

Easy Pairing between In-vehicle Equipment and Smartphone using Bluetooth® Low Energy

Hideaki TERADA

Akihiro KURITA

Takaaki NAKANISHI

Jun KAKENO

Masahiro MIYATA

Masahiro KAMIYA

Abstract

We, DENSO TEN conduct the quality improvement activity of Car Multimedia products (hereinafter “products”) to aim for the improvement of car user satisfaction every year, and use the inquiry information from our customers as the index. As the result of analysis for Bluetooth® function, we found that many users say “the connecting (pairing) operation between products and smartphone is complex and difficult to be understood.” Therefore, we have developed a system that solves the complex pairing operation toward the improvement of user satisfaction.

This time, we have developed two types of system which enable the pairing with “less operating procedure” and “easy operation” using Bluetooth® Low Energy technology, which enables transmitting and receiving data without pairing between devices with super-low power consumption, which is rapidly spreading in the market. We introduce the system using cloud and the stand-alone system in this paper.

1. Introduction

We, DENSO TEN conduct the quality improvement activity of Car Multimedia product (hereinafter “product”) to aim for the improvement of car user satisfaction every year, and use the inquiry information from our customers as the index.

We analyzed Bluetooth® function among product functions. (Fig. 1) As the result, we received the following opinions from many customers.

- ① The connecting (pairing) operation between product and smartphone is complex.
- ② The calling between product and smartphone is interrupted.
- ③ Telephone book is not displayed correctly.

Regarding the opinion ② and ③, the occurrence frequency is low, and narrowing down the cause including the behavior of many smartphones is necessary. Accordingly, we determined that opinion ② and ③ are excluded from the discussions in this paper because we forecast the measure for their opinions may be too various to be concluded. On other

hand, opinion ① is request for improvement toward product specification and we can take measures tightly targeted to the request. Then, we elaborate a technology that solves the complex pairing operation toward the improvement of user satisfaction.

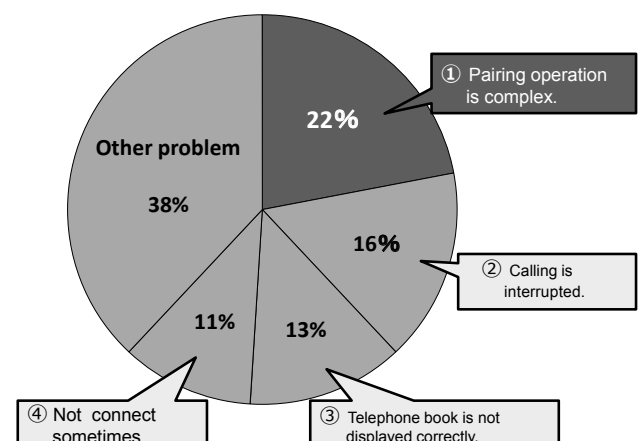


Fig. 1 Inquiry Ratio for Bluetooth® function of DENSO TEN Products

2. Estimated problem in “pairing operation”

We estimated two problems which users feel “complex operation” in pairing operation between product and smartphone. (Fig. 2)

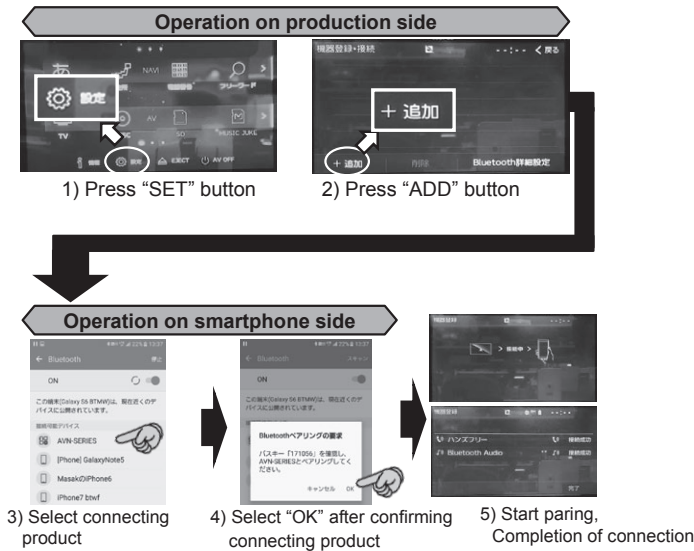


Fig. 2 Pairing Operation between Conventional DENSO TEN Product and Smartphone

- Because of difficulty to find a starting button for pairing on the side of product, several button operations are needed.
- Operation on the side of smartphone as well as product is needed.

