Technology Reports

UWB | Ranging Technology | Osaifu-Keitai

Study on Practical Application of the Touchless Function to Osaifu-Keitai Using UWB Ranging Technology

Communication Device Development Department Maiko Murakami Akio Goda Junichi Sawase

In recent years, as there has been a push to make payments cashless, the use of new technologies such as QR/barcode payments has been expanding. NTT DOCOMO has been providing a contactless payment service called "Osaifu-Keitai" for some time, but with the aim of realizing even greater convenience and new user experiences, we are currently studying practical application of Osaifu-Keitai technology to support a touchless function that enables users to make payments simply by standing or passing by a designated location, using UWB, a radio technology that enables highly accurate range measurement. This article describes the details.

1. Introduction

In recent years, Ultra Wide Band (UWB), a medium-range radio technology, has been gaining attention as it has started to be incorporated into a variety of smartphones. UWB holds promise for use in a variety of use cases because of its highly accurate ranging function that takes advantage of radio wave characteristics. Japan is also evolving toward cashless payment systems and the use of QR code/barcode payments are expanding on the existing credit cards and electronic money. In light of these circumstances, NTT DOCOMO is aiming to combine the Osaifu-Keitai it currently provides with UWB to realize Osaifu-Keitai that supports the touchless function as a new means of payment. This article describes studies, technical verifications, and issues for creating new use cases and User Experiences (UX)*1 in the payment field utilizing UWB ranging technology.

*1 UX: A general term for the experiences gained through the use or consumption of certain products or services.

2. "Payment: Touchless-enabled Osaifu-Keitai" Using UWB

2.1 What is UWB?

UWB is an ultra-wideband medium-range radio communication technology. Institute of Electrical and Electronics Engineers (IEEE)*2 802.15.4a, which is the standard specification for UWB, defines it as communications using the 3.1 to 10.6 GHz band. As well as high-speed communication using a wide bandwidth, UWB has the ability to measure the distance and angle of objects with high accuracy. This ranging function uses a method called "time of flight," which measures the time it takes for a signal to propagate, and calculates the distance by multiplying the time by the propagation speed.

UWB was institutionalized in Japanese Radio Law for communications applications (3.4 – 4.8 and 7.25 – 10.25 GHz bands) in 2006, for automotive radar applications for collision prevention (22 – 29 GHz band) in 2010, and for sensor applications (7.25 – 10.25 GHz band) in 2013. However, the applications for communications and sensors have been limited to indoor use. Later however, with expectations for various applications and increasing needs for outdoor use, the law was amended in May 2019 to allow outdoor use in the 7.587 – 8.4 GHz band. With this amended law, UWB has started to be installed in a variety of smartphones and peripheral devices.

2.2 Activity Status of Standardization Organizations

Even since before the amendment of the Radio Law in Japan, the activities of standardization organizations related to UWB have been getting busier. The following summarizes the activities of each of these organizations.

- IEEE802.15.4 [1]

  IEEE802.15.4 defines physical layer*3 and logical layer*4 specifications to enable low data rate radio connectivity and precise ranging between devices that do not require batteries or require very limited battery power. Standardization of UWB is underway in the IEEE802.15.4 working group.

  802.15.4a [2] establishes the physical layer for ranging, and 802.15.4z [3], which was released in August 2020, strengthens the security of the physical layer defined in 802.15.4a and establishes the logical layer.
- Car Connectivity Consortium (CCC) [4]

  CCC is an international industry organization that formulates use cases for smartphone-linked vehicles and related specifications for the service layer*5. Based on IEEE802.15.4z, it is planning to formulate next-generation specifications for digital keys that use UWB and Bluetooth Low Energy (BLE)*6. As of March 2021, 129 companies, including automobile, in-vehicle equipment, component and smartphone manufacturers are currently participating in the organization.
- FiRa Consortium (FiRa)

  FiRa is an industry group that aims to ensure interoperability among UWB products to realize UWB use cases. It is planning to establish a certification program based on IEEE802.15.4z. 65 companies (as of March 2021) that use UWB (component, smartphone and electrical equipment manufacturers, etc.) are currently participating.

*2 IEEE: The world's largest technical professional organization (international academic society) dedicated to the advancement of technology in the field of electrical and information engineering.

*3 Physical layer: Defining physical connections and transmission methods, the first layer of the OSI reference model. The OSI reference model classifies and defines communication functions.

*4 Logical layer: Defining methods for identification and collision avoidance so that communications between physically connected devices are performed smoothly, a part of the second layer of the OSI reference model. The OSI reference model classifies and defines communication functions.

