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An Indoor Autonomous Positioning System including Emergency Signal Distribution Functions

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***Abstract*—In this paper, we propose an indoor autonomous positioning system with an emergency signal distribution mechanism. In normal situations, this system can provide some indoor navigation services using mobile devices, whereas in abnormal situations, under this system, the mobile device can receive emergency signals. Namely, our proposed system can distribute emergency signals. Moreover, in the emergency case, the information on current positions in addition to emergency situations can be provided, because the position estimation in the proposed system can be continued even if the emergency signal is distributed. This point is the main contribution in the indoor positioning system research field. We verify the proposed system at Yokohama Landmark Plaza which is one of the popular shopping malls in Japan. The experimental results show that the proposed positioning system can work effectively for the services in the normal and abnormal cases.**

***Keywords* — Indoor Autonomous Positioning; Indoor Navigation; Particle Filter; Emergency Signal Distribution.**

I. INTRODUCTION

Recently, many services using smart phones or mobile phones have been proposed with the development of ubiquitous computing technologies. As one of the typical examples, there exists the indoor positioning technique. This technique is useful in the place where the radio wave for the GPS is not received.

The positioning system might be roughly divided into two types: server-side positioning system and autonomous positioning system. In the server-side positioning system, all information used for the positioning are transferred to a server, and then the position is estimated in the server. The merit of the system might be that all user's position information can be understood. However, the demerit might be that as increasing the number of users, a heavy calculation is imposed to the server, and hence the positioning service will be stopped. As the conventional server-side positioning systems, for example, the system based on wireless LAN (e.g., RADAR [1], Ekahau [2], AirLocation II [3]), the system using Zigbee network[4], and the system carried out with UWB [5] have been proposed until now. On the other hand, in the autonomous positioning, the system using GPS is the most famous one. This system works stably, even if the number of users is increased. In the conventional indoor autonomous positioning system, the indoor the GPS method (IMES) has been developed [6], but the number of conventional systems is not so much.

In this paper, we propose an indoor autonomous positioning system using our own sensor network platform. The proposed network is consisted of two our original protocols, each of which is called ComPass-B and ComPass-B ESD, respectively, in this paper. The ComPass-B is a protocol with respect to the packet used to estimate users' positions. The ComPass-B ESD is a protocol with respect to the packet used to transmit emergency information to the user. Namely, the proposed system has capability of estimating user's positions and sending emergency information simultaneously. Showing this new approach is the main contribution of this paper. The packet is transmitted by using our original sensor node which is based on IEEE802.15.4 and ZigBee, where the sensor node is called ComPass-Z in this paper. Users carry mobile devices with the user-side ComPass-Z and the user's position is calculated in the mobile device and then the estimate position and/or emergency information are shown in the mobile device, where the mobile device is assumed to be e.g., smart phones and cellular phones, and the user-side ComPass-Z is basically the same as the one placed at indoor environments.

In order to show the effectiveness of the proposed positioning system, we install and test the proposed system at the Yokohama Landmark Plaza (YLP) which is one of the popular shopping malls in Japan. The experimental results are presented to show the validity of the proposed positioning system.

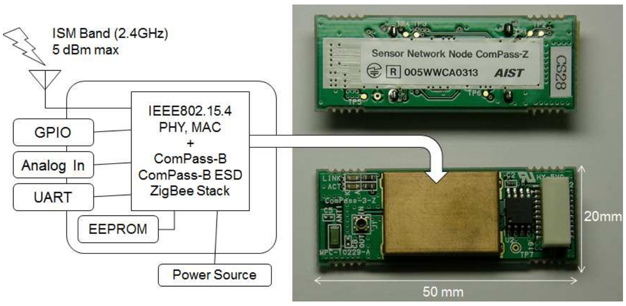


Figure 1. The Architecture and PCB Image of ComPass-Z.