From the above, considering the operation on the side of not only product but also smartphone, we have developed the system which can register the device in order to solve the complex pairing operations with “less operation procedure and easy operation” by using Bluetooth® Low Energy (hereinafter “Bluetooth®LE”) and Cloud.

3. Bluetooth® Low Energy (Bluetooth®LE) technology

Bluetooth®LE is short-range wireless communication standard using 2.4 GHz wireless. Main features of Bluetooth®LE are super-low power consumption with which operation from 5 to 10 years with a button battery, and capability of transmitting and receiving data without pairing between devices. This standard has rapidly spread in the market in accordance with good

sales of application software adapted for Bluetooth®LE due to the release of the framework supported as standard for smartphone to a developer. In the market, a service that transmits discount coupons to smartphone when customers enter a shop and the like are popular. (Fig. 3)

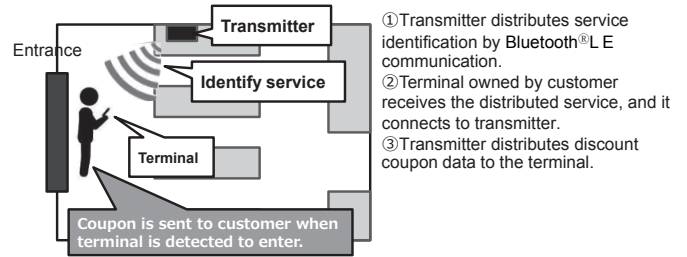


Fig. 3 Service Example using Bluetooth®LE

We elaborate the scheme of the Bluetooth®LE device communication including broadcast communication which communicates between Bluetooth®LE devices, and transmitting and receiving Bluetooth®LE data. (Fig. 4)

- Defined the transmitting side of Advertisement Packet as Peripheral and receiving side as Central.
- When Central requests additional information such as device name, Central transmits “SCAN_REQ”, then Peripheral transmits information with “SCAN_RSP”. (① in Fig. 4)
- When Central transmits “CONNECT_REQ”, Bluetooth®LE connection has completed. (② in Fig. 4)
- After establishment of Bluetooth®LE connection, transmitting and receiving of data is possible with Generic Attribute Profile (hereinafter “GATT”) communication service. (③ in Fig. 4)

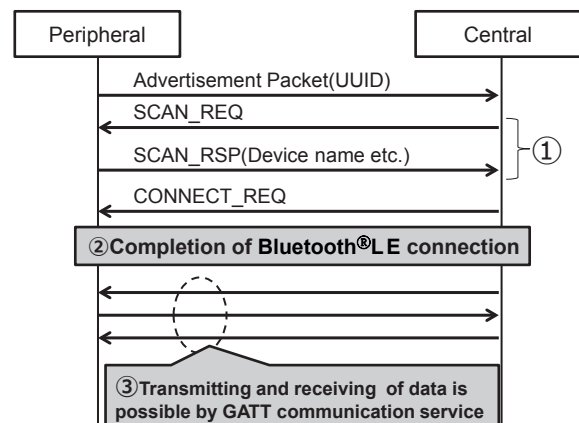


Fig. 4 Sequence of the Sending and Receiving of Bluetooth®LE Data

Supplements of sequence are shown below.

- UUID is an abbreviation for Universally Unique Identifier. It has 128-bit wide identifier, and indicates the service type offered by Bluetooth®LE. When applied service is not included in the service defined by Bluetooth® SIG (example: Battery Service), an original UUID is created and used.
- Advertisement Packet includes UUID (128-bit) which identifies the service.
- Transmitting interval of Advertisement Packet is from 20ms to 10.24s and can be set at the value of integral multiple of 0.625ms.
- Encrypted communication is not supported.

4. Easy pairing using Bluetooth®L E

Conventionally, “User” on the smartphone side confirms the connecting product to prevent the wrong pairing of product and smartphone. This time, we have developed the scheme to prevent the wrong pairing without the confirmation by “User”. In accordance with this scheme, we developed two types of security system which prevents “specific information of product and smartphone” from being intercepted by a malicious third party.

