Improving Indoor Positioning Performance in an Emergency Deployment System

JaeMin Hong[1,2], KyuJin Kim[1,2(✉)], and ChongGun Kim[1,2]

[1] Department of Computer Engineering, Yeungnam University, Gyeongsan, South Korea
{hjm4606,kayjay6t}@naver.com, cgkim@yu.ac.kr
[2] Department of Nursing, Kyungpook National University, Daegu, South Korea

Abstract. The proposed real time emergency position control system can treat real-time emergency messages between servers and mobile clients based on reply from the client by using multiple communication methods. Especially in the general hospital environment, in order to avoid patient anxiety caused by emergency situations, the system informs calmly the emergency situation to the person who has to react the situation by using one-way broadcast communications. The accuracy and performance of positioning system are important to increase reliability on the proposed system. The power consumption rate of mobile devices have analyzed and the process of positioning data is verified for one-way communication and two-way communications.

Keywords: Bluetooth LE · Wi-Fi · Power consumption · Indoor positioning Fingerprint · Kalman filter

1 Introduction

In a general hospital environment, in case of emergency, it is needed to send the emergency information in real time to the persons in charge by using SMS or telephone call for respond the situation. The persons in charge with the corresponding situation have to respond as soon as possible. Based on the general emergency call method, if the emergency information cannot be timely conveyed to the persons in charge, there will delayed the deployment of the persons in charge and cannot respond be in time. A system that can send emergency information to persons in charge by using multiple communication methods when an emergency situation occurs and the persons in charge can respond to the emergency in real time is proposed. The system is also can record and manage all emergency activity information.

Figure 1 shows the multiple communication concept of the proposed system.

2 Previous and Related Studies for Indoor Positioning

In this study, the management server uses one-way broadcast communication to send emergency alarm message to persons in charge, according to the emergency reaction protocol, then change to two-way communications by confirming from the client to

J. J. Jung et al. (Eds.): BDTA 2017, LNICST 248, pp. 49–59, 2018.
https://doi.org/10.1007/978-3-319-98752-1_6

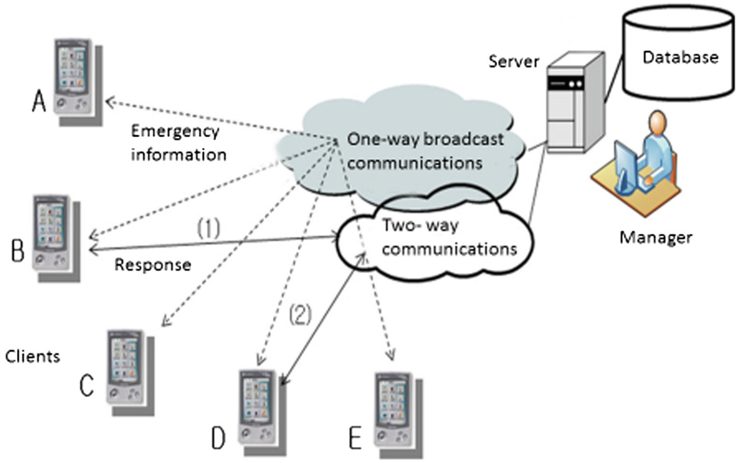

Fig. 1. The communication concept of the emergency deployment system

exchange emergency information with clients, all the activities and position of the responder are tracked in real time.

Bluetooth LE (Bluetooth Low Energy), visible light communication technology, SMS message can be used as one-way broadcast communication method, Wi-Fi and cellular mobile communications can be used as two-way TCP communication methods in this system.

2.1 Bluetooth LE

By growing importance of IoT (Internet of Things), Bluetooth LE application is also diffused. Compared with the Bluetooth, it does not need to maintain a long connection, therefore power consumption is also greatly reduced.

BLE does not need pairing that can send data to multi clients in one-way, this process is called Advertising. All the terminals which Bluetooth enabled can receive the advertising data. When a message is transmitted via advertising, the message can be receiving by multi users in the same time.

