Proposal of a bus location system based on participatory sensing with BLE devices and smartphones

Katsuhiro Naito
Department of Information Science, Aichi Institute of Technology,
1247 Yachigusa, Yakusa, Toyota, Aichi 470-0392, Japan

Katsuyuki Tanaka
Graduate School of BusinessAdministration and Computer Science,
Aichi Institute of Technology,
1-38-1 Higashiyamadori, Chikusa, Nagoya, Aichi 464-0807, Japan

ABSTRACT

Bus location systems are focused to enhance service quality of public transportation. The traditional issues in the bus location system are difficulties to install expensive special devices and expensive operational expenses for network systems. Recently, some researchers utilize smartphones to measure the environment and to collect information. Additionally, participatory sensing methods, where many common people collaborate to collect data with their own smartphone, have been focused for bus location systems. On the contrary, the developed application for the participatory sensing method has an issue of energy management because the application works continuously in a background process, and consumes much energy. This paper proposes a collaborative mechanism with Bluetooth Low Energy (BLE) beacon devices and smartphones to realize a bus location system. The proposed mechanism employs BLE devices as a beacon device that triggers our special application for smartphones. Therefore, the special application can be automatically launched when a beacon message arrives on the smartphone, and it does not work continuously in a background process. As a result, the proposed system can collect bus location by smartphones in participatory sensing manner without excess energy consumption. In the experiment, we have set up for the bus route of our university transportation service into the smartphone application. Experimental results demonstrated that the developed application can measure its position by a location service and upload the measurement location automatically.

Keywords: Bus location system, BLE, Participatory sensing

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1. Introduction

Bus location systems are becoming popular to enhance the effective operation and service quality of public transportation because a deterioration of service quality causes a decrease in number of passengers [1], [2]. Recent systems try to estimate arrival time of a bus according to realtime location of each bus[3]. Therefore, some researchers have proposed estimation algorithms of arrival time in public transportation systems[4], [5], [6].

Traditional bus location systems employ cellular networks to collect a location of each bus due to easy implementation and installation of the system. Typical systems consist of bus location units with a cellular module on a bus, a data collection server, and an application for checking a bus location. Since the bus location units are usually special devices for the bus location service, the unit cost is sometimes a main reason of difficulty to install the units on all buses. Additionally, the use of a cellular network leads to the payment to operate the bus location service. As a result, many transit agencies lacking the funding may not start and maintain a bus location service.

Multi-hop networks are a candidate method to reduce operational expense of a bus location system because some technologies for sensor networks can be applied[7], [8]. All wireless devices in a multi-hop network communicate with each other to construct a communication route by a routing protocol. Therefore, typical routing protocols employ complex mechanisms to maintain a route in a network [9]. Additionally, install cost of many wireless devices covering a bus transportation service area may be an issue in some transit agencies with scarce funding.

Employing mobile phone sensing is a new trend to realize a data collection service in public transportation vehicles because consumer devices have a big benefit to reduce development and installation cost [10]. Additionally, some researchers try to use participatory sensing method, where many common people collaborate to collect data with their own smartphone [11], [12]. As a result, some bus location services based on a participatory sensing method have been proposed [13], [14].

On the contrary, the developed application for the participatory sensing method has an issue of energy management because the application works continuously in a background process to collect a bus location. Hence, typical common people may not accept the installation of the application because the operation period of a smartphone will be short due to the continuous operation of the application. As a result, more practical mechanisms are required to realize a bus location service based on a participatory sensing method.

This paper proposes a collaborative mechanism with beacon devices and smartphones to realize a bus location system. The proposed system consists of beacon devices on a bus, a smartphone application for common people, a cloud service for data collection and distribution, and an application to check the bus location. The proposed mechanism employs Bluetooth Low Energy (BLE) devices as a beacon device that triggers our special application for smartphones. Therefore, the special application can be automatically launched when a beacon message arrives on the smartphone, and it does not work continuously in a background process. The contributions of this paper are 1) proposal for new collaborative mechanisms based on BLE, 2) proposal of practical participatory sensing method, and 3) development of a new type of bus location system. In the experiment, we have set up for the bus route of our university transportation service into the smartphone application. Experimental results demonstrated that the developed application can measure its position by a location service and upload the measurement location automatically.

