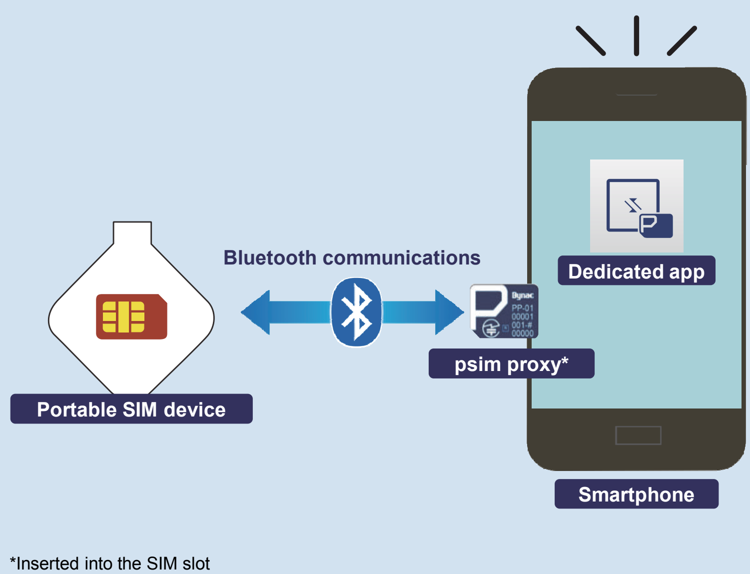


Figure 3 Connection image of a Portable SIM device and psim proxy

Table 1 PSIM Suite licensing content

(1) Portable SIM device technology	(2) psim proxy	(3) Portable SIM software
・Firmware source code ・Hardware circuit diagram ・Related documents	・SIM-type hardware with Bluetooth ・Firmware binary ・Dedicated app source code (Android™/iOS) ・Dedicated app related documents	・App source code (Android™) ・Related documents ・Chipset software*

*Some vendors only

Android™: A trademark or registered trademark of Google Inc.
iOS: A trademark or registered trademark of Apple in the United States and other countries.

"+d*3" initiative to create new value. Through this, Cerevo has developed SIM CHANGER⊿ in an extremely short amount of time. Its release and confirmation of market reaction has led to manufacture and sales.

4) Portal Site Built

To enable many users to use Portable SIM technologies, it is necessary to diversify products and services that use PSIM Suite. To provide PSIM Suite licenses to many companies, we opened a portal site at the same time as commencement of the licensing to provide descriptions of the Portable SIM technology, an overview of the licensing as well as examples of its use (**Figure 4**) [4].

Companies interested in the licensing of this technology can use the site to download handouts and make inquires, and close a licensing agreement.

With the commencement of PSIM Suite licensing, this article has presented details of the PSIM Suite license and the case of Cerevo, a hardware start-up involved in the first-round licensing of the technology. Going forward, we would like to expand the number of licensers and broaden the range of

*3 **+d:** The name of an NTT DOCOMO initiative for creating new value together with partner companies.

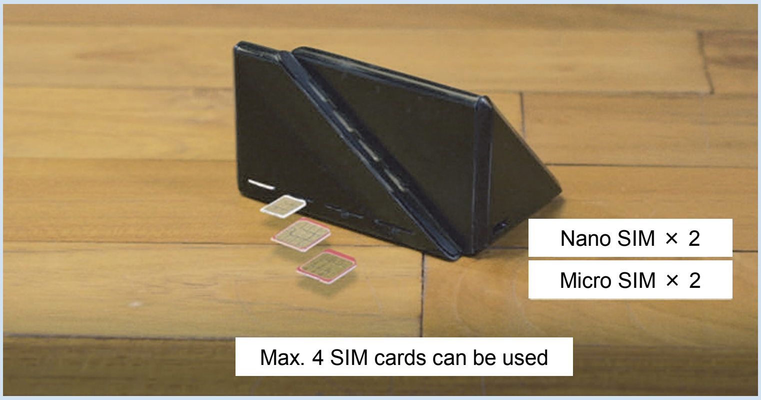


Photo 1 SIM CHANGER⊿

Figure 4 PSIM portal site

new services using Portable SIM technology.

References

[1] A. Shibutani et al.: "Portable SIM: Empowering the User in the IoT Era," NTT DOCOMO Technical Journal, Vol.16, No.4, pp.22-30, Apr. 2015.