The BLE device for advertising is called beacon and it is possible to indoor positioning by using RSSI (Received Signal Strength Indication) value of beacon signal [1]. For indoor positioning using beacons, Cell ID method is mainly used. It is a method of judging in which cell the position of its own is located based on the information received from the fixed node. This method is easier and simpler than other methods, but has the disadvantage of low accuracy. Indoor positioning using beacons is mainly used for hospital, department store and etc.

2.2 Two-Way Communication and Indoor Positioning Based on Wi-Fi

Socket communications have two major transport layer protocols, TCP (Transfer Control Protocol) and UDP (User Datagram Protocol).

The UDP communication has no handshaking dialogues among the processes for session, and cannot provide any reliability control so there is no guarantee of delivery, ordering, or duplicate protection of datagrams. The TCP communication provides reliable, ordered and error-checked delivery of a stream of octets between processes which are running on hosts based on IP network. In this study, TCP is used for socket communications.

A TCP communication is requested by using the IP addresses and port numbers of two processes. The client starts the connection and if the server does not accept the response, the connection will be failed. If connection is created, data can be exchanged through the socket between the server and client. The TCP can provide error control and flow control, if the data not received properly, it can be requested again [2].

GPS (Global Positioning System) is the most widely used outdoor positioning system. But in the indoor environment, GPS cannot work properly. Therefore, many research of indoor positioning are in progress. For example, visible light communications [3], BLE signal strength [1, 9], Wi-Fi signal strength and so on can be used [4, 5]. For finding the coordinate of mobile object in indoor environment, fingerprint and triangulation methods are widely used.

The triangulation method is a geometric method of computing a coordinate by calculating each distance from three reference points. It is necessary to be able to obtain the correct distance from the wireless AP as reference point so that the correct position can be traced [10].

Fingerprint method is RSSI (Received Signal Strength Indication)-based, but it simply relies on the previously recorded data of the signal strength from several reference access points in the proper range. Storing this information in a database along with the known coordinates of the tracking device is clone in an offline phase. During the online position decision phase, the current RSSI vector at an unknown location is compared to those stored in the fingerprint DB and the closest matching position is returned as the estimated user location [8].

Wi-Fi or BLE signal strength can be used for calculating distance for using the fingerprint method.

2.3 Emergency Deployment System in a General Hospital

When a patient meet in an emergency situation, this system can send the emergency notice to the persons in charge on various departments, then by the confirming to the notice which means the corresponding departments can give an initial solution. Indoor positioning is used to guide the persons in charge to the current location of the patient, then lead those on the most appropriate route to the operating room.

In an emergency situations, excessive noise in a hospital has been attributed to negative clinical outcomes to patients and perhaps give negative performance and stress as well to all staffs. It is essential to use a plain language emergency code only for an appropriate individuals to initiate an immediate and appropriate response.

When initiating an emergency code call by the control center in a general hospital setting, the notification process for specific doctors and nurses will be initiated with single-way multiple task communication. Once the emergency code message has been effectively sent to emergency responders, staff will press button to open bilateral one to one communication and exchange information about the target locations and specific emergency operational plan with server. Start with confirmation response from emergency response staffs, initiating protocol information will be recorded in server.

Server with location tracking system manage staff's current position, moving route and the time required after confirmation response in real time. If delayed response is occurred, server sends urgent messages and emergency operational plan to emergency response staff. But if emergency response staff cannot response emergency call, server initiates a contingency plan. It provides alternate medical staff and notifies other emergency response staff about current situation. Emergency code should be finished when situation has been managed or resolved.

Every process such as the time required from beginning to end, staff location per time, situation status and so on is recorded in database. With these data, further analysis and improvement of the system will be managed.

3 Comparison of Energy Consumption on Wi-Fi and BLE

Different communication methods not only have difference on data rate and communication distance, power consumptions are also different. Therefore, the power consumption tendencies are seriously considered in the proposed system.