2. iBeacon

We employ BLE as a communication device because power consumption of BLE is quite low and almost all smartphones implement a BLE module[?]. Since the proposed method requires an automatic operation mechanism of smartphone application, we use iBeacon on BLE communication to activate the scanning application by the beacon device.

BLE has some points that realize low consumption electricity. Conventional Bluetooth scans all 79 channels to find communication partner at the beginning of communication. On the contrary, BLE reduced scan channels to only 3 . Therefore, scan time is largely reduced. Additionally, BLE has reduced the number of communication channels that are available in between 2402 - 2480MHz from 79ch (1MHz interval) to 40ch (2MHz interval). Therefore, the peak power consumption can be reduced by the simplification of the high frequency circuit block.

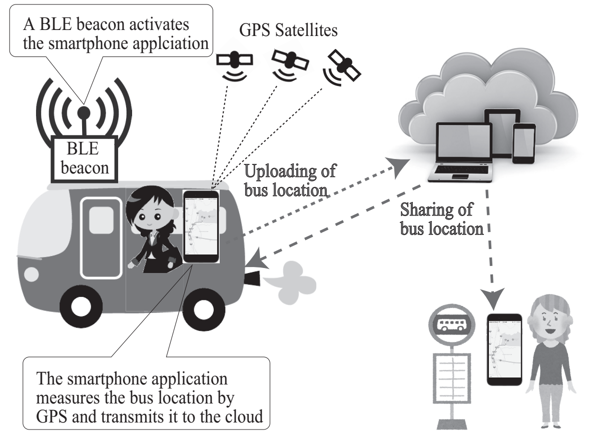

Fig. 1. Cooperative bus location system with beacon devices and smartphones.

iBeacon is a beacon protocol developed by Apple. The detail specification of iBeacon is defined on BLE. Therefore, all BLE device can support the iBeacon function. The iBeacon message includes Universally Unique Identifier (UUID), major and minor values. UUID is used to recognize a specific service. The Major and Minar values are used to differentiate each beacon.

3. Bus location system based on participatory sensing

3.1. System model

Fig. 1 shows the overview of the proposed bus location system. The proposed system consists of a beacon device that is mounted on a bus, a smartphone application for common people, a cloud service for data collection and distribution, and an application to check the bus location. The proposed method focuses on beacon technologies for BLE communication [16], [17]. The benefit of the beacon technologies for smartphone OSs is that smartphone OSs can monitor all beacon messages instead of each smartphone application. As a result, the proposed system can solve energy issues in a participatory sensing. The following describes each module.

- Beacon device

  A beacon device includes a microcomputer and a BLE module. Recently, some vendors release a special System on Chip (SoC) for BLE. The price of SoC is typically cheap comparing to a special microcomputer device.
  The main functions of the beacon devices are to trigger an application installed on neighboring smartphones using the iBeacon function. The proposed system uses a location service of smartphone OS. Therefore, the application transfers received information from a beacon device and an obtained location to a cloud service.

In our prototype implementation, we use iBeacon as a beacon message because iOS system does not permit a process to work in a background process. iBeacon message includes a UUID, a major value and a minor value. iOS system can trigger an application according to registed UUIDs. While Android OS permit a background processing at this time, it may limit the background processing of each process in the near future to reduce power consumption. We can use Eddystone for Android OS. Beacon messages can activate a specific application by using the OS function. Therefore, A beacon device can control the specific application on smartphones remotely.

- Smartphone application
  The functions of the application can be roughly classified into searching for a beacon device, acquiring location information from a location service, and sending location information to the cloud service. The scanning application generally should not search a beacon device not to consume a battery energy. Additionally, iOS does not permit the background processing of applications more than 10 seconds. Therefore, this paper focuses on an application of iOS system, and employs the iBeacon function to trigger the background processing of the suspend scanning application. The application registers its target UUID to iOS system. iOS system calls a delegate function in the application when it receives iBeacon message including the target UUID.
- Cloud service
  The proposed system is one of participatory sensing methods. Therefore, a management function is required to collect information. Cloud service manages a UUID, major and minor values of each bus and bus routes information. The smartphone application can download these information from the cloud service. Then, it registers the UUID to iOS system to activate the iBeacon notification function. It also recognizes each bus by checking major and minor values. Additionally, the cloud service can show a location of each bus on a map. Hence, administrators and passengers can also check the operational status of each bus.

