Concept Design of Estimation Scheme for Social Graph Based on Occupancy Time in Space

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ABSTRACT

Taking care of students is effective work to avoid repeating a year or dropping out in education institutes. As taking care process, human relations among students is a related factor to find a care-required student. Additionally, dynamic changes in human relations require continuous recognition of students to taking care. As the recognition scheme of students, indoor positioning methods are candidate technology to track students with cheap wireless devices. Bluetooth, WiFi, and IEEE 802.1.5.4 are usually used for conventional service according to the decreasing costs of the devices. Bluetooth Low Energy (BLE) is the low energy standard of Bluetooth and is suitable for long operation with a battery. Since the authors have been proposed a concept design of an estimation scheme for social graph based on occupancy time in space, this paper extends the proposed position estimation scheme. It evaluates the estimation performance of the grid position as the fundamental location information for the social graph estimation. The proposed scheme uses a BLE beacon to track each student and recognizes a student share time in the same space. It also estimates social relations among students. We have developed a prototype system for tracking BLE beacon and estimating a location according to RSS values from the BLE beacon. In the evaluation, we have developed a special classifier to estimate a grid position according to the received RSS values. The classifier is trained by actual measurement data. The evaluation results show that the classifier can estimate a correct grid position with more than 90% by receiving one set of RSS values.

Keywords: Social graph estimation, Bluetooth, BLE, Indoor Positioning, Position Estimation, SVM

1. Introduction

The spread of cheap wireless devices makes it easy to realize indoor positioning methods [1]. The 2.4GHz ISM band is typically used to estimate the position of a device because various types of wireless devices support this free-licensed band. For example, WiFi, Bluetooth, and IEEE 802.15.4 devices support this band and are used for indoor positioning methods. Services generally select an adequate standard according to the requirement because each standard has its benefits such as easy installation, low energy operation, etc [2].

IEEE 802.15.4 is traditionally used for sensor networks. Therefore, a special mechanism is required for measurement based on IEEE 802.15.4 devices. WiFi is also used for high-speed communication. Since the general WiFi driver has a function to measure Received Signal Strength (RSS) of a received packet, a position estimation based on RSS is possible. Bluetooth is typically used for a personal area network such as connecting between a smartphone and peripheral devices and is used as a wireless beacon device [3].

Bluetooth Low Energy (BLE) is the low energy standard of Bluetooth and is suitable for long operation with a battery. Even if BLE has two types of communication: beacon mode and communication mode, beacon mode is typically used for indoor positioning methods [4]–[6]. The conventional schemes use the RSS value of a received packet to estimate a distance for predicting a position [7]. Since RSS fluctuates in a real environment, fingerprinting based methods have been proposed [8]–[10]. Recently, machine learning schemes try to improve an estimation performance based on fingerprinting [11]–[13] With these technologies, we can take care of human activities.

Recently, education institutes have to take care of students to avoid repeating a year or dropping out. For these purposes, human relations among students is an important factor. Since it is not easy to track the whole student on campus, we try to use an indoor positioning scheme to estimate a human relation. Generally, students tend to make some groups and move on campus together. Therefore, it may be possible to estimate a human relationship when some students are captured at the same time and same locations.

As the previous work, the authors have proposed a concept design of an estimation scheme for social graph based on occupancy time in space [14]. It uses BLE communication to detect a student because the BLE tag is a cheap and long life device, and general smartphones support BLE communication. The proposed scheme assumes that all students have a BLE beacon. Additionally, we also install many BLE receivers into several locations on campus. Since the BLE receivers can detect a BLE beacon when a student walks near the BLE receivers, our system can recognize a student with time and a position and estimates social relations among students. The main target of the scheme is to find lonely students who do not have any relations with other students and to take care of them. We have developed a prototype system for tracking BLE beacon and estimating a location according to RSS values from the BLE beacon. In the evaluation, we have developed a special classifier to estimate a grid position according to the received RSS values. The classifier is trained by actual measurement data. The evaluation results show that the classifier can estimate a correct grid position with more than 90% by receiving one set of RSS values.