3.1 Required Energy for Operating Hardware Modules

The WL18xxMOD WiLink 8 Single band Combo Module developed by TI which is widely used in portable mobile devices has be selected for power consumption analysis of Wi-Fi device. One important selection reason is the chip on the device uses the same antenna for Wi-Fi and Bluetooth communications.

The chip's operating power of Wi-Fi communication showed on Table 1 [6]. It can be seen that, depending on the negotiation data rate and the encoding method, the operating power of chip at 49 mA to 85 mA when the chip used as a Wi-Fi receiver. As a Wi-Fi transmitter, the operating power of chip surged to 238 mA to 420 mA.

The chip's operating powers of Bluetooth BR (Basic Rate) and EDR (Enhanced Data Rate) communication showed on Table 2 [6], The operating power of each case in a range from 178 μA to 33 mA.

Table 3 showed the chip's operating powers of Bluetooth LE (BLE). The current values are from 124 μA to 266 μA [6].

The power consumption of Wi-Fi is a thousand times than that of Bluetooth LE.

3.2 Energy Consumptions Based on Software Structure

The power consumption of TCP/IP based two-way communication protocol via Wi-Fi, one-way Bluetooth LE communications, and using Google Cloud Message (GCM) Push [7] are tested. The confirmation of power consumption software used in this study is done based on the BroadcastReceiver function of the Android operating system. Figure 2 is the flow chart of this program. When an event is transmitted from the Android system, the receiver application which is corresponded can be executed.

Table 1. Operating current of Wi-Fi communication

	SPECIFICATION ITEMS	TYP (AVG)	UNITS
Receiver	Low-power mode (LPM) 2.4 GHz RX SISO20 single chain	49	mA
	2.4 GHz RX search SISO20	54	
	2.4 GHz RX search MIMO20	74	
	2.4 GHz RX search SISO40	59	
	2.4 GHz RX 20 M SISO 11 CCK	56	
	2.4 GHz RX 20 M SISO 6 OFDM	61	
	2.4 GHz RX 20 M SISO MCS7	65	
	2.4 GHz RX 20 M MRC 1 DSSS	74	
	2.4 GHz RX 20 M MRC 6 OFDM	81	
	2.4 GHz RX 20 M MRC 54 OFDM	85	
	2.4 GHz RX 40 M MCS7	77	
Transmitter	2.4 GHz TX 20 M SISO 6OFDM 15.4 dBm	285	
	2.4 GHz TX 20 M SISO 11 CCK 15.4 dBm	273	
	2.4 GHz TX 20 M SISO 54 ODFM 12.7 dBm	247	
	2.4 GHz TX 20 M SISO MCS7 11.2 dBm	238	
	2.4 GHz TX 20 M MIMO MCS15 11.2 dBm	420	
	2.4 GHz TX 40 M SISO MCS7 8.2 dBm	243	

Table 2. Operating currents of Bluetooth

USE CASE	TYP	UNIT
BR voice HV3+sniff	11.6	mA
EDR voice 2-EV3 no retransmission+sniff	5.9	mA
Sniff 1 attempt 1.28 s	178.0	μA
EDR A2DP EDR2(master). SBC high quality – 345 kbps	10.4	mA
EDR A2DP EDR2(master). MP3 high quality – 192 kbps	7.5	mA
Full throughput ACL RX: RX-2DH5	18.0	mA
Full throughput BR ACL TX: TX-DH5	50.0	mA
Full throughput EDR ACL TX: TX-2DH5	33.0	mA
Page scan or inquiry scan (scan interval is 1.28 s or 11.25 ms, respectively)	253.0	μA
Page scan and inquiry scan (scan interval is 1.28 s and 2.56 s, respectively)	332.0	μA
* Current is measured at output power as follows: BR at 11.7 dBm; EDR at 7.2 dBm		

In power consumption evaluation, data package sends total 60 times in 10 min. Then the power consumption results are measured after completion of communications. Samsung Galaxy S3 is used as receiver, ipTime A3004 wireless router is used as Wi-Fi transmitter, Raspberry Pi 3 is used as BLE transmitter in this experiment. The results of power consumption experiment are shown on Table 4.