Currently, the most specified use case of UWB, and the one that is on the verge of practical application, is the use of UWB as a digital key fob for vehicles, which is being discussed in the CCC. Conventional digital key fobs for cars use Low Frequency (LF)*7 radio waves to unlock the door, but there have been incidents of cars being stolen by relay attacks, in which the thief intercepts and retransmits the radio waves transmitted by the key fob to unlock the door when the owner is away. In this regard, UWB can prevent relay attacks because the distance from the real key fob cannot be falsified thanks to the time of flight ranging function.

Although various other use cases for UWB are under development by FiRa, and the use of UWB is being considered for a wide range of applications such as unmanned shops and house locks, as of March 2021, practical application is still some way off.

2.3 How Conventional Osaifu-Keitai Works

Osaifu-Keitai is a contactless payment service that uses a mobile FeliCa®*8 chip embedded in a mobile handset. The underlying technology is FeliCa, a contactless IC card technology developed by Sony Corporation. Feature phones or smartphones equipped with FeliCa chips offer a high level of convenience by enabling multiple payment services on a single handset. These chips also incorporate safety and security features such as unlocking through identity authentication. The chips were first installed in the mova 506i series in July 2004, have since been installed in many i-mode handsets, and were made available for Android handsets in 2010. Today, not only NTT DOCOMO handsets but also many handsets of other telecommunications carriers and subscriber identity module (SIM)-free*9 handsets distributed in Japan are compatible with Osaifu-Keitai.

There are two main hardware components that make Osaifu-Keitai possible: embedded Secure Element (eSE) and Contactless Frontend (CLF) (**Figure 1**). eSE is a tamper-resistant*10, highly secure chip that executes security-critical applications and stores data. The CLF is a radio chip that controls the front end of contactless communications with the outside of the handset. Its radio technology complies with Near Field Communication (NFC) Forum*11 specifications, and uses radio waves in the 13.56 MHz frequency band to send and receive FeliCa commands when the handset is within a few centimeters of a reader/writer. The FeliCa commands are then sent to the eSE, and the mobile FeliCa application in the eSE performs a series of processes such as interpreting and responding to commands and updating recorded e-money balance information. This makes payment operations equivalent to those of a standalone FeliCa card possible on mobile handsets.

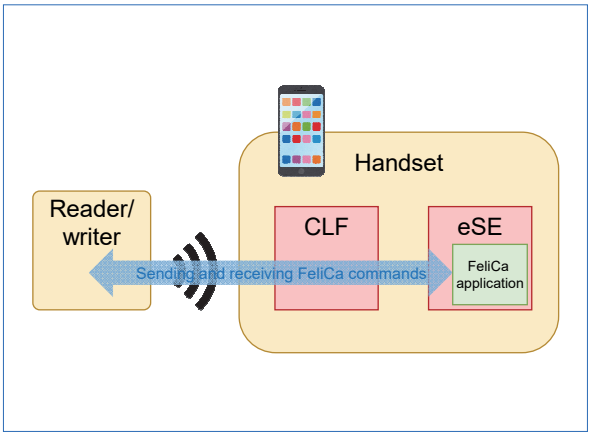

Figure 1 Configuration of Osaifu-Keitai

*5 Service layer: The layer that specifies the protocols to be used by services.
*6 BLE: A short-range radio communication technology standard with low power consumption and low cost.
*7 LF: Long wave. Radio waves in the frequency band of 30 to 300 kHz.
*8 FeliCa®: A contactless IC card technology developed by Sony Corp. A registered trademark of Sony Corp.
*9 SIM-free: Having no restrictions on the use of a SIM from a different telecommunications carrier when inserted into a handset.

Originally, NTT DOCOMO used eSE, which was developed exclusively for mobile FeliCa. However, from 2019, we have increasingly been using general-purpose secure chips compliant with the standard specifications specified by the GlobalPlatform*12. This has made it possible to standardize handset hardware between global models and models for the Japanese market, making it even easier for handset manufacturers to support Osaifu-Keitai. It is also worth noting that such general-purpose eSE chips can be used for service applications other than Osaifu-Keitai, opening up possibilities for a variety of secure services other than FeliCa-based payment services, such as digital keys and identity authentication.

2.4 Changes from Traditional Osaifu-Keitai to Touchless-enabled Osaifu-Keitai

NTT DOCOMO is considering touchless support combining UWB and Osaifu-Keitai, because we want to provide UX that enables easy payment even when it is not easy to take out the smartphone and hold it over a reader/writer, such as when the user's hands are full, when the user keeps the smartphone in the back of their bag, or when making a payment in a drive-through.

