Technology Reports
IoT Lean Style Parking Lots
Special Articles on Next-generation Mobility Services

The “docomo Smart Parking System” —IoT based Pay Parking Solution—

Innovation Management Department Shoh Shimamura Kanako Kuwano
Takashi Yuuki Yuuki Nishino

Recent years have seen initiatives in a variety of industries on using ICT to optimize existing social systems. As part of this trend, NTT DOCOMO has taken up the challenge of open innovation with the pay parking industry, which continues to increase in importance as infrastructure in our automobile-supported society. This article gives an overview of the “docomo Smart Parking System™*1” project being commercialized as a concrete outcome of this challenge, and describes technological features of this solution.

1. Introduction

Pay parking, which supports our everyday, automobile-based transportation environment, appeared in the 1990s in Japan, and reached its current form through successive improvements and advancements.

From the perspective of drivers, pay parking is a sharing economy*2 service that enables them to temporarily rent parking space near their destination. From the perspective of land owners, it provides a business model for generating return from land assets. These effects have multiplied, leading to establishment of more pay parking, so that as of 2018, there were approximately 85,000 parking lots [1] operating throughout Japan.

However, the following issues have recently appeared in the pay parking market.

- Required to support Web-based business models such as Mobility as a Service (MaaS)*3 and cashless transactions

*1 docomo Smart Parking System™: A trademark of NTT DOCOMO, INC.
*2 Sharing economy: An economy created by lending, sharing or exchanging goods and services. In a narrow sense, the sharing economy usually entails individuals offering their unused products or assets, or their services to others.

- Drivers are unable to find places to park easily
- A shortage of land suitable for pay parking in urban centers

Considering such conditions, NTT DOCOMO initiated its “docomo Smart Parking System” project in June 2016, with the goal of using its ICT know-how to enable both of the following.

- A system that can utilize small land areas, where it has been difficult for parking lot operators to use existing pay parking systems
- Pay parking services that provide additional convenience for drivers

NTT DOCOMO began offering a commercial service in October 2017 (**Figure 1**). This article gives an overview of the project and describes technical features of the solution.

2. System Overview

2.1 System Architecture

The docomo Smart Parking System project is developing a solution based on the concepts of:

- Reducing construction and operating costs
- Adapting to changes in the market environment
- Providing a User eXperience (UX)*4 that gives broad support for actions before and after using a parking space

The system architecture is shown in **Figure 2**. The system consists of four components: “Smart Parking Sensors,” which are IoT devices that detect when a vehicle enters or leaves a parking space; a gateway*5, which connects these sensors to a server; a parking lot management server in the cloud; and the “Smart Parking Peasy®*6” (hereinafter “Peasy”) application, used by drivers when