Table 3. Operating current of Bluetooth LE(BLE)

USE CASE	TYP	UNIT
Advertising, not connectable	131	μA
Advertising, discoverable	143	
Scanning	266	
Connected, master role, 1.28 s connect interval	124	
Connected, slave role, 1.28 s connect interval	132	
*All current measured at output power of 7.0 dBm		

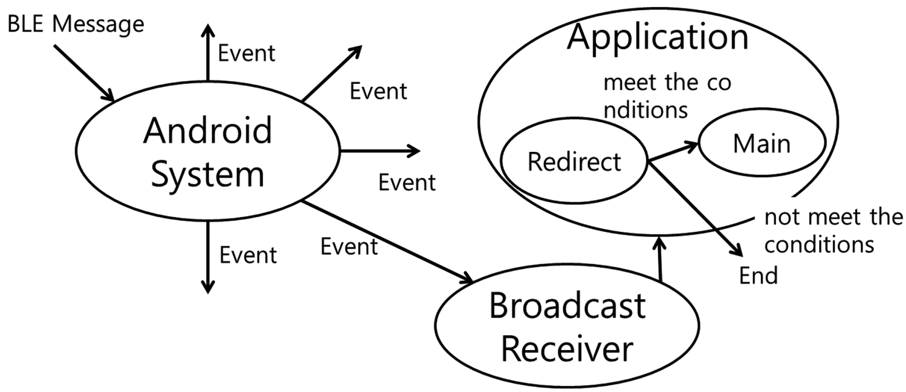

Fig. 2. Flow chart of power consumption analysis program

Table 4. Result of Power consumption experiment

Communication method	TCP/IP based own Communication protocol via Wi-Fi	Bluetooth LE	GCM Push
Battery consumption	9%	2%	1%

As shown at the tables, Bluetooth LE communication and GCM Push consumes less power than Wi-Fi communication in both tests.

It is definite that the needed operating power based on hardware modules of Wi-Fi is a thousand times higher than those of Bluetooth LE communications. From a software point of view, the difference of power consumption is also obvious. Therefore, in this system, GCM Push and BLE communication are preferred for sending an emergency one-way notification to conserve power, and Wi-Fi communications is used for ending the specific solution among the server and clients because a large amount of data exchange is required in this process.

3.3 The Process for Switching Between One-Way and Two-Way Communications

BLE requires less energy but, Wi-Fi requires a relatively large amount of energy. For the robustness of the device which should always wait for communication, BLE is used for one-way communication. And Wi-Fi is used for two-way communication for indoor positioning and emergency information transmission.

Figure 3 shows the process for switching between one-way and two-way communications.

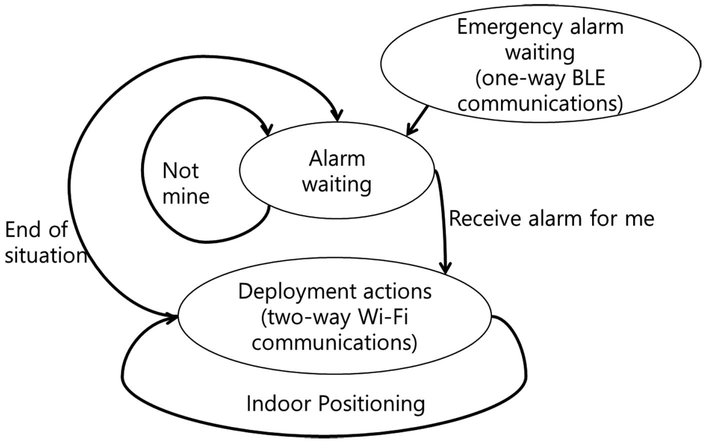

Fig. 3. The process for switching between one-way and two-way communication

4 Indoor Positioning Based on Fingerprint

For indoor positioning using fingerprint, The tracking data must be collected in advance. We store the pre-collected tracking data based on RSSI value at various indoor positions in the database.