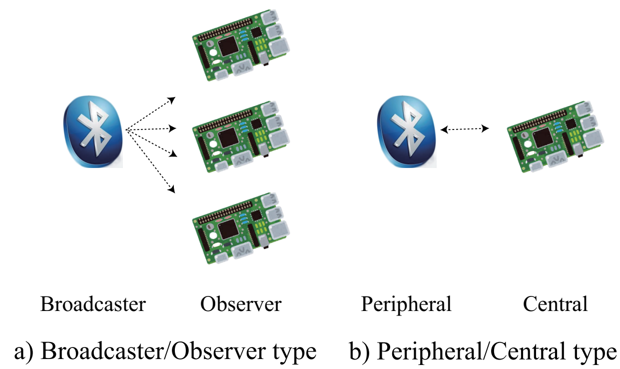

Fig. 1. Communication type of BLE.

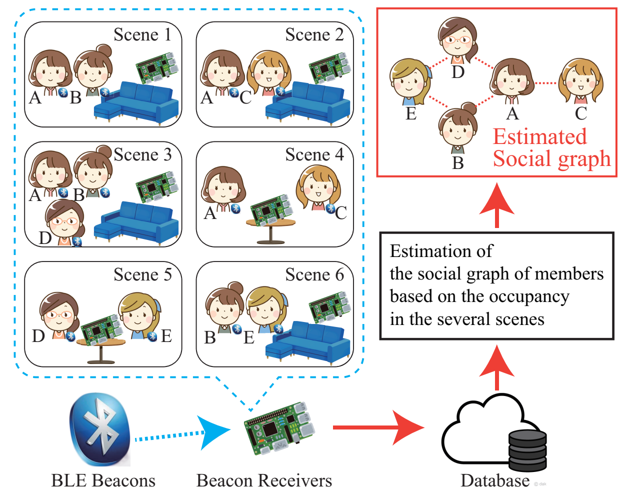

Fig. 2. Overview of social graph estimation scheme.

2. Bluetooth Low Energy

Classic Bluetooth is a well-known protocol in Bluetooth standard designed by the Bluetooth Special Interest Group (SIG). Bluetooth Low Energy (BLE) is a new wireless personal area network technology designed for low power communication. It is not backward-compatible with the previous Classic Bluetooth because the target of BLE is low-energy consumption, not increasing of throughput.

It uses the same 2.4 GHz radio frequencies as Classic Bluetooth, however, uses a different set of channels. Gaussian frequency shift modulation is employed as a simpler modulation scheme to reduce power consumption. Neighbor devices can detect a BLE device by receiving broadcasting advertising packets. One of the three separate channels is randomly selected to transmit these packets to reduce the interference of signals.

2.1. Communication type

BLE introduces GAP (Generic Access Profile) and GATT (Generic attribute profile) roles for flexible usages. GAP is the layer that defines some communication functions of the

BLE system. The defined roles by GAP are Central, Peripheral, Broadcaster, and Observer. GATT is the layer to define the data structure of the BLE system. Even if the conventional Bluetooth only supports serial communication, BLE generalizes the communication scheme through the GATT. As the communication types of the BLE system, BLE defines two types: Broadcaster/Observer type and Peripheral/Central type shown in Fig. 1.

