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ORIGINAL CONTRIBUTION

An Implementation of Smartphone Based VTS

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***Abstract*— This study proposes the development of an IoT application with computation, analysis, display, and notification mechanisms based on GPS, BLE, mobile communications, and SMS technology on iOS and Android smartphone operating systems. Advancements in smartphones and mobile communication technology have ushered in a generational trend of connectivity for all devices; using smartphones as a platform to manage vehicles online has become the trend. Smartphones using Bluetooth to bind vehicles and then send out GPS tracking information, including real-time data computation, analysis, display, and notifications, have turned IoT applications into reality. The research methods and procedure of this study are categorized into A) system structure, B) main application structure, C) QR code Bluetooth pairing, D) data processing, transfer, and retransmission mechanisms, and E) emergency incident and notification mechanisms. This study integrates QR code pairing, mobile notifications, Firebase Cloud Messaging (FCM), automatic retransmission mechanism for GPS tracking information, exception management, and emergency notification to achieve a lightweight electronic tracking and management App for implementing a Vehicle Tracking System on the smartphone. This study can be applied to all Bluetooth connected IoT applications; the principle is using smartphones and Bluetooth connectivity to connect items that cannot connect to networks.**

***Index Terms*— VTS, QR Code, FCM, Exception Management, Bluetooth, Automatic Retransmission Mechanism**

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I. INTRODUCTION

With the trend of the Internet of Things (IoT) [1], people, events, and items can be tracked and managed in real-time. This is already a goal for major companies and is common in smartphones which can be seen in daily life of urban areas where smartphones feature internet connectivity. According to international data analytic companies, the utilization rate of Android systems on smartphones was 74.69% while iOS was 22.34%, with other systems accounting for 1% [2, 3, 4]. Many products can be tracked and managed through smartphones; this primarily utilizes the mobile phone's mobile communications [5], GPS system [6], Bluetooth module, and other mechanisms implemented into products (e.x.: cars, EVs, electric scooters) and connected to networks via smartphone functionality [7].

For managers in fleets of vehicles or general home users, the problem of unable to track vehicle application data has become a problem faced in the industry; therefore, developing a VTS (vehicle tracking system) [8] with high readability, better functionality, and lower price is an urgent matter.

Comparisons and analysis of current tracking products on the market are as follow in Table I. The following problems were discovered after comparison:

1. Poor readability and functionality. Current VTS on the market often only contain tracking functions but cannot display speed, distance, fault lights, remaining battery (oil), and other basic information. They cannot show the status or further information for fault lights.
2. Poor convenience. VTS on the market must be setup by professionals and cannot be quickly removed and reused.
3. Emergency notice. VTS on the market only provide emergency warnings for electronic fence and not for vehicle faults.
4. Higher price. Requires additional subscription with telecom companies for network services.

TABLE I
SOME INDEX WEIGHTS

	Proposed System	Yun Fon G-8	BoBe	eNonda ZUS
Front display	Y	N	N	N
Front data analysis	Y	N	N	N
Vehicle power link	N	Y	N	Y
GPS	Y	Y	Y	Y
Local storage	Y	N	N	N
Remote data transfer	Y	Y	Y	Y
Vehicle fault alarm	Y	N	N	N
Vehicle search function	Y	Y	Y	Y
SOS beacon	Y	N	N	N
Bluetooth	Y	N	N	N
Price	Low, uses smartphone sim card	High, Requires additional sim card	High, monthly fee to telecom company	High priced unit

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This study uses Bluetooth pairing with vehicles to collect integrated data displayed in the front for upload to a backend server; in the event of an emergency, SMS (Short Message Service) messaging functionality is used to notify friends, family, or administrators along with a push notification via Firebase Cloud Messaging (FCM) to friends, family, or administrators. A local push notification on the smartphone will alert users of their vehicle status. The goal of this study is using smartphones to save on applying for additional network services from telecom companies for sending tracking information.

II. BACKGROUND KNOWLEDGE AND RELATED WORK

In 2015, Ozen et al. [9] proposed an Energy aware real-time location tracking device based on GPS sensor design using Android smartphones. The mixed location technology utilizes other inertial sensors and data transmission mechanisms to increase energy efficiency.

