ComEX

IEICE Communications Express, Vol.1, No.2, 72–77

ZigBee-based scheme for location information and data transmission

Takefumi Hiraguri[1a)], Hiroshi Takase[1], Takuya Sugishita[1], Takayuki Kimura[1], Minoru Aoyagi[1], and Kentaro Nishimori[2]

[1] *Faculty of Engineering, Nippon Institute of Technology*
4–1 Gakuendai, Miyashiro-machi, Saitama, 345–8501, Japan
[2] *Graduate School of Science and Technology, Niigata University*
8050 Ikarashi 2-no-cho, Nishi-ku, Niigata 950–2181, Japan
a) *hira@nit.ac.jp*

Abstract: This paper proposes a ZigBee-based system and scheme to obtain location and vital health information. ZigBee systems are wireless communication systems defined by IEEE 802.15.4. Location information is obtained using a Link Quality Indication (LQI) function of the ZigBee system, which means the received signal strength. Vital health information is received as ZigBee sensor data when the terminal stations are moving. The proposed scheme facilitates the management of action history and health conditions for medical patients. Experiments using an actual ZigBee system confirm that the proposed scheme provides accurate location and vital health information using sensor data.

Keywords: ZigBee, sensor data, location and route information
Classification: Terrestrial Wireless Communication/Broadcasting Technologies

References

[1] IEEE 802.15.4-2006 Std., “Wireless Medium Access Control and Physical Layer Specifications for Low-Rate Wireless Personal Area Networks,” IEEE Computer Society, Sept. 2006.
[2] J. Blumenthal, R. Grossmann, F. Golatowski, and D. Timmermann, “Weighted Centroid Localization in Zigbee-based Sensor Networks,” *Proc. IEEE WISP 2007*, Digital object ID 10.1109/WISP.2007.4447528, Oct. 2007.
[3] C. Gomez, A. Boix, and J. Paradells, “Impact of LQI-Based Routing Metrics on the Performance of a One-to-One Routing Protocol for IEEE 802.15.4 Multihop Networks,” *EURASIP Journal on Wireless Comm. and Networking*, vol. 2010, Article ID 205407, July 2010.
[4] Rec. ITU-R P.1238-6, “Propagation data and prediction methods for the planning of indoor radio communication systems and radio local area networks in the frequency range 900 MHz to 100 GHz,” ITU-R Recommendations, 2009.
[5] [Online] http://www.threet.co.jp/zigbee/
[6] H. Ssuzuki, T. Hiraguri, and H. Takase, “Evaluation of Sensor Data Trans-

DOI: 10.1587/comex.1.72
Received June 06, 2012
Accepted June 20, 2012
Published July 10, 2012

IEICE Communications Express, Vol.1, No.2, 72–77

mitting with Restricted Communication area on ZigBee system," *Proc. IEICE general conf. 2012*, B-8-37, March 2012.

1 Introduction

This paper proposes a concept and scheme for the management of action history and health conditions of patients and residents in a hospital or medical and welfare institution in order to provide comprehensive medical care. The proposed system is composed of a terminal station and multiple access points of ZigBee, which is defined by IEEE 802.15.4 [1]. The user moves while carrying a ZigBee terminal. We aquire the location information by the received signal strength indicator (RSSI) obtained when the ZigBee terminal connects to the access point. Furthermore, information about body functions of the user (temperature, pulse, blood pressure, etc.) is simultaneously transmitted to an outside network in the form of several hundred kilobytes of sensor data via the access points of ZigBee. This system can facilitate the management of action history and health conditions of patients and residents. However, for practical usage, the method to obtain reliable location information and bodily function information must be improved by considering the variation due to the given propagation environment [2].

In this study, the communication area is optimally controlled, and hence, reliable location information is obtained. The terminal station connects to the specific access point by utilizing the radio propagation characteristics. The effectiveness of the proposed scheme was confirmed by experiments.

2 Proposed system and scheme

The proposed system is configured using multiple ZigBee Routers (ZRs) of access points and a ZigBee End Device (ZED) of a terminal, as shown in Fig. 1 (a). The user carries the ZED, and the ZED connects to ZRs whenever the user moves. Then, the ID and Link Quality Indication (LQI) information [5] is obtained for the ZR that the ZED connects to. This information is sent to the ZigBee Coordinator (ZC) that controls the ZR in a centralized manner. LQI is an RSSI, which is used in the ZigBee system, and it is set to an individual value obtained by normalizing the received power to a value between 1 and 255 [1, 3]. The ZC manages the location information and the migration pathway based on the location information, which is saved on the Personal Computer (PC) in the outside network. In control management of the PC in the proposed scheme, the value "1" is set when the ZED approaches a ZR, and the value "0" is set when the ZED moves away from a ZR. Thus, the value "1" or "0" is set according to the value of LQI. These values are managed in the time specific to each ZR. Therefore, the system administrator can determine the movement history of the user with the help of these values if ZR is configured at the pre-determined location in advance.