Figure 3 shows an experimental environment with 4 APs in corridor. Tracking data is collected at 108 points.

4.1 Methods of Collecting Tracking Data

For accurate tracking data, accurate RSSI values should be collected. But RSSI values have errors and are measured differently each time. Mean, median, Kalman filter can be used to collect accurate RSSI value.

The mean is the average value of all data. The operation is simple, but if there is extremely large error, the value can be distorted.

The median is the middle value among the collected data sorted by size. If the number of data is odd, select the middle value, and if it is even, average the two numbers on both sides of the middle.

The Kalman filter is based on measurements made according to time and can give more accurate results than other measurements [11]. It can process data containing noise, and can optimal statistical prediction.

Table 5 shows RSSI values of AP1 measured at any point, and Fig. 4 shows comparison of results of mean, median, and Kalman filter.

Table 5. RSSI values of AP1

	1	2	3	4	5	6	7	8	9	10
RSSI (dBm)	−64	−58	−59	−59	−64	−57	−56	−56	−58	−59
	11	12	13	14	15	16	17	18	19	20
RSSI (dBm)	−60	−58	−59	−59	−62	−57	−56	−56	−58	−64

4.2 Calculating Similarity Distance

Fingerprint uses not the absolute distance but the similarity distance. The similarity distance should be calculated using the RSSI value at each test point with the pre-collected RSSI value in the tracking data. We use the K-NN (K-Nearest Neighbor) algorithm to calculate the similarity distance.

$$D_i = \left(\sum\nolimits_{j=1}^{n} \left|S_j - S_{ij}\right|^q\right)^{1/q} \tag{1}$$

In K-NN algorithm of Formula (1), ‘n’ is the total number of wireless APs, ‘j’ is the ID number of wireless APs, and ‘i’ is the test point number where the signal strength is collected. ‘q’ is a distance constant, that has 1 for Manhattan distance method and 2 for Euclidean distance method. ‘D_i’ is the similarity distance, ‘S_j’ is the signal strength of the j^{th} AP at the positioning point, and ‘S_{ij}’ is the signal strength of the j^{th} AP at the i^{th} collection point [12].

The nearest point can be found by comparing the similarity distance obtained at each point. But it is inefficient to calculate the similarity distance of all 108 points and then compare them.

After finding the nearest AP using the Cell ID method, it is possible to reduce the amount of calculation by comparing only the data around the AP. Figure 5 shows the range where the signal intensity of each AP is the strongest, and we can select from 18 to 36 points for each AP.

When calculating using the selected data, the amount of computation is reduced to 1/3 compared to the total data, and the computation time also decreases.