4.1 Easy pairing using Cloud

We elaborate the development contents of easy pairing using Cloud.

4.1.1 System configuration

Our developed system consists of “smartphone application” working as a Peripheral, “product software” working as a Central and “Cloud application” which controls smartphone and product. (Fig. 5)

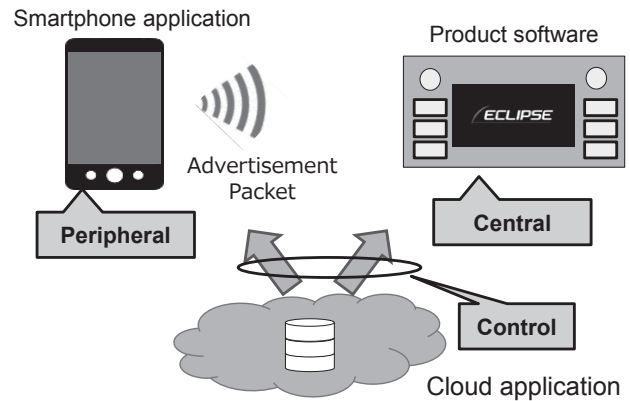


Fig. 5 System Configuration

4.1.2 Development content

Sequence of easy pairing using Cloud which is originally formulated by DENSO TEN is shown in Fig. 6.

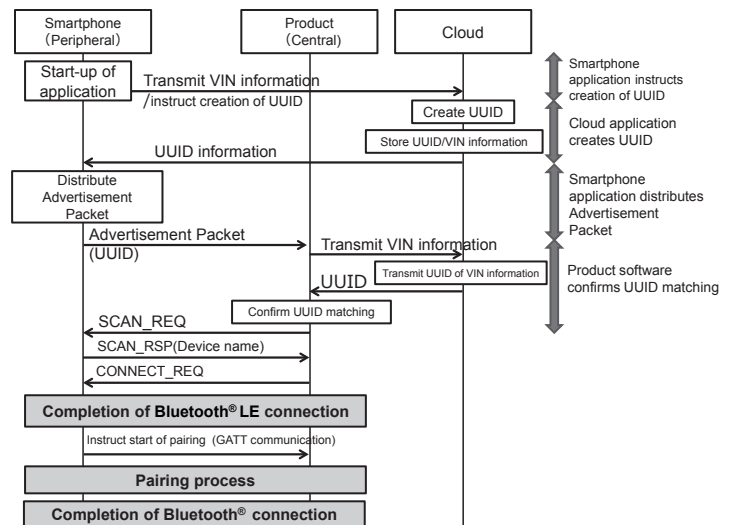


Fig. 6 Easy Pairing Sequence Using Cloud

We use Vehicle Identification Number (VIN) to associate the product to be paired with smartphone, and Cloud application manages the VIN to prevent the interception of VIN information. The following show the pairing procedure between the product and smartphone.

- (1) On start-up, the smartphone application transmits VIN information to Cloud, and requests the Cloud application to create UUID.
- (2) The Cloud application creates UUID from the random number based on VIN information, and

VIN and UUID are stored in the Cloud application. (Fig. 7)

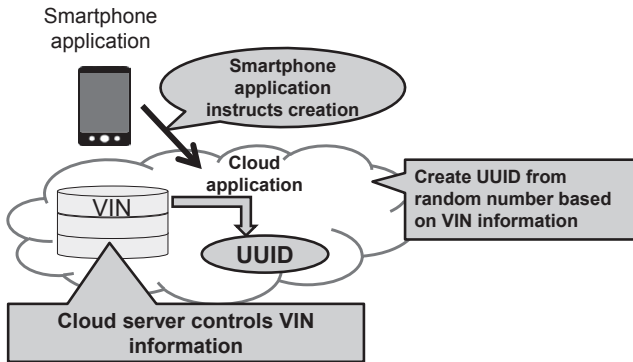


Fig. 7 Scheme of UUID Creation

(3) The smartphone application distributes Advertisement Packet after obtaining UUID from Cloud application. (Fig. 8)