3.2. Communication signaling

Fig. 2 shows the detail signaling process of the proposed system. The beacon devices use BLE communication to advertise its service to smartphones in its bus. In our implementation, we employ iBeacon that is supported by iOS and Android OS. Therefore, the proposed system uses a UUID to identify the proposed bus location service in smartphone OSs, and uses a major value and a minor value as a vehicle ID to identify each bus. The cloud service assigns a UUID for a bus location service, and major and minor values to recognize a bus vehicle. These information is registered into a beacon device. The following is the description of the signaling.

1) Installation of application
   The proposed system assumes that passengers or drivers install the developed application into their smartphone to collect a bus location.
2) Initialization of application
   The application downloads the configuration parameters from the cloud service. Mandatory information is a UUID of the proposed service because the UUID is used to detect beacon devices.
3) Registration of UUID to iBeacon service
   The application registers the downloaded UUID to iBeacon service. iOS notifies the application when the registered UUID is received.
4) Starting of beacon messages detection procedure
   iOS starts a scanning process of the beacon messages in background processing, and suspends the application not to reduce the consumed power.
5) Periodic broadcasting of beacon messages
   The beacon device broadcasts a beacon message including the UUID, the major and minor values. The UUID is same in whole buses and the major and minor values are unique for each bus.
6) Detection of beacon messages
   iOS notifies the application when it detects the registered UUID in the received iBeacon message. The notified application can start the function in background processing for a few seconds.
7) Location measurement
   The application estimates the location of the smartphone instead of the location of the bus by using the location service. iOS provides the location information estimated by environmental information such as GPS, WiFi signal etc.
8) Uploading of location information
   The application uploads the location information to the cloud service with the major and minor values. The cloud service stores the uploaded information as the latest bus location.
9) Downloading of bus location
   The application has a browsing function of a bus location. It requests location information of each bus in a target area. The cloud service responses the requested location information. Finally, the application shows the bus location on the map.