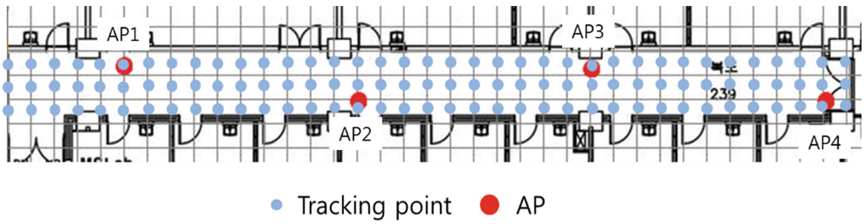

Fig. 4. An experimental environment in corridor

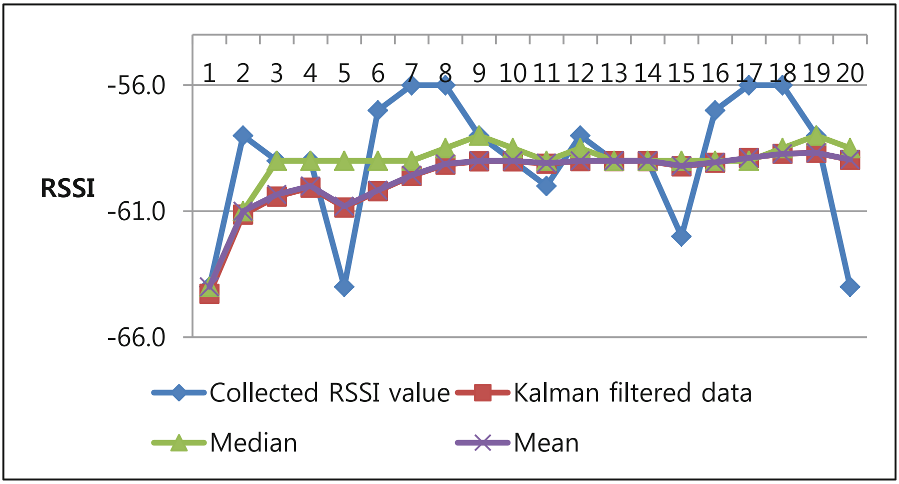

Fig. 5. Comparison results of Mean, Median and Kalman filter

4.3 Position Tracking and Error Analysis

Tracking data is collected by filtering 30 RSSI values at each tracking point. And then, as shown in Fig. 6, position tracking was performed 5 times at 10 positioning points (Fig. 7).

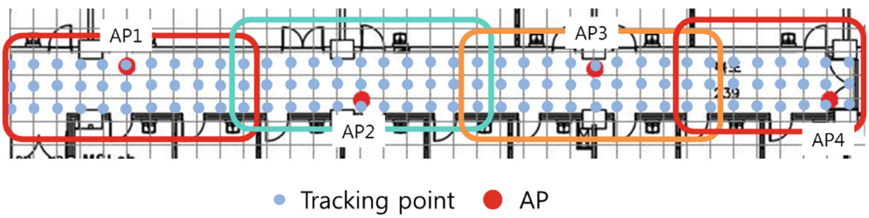

Fig. 6. The range where the signal intensity of each AP is the strongest

The errors in each positioning point are as shown in Table 6.

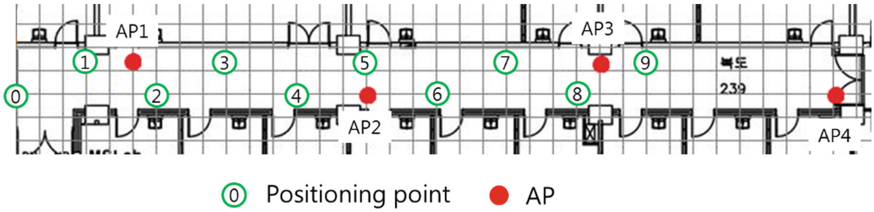

Fig. 7. 10 positioning point in experimental environment

Table 6. The errors of indoor positioning using fingerprint in each point

	1	2	3	4	5	Avg.
Point 0	3.1 m	2.6 m	1.8 m	5.1 m	3.3 m	3.18 m
Point 1	1.2 m	0.7 m	1.1 m	0 m	2.4 m	1.08 m
Point 2	2.1 m	2.2 m	2.5 m	1.8 m	3.3 m	2.38 m
Point 3	5.7 m	9.1 m	4.8 m	6.4 m	7.1 m	6.62 m
Point 4	4.5 m	8.1 m	16.2 m	8.4 m	5.4 m	8.52 m
Point 5	3.1 m	2.6 m	2.2 m	1 m	2.2 m	2.22 m
Point 6	1.8 m	0 m	4.8 m	3.1 m	2.9 m	2.52 m
Point 7	5.4 m	11.6 m	8.2 m	6.1 m	7.4 m	7.74 m
Point 8	8.2 m	6.1 m	3 m	4.5 m	4.1 m	5.18 m
Point 9	4.1 m	3.8 m	6.2 m	4.4 m	3.8 m	4.46 m
Avg.	3.92 m	4.68 m	5.08 m	4.08 m	4.19 m	4.39 m

The errors of indoor positioning using fingerprint in each point are from 0 m to 16.2 m. The average error is about 4.39 m. For the purpose of positioning a moving object in the building, the error is tolerable.