[2] Makuake home page (In Japanese).
https://www.makuake.com/

[3] Makuake: "4 subscription SIMs manipulated freely. 'SIM CHANGER Delta' for switching communications lines," (In Japanese).
https://www.makuake.com/project/simchanger/

[4] PSIM Suite home page.
http://portablesim.idc.nttdocomo.co.jp/en/index.html

News

Best Paper Award at IEEE PIMRC 2016

Tatsunori Obara, Yuki Inoue, Satoshi Suyama and Yukihiko Okumura of 5G Laboratory, NTT DOCOMO Research Laboratories, and Yuichi Aoki and Jaekon Lee of Samsung Electronics Co., Ltd. received the "Best Paper Award" at the Institute of Electrical and Electronics Engineers International Symposium on Personal, Indoor and Mobile Radio Communications 2016 (IEEE PIMRC 2016), an international conference held in Valencia, Spain from September 5 to 7, 2016.

Held regularly since 1991, this conference is one of the flagship conferences of the IEEE Communications Society. This year 903 papers from approximately 60 countries were submitted, and approximately 49% were accepted. From among these, the Best Paper Award was conferred for three papers assessed for their superior accomplishments.

The award-winning paper is titled "Experiment of 28 GHz Band 5G Super Wideband Transmission Using Beamforming and Beam Tracking in High Mobility Environment." The "5G" 5th generation mobile communications system is to go into commercial service by 2020, and compared to 2010 services, will offer communications capacities 1,000 times greater and achieve user data rates 100 times faster. Hence, studies into these technologies are being actively pursued around the world. To contribute to the early creation of 5G, NTT DOCOMO has been conducting transmission experiments with cooperation of 13 of the world's major vendors to test elemental technologies key to 5G efficiency and effectiveness. Because high frequency bands will be used to secure wide frequency bandwidth, we are conducting experiments into multi-antenna transmission technologies such as beam forming*1 to verify their effectiveness.

Through experiments on beam forming and beam tracking technologies done in cooperation with Samsung Electronics, the paper presented results of throughput evaluations made in high-speed moving environments and clarified the effectiveness of the 28 GHz band.

28 GHz is one of leading candidates of frequency band for 5G. Because radio waves in high frequency bands such as 28 GHz have high straightness and high propagation loss with distance, applying them to cellular mobile communications is problematic. In recent years, it has been shown that it is possible to achieve high-speed communications and significantly reduce these losses due to distance in the 28 GHz band by applying beam forming technologies with Massive Multiple-Input Multiple-Output (Massive MIMO) *2 and super multi-element antenna arrays. The equipment used in this experiment is capable of maximum 3.77 Gbps throughput by using a combination of spacial multiplexing technology with a 96-element Massive MIMO antenna base station and an eight-element terminal using analog beamforming technology. This equipment also uses beam tracking functions to switch beams adaptively to follow the movement of the terminal. The terminal equipment also uses a compact antenna simulating the smartphone shape, so that the experimental environment reflects actual assumed usage scenes. The experiment verified beam forming and beam tracking technologies in high-speed moving environments and successfully reached a maximum throughput of 3.77 Gbps even at mobile speeds of 60 km/h, and also achieved more than 1 Gbps throughput at a distance of 500 m from the base station.

The paper received the award for presenting the effectiveness of the 28 GHz band in 5G by clarifying that high throughput is possible with beam forming and beam tracking technologies in real-world usage scenes.

*1 **Beam forming:** A technique for increasing or decreasing the gain of antennas in specific directions by controlling the amplitude and phase of multiple antennas to form radiation patterns.

*2 **Massive MIMO:** Technology that adopts super multi-antenna arrays consisting of greater numbers of antennas in MIMO systems, which transmit radio signals multiplexed in the space domain by using the multiple antenna elements for transmission and reception. This technology can secure a desired service area by using sharply formed radio beams to compensate for the radio propagation losses that accompany high-frequency band usage, and achieves high-speed data communications by multiple stream transmission.