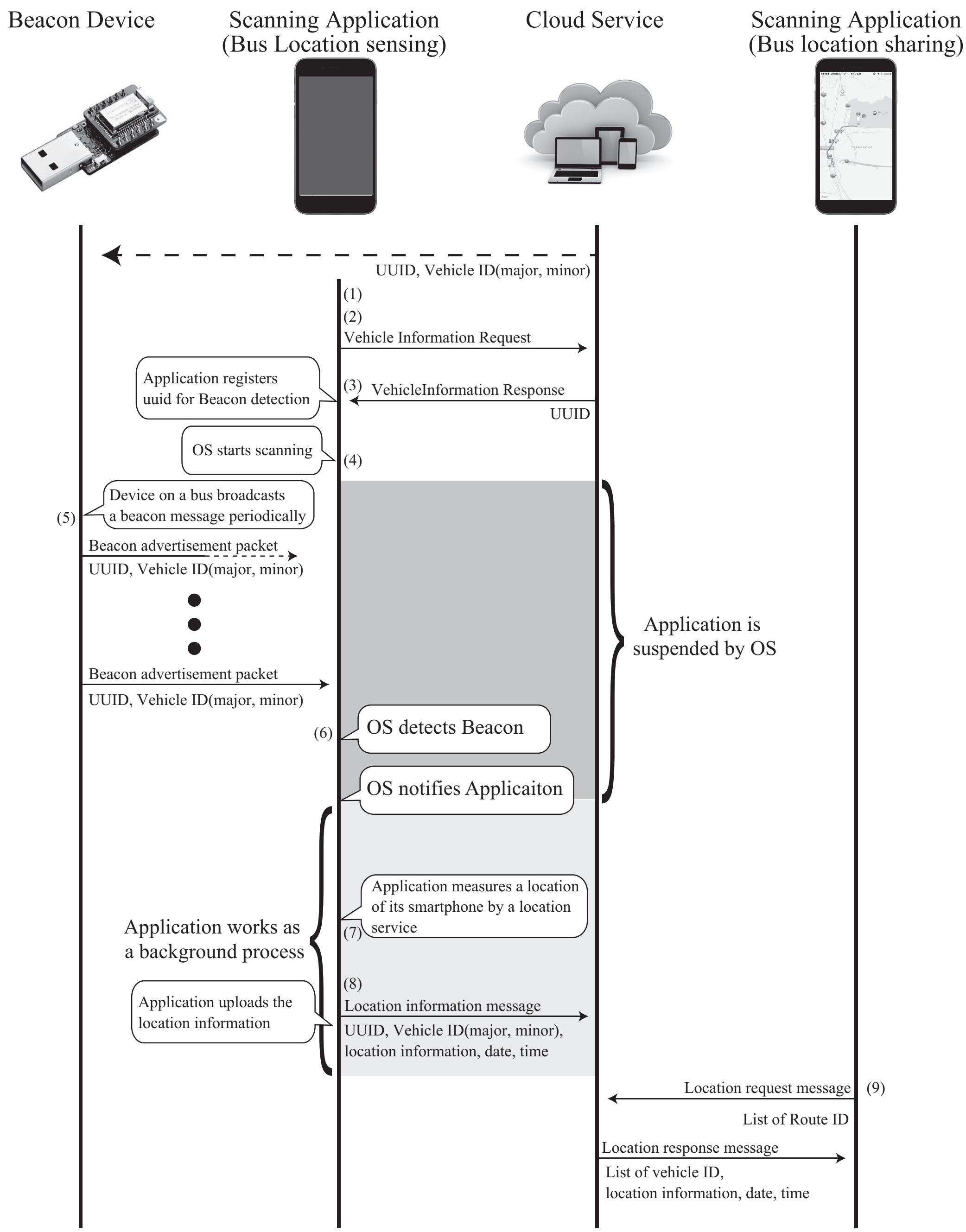

Fig. 2. Signaling process.

3.3. Implementation

Tab. I is the implementation environments. We have developed the beacon program for BLE device. RedBearLab nRF51822 supports mbed environment that is the web-based development environment for ARM microcontrollers. nRF51822 is a special SoC for BLE. It is built around a 32-bit ARM Cortex M0 CPU with 256kB flash + 16kB RAM. The UUID, the major and minor values are implemented as hard coding in the prototype implementation. Therefore, the configuration parameters are installed when the developed program is written into the microcontroller. The microcontroller transmits iBeacon messages including the UUID, the major and minor values periodically in order to trigger the smartphone application.

The proposed mechanism supports various beacon technologies. iOS is the strictest operating system for applications to

TABLE I
IMPLEMENTATION ENVIRONMENTS

Beacon device	Device	RedBearLab nRF51822
	BLE Chipset	Nordic nRF51822
Smartphone	Device	iPhone 6
	OS	iOS 8
Cloud Service	OS	Cent OS 7
	Web Server	Apache
	CGI	PHP
	DB Server	MySQL

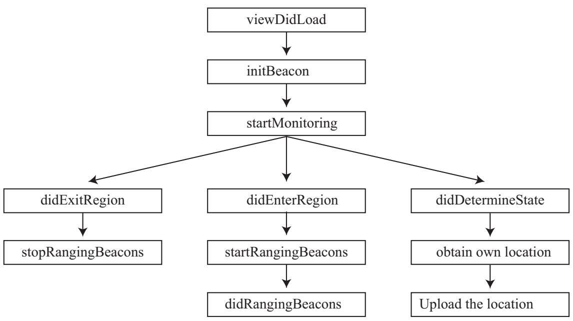

Fig. 3. Flowchart of smartphone application.

reduce power consumption. Therefore, background processing of typical applications is permitted within 10 seconds. As a result, conventional implementation method cannot collect location information continuously when the application works in a background process. We have developed the prototype program for iOS 8. We have used CLLocation Manager to collect location information from iOS, and have used CLBeaconRegion to detect iBeacon message. Detail flowchart is shown in Fig. 3.

The prototype cloud service has been developed on Cent OS 7. Since iOS developer environment has useful HTTP API, we have employed HTTP as a communication protocol between the application and the cloud service. Therefore, we have installed the Apache server as an HTTP server. Additionally, we have developed a web application to collect bus location from the application and to distribute location of each bus in a requested area. The web application is developed with PHP and mySQL server.

4. EXPERIMENTAL RESULTS

In the experiment, we have set up for the bus route of our university transportation service into the smartphone application. Hence, the smartphone application can correct for the influence of error in location service. Fig. 5 shows the route of the school buses. The bus route is about 900 m and the width of the road is about 7 m.