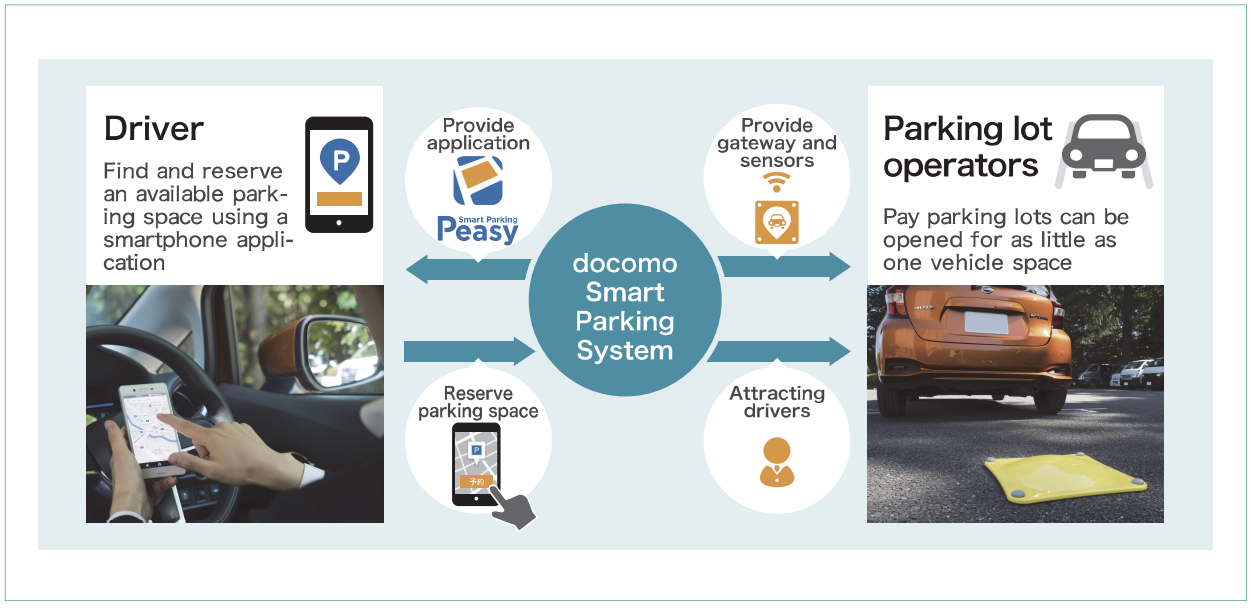

Figure 1 Scheme

*3 MaaS: A new mobility concept, in which all means of transport are handled seamlessly in a single service.
*4 UX: A general term for the experiences gained through the use or consumption of certain products or services.
*5 Gateway: An intermediate device that has functions such as protocol conversion and data transfer, to allow communication between devices. In this article, it refers to a specific device developed to collect and relay data to be sent from sensors to the server.
*6 Smart Parking Peasy®: A trademark or registered trademark of NTT DOCOMO, INC.

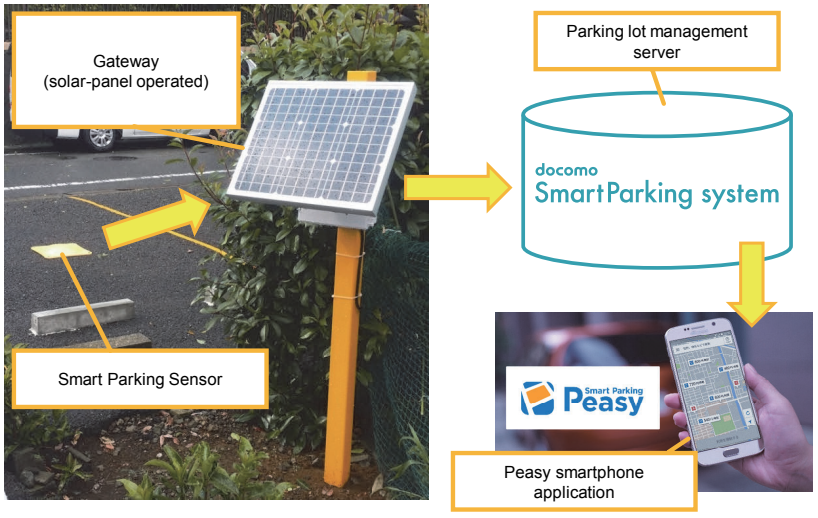

Figure 2 System architecture

using a parking lot.

2.2 System Functionality

The functionality and process of each of the elements that comprise the system are described in detail below.

1) Smart Parking Sensors

A Smart Parking Sensor (hereinafter “the sensor” or “the sensors”) is installed in each parking space in the parking area. The sensors constantly monitor whether a vehicle is parked in the space where they are installed, and periodically send the data to a gateway using 920 MHz band short-range radio communication.

These sensors are smaller and lighter than existing devices used to detect vehicles in pay parking lots and are designed to be fixed to the surface of the ground using anchor bolts. This allows them to be installed easily, without using heavy construction equipment or special tools, and only minor excavation is needed so the site can be restored easily when they are removed. The sensors have built-in batteries, so no electrical work is needed. Since neither electrical nor wired communication work is required, the sensors can be installed inexpensively and with less work than when using other existing devices.

The sensors are made using polycarbonate resin material. Based on the assumption that only one of the four wheels of an average-weight vehicle could rest on the sensor, they are guaranteed to be able to withstand loads of over 2,500 N. They are also water and dust resistant equivalent to class IP67*7, and can operate for approximately two years without changing the internal batteries. Thus, they can operate continuously for long periods in a natural, outdoor environment.

*7 IP67: IP67 and IP65 are IP codes specifying protection classes used in Japan Industrial Standards (JIS). The first digit indicates dust resistance and the second digit indicates water resistance.

2) Gateway

Generally, a single gateway is installed in each parking lot. The gateway receives sensor data from the sensors installed in each parking space and periodically sends it to the parking lot management server in the cloud. Data transmission between the gateway and the parking lot management server is done using LTE wireless communication, so no construction effort is needed for communication between devices for this system. Sensors can be up to approximately 30 m from the gateway, so there is some flexibility in selecting the location of the gateway according to the layout of the parking lot. One gateway is able to connect with up to ten sensors simultaneously.