In 2014, Sujatha et al. [10] proposed a bus tracking system for smartphones. Smartphones with internet connectivity can automatically transmit a bus's latitude and longitude coordinates to servers and provide bus location data to any users that require this information without having to call or communicate via other methods and disturb riders on the bus.

In 2018, Qian et al. [11] designed an anti-theft alarm and tracking system for cars based on Android systems. The internal sensors of an Android phone transmit suspicious activity messages through the internet to the owner's smartphone.

This study transfers GPS and vehicle data to a backend for computing to identify suspicious incidents and utilize smartphone notification, FCM, or SMS to notify the user depending on severity to conserve power.

III. RESEARCH METHOD AND PROCEDURE

The research methods and procedure of this study are categorized into A) system structure, B) main application structure, C) QR code [12] Bluetooth pairing, D) data processing, transfer, and retransmission mechanisms and E) emergency incident and notification mechanisms, as detailed below:

A. System Structure

This study proposes a VTS based on smartphones using Bluetooth to receive vehicle data for display on smartphones. The vehicle data is combined with smartphone GPS data for integrated vehicle data. Once the data is ready, mobile communication is used to connect to the internet using HTTPS to upload data to cloud-based servers for display in the system as in Fig. 1.

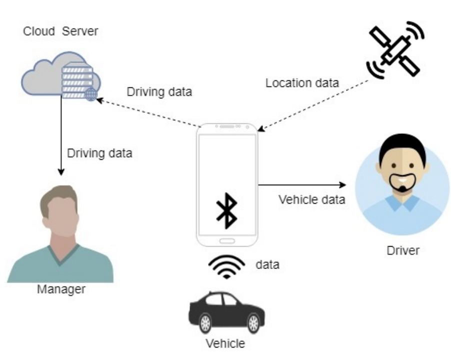

Fig. 1. System structure diagram

B. Main Application Structure

The main application structure of this system is shown as in Fig. 2, as explained below:

1. Once the application in smartphone is activated, scan QR code in the device, i.e. the vehicle, to pair with Bluetooth to determine if a successful connection has been established with the device.
2. If the Bluetooth connection fails, verify whether the device Bluetooth is on; if yes, try again. 3. Once a connection is established, use the subscribed vehicle characteristics to receive the vehicle data through BLE.
4. Integrate the received vehicle data and GPS data into vehicle data, and then upload vehicle data through HTTPS to the cloud-based server at 15-second intervals.
5. Interrupt the Bluetooth connection to stop data uploading and thus release the subscribed vehicle characteristics.

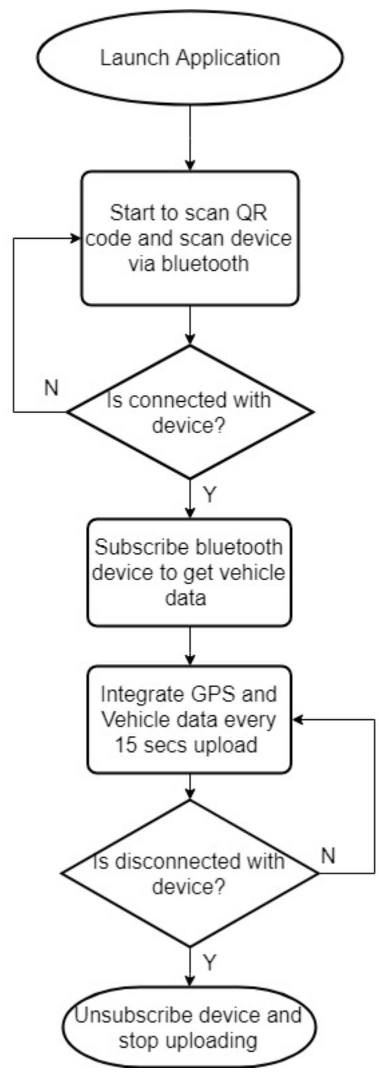

Fig. 2. Application process

C. QR Code Bluetooth Pairing

The application structure in this study utilizes communication between the smartphone and vehicle via Bluetooth; smartphones must connect via Bluetooth to receive data. In order to shorten pairing time for user convenience, vehicles are labeled with QR codes (Quick Response Code) that provide MAC addresses (Media Access Control Address) so that smartphones can scan using camera functions as identifying codes of vehicles. The Bluetooth broadcast packet scanned by the smartphone retrieves as MAC address for pairing with the scanned QR code to achieve swift pairing.