- Broadcaster/Observer type
  Broadcaster/Observer type is usually used for beacon service, where some devices detect a BLE device by receiving periodic beacons. A device in the Broadcaster role does nothing more than transmitting packets to its surroundings. Since the Broadcaster/Observer type does not establish a connection, such a device does not require a receiver. The Observer is the different role of the Broadcaster. It passively listens to the Broadcaster to find the BLE device and proceeds the process when it receives the advertising packets. The Broadcaster usually transmits a packet with a long interval period to reduce the power consumption of the device. As a result, the lifetime of the device increases to 2-3 years as the advertising interval increases to a few seconds.
- Peripheral/Central type
  Peripheral/Central type is used to exchange data between devices. Since GATT defines a common structure to exchange data, any data can be easily transferred through the common structure.
  The Peripheral generally transmits advertising packets periodically and stays put until some Centrals decide to connect with it. As an example of a consumer device, a peripheral transmits advertising packets to broadcast service, and anyone can access to the service.
  The Central is a role to find the Peripheral and communicate with it. Typically, smartphones work as the Central.

2.2. iBeacon

The central device should generally scan the beacons continuously in traditional beacon protocols. Therefore, This scanning causes the consumption of electric power.

iBeacon is a Bluetooth advertising protocol developed by Apple in 2013 [15]. It optimizes the scanning mechanism for smartphones. Therefore, an application can detect the Peripheral device with low power consumption. The function of iBeacon is supported in the iOS Location Services and the Core Location framework. The Core Location API provides information about detected iBeacon devices when the smartphone enters and exists a range of transmission range of the iBeacon device.

Each iBeacon device has a universally unique identifier (UUID) as a unique identifier. According to the standard, iBeacon messages include three parameters: UUID, additional values called a major value, and a minor value.

3. Estimation scheme for social graph

3.1. Concept design

Avoiding repeating a year or dropping out has become an important task for education institutes such as universities, colleges, etc. Therefore, many institutes focus on how to take care of students. Some educators have pointed out that human relations among students affect motivation for studying in universities because a lack of human relations reduces the chance for conversation. For these purposes, human relations among students is an important factor in recent education institutes. Generally, it is not easy to grasp the human relations of the whole student on campus due to technical and privacy issues. Therefore, they require a tracking scheme to collect information on the human relations of students in consideration of individual privacy. As a solution, we have proposed an indoor positioning scheme to estimate a human relationship based on information about detection point and timing.

Generally, students tend to make some groups in their school life. Isolated students also have a strong tendency to drop out because of a lack of chance to make conversation with friends. Therefore, finding isolated students is an important activity to take care of these students in recent school operations. However, it is difficult to find isolated students on campus because they just come to a school to attend some classes. Therefore, the proposed system focus on typical students who move on campus with friends. Since they make some group for moving on campus, the proposed system may recognize a group. Additionally, the proposed system may detect a similar group in a different place and timing, it can estimate a human relation among students, and find a isolated student who does not belong to any group. As the purpose of this scheme, the indoor positioning scheme requires accuracy to detect a group.

Fig. 2 shows the concept design of the proposed estimation scheme for the social graph. As the recognition target in the proposed system, a school manager requests for students to bring their own BLE beacon for tracking. Each BLE beacon has a unique major and minor IDs as an identifier. Therefore, the system can recognize each student by receiving a beacon including these parameters.

The school manager also put some beacon receivers in some space such as the lunchroom, study rooms, library, etc. because students tend to use these spaces with friends. BLE beacons transmit a beacon message with a long interval period such as