II. THE PROPOSED METHOD

A. *ComPass-Z: The Proposed Sensor Node Based on IEEE802.15.4 and ZigBee*

The proposed positioning system is assumed to be a sensor network which is consisted of a number of sensor nodes, where the sensor node is called ComPass-Z in this paper. The ComPass-Z is shown in Fig. 1. The ComPass-Z consists of an integrated MPU module including, e.g., an AD converter, an IEEE802.15.4 radio baseband module, a surface mounted antenna, and so on (see Fig.1). Some sensors, e.g., temperature, humidity, and acceleration sensors can be attached into the outer connector. The ComPass-Z has been certified by the governmental agency (TELEC: 005WWCA0313).

A number of ComPass-Zs are placed at indoor environments. Then a wireless sensor network is constructed and in the network area, the positioning system is carried out.

B. *The proposed positioning system*

The proposed positioning system is implemented by using beacon packets transmitted from the ComPass-Z. The position estimation is carried out in the user's mobile device with the user-side ComPass-Z, where the communication between the ComPass-Z placed at the indoor environment and the user-side ComPass-Z is implemented with the ComPass-B protocol. The overview of the proposed positioning system is shown in Fig. 2.

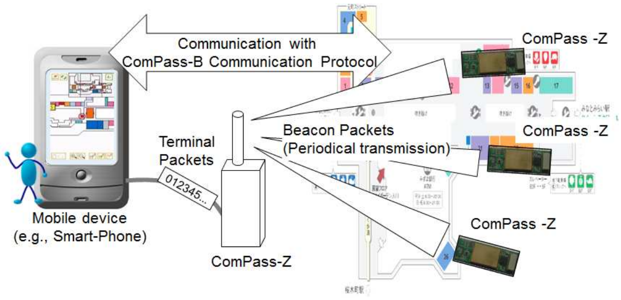


Figure 2. The proposed indoor autonomous positioning system with the ComPass-Z.

The proposed positioning algorithm utilizes two radio signal strength (RSS) patterns transmitted from the beacon packets; one is the reference RSS patterns which are pre-observed at a number of positions, the other is the current RSS pattern corresponding to the current position. Namely, by matching these two patterns, the current position is estimated. In this paper, this matching is carried out by using a particle filtering. Fig.3 shows the procedure of the particle filtering of our proposed positioning algorithm.

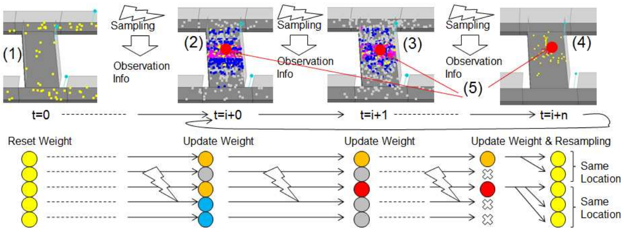


Figure 3. The Overview of Particle Filter for Positioning.

In Fig.3, the procedures of (1) to (4) are as follows:

(1) Initialize the particles,

(2) Compare the current RSS pattern with the reference RSS patterns for the locations of the particles, using the Manhattan distance,

(3) Update the weights of the particles using the comparison result,

(4) Resampling the weights of the particles,

where (5) in Fig.3 represents the estimated position by the particle filtering, which is calculated by the weighted average for the weight values of the particles.

C. *The emergency signal distributing system*

In the emergency distribution case, at first, the administrator of the system transmits an emergency packet (E-Packet) to the ComPass-Z placed at the indoor environment. Next, the ComPass-Z receives an emergency message from the E-Packet, and then transmits the beacon packet with the emergency message (E-Packet) to the user's mobile device. Then, the communication between the ComPass-Z placed at the indoor environment and the user-side ComPass-Z of the mobile device is implemented with the ComPass-B ESD. Finally, the message is shown in the mobile device and then the user recognizes an emergency situation. Fig.4 shows the procedure of the emergency signal distributing system.