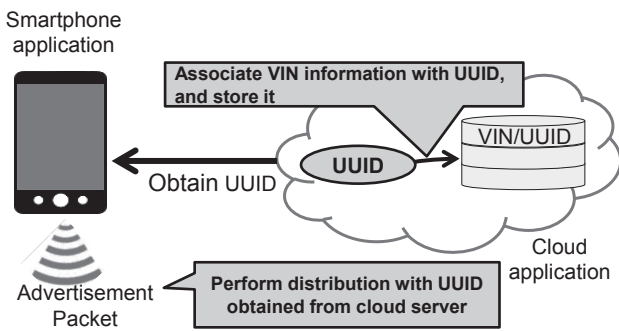


Fig. 8 Scheme of Advertisement Packet Distribution

In addition, the smartphone application randomly creates UUID by each start-up. Then even if the value of UUID was known to third party by interception of communication, there is no matter for it to be abused because it will be different on the next start-up.

(4) When receiving Advertisement Packet, the product software connects the Cloud application. Then, the product software compares UUID of own VIN information and UUID of the Cloud application. When UUID is the same, the product software starts pairing operation with the smartphone.

4.1.3 Evaluation

In this system, pairing operation to complete Bluetooth® connection between product and smartphone by user is easy, just start-up of the

smartphone application, and the number of operations was reduced by three times compared to conventional one. (Table 1)

Table 1 Comparison of Number of Pairing Operation

Number of times	Conventional operation	New operation
1	Press "SET" button of product	Start-up of smartphone application
2	Press "ADD" button of product	—
3	Select connecting product by smartphone	—
4	Select "OK" after confirming connecting product by smartphone	—

4.2 Easy pairing of stand-alone system

The previously shown easy pairing system using Cloud needs network environment. On the other hand, in case of being impossible to establish the network environment, we have developed the other system which enables easy pairing without network.

4.2.1 System configuration

Our developed system consists of "smartphone application" working as a Peripheral and "product software" working as a Central.

4.2.2 Development contents

We associate product with smartphone for pairing using BD address by which Bluetooth® devices can be identified. However, Bluetooth®LE communication at non-pairing status has high risk of information interception compared to encrypted communication. (Fig. 9)



Fig. 9 High Risk of Information Interception in Bluetooth®LE Communication

Then, we studied out the method to make the camera of smartphone directly read QR code in which BD address of product is embedded so as to transmit the BD address without information interception by

third party. (Fig. 10)

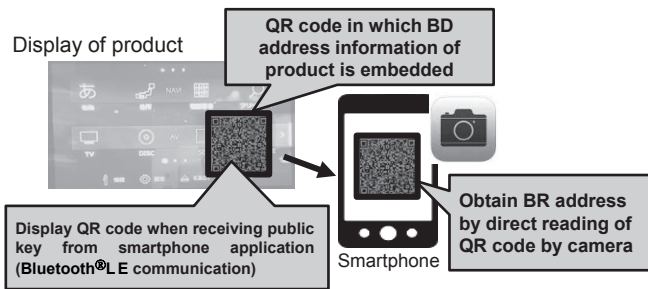


Fig. 10 Obtaining BD Address due to reading of QR Code

The sequence of easy pairing in stand-alone environment which we originally designed is shown in the following. (Fig. 11)

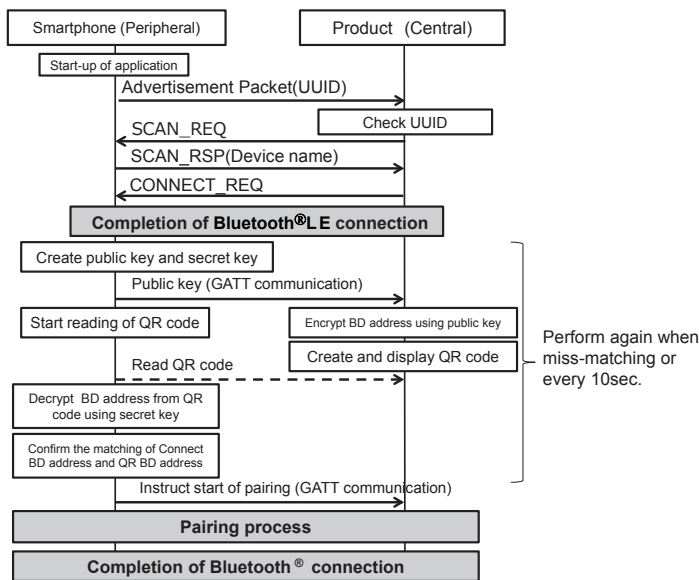


Fig. 11 Easy Pairing Sequence under Stand-alone Environment

The procedure of pairing between product and smartphone is shown in the following.