The act of holding a handset over a reader/writer not only exchanges payment data, but also confirms the user's intention to make a payment. Therefore, in the case of a touchless system, confirmation of the user's intention to make a payment must be obtained through some other action. To solve this problem, we decided to use UWB, which has highly accurate ranging performance, to set up a specific area for payment, and view the user as expressing intention to make a payment by staying in or passing through that area. **Figure 2** shows the different methods of confirming

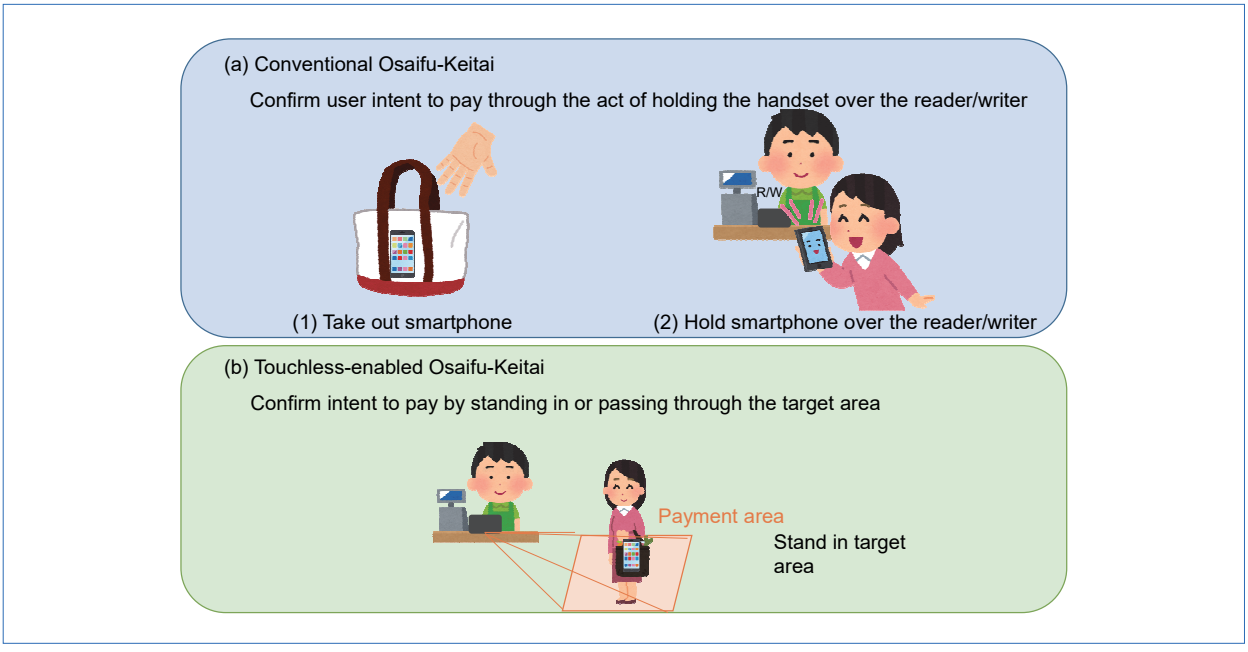

Figure 2 Different methods of confirming payment intention

*10 Tamper-resistant: A property that prevents integrated programs, data and other digital information from unauthorized referencing or rewriting.

*11 NFC Forum: An international standardization organization that aims to promote and develop technical specifications for the short-range radio technologies known as NFC.

*12 GlobalPlatform: An international standardization organization that formulates trials for IC cards and security technologies, including credit cards and SIM cards.

such intention.

Instead of using NFC for radio exchange of payment information as in the conventional Osaifu-Keitai as described above, BLE is used as the mechanism to achieve payment in combination with the UWB ranging function. **Figure 3** shows the differences with the conventional Osaifu-Keitai. Here, BLE is used because currently international standardization has not been completed for communications other than ranging data with UWB, so interoperability remains an issue.

3. Actions to Achieve Touchless Compatibility

3.1 Challenges for Practical Application

As mentioned above, UWB holds promise for use in a variety of future cases, although three conditions are necessary for it to actually become popular as social infrastructure around people.