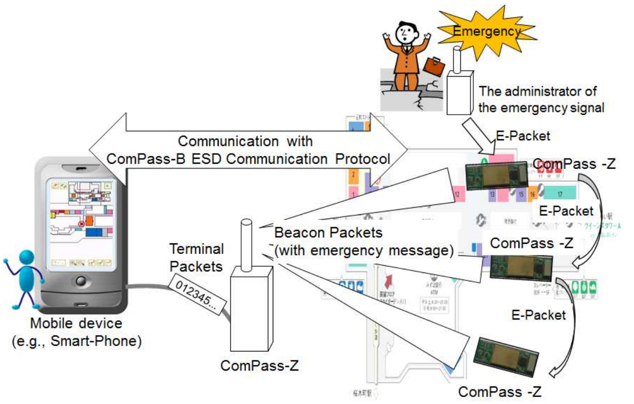
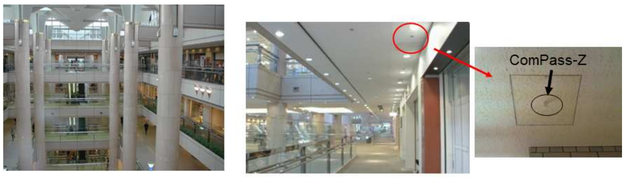


Figure 4. The procedure of the emergency signal distributing system.

We note that the beacon packet with the emergency message can be also used to estimate the user's position, and hence the user can recognize his or her own current position in addition to the emergency information. Therefore, our system can provide such a service that the location of the emergency exit which is the nearest to user's current position can be indicated.

III. THE EXPERIMENTAL RESULTS

We installed the proposed positioning system into the YLP. Fig.5 shows the overview of the setup of the system.



(a) The interior of the YLP (b) The setup position of the ComPass-Z

Figure 5. The overview of the proposed positioning system in the YLP.

A number of ComPass-Zs were set to the ceilings of the corridors of 2F, 3F, and 4F in the YLP, where each ComPass-Z uses the commercial AC power source. As the user mobile device, a smart phone (Softbank X02T) was used, where the user-side ComPass-Z was connected with the smart phone via Bluetooth (see Fig.6).

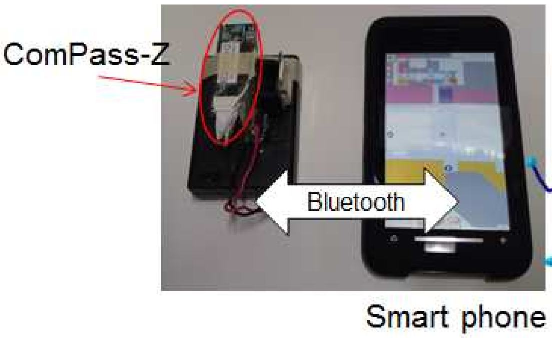


Figure 6. The user mobile device.

A. *The positioning experiment results*

To demonstrate the validity of the proposed system, many experiments were conducted. In this subsection, a tracking estimation result is shown. A person carrying the smart phone (see Fig.6) walked on a corridor of the fourth floor in the YLP. Then the RSS values with respect to each track point were received by the user-side ComPass-Z and the RSS values were transmitted to the smart phone via Bluetooth. Fig.7 shows the track points of the person changing with time (green dot-link-line), where the track points represent a ground truth plotted every one second. In the smart phone, the positioning algorithm using a particle filtering is executed based on the RSS values at each track point, and by using the reference RSS values with respect to the positions of scattered particles, the true track point is estimated, where the number of particles is set to be 500. The red dot-link-line in Fig.7 represents the tracking estimation result. From this result, it can be seen that the average error distance between the estimated positions and the true track points was 2.66 m, where it is assumed that the person walks with a constant speed (1m/s).