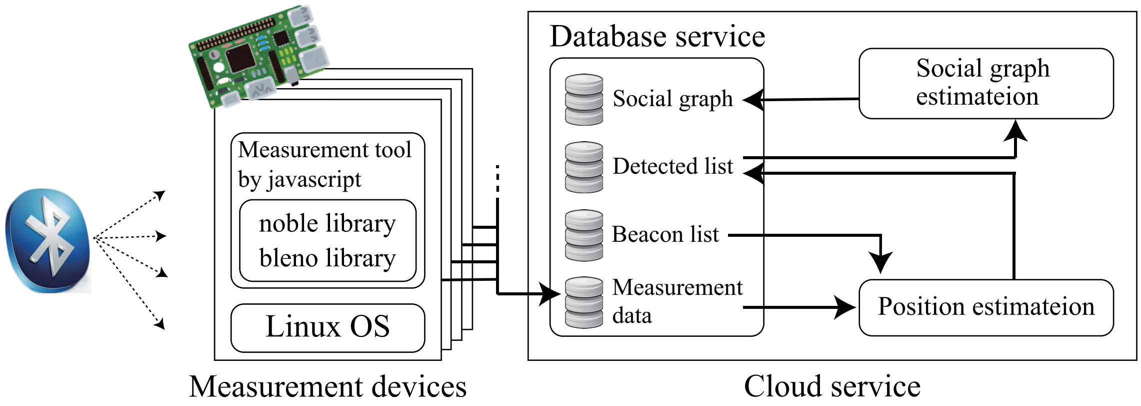

Fig. 3. System model.

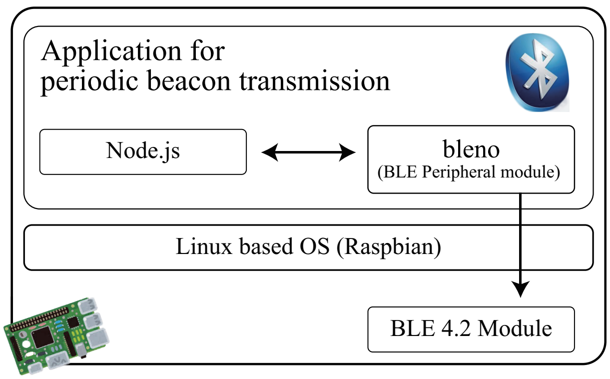

Fig. 4. Prototype model of the beacon device.

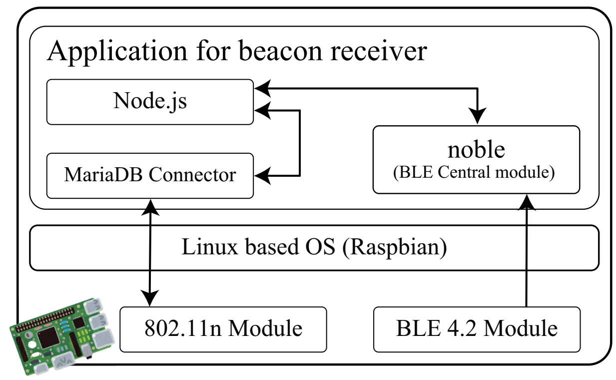

Fig. 5. Prototype model of the beacon receiver.

more than one second. The interval period depends on the trade-off between a real-time detection performance and energy saving performance. As we focus of the behavior of students, almost all students may stay for a while in public space. In these spaces, the proposed system can detect the same beacon continuously. As a result, the system can recognize that some students use the same space at the same time. Since it also collects these recognition scenarios in various spaces, it can estimates that someone makes a group with friends. Finally, it finds a isolated student who is not in the groups.

3.2. System model

Fig. 3 shows the detailed system model of the proposed social graph estimation scheme. As a tracking device, we use a BLE beacon that works for a long time with a small size of the battery. Even if any beacon messages work for our proposal, we use iBeacon as a beacon message due to easy installation. Since the price of the iBeacon products is around $20, the installation cost of the proposed system may be acceptable for school usage. The proposed system assumes that each student has this iBeacon device.

TABLE I
DATABASE FOR BEACON LIST.

No.	column	Description	Type
1	id	Index Number	INT
2	ibeacon_id	iBeacon's ID	INT
3	personal_id	Related Personal ID	CHAR

TABLE II
DATABASE FOR MEASUREMENT DATA.

No.	column	Description	Type
1	id	Index Number	INT
2	receiver_id	beacon receiver's ID	INT
3	ibeacon_id	iBeacon's ID	INT
4	recv_time	Received time of Beacon	DATETIME
5	rss	Received Signal Strength	FLOAT

The proposed system consists of iBeacon devices, some beacon receivers, and the cloud service. Each iBeacon device transmits an iBeacon message, including a UUID, major, and minor values periodically. Typically, the iBeacon device will work for a year with a CR2032 battery. The beacon receivers should be installed in many places on campus. Therefore, we

TABLE III

DATABASE FOR DETECTED LIST.