- The first is the development of international standards. In the case of radio devices, "minimum commitments" such as radio performance standards and communications protocol specifications are necessary to ensure that any combination of devices can communicate and operate with each other. Such rules are often specified by international standardization bodies. Organizations that specify technical specifications for UWB include the aforementioned IEEE, CCC and FiRa. While the IEEE has completed the specifications of the base physical and logical layers, CCC and FiRa are currently working on the specifications of the higher layers, related to service specifications.
- The second is popularization of UWB-enabled devices. Broadly speaking, these are either

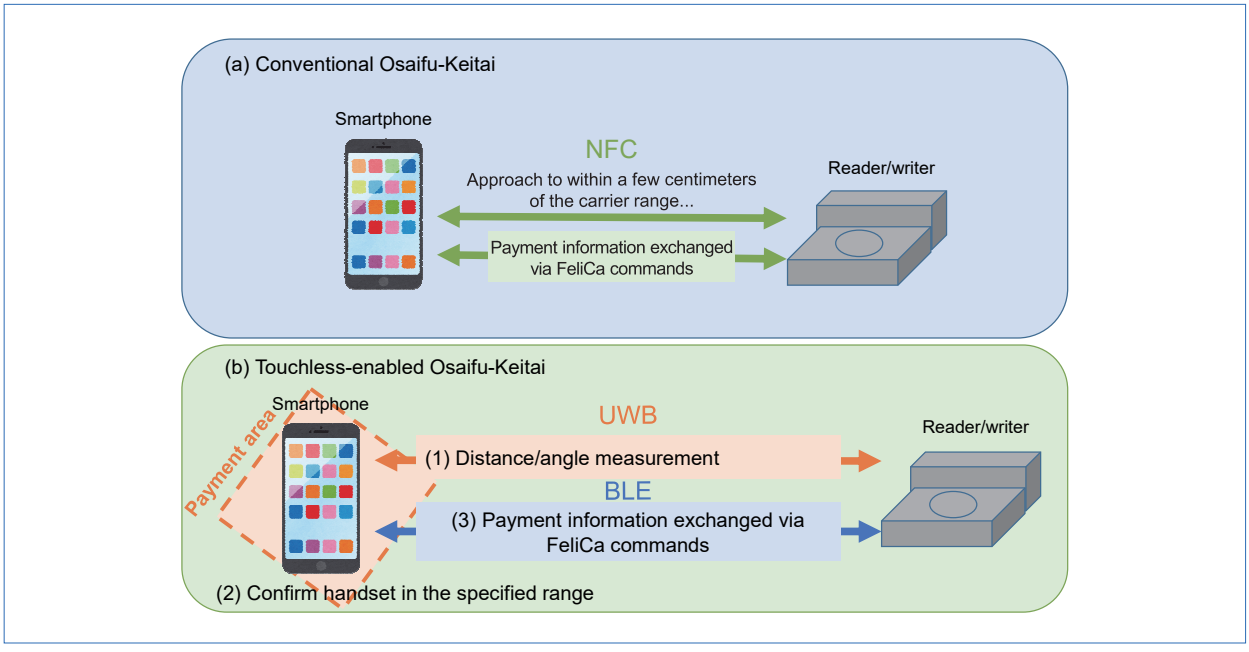

Figure 3 Comparison of methods

smartphone terminals used by end users or reader/writers that serve as communication partners. For the former, some handset manufacturers began installing UWB in smartphones since around 2020, but these are still limited. Thus, it is essential to expand the number of compatible models and supporting manufacturers. As for the latter, there are a variety of devices for different uses such as payment terminals connected to Point Of Sale (POS) registers[*13] in retail outlets, in-vehicle devices for digital key door opening and digital signage[*14] terminals for displaying advertisements on streets. It is not easy to popularize use of these services due to complex factors such as the needs of each service, commercial flows and cost effectiveness.

- The third is the emergence of service providers using UWB-equipped devices. The mere existence of UWB-equipped devices will not bring benefits to end users. Only when services using these devices are launched will they provide convenience to end users and lead to business profits for service providers. For such business decisions to be made, it is necessary that the set of smartphones and reader/writer devices are sufficiently widespread in the market to form a basis for service provision.

These three conditions will not be satisfied "in sequence." For example, "products can be developed because standard specifications have been decided," "services can be started because smartphones have become popular," "products can be developed because there is demand for services," and "specifications can be matured through trial and error with actual products and services" – similar to the so-called problem of whether the chicken or the egg comes first.

NTT DOCOMO has experienced this kind of issue many times in the business world with the birth of various new technologies and services such as Osaifu-Keitai. Therefore, we will develop working devices for verification first, and from the early stages collaborate with service providers to exchange opinions and think together about how to implement these technologies in their services, with the aim of breaking out of a chicken and egg situation as quickly as possible.