Android bluetooth pairing: In Android systems, the system will save the MAC address scanned from the Bluetooth broadcast packet and VTS can read this to determine the vehicle's identifier code with a few simple steps. Next, when VTS scans the QR code and retrieves a corresponding MAC address, it will attempt to pair the MAC address given from the QR code and the actual device's Bluetooth for pairing. Once an identical MAC address is found the smartphone will automatically connect and pair with the device. If pairing fails, inspect if Bluetooth is activated in the vehicle as shown in Fig. 3:

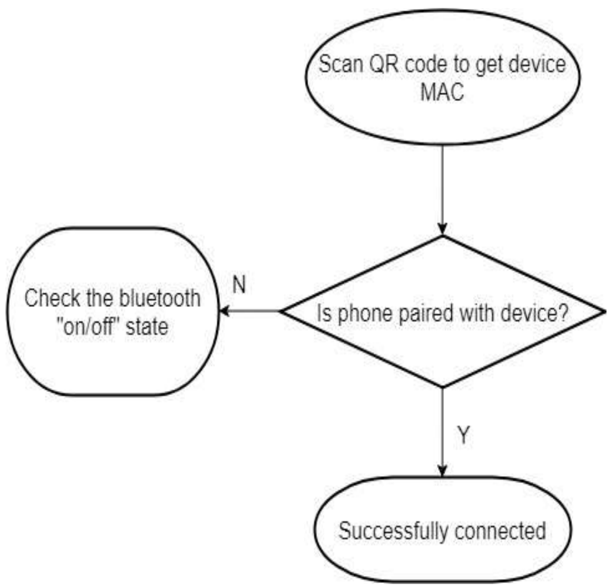

Fig. 3. Bluetooth pairing process

iOS bluetooth pairing: For iOS smartphones, this study scans QR code for a MAC address to conduct pairing. When a Bluetooth broadcast packet is received from a nearby device, EIR (Extended Inquiry Response) data within the packets are read to retrieve the device MAC address. Subsequent steps are identical to Android systems by verifying results and successfully pairing if a QR code scanning finds a corresponding MAC address. If pairing fails, inspect if Bluetooth is activated in the vehicle.

D. Data Processing, Transfer, and Retransmission Mechanisms

Bluetooth data processing: BLE (Bluetooth Low Energy) controls device roles in the GAP (Generic Access Profile) protocol. The vehicle in this study's scenario (Fig. 4) is a peripheral device and the smartphone is the central device. Peripheral devices must send broadcast packets so the central device can receive them, at which point the central device will initiate pairing.

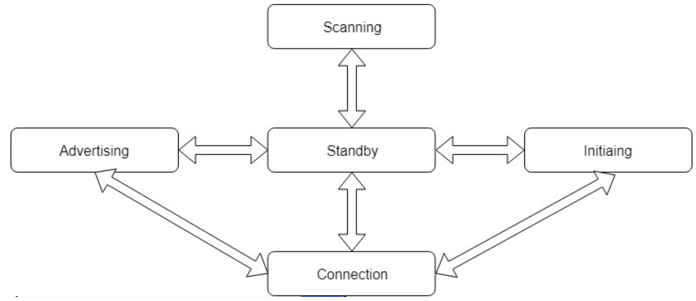

Fig. 4. Bluetooth status chart

BLE transmission uses the GATT (Generic Attribute Profile) protocol. Internal data structure is one or multiple services, each including one or multiple characteristics (Fig. 5).

In this study, the BLE module of a vehicle must perform a service with 2 characteristics; one is the notify property responsible for sending data to the smartphone while the other property is write, responsible for receiving messages sent from the smartphone.