Gateways also can work with solar panels and internal batteries, which provide power to enable gateways to operate continuously. Thus, gateways can operate in spaces where environmental factors make it difficult to provide a power source, such as vacant land. For indoor parking lots and other areas where light is insufficient for solar panels, gateways can also be installed using an ordinary household power outlet.

As with the sensors, gateways can also be installed without requiring any special tools, and the devices have IP65-level water and dust resistance. Gateways are also equipped with failsafe functionality. If communication from the gateway is temporarily interrupted, data will be stored within the gateway and will be retransmitted when communication resumes. Thus, they can handle situations where communication could become unstable due to radio interference or other environmental factors.

These features realize highly available system operation and very flexible system installation.

Photographs of the sensor and gateway are shown in **Figure 3**, and specifications are shown in **Table 1**.

Smart Parking Sensor

Gateway
(AC power operated)

Figure 3 Sensor and gateway photographs

Table 1 Basic specifications for a sensor and gateway

	Smart Parking Sensor	Gateway
Dimensions	388 mm (*D*) × 388 mm (*W*) × 46 mm (*H*)	105 mm(*D*) × 290 mm (*W*) × 208 mm (*H*) (Solar panel: 445 mm (*D*) × 510 mm (*W*) × 40mm (*H*))
Waterproof/ Dustproof	IP67	IP65 (Solar panel: IP67)
Weight	3.05 kg	1.55 kg (Solar panel: 3.5 kg)
Communication	920 MHz band communication	920 MHz band communication (between sensors and gateway) LTE (between gateway and server)
Operating voltage	DC3.3 V	DC3.8 V
Operating environment	Temperature: −20°C to 70°C*	Temperature: −20°C to 60°C
	Humidity: 0 to 100%	Humidity: 0 to 100%

* For outdoor installations on asphalt, external temperature approx. 45°C

3) Parking Lot Management Server

The parking lot management server (hereinafter “server”) centrally manages the state (occupied or not, rate settings, settings for when the parking lot is open or closed, etc.) of all parking spaces with sensors installed, throughout Japan in real time.

The server has the following functionality.

(a) Parking lot availability management

The availability state of each individual parking space is managed by the server, based on the sensing data sent by the gateways. Parking space availability is also displayed in real time, based on parking lot information on the server, in an application called Peasy, which will be described below. The application is able to compute the remaining available parking spaces in a parking lot from the total number of parking spaces, the number reserved, and the number that are occupied, and to update the display of parking space availability.

(b) Parking fee settlement

The server computes the driver’s parking fees based on fee settings in the server and the times of entering and leaving the parking space. The system completes payment processing on-line, so equipment to accept cash payments does not need to be installed at the parking lot. Fees can be configured in units of as little as one yen, and one minute, and detailed settings can be set for days of the week or hours of the day can be made, to balance supply and demand.

(c) Monitoring sensor and gateway faults

The server continuously monitors data sent from sensors and gateways, so it is able to detect unauthorized parking and any problems, such as low battery levels or other device faults, in real time, 24 hours-a-day,

and 365 days-a-year. If a problem is detected, the server automatically sends an alert classified by type of problems to the maintenance department. The maintenance department can then arrange operations on-line, such as restarting the sensor or gateway, telephoning or emailing the user, or arranging to send personnel to handle it on-site, depending on the type of alert received. If on-site maintenance is needed, the maintenance person can check the type of alert and the location of the parking lot and parking space where the trouble is occurring beforehand, and prepare the necessary equipment and materials efficiently, before departing for the site.

(d) Management functionality for parking lot operators

A management system for parking lot operators is also provided, allowing dynamic settings such as changes to parking rates, or temporary closures for parking lots by day of the week and time of day. In most conventional parking lot systems, these management functions required going to the site and changing settings on the devices, but with this system, changes to settings can be made on-line in real time. This helps reduce the workload for managing parking lots, even when parking lot operators manage parking lots that are spread widely across a region by utilizing idle land in scattered locations.

2.3 Parking Lot Service Functionality

Peasy is a smartphone application that enables drivers to use parking lots where the system has been installed. By registering their account after installing the application, drivers are able to use parking lot services provided by the system. Screen images of the sequence of operations when using a parking lot with Peasy are shown in **Figure 4**. The main services provided by Peasy are described below.