- (1) The smartphone application distributes Advertisement Packet to the product software on start-up.
- (2) The product software connects to smartphone with Bluetooth®LE communication after receiving Advertisement Packet.
- (3) The smartphone application transmits a public key with GATT communication to the product software, and starts the reading of QR code.
- (4) The product software encrypts BD address by using public key, and creates and indicates QR code. (Re-creation of QR code every 10 seconds for prevention of reuse)

- (5) The smartphone application decrypts the QR code read out (Fig. 12), and confirms the matching of BD address. If it is the same BD address, perform pairing with the smartphone.

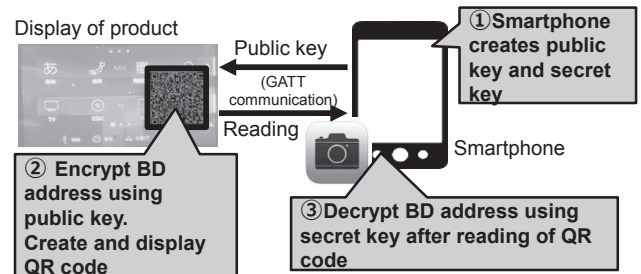


Fig. 12 Scheme of Encryption and Decryption of BD Address

4.2.3 Evaluation

In this system, pairing operation to complete Bluetooth® connection between product and smartphone by user is easy, just start-up of the smartphone application, and the reading of QR code, and the number of operation was reduced by two times compared to conventional one. (Table 2)

Table 2 Comparison of Number of Pairing Operation

Number of times	Conventional operation	New operation
1	Press "SET" button of product	Start-up of smartphone application
2	Press "ADD" of product	Read QR code by smartphone
3	Select connecting product by smartphone	—
4	Select "OK" after confirming connecting product by smartphone	—

Pairing method which adapts to the user convenience and the service offering environment can be chosen from the point of view of advantage and disadvantage of newly developed two types of system. (Table 3)

Table 3 Comparison of Advantage with Disadvantage

	System using Cloud	Stand-alone system
Advantage	<ul style="list-style-type: none"> • User operation is complete in one time (start-up of smartphone application) • Reuse of UUID is not possible in case of interception of UUID 	<ul style="list-style-type: none"> • Network environment is unnecessary • Realize system only by product and smartphone • BD address is very difficult to be intercepted, and reuse of it is not possible in case of interception of UUID
Disadvantage	<ul style="list-style-type: none"> • Need network environment • Need pre-registration of VIN information 	<ul style="list-style-type: none"> • User operation is complete in two times

5. Conclusion

We have developed the system using Bluetooth®LE technology to respond to the improvement request from many users, which is “complex connecting (pairing) operation between product and smartphone.” As for the stand-alone system, we continuously develop the method to embed BD address information other than QR code, and we will work on the proposal to automotive manufacturers and application to our products.

- Bluetooth® is a registered trademark of Bluetooth SIG, Inc.
- QR code is a registered trademark of DENSO WAVE Incorporated.
- ECLIPSE is a registered trademark of DENSO TEN Limited.

Profiles of Writers



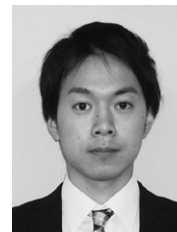
Hideaki
TERADA

SS Engineering
Group
Middleware
Engineering Dept



Akihiro
KURITA

SS Engineering
Group
Middleware
Engineering Dept



Takaaki
NAKANISHI

SS Engineering
Group
Middleware
Engineering Dept



Jun
KAKENO

DENSO TEN
AMERICA Limited



Masahiro
MIYATA

Denso Ten
Technology Limited



Masahiro
KAMIYA

SS Engineering
Group
Middleware
Engineering Dept