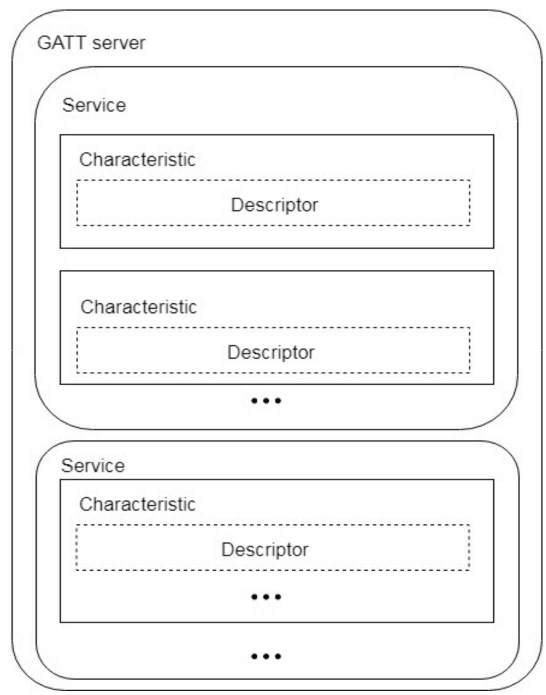

Fig. 5. Bluetooth data structure

Data upload and retransmission: Process as follows (Fig. 6):

1. When VTS receives Bluetooth data, vehicle and GPS data must be integrated in the transfer format then uploaded.
2. When the upload fails, this data is saved in local storage on the smartphone while creating a file that will be retransmitted to achieve this function.
3. Once upload is successful, the system will check for files that need to be retransmitted; if found, the file data will be read and then resent. Once the transfer is complete, this file will be deleted.
4. If resending fails, this data will be re-written into a file to ensure data integrity.