No.	column	Description	Type
1	id	Index Number	INT
2	detected_time	Detected time of group	DATETIME
3	own_pid	Detected personal ID	CHAR
4	friend_pid_list	Detected friends' personal ID list	CHAR

TABLE IV

DATABASE FOR SOCIAL GRAPH.

No.	column	Description
1	node	personal ID
2	relationship	relationship for for graph structure
3	property	property for graph structure

assume that the beacon receivers should be developed as a small device based on a microcomputer board. Each beacon receiver should connect to the cloud service to inform the recognized iBeacon devices. The cloud service also consists of the database function, the position estimation function, and the social graph estimation function.

3.3. Database model

The database function has two types of database systems based on relational database and graph database. As the initial design, the proposed system defines four tables to handle the information. Table I is the database table for the beacon list. The table is used to manage the relationship between personal information and Beacon device. Table II is the data collection database. The table includes the ID of the beacon receiver, detected beacon ID, detected date&time, and RSS. The position estimation function can estimate a group with the information. Table III is the detected group list by the position estimation function. The table includes a personal ID and related friends' personal ID. The social graph estimation function uses this table to estimate the graph topology among students. Table IV is the basic table structure for the graph database because the output of the social graph estimation function is graph data.

4. PROTOTYPING

We have developed a prototype system to confirm the basic idea of the proposed system. As the beacon and the beacon receiver, we have used Raspberry Pi 3 Model B+ that supports Bluetooth 4.2/BLE on board. Since Raspbian that is a Linux based OS works on Raspberry Pi 3, we use noble [16] and bleno [17] library to use Bluetooth communication function.

4.1. Beacon device

Fig. 4 shows the detail implementation model of the prototype beacon device. We have developed an application to transmit iBeacon messages periodically by Java Script. The application uses Node.js and bleno library because the beacon device works as the BLE Peripheral. It also configures some parameters such as message data, transmission power, transmission timing, transmission interval, etc. for iBeacon transmission.

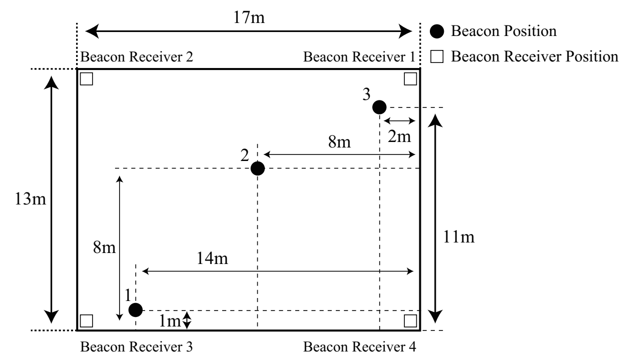

Fig. 6. Measurement environment.

TABLE V

AVERAGE OF RSS.

Position No.	1	2	3
Receiver1	-68.2	-59.1	-48.1
Receiver2	-63.6	-62.2	-59.8
Receiver3	-48.0	-60.0	-61.0
Receiver4	-71.8	-62.3	-57.6

Unit: dBm

4.2. beacon receiver

Fig. 5 shows the detail implementation model of the prototype beacon receiver. We have also developed an application to receive iBeacon messages continuously by Java Script. The application uses Node.js and noble library because the beacon receiver works as the BLE Central. Since it also informs the detected beacon information such as RSS, beacon ID, detected DateTime to the cloud service, we use the WiFi interface to access IP networks. We employ MariaDB, which is the relational database service, as the database function in the cloud service. Therefore, the application uses MariaDB connector to access MariaDB services directly over IP networks.