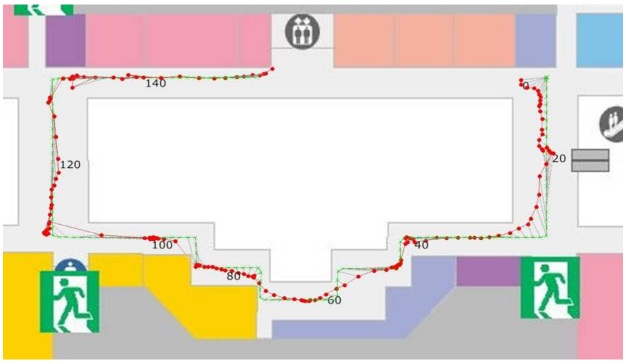


Figure 7. The tracking estimate result using the particle filter.

Let us consider the case of a positioning algorithm without using the particle filtering. Namely, by matching the current PSS pattern with all reference RSS patterns with respect to the track points (all green dots), the true track point is estimated. The red dot-link-line in Fig.8 represents the estimate result. It can be seen that the estimation error (5.69 m) is much worse than the result obtained by using the particle filtering. From these results, we conclude that in the indoor positioning in large buildings where there exist many people and a lot of wireless signals, the particle filtering is an effective algorithm for the positioning and/or tracking.

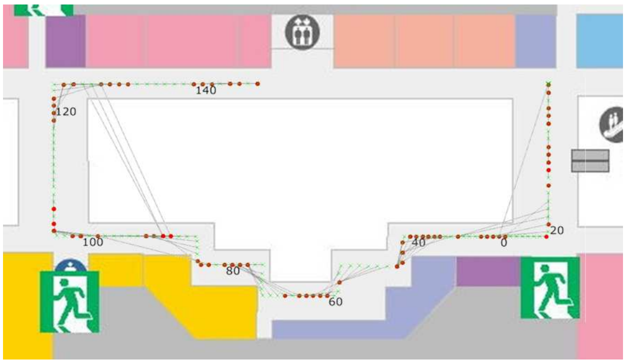
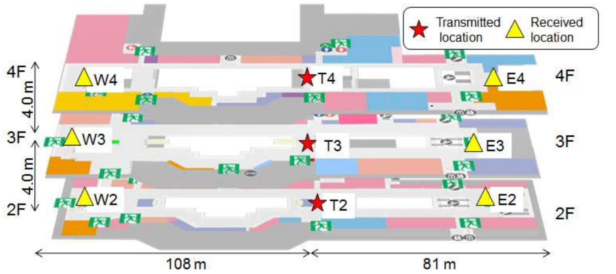


Figure 8. The tracking estimate result without using the particle filter.

B. *The propagation speeds of emaergency signals*

In this subsection, the propagation speed of the emergency packet (E-Packet) of the proposed emergency signal distributing system is shown. Fig.8 shows the measurement condition and the result.



Time Distance Speed		To West Side			To East Side		
		W2	W3	W4	E2	E3	E4
From	T2	5.66 S 103.94 m 18.91 m/S	5.20 S 104.017 m 20.56 m/S	5.49 S 104.25 m 19.58 m/S	7.22 S 71.70 m 10.70 m/S	4.59 S 71.80 m 19.62 m/S	5.29 S 72.14 m 15.67 m/S
	T3	4.23 S 99.87 m 25.67 m/S	3.97 S 99.79 m 29.61 m/S	4.85 S 99.87 m 22.51 m/S	6.40 S 76.53 m 12.69 m/S	4.40 S 76.43 m 18.61 m/S	5.80 S 76.53 m 14.51 m/S
	T4	3.90 S 101.96 m 27.68 m/S	3.61 S 101.72 m 29.65 m/S	3.93 S 101.64 m 27.46 m/S	7.22 S 80.05 m 11.49 m/S	5.28 S 79.75 m 15.91 m/S	7.01 S 79.65 m 12.18 m/S

Figure 9. The results of the propagation speed tests of emergency signals.