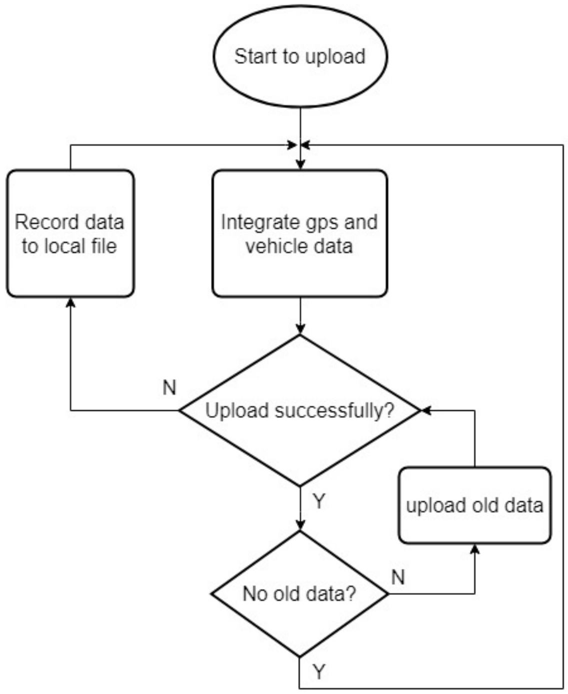

Fig. 6. Data upload and retransmission process

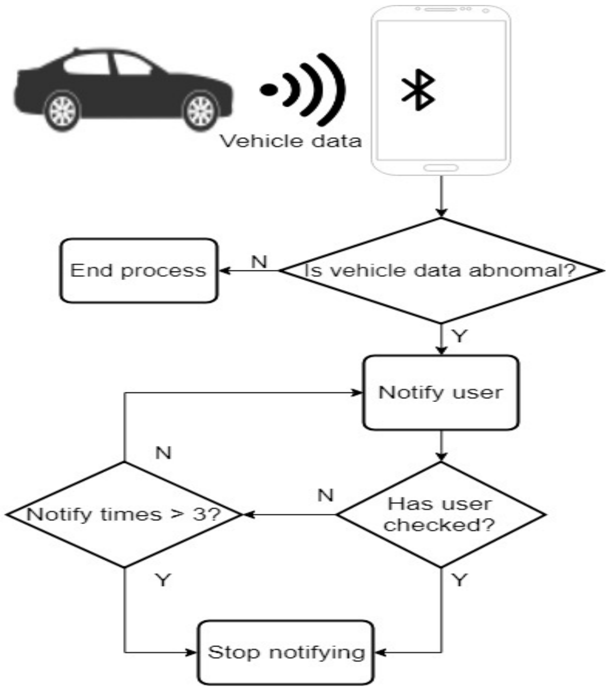

Fig. 7. Local notification

Emergency event and notification mechanism: The emergency events in this study are based on severity level in SNMP (Simple Network Management Protocol) with 8 levels of severity (Table **??**), 0∼3 are marked red and require immediate attention, 4 is yellow and requires notification, 5 is gray and does not impact use but requires awareness, 6 7 are green and normal. The vehicle will transfer these event data to the smartphone. This study sets requirements that any severity level below 3 require FCM and local smartphone push notifications to remind the user and emergency contacts. When severity reaches 0, a SMS message is required to deliver to the phone of the emergency contact.

TABLE II
SEVERITY LEVEL

0	Emergency
1	Alert
2	Critical
3	Error
4	Warning
5	Notice
6	Informational
7	Debug

Local notification: Process as follows (Fig. 7)
1. When vehicle data is received, the system will determine whether there is an abnormal event within the data.
• If one exists, the user will be notified.
• If none exists, the process is complete.
2. Next, the system will determine if there is a check from user to confirm the abnormal event.
• If the notifying is checked, it will cease.
• If not, the notification count is determined.
3. Determine whether the count has reached 3.

FCM notification: Process as follows (Fig. 8)
1. Once the VTS uploads driving data to the cloud-based server, it will determine whether there is an abnormal event in driving data.
2. If an abnormal event exists in driving data, FCM will issue a notification to the user's smartphone and emergency contact, or another party.

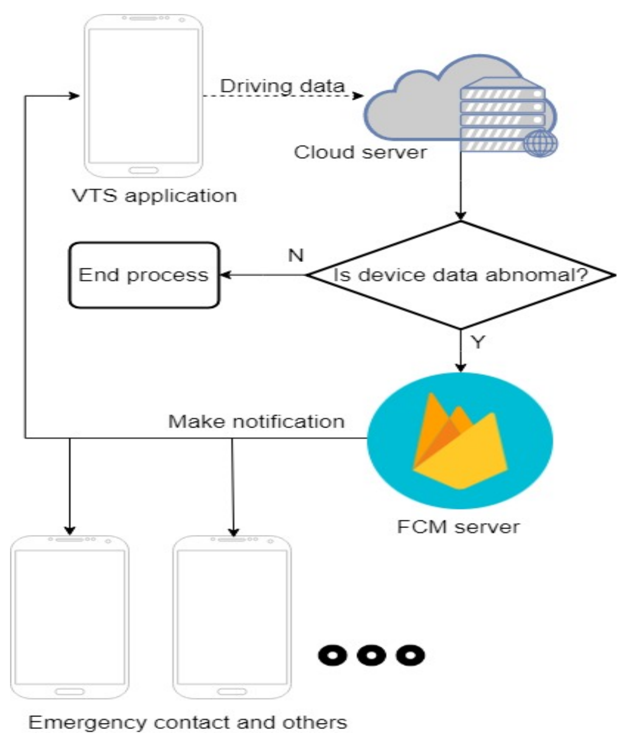

Fig. 8. FCM notification

IV. EXPERIMENT METHOD AND RESULTS

In order to test Bluetooth, this study created a vehicle device simulator (Fig. 9) for the services, characteristics, and the Bluetooth broadcast packets required for iOS pairing for the vehicle's Bluetooth module. Through vehicle data packet formats as shown in Table III , values are provided to verify the read/write functionality of Bluetooth communications.