4.3. Cloud service

Since the database service has the beacon list of beacon identification and RSS information of recognized beacon identification, the system can estimate the position of the recognized beacon. Additionally, this position information is stored on the detected list in the database service. Since the position of each student is required to estimate a human relation, we have developed a special classifier to estimate a grid-based position according to the received signals. As the leaning scheme, we

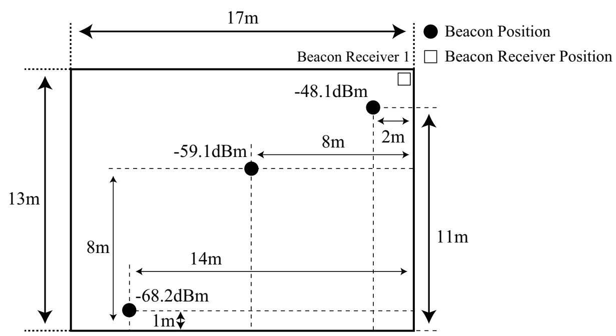

Fig. 7. Measurement example (Receiver 1).

TABLE VI
VARIANCE OF RSS.

Position No.	1	2	3
Receiver1	25.8	28.5	16.4
Receiver2	18.0	25.9	1.7
Receiver3	2.1	1.5	40.5
Receiver4	32.3	44.1	54.1

Unit: dBm

have employed SVM (Support Vector Machine), which is a well-known machine learning scheme. As the classifier can estimate the position of each student in each scenario, the system can estimate a student group. Therefore, it also estimates the social graph according to the group.

5. EVALUATION

5.1. Measurement

We have evaluated the RSS values of the beacon with the prototype system. Fig. 6 shows the layout of the lecture room. The square marks are the position of each BLE beacon receiver. The circle marks are the position of the BLE beacon. The height of the devices is 1.2 meters. We have measured multiple RSS values for 1,512,750 measurements in the grid positions.

Fig. 7 shows the example of RSS values in the measurement result at BLE beacon receiver 1. Table V is the average values of RSS for each measurement position and BLE beacon receiver. Table VI is the variance of Table V. The results find that the variance increases when the average RSS value decreases. Therefore, the install position of the BLE beacon receiver is important to obtain the RSS value with a small variance.

5.2. Position estimation

We have developed a classifier to estimate a grid position according to the received RSS values based on SVM (Support Vector Machine). As the kernel method in SVM, we used RBF(Radial Basis function Kernel) that is usually used for general purposes. The detail parameters are shown in Table VII.

TABLE VII
PARAMETERS FOR SVM.

Kernel	RBF(Radial Basis function Kernel)
Cost parameter C	100
γ	1000

TABLE VIII
ESTIMATED GRID POSITION RATIO.

Error Distance [m]	X	Y
0(Correct Grid)	0.927	0.922
0 - 0.5	0.019	0.011
0.5 - 1.5	0.007	0.015
1.5 - 2.5	0.011	0.01
2.5 - 3.5	0.022	0.009
3.5 - 4.5	0.005	0.009
4.5 - 5.5	0.001	0.007
5.5 - 6.5	0.005	0.008
6.5 - 7.5	0.002	0.004
7.5 -	0	0.005

We have evaluated the classifier with k -fold cross-validation with $k = 5$. The estimated grid error ratio is shown in Table VIII. We have found that the classifier can estimate the correct grid position with more than 90% by receiving one set of RSS values. Typically, the classifier can estimate a position based on multiple receptions of the RSS values set. Therefore, our classifier can be used for efficient indoor location service.

6. CONCLUSION

This paper has proposed a concept design of an estimation scheme for social graph based on occupancy time in space. The proposed scheme uses a BLE beacon to track each student and recognizes a student share time in the same space. It also estimates social relations among students. The main target of the scheme is to find lonely students who do not have any relations with other students and to take care of them. We have developed a prototype system for tracking BLE beacon and estimating a location according to RSS value from the BLE beacon.

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