3.2 Development and Evaluation of a Prototype UWB-enabled Smartphone

Working prototypes, or devices that enable verification of touchless-enabled Osaifu-Keitai, are a smartphone equipped with UWB with touchless-enabled Osaifu-Keitai functions, and a reader/writer device capable of communicating with the smartphone using the same radio bands and protocols. Since these two items do not yet exist in the world, we developed hardware and software for verification with the cooperation of four partner companies in the UWB study.

The roles of the four partner companies are as follows:

- Sony Corporation: Development of prototypes of UWB-enabled reader/writer devices and software
- FeliCa Networks, Inc: Development of UWB-enabled FeliCa middleware[*15] and applications

*13 POS register: A system equipped with point-of-sale information management functions to manage money for sales and inventory status of goods in real time.

*14 Digital signage: Advertising media using digital technology. Using displays or projectors to change advertising content in response to time or location, this technology is gaining attention as an alternative to conventional advertising media such as posters, etc.

*15 Middleware: Software positioned between the OS and user applications, and that provides common functions for multiple applications, thereby enabling efficient application development.

- NXP Semiconductors: Provision of IC chips for UWB and development environment/technical information on UWB
- SHARP Corporation: Development of UWB-enabled smartphone prototypes and software

There are two major points of view for verification of the smartphone and reader/writer devices developed through the above system.

- The first is how to achieve enough ranging accuracy to identify the user's intent to pay. To prevent erroneous payments, we thought that the area where intent to pay is indicated should be limited to the space of a single person, and accuracy targets should be set to +/- 10 cm in distance error and +/- 10 degrees in angle error.
- The second is to solve the problem of installing the technology in smartphones. New UWB radio installation should be specified and designed so that it does not interfere with other radios or consume an extremely large amount of battery power while in use.

Under these objectives, as a result of ranging with the designed and developed prototype smartphone and reader/writer device in a test environment with no obstacles in between and the smartphone fixed, the measurement errors in distance and angle were kept within the target values, and payment processing could be performed within the specified range. We were able to confirm that there were no interference problems with other radios, and battery consumption was kept to a minimum by turning off the UWB chip power when ranging was not being performed.

3.3 Verification with Service Provider Partners

Although the aforementioned performance targets were met, there are still issues to be addressed for practical application. Since it is necessary for users to be able to actually use touchless Osaifu-Keita in any environment with a low probability of failure, it is necessary to test the smartphone in various environments. For example, assuming that the phone is placed in a bag, there are many factors that could affect radio communications such as the direction of the phone in the bag, the material of the bag and its contents, the combination of usage patterns and the environment in which the phone is placed, and distance, etc. Various factors that could affect wireless communication can also be assumed when considering usage scenes where Osaifu-Keitai is already in use, such as in front of cash registers in retail outlets, near ticket gates in stations and in front of vending machines, etc.

With the current specifications of the prototype, it is difficult to detect the smartphone location in cases where a person is between the smartphone and reader/writer device and their body blocks the signal, such as when making a payment with the smartphone in the back pocket of the pants. Such cases require hardware improvements such as antenna relocation. In some usage scenarios, where location determination and payment processing need to be completed while passing through a certain area, the detection range and process start position also need to be reviewed because high processing speed is required.

Going forward, it will be necessary to conduct verification considering use cases in various environments where Osaifu-Keitai is actually used and

identify what improvements are necessary.

To achieve this goal, we will continue to build cooperative relationships with various partners and conduct a wide range of verification testing to enable the use of various services.

4. Conclusion

This article has described details of study, technical verification, and issues for providing new UX by creating new use cases of payments with touchless-enabled Osaifu-Keitai using UWB ranging technology. To make the act of payment more seamless through touchless-enabled Osaifu-Keitai, we will focus on the following aspects to verify its practical usage.

- Whether it can be used successfully in a variety of environments (availability)
- Whether payment is processed on the wrong person's handset (security assurance)

Although this article focuses on payment, the high-precision ranging function of UWB is a technology that can be applied to other fields. Hence, we would like to expand UWB use cases (advertisement distribution and digital keys, etc.) in stages. Also, to build hardware environments, we will also actively study the introduction of UWB terminals while observing market trends.

REFERENCES

[1] IEEE 802.15.4-2020: "IEEE Standard for Low - Rate Wireless Networks," Jul. 2020.
[2] IEEE 802.15.4a-2007: "Amendment 1: Add Alternate PHYs," Aug. 2007.
[3] IEEE 802.15.4z-2020: "Amendment 1: Enhanced Ultra Wideband (UWB) Physical Layers (PHYs) and Associated Ranging Techniques," Aug. 2020.
[4] Car Connectivity Consortium: "Digital Key Release 2.0 White Paper," 2020.