TABLE III
VEHICLE DATA PACKET FORMAT

Type	ID	Length	Data 1		
3	1	3	e7	03	00

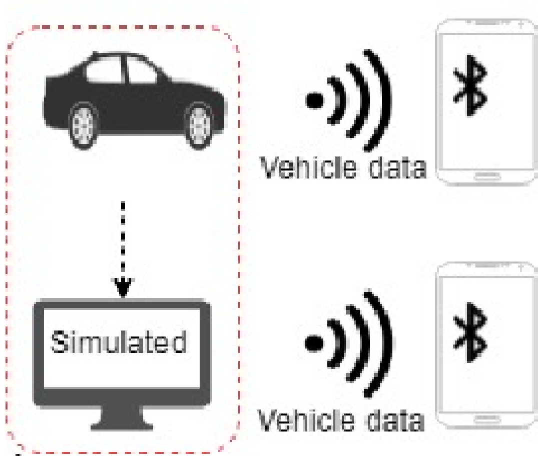

Fig. 9. Device simulation chart

A. Bluetooth Test Results

When the smartphone is not connected to the simulation device as shown in Fig. 10, the screen status on iOS and Android phones are gray; when smartphones are connected, the smartphone's read/write simulation device sends packets and displays data on the screen. As shown in Fig. 11, the upper half screen displays speed, total distance, and timing data; the lower half screen displays the bar of status icons, lighted up depending on severity level, and the Bluetooth connection button to start use.

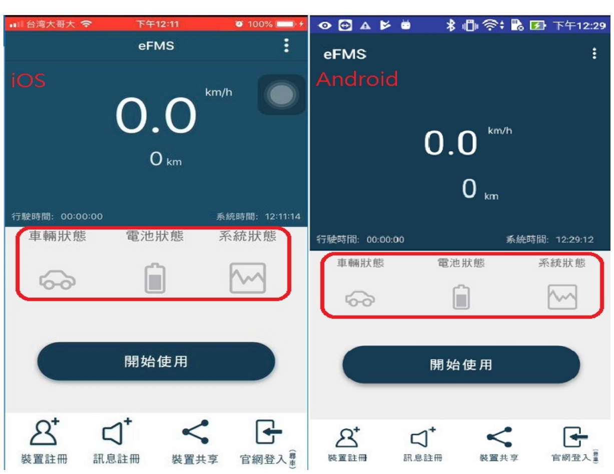

Fig. 10. Unconnected Status, iOS (left) and Android (right)

Fig. 11. Successfully Connected Status, iOS (left) and Android (right)

As shown in Fig. 12, tapping on any item in the status bar will display detailed data and vehicle status.

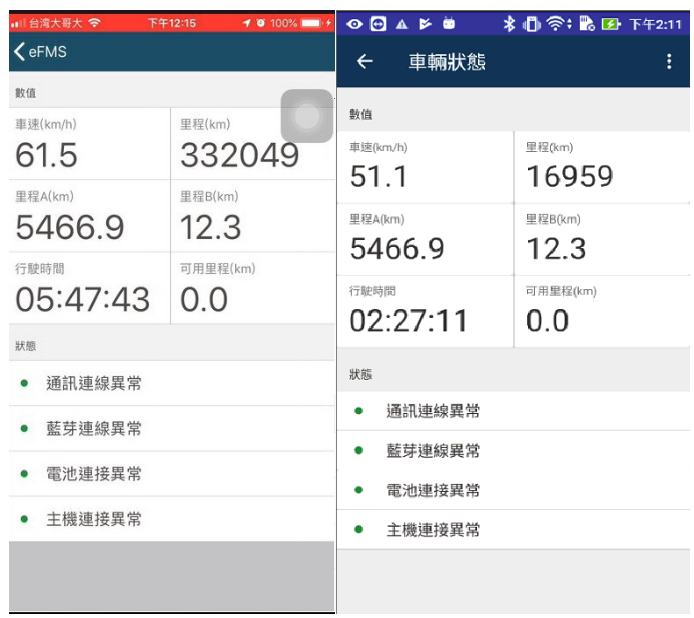

Fig. 12. Views of detailed status of a vehicle, iOS (left) and Android (right)

B. Data Upload, Retransmission

The monitoring screen (Fig. 13) of the back end on the cloud-based server shows that data is uploaded at 15-second intervals; the server log verifies successful uploads.