In the measurement condition (see the upper figure in Fig.9), the E-Packet was transmitted from three locations (red star, T2, T3, and T4) which are the middle place of each floor (2F, 3F, and 4F) in the YLP, and the receive points are 6 locations (yellow triangle, E2, E3, E4 and W2, W3, W4) which are the east and west sides of each floor in the YLP. The lower figure in Fig.9 shows the results of the propagation speed for each pair of the transmitted and received locations. From these results, it is seen that the average transmitted speeds for the east and west sides are 14.7 m/sec and 24.6 m/sec, respectively. The message of the emergency signal can be delivered to the user within about 7 sec.

For example, since the quake time of big earthquakes is more than ten seconds, if the emergency message (e.g., emergency exit information) is transmitted to the user at the same time when the earthquake early warning whose service is provided by the Meteorological Agency in Japan is announced, then the emergency message may be an useful information for the user, because the user cannot move during earthquake and the emergency message can be received within at most seven seconds.

IV. DISCUSSION AND CONCLUSIONS

We have proposed an autonomous positioning system with an emergency signal distributing system. In the proposed positioning system, since the estimate error is about 2.6 m, it is considered that the system can be applied to an indoor navigation service (see Fig.10(a)) which is capable of indicating direction guides at the intersection of corridors (see Fig.10(b)).

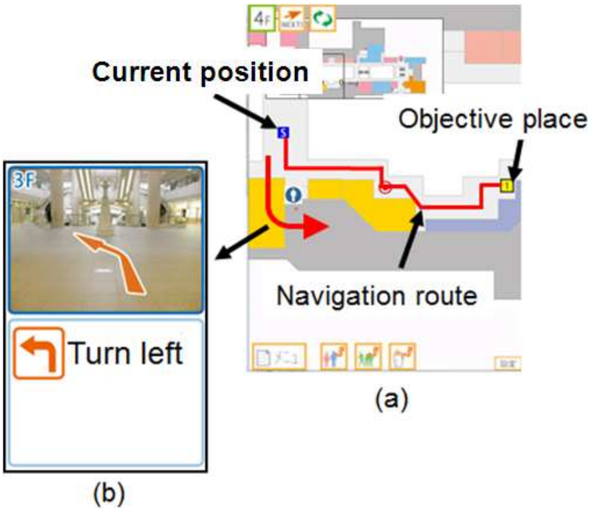


Figure 10. An indoor navigation service

By using the ComPass-B ESD, our system can achieve the positioning and the emergency signal distributing simultaneously. Therefore, in ordinary situations, the proposed system can provide indoor navigation services (see Fig.11(a)), whereas in emergency situations, the proposed system can be used as an evacuation guidance system, which can provide the nearest emergency exit to the current user location (see Fig.11(b)). Therefore, our proposed system can provide the positioning and the emergency signal distributing services simultaneously. This new approach is the main contribution in the indoor poisoning field.

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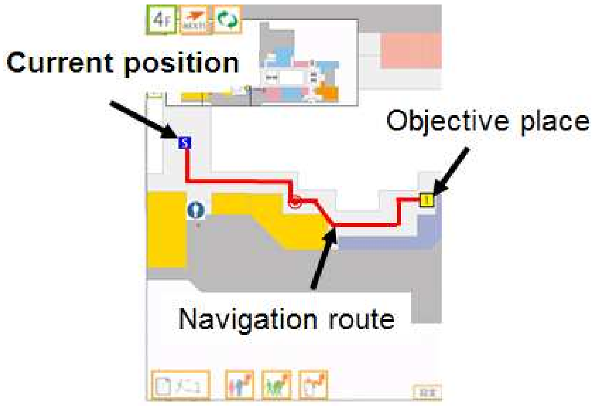

(a) Ordinary situation

(b) Emergency situation

Figure 11. An indoor navigation service.

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