IEEE
UNIVERSITAT POLITÈCNICA DE VALÈNCIA
IEEE COMMUNICATIONS SOCIETY

The 27th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications

PIMRC 2016

Presents the

BEST PAPER AWARD

Tatsunori Obara, Yuki Inoue, Yuuichi Aoki, Satoshi Suyama, Jaekon Lee and Yukihiko Okumura

"Experiment of 28 GHz Band 5G Super Wideband Transmission Using Beamforming and Beam Tracking in High Mobility Environment"

Valencia, Spain - September 4-7, 2016

Narcis Cardona. General Chair, PIMRC'16

Best Paper Award at ISAP2016

Tetsuro Imai and Koshiro Kitao of 5G Laboratory received the Best Paper Award at the 2016 International Symposium on Antennas and Propagation (ISAP2016) held in Ginowan City, Okinawa Prefecture from October 24 to 28, 2016. ISAP2016 is an international conference on antennas and propagation held in the Asia region annually. This year, there were 545 papers listed in the final program from papers registered from 34 countries. The winning paper is entitled "Path Loss Characteristics between Different Floors from 0.8 to 37 GHz in Indoor Office." This paper clarified path loss characteristics in indoor office environments in the 0.8 to 37 GHz bands, based on results of experiments conducted jointly by NTT DOCOMO and NTT Access Network Service Systems Laboratories with the aim of evaluating the 5th Generation mobile communications systems (5G).

The clarification of path loss studied in this paper is crucial for the design and evaluation of mobile communications systems, and to date has included many studies such as the so-called Okumura - Hata model*1 [1]. While historically studies have focused on 6 GHz and below [2], recent years have seen the studies undertaken in academia and standardization organizations into 6 to 100 GHz frequencies, which are expected to be used in the future [3] - [5]. Studies on path loss characteristics mainly discuss loss increase related to distance between base and mobile stations, while studies on frequency characteristics of path loss are also important in deciding on frequencies to be used by services.

2016 INTERNATIONAL SYMPOSIUM ON ANTENNAS AND PROPAGATION
The Institute of Electronics, Information and Communication Engineers

IEICE Communications Society

ISAP 2016

Best Paper Award

is presented to

Motoharu Sasaki, Minoru Inomata, Wataru Yamada, Naoki Kita, Takeshi Onizawa, Masashi Nakatsugawa, Koshiro Kitao and Tetsuro Imai

for the paper entitled

Path Loss Characteristics between Different Floors from 0.8 to 37 GHz in Indoor Office Environments

October 27th, 2016

Toru Uno
General Chair of Steering Committee, ISAP 2016

Toru Uno

Jiro Hirokawa
Chair of Technical Program Committee, ISAP 2016

Jiro Hirokawa

This award-winning paper studied path loss between floors based on experiments conducted in indoor office environments with the aim of contributing to 5G design and evaluation. Specifically, this entailed measuring path loss on five frequencies, 0.8, 2.2, 4.7, 26 and 37 GHz in an NTT DOCOMO office building to analyze the relationship between path loss and frequency. As a result of these analyses, we found that in environments in which radio waves have to travel through more floors, the path loss increases related to frequency tended to be small, which meant that the effect of high frequency waves arriving at the receiver via the outside of the building was more dominant than waves traveling through floors. These results were acclaimed at ISAP2016. Please refer to the award-winning paper for details of the findings of this study.

References

[1] M. Hata: "Empirical formula for propagation loss in land mobile radio services," IEEE Trans. Veh. Technol., Vol.VT-29, No.3, pp.317-325, Aug. 1980.

[2] ITU-R Report M. 2135-1: "Guidelines for evaluation of radio interface technologies for IMT-Advanced," Dec. 2009.

[3] T. S. Rappaport, G. R. MacCartney, M. K. Samimi and S. Sun: "Wideband Millimeter-Wave Propagation Measurements and Channel Models for Future Wireless Communication System Design," IEEE Trans. Commun., Vol.63, No.9, pp.3029-3056, Sep. 2015.

[4] 3rd Workshop on Mobile Communications in Higher Frequency Bands (MCHFB): "White paper on '5G Channel Model for bands up to 100 GHz'." http://www.5gworkshops.com/5GCM.html

[5] 3GPP TR38.900 V14.1.0: "Study on channel model for frequency spectrum above 6 GHz (Release 14)," Sep. 2016.

*1 **Okumura - Hata model:** Yoshihisa Okumura reported the so called "Okumura curve" which indicates the relationship between distance from a base station to a mobile station and received field strength based on the results of measurements in the 150 to 1,500 MHz bands taken in various environments such as urban, suburban and open areas. Using this curve, Masaharu Hata formulated the Okumura - Hata model using parameters such as base station height and distance between base and mobile stations.

NTT DOCOMO
Technical Journal Vol.18 No.4

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