(a) Account registration

Users can register and log in to Peasy using a LINE™*8 account, a Facebook®*9 account, or a Google™*10 account. The system has been designed to be easy to use, even for the first time when the parking lot at a driver’s destination is using the system. This reduces the effort required before using the system for the first time, by having the driver select and register with an account they already have, and not requiring them to create a new ID and password for Peasy.

(b) Reserving and using a parking space

Peasy provides a service that enables drivers to reserve an available parking space 30 minutes before they arrive, free of charge. This enables drivers to decide where they will park while they are traveling to their destination, reducing the inconvenience of looking at signs to find available parking near the destination after arriving, and the accompanying risk of accident. While a parking space is reserved for a driver, the system displays the space as occupied to other drivers and does not accept multiple reservations for the space.

When a driver enters a space that they

*8 LINE™: LINE is a trademark or registered trademark of LINE Corporation.
*9 Facebook®: A registered trademark of Facebook, Inc.
*10 Google™: A trademark or registered trademark of Google LLC.

Figure 4　Using a parking lot with Peasy

have reserved, a push notification is sent to the driver's Peasy application to confirm their intention to start using it. Instructions to start parking are displayed on the application. When the driver follows these instructions, the system relates the driver, the vehicle parked in the space, the driver's account, and the payment method, so the driver can finish preparation for payment before leaving the parking space.

(c) Automatic cashless settlement

Through the steps in (a) and (b), the driver can have payment of parking fees completed automatically when they leave the parking space. Existing pay parking systems require paying cash to a machine in the parking lot to settle payment before leaving the parking lot, but this inconvenience is not necessary with Peasy.

When the vehicle leaves the parking space, the sensor detects that it has left and automatically records the time. Based on this departure time, and the similarly detected entry time for that parking space, the server automatically computes the parking fee. This fee is settled automatically using a credit card that the driver has preregistered in Peasy. Thus, drivers need not wait for payment to complete, and can proceed to their next destination.

(d) Electronic receipts, aggregated payment for corporations

Peasy is able to issue digital receipts for settlement of expenses. Compared with paper receipts, this reduces the risk that the driver could lose them, and for the parking lot operator, it avoids difficulties with paper jams and maintenance costs such as replenishing paper, printer ink and other consumables.

For corporate drivers, there is also a service for aggregate payments by corporate account, which issues a single invoice to the account after aggregation. For corporations using this service, a single receipt is issued monthly, aggregating the parking fees for each corporate account. This receipt can be processed directly by the company’s accounting department, simplifying the settlement of expenses.

2.4 Response from Users

After drivers used Peasy at a parking lot for the first time, NTT DOCOMO asked them to respond to an optional survey through the application. The survey responses are shown in **Figure 5**:

- 89% of users responded 4 (“Satisfied”) or greater on a 5-step scale.
- 92% of users responded 4 (“I would like to use the service again”) or greater on a 5-step scale.

3. Lean-style Solution Development

To develop a high-quality service within constraints, such as project organization with a small staff, market environment with high uncertainty, and equipment operating conditions in a largely-unknown outdoor parking-lot environment, the docomo Smart Parking System project was managed using a “Lean style*11.” NTT DOCOMO applied this style for development the entire solution, including servers, applications, and also sensors and other specialized devices.

Below, we give an overview of the development process for a representative element of the project, the sensors.