Fig. 6 shows the example of bus location viewer. From the measurement results, we have found that the smartphone application can track the bus location even if the smartphone exists in the bus. Additionally, we have found that the smartphone application can perform whole functions: measurement and uploading of bus location within 10 [s] that is the allowable period of background processing in iOS.

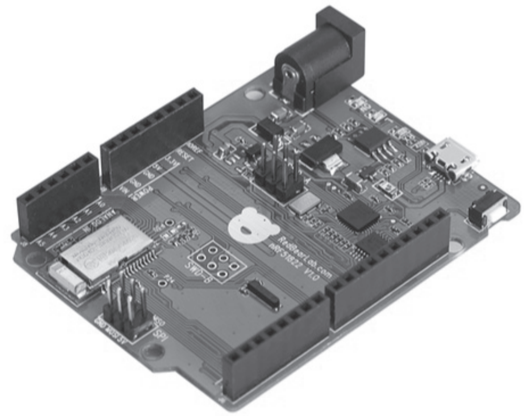

Fig. 4. Overview of beacon device.

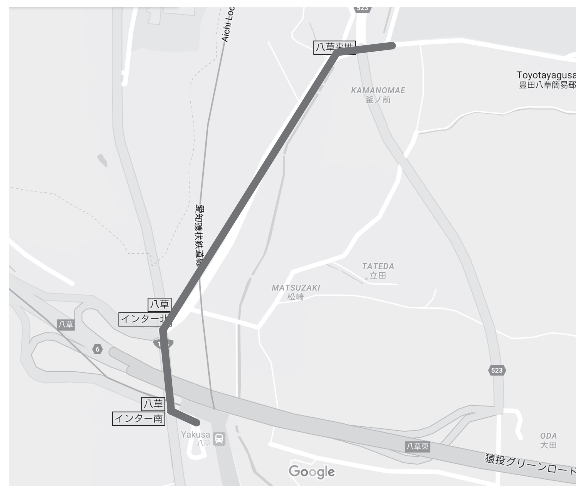

Fig. 5. Experimental bus route.

5. CONCLUSION

This paper has proposed a collaborative mechanism with beacon devices and smartphones to realize a bus location system. The proposed mechanism employs BLE devices that trigger our special application for smartphones. Therefore, the special application can be automatically launched when a beacon message arrives on the smartphone. In the experimental evaluation, we have developed the proposed system on a typical wireless SoC module for BLE and the iOS system. The experimental results demonstrated that the developed system works well as a bus location system.

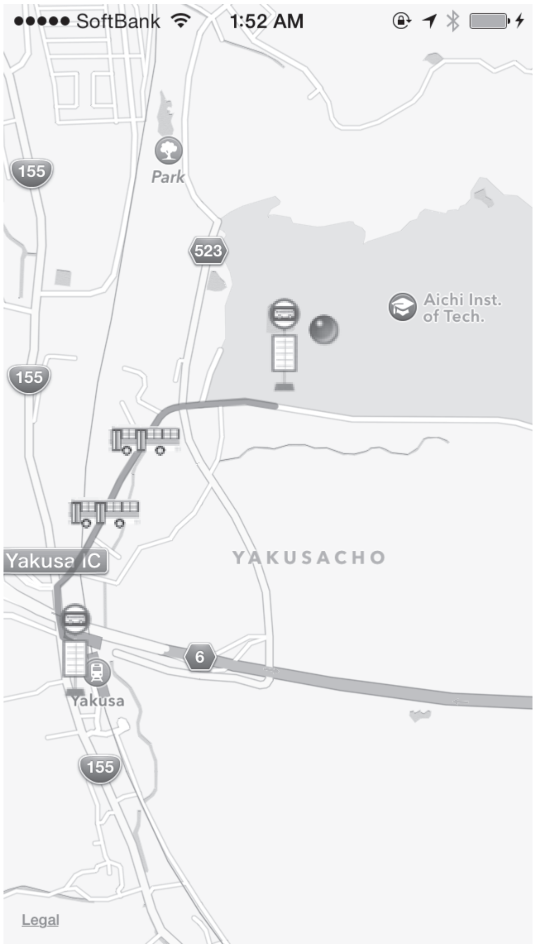

Fig. 6. Example of bus location viewer.

ACKNOWLEDGMENT

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