5 Conclusions

An Emergency Deployment System based on multiple-communications. For practical alarm system model is designed and some experiments for checking the performance of unit technologies are performed.

For the multiple communication methods, energy consumptions of 1 to N one-way communication for sending one way codes and communication method for guiding and tracking the responders have been analyzed. The GCM Push and BLE communications are preferred for sending an emergency one-way notification to conserve power. Wi-Fi communications are preferred for two-way communications among the server and clients because a large amount of data exchange is required in this process.

The effects of indoor positioning based on fingerprint is analyzed. The experiment result shows that the proposed system can be used as practical one.

For improving accuracy of positioning, some better methods have to be studied. One candidate method is UWB (Ultra Wide Band) for better accurate positioning decision.

Acknowledgement. This research was supported by The Leading Human Resource Training Program of Regional Neo industry through the National Research Foundation of Korea (NRF-2016H1D5A1909408) funded by the Ministry of Science, ICT and future Planning, and the BK21 Plus Program funded by the Ministry of Education (MOE, Korea) and National Research Foundation of Korea (NRF).

References

1. Ahn, H., Lee, P., Hong, J.: An algorithm of localization by using the score of multiple power beacon signals in wireless sensor networks. Korea Comput. Congr. **37**(1)(D), 165–169 (2010)
2. Stallings, W.: Data & Computer Communication, 10th edn. Pearson Education, Inc. (2014)
3. Kong, In-Yeup, Kim, Ho-Jin: Experiments and its analysis on the identification of indoor location by visible light communication using LED lights. J. Korea Inst. Inf. Commun. Eng. **15**(5), 1045–1052 (2011)
4. Vasisht, D., Kumar, S., Katabi, D.: Decimeter-level localization with a SingleWiFi access point. In: 13th USENIX Symposium on Networked Systems Design and Implementation (NSDI ’16)
5. Pathak, O., Palaskar, P., Palkar, R., Tawari, M.: Wi-Fi indoor positioning system based on RSSI measurements from Wi-Fi access points – a tri-lateration approach. Int. J. Sci. Eng. Res. **5**(4), April 2014
6. WL18xxMOD WiLink™ 8 Single-Band Combo Module – Wi-Fi®, Bluetooth®, and Bluetooth Low Energy (LE). http://www.ti.com
7. Google Cloud Messaging (GCM) Push. https://developers.google.com/cloud-messaging/
8. Wireless LAN-Based LBS Services, Hakyong KIM, April 2006
9. Bluetooth Indoor Localization System, Gunter FISCHER, Burkhart DIETRICH, Frank WINKLER
10. Dong, Q., Dargie, W.: Evaluation of the Reliability of RSSI for Indoor Localization, August 2012
11. Park, J., Jung, M.A., Yoon, S., Lee, S.R.: System design for location determination inside the ship. J. Korean Inst. Commun. Sci. **38**(2), 181–188 (8 p.) (2013)
12. Hatami, A., Pahlavan, K.: Comparative statistical analysis of indoor Positioning using empirical data and indoor radio channel models. In: IEEE Communications Society Subject Matter Experts for Publication in the IEEE CCNC 2006 Proceedings, pp. 1018–1022 (2006)
13. Heo, S.J., Cho, C.H., Kim, J.Y.: Advertising implications of beacon technology - focusing on tam to predict user acceptance of beacon application. Korean J. Advert. Public Relat. **17** (3), 98–137 (2015)
14. Smith, T.F., Waterman, M.S.: Identification of common molecular subsequences. J. Mol. Biol. **147**, 195–197 (1981)