The main requirements for the sensors were

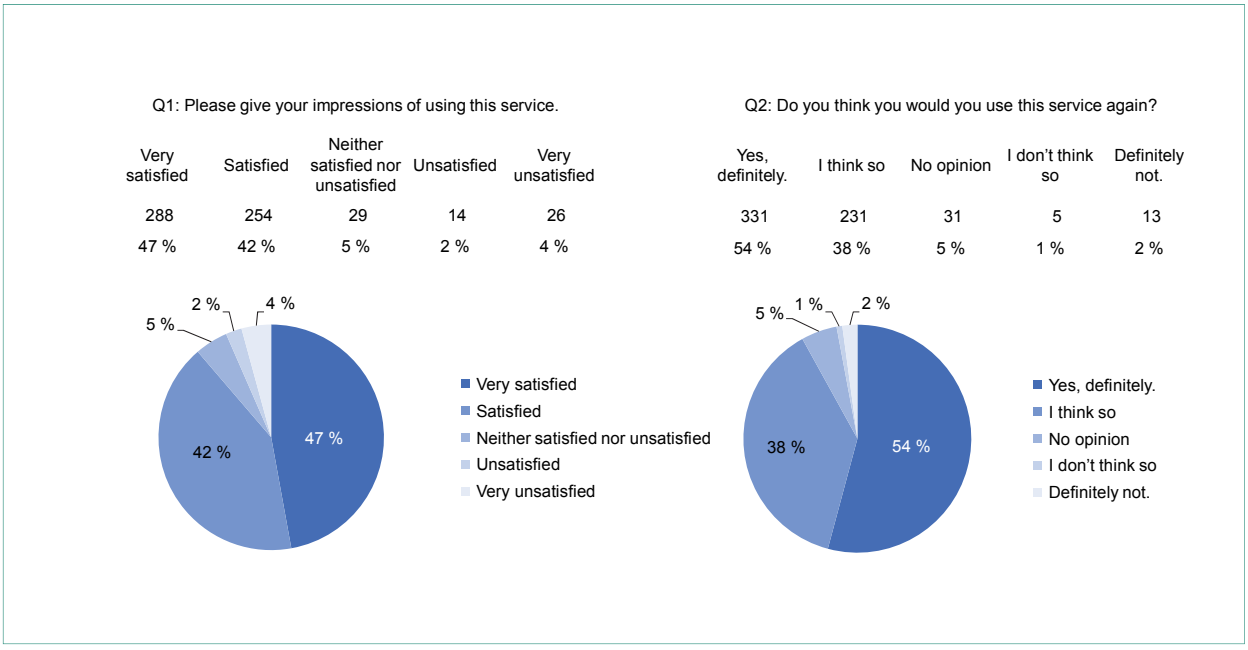

Figure 5 Survey of users after using Peasy (N = 611)

*11 Lean style: A method of implementing projects with uncertain goals, starting small and using feedback from customers and the market for guidance.

as follows:

- Operational accuracy: Vehicle detection accuracy, wireless communication accuracy
- Construction simplicity: Can be installed without roadway or electrical construction
- Durability: Withstands the weight of a vehicle, low power consumption, continuous operation in a natural, outdoor environment

NTT DOCOMO developed and implemented a dedicated sensor satisfying all of these requirements.

While building the first theoretical prototypes, we repeated a trial and error process, building knowledge within the project team and gradually increasing development efficiency, following the steps below.

(1) Repeated laboratory vehicle-detection tests and selection of the detection method and basic device structure.
(2) Install the prototype in an operating real, outdoor pay parking lot, measure noise due to changes in weather and the location of the vehicle, and analyze and estimate noise factors using multiple sets of test data.
(3) Based on the data obtained in (2), determine a model to improve noise resistance and to achieve accuracy similar to or better than vehicle detection devices currently used for pay parking.

In this process, we prioritized shortening the feedback cycle by performing development in-house, and at our busiest times, we were able to achieve multiple prototype improvements in a single week, steadily increasing accuracy.

Later, when moving into mass production, we made additional improvements to water and dust resistance, weight tolerance, communication power, and low power consumption. Regarding quality, during that time, we also installed the equipment in multiple parking lots to increase the number of trials, and as a result, we successfully reached mass production in approximately 1.5 years from the theoretical prototype.

4. Conclusion

This article has given an overview of the docomo Smart Parking System project and described some technical features of it.

NTT DOCOMO began commercially offering this system in October 2017. In addition to the technical aspects discussed in this article, we also adopted Lean style in development of sales channels. We continue to learn about the pay parking market, and are reflecting knowledge gained for further penetration of the market. In particular, we are developing the market focusing on metropolitan areas like Tokyo, Osaka, and the Kansai area, where there tends to be an excess of demand for pay parking.

This solution has received awards including the 2017 Good Design Awards, “Good Design Best 100,” and “Good Design Special Award [Design for the Future]” [2], and the “Best Selection” award from the 2017 JPB Awards, sponsored by the Japan Parking Business Association [3]. Our concept also has been very highly evaluated within and outside the pay parking industry.

In the future, we will continue to search for more advanced solutions for the opposing requirements

of low power consumption and high detection accuracy, strengthening our contribution in support of further advancements in the pay parking industry.

REFERENCES

[1] Japan Parking Business Association: “Survey and Analysis of Conditions in the Automobile Pay Parking Market, 2018 Ed.,” May 2019 (In Japanese).
[2] Japan Institute of Design Promotion: “Smart Parking [Smart Parking Peasy] | Complete list of the winners | Good Design Awards,” Nov. 2017.
https://www.g-mark.org/award/describe/45413?locale=en
[3] Japan Parking Business Association: “Japan Parking Business Association (JPB): JPB Award Past Recipient Works,” May 2017 (In Japanese).
https://www.gia-jpb.jp/award.html