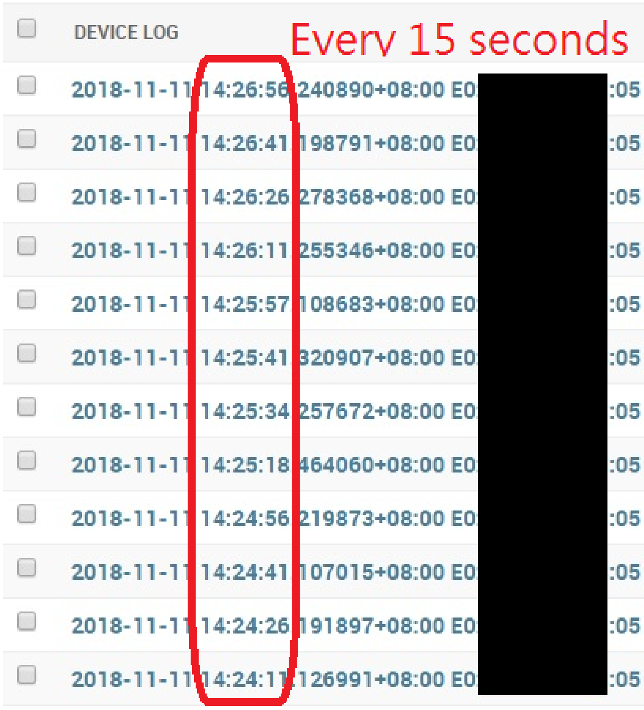

Fig. 13. Server log

Next, if driving data uploads fail, they are saved into a file in the local storage of the phone. Fig. 14 shows the backup file that will be retransmitted on the Android system. Once this file exists, successful completion of current packet uploads will result in the phone automatically transferring all other files waited for retransmission to the cloud-based server.

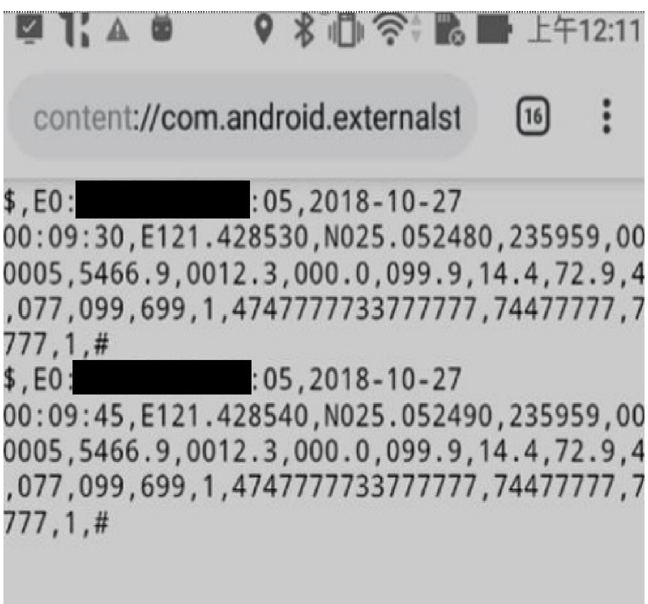

Fig. 14. Android retransmissioning Files

C. Emergency Event Notification

Local notification: When the severity level of vehicle data is between 0 3, the phone will notify the user with a pop-up window for user verification (Fig. 15).

Fig. 15. Local Notification, iOS (left) and Android (right)

FCM notification: When the cloud-based server receives driving data with severity levels between 0∼3, FCM will also notify both the emergency contact and the user requiring for confirmation (Fig. 16).

Fig. 16. FCM notification, iOS (left) and Android (right)

SMS notification: When vehicle data contains events with severity level 0, smartphones will automatically send a SMS message to the emergency contact; however, the iOS one would pop up a SMS permission window and not send the SMS message until users submit the sending permission (Fig. 17).

Fig. 17. iOS message sending screen

V. CONCLUSION AND IMPLICATIONS

Through testing, the smartphone based VTS (vehicle tracking system) proposed in this study is equipped with automatic QR code Bluetooth pairing, vehicle data access, GPS location data access, status identification, data upload, front display, and provides data retransmission to maintain data integrity along with an abnormal event notification with local, FCM, and SMS notification mechanisms so that administrators, family, or friends can immediately track emergency events. This study can be applied to all Bluetooth connected IoT applications; the principle is using smartphones and Bluetooth connectivity to connect items that cannot connect to networks. This mechanism can greatly reduce communication costs while the programmability of smartphones can allow VTS to present more flexible and powerful functions.

Declaration of Competing Interest

The authors declare that there is no conflict of interest.

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