However, it is difficult to determine the threshold value of LQI when

DOI: 10.1587/comex.1.72
Received June 06, 2012
Accepted June 20, 2012
Published July 10, 2012

ComEX

IEICE Communications Express, Vol.1, No.2, 72–77

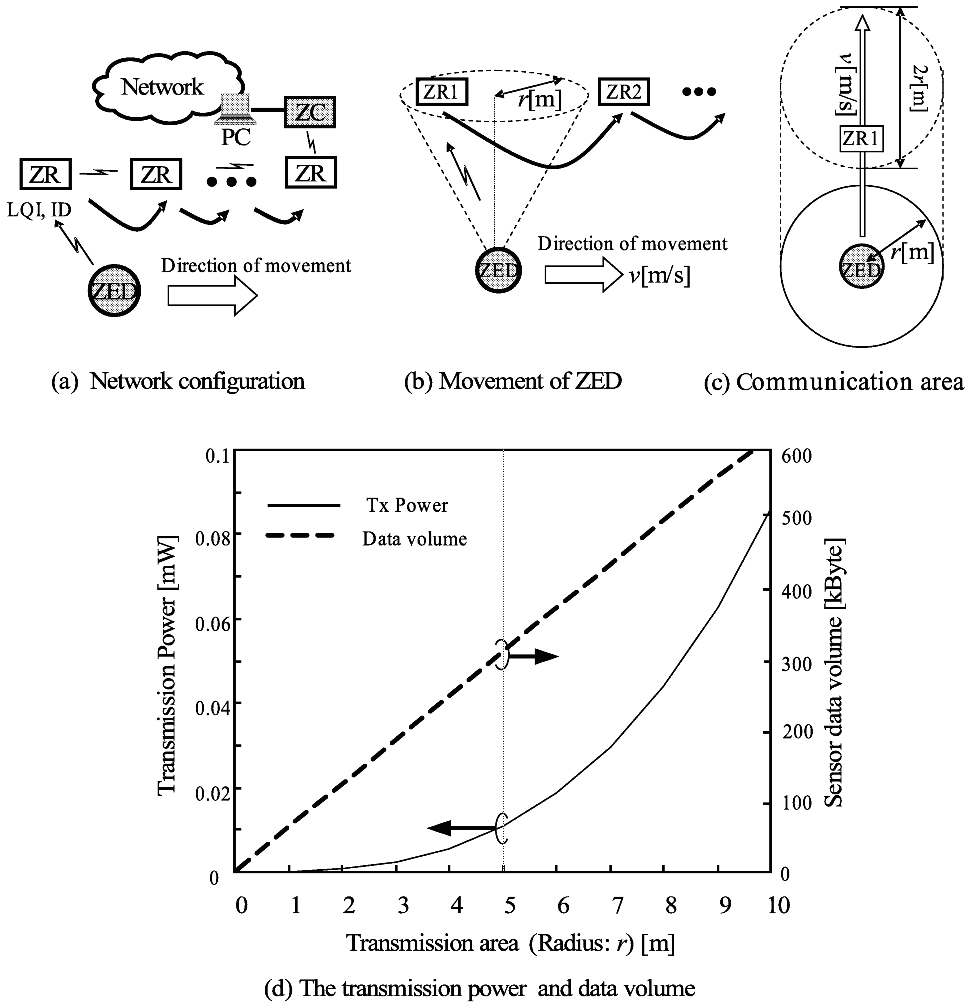


Fig. 1. Network configuration and communication area

the values "1" and "0" are based on RSSI because the propagation environment changes owing to factors such as multipath signals, shadowing effect, or both, especially in indoor scenarios. This effect may cause errors in the determination of the ZR that is the nearest to the ZED.

This issue is addressed by controlling the communication area of a ZED such that the ZED can connect to the nearest ZR. The radius of the communication area of the ZED is set to r [m], and the ZED communicates with the nearest ZR as shown in Fig. 1 (b). The key point is that the communication area is controlled within a range that is outside the range of ZR2. Therefore, the transmitting power of ZED is adjusted, and a small communication area can be considered. A tangible explanation can be provided as follows:

When the communication area is extremely small, the ZED cannot connect to the ZR with which it wishes to communicate. Moreover, the ZED transmits sensor data related to vital health information to the ZR when the ZR or user is moving, and hence, the transmission of this information is impossible if the area is extremely small. Let the walking speed of a human be v [m/s] and the link rate of ZigBee be R_L [bps]. When the ZR passes the center of the communication area of the ZED, as shown in Fig. 1 (c), the volume of sensor data with vital health information that the ZED can

DOI: 10.1587/comex.1.72
Received June 06, 2012
Accepted June 20, 2012
Published July 10, 2012

IEICE Communications Express, Vol.1, No.2, 72–77

transmit is represented as:

$$c = \frac{2rR_L}{8v}, \tag{1}$$

where c [KB] is the volume of sensor data. For example, the data volume c is approximately 300 KB if the walking speed of a human $v = 1.0$ m/s, the radius of the communication area $r = 5$ m, and ZigBee link rate $R_L = 250$ Kbps (The link rate is in conformance with ZigBee IEEE 802.15.4 standard.). Next, the transmission power to control the communication area radius is calculated as follows:

$$P_t = P_r - (G_t - L_p + G_r) \tag{2}$$

$$L_p = 10\log_{10}\left(\frac{4\pi r}{\lambda}\right)^n \tag{3}$$

where P_t is the transmitted power [dBm], P_r is the received power [dBm], G_t/G_r is the antenna gain at the transmitter or receiver [dBi], and L_p is the propagation path loss [dB]. P_t is determined by the relation between P_r and r because the reception sensitivity of RSSI is -97 dBm in this module. G_t and G_r are set to 2 dBi. L_p in Eq. (3) is calculated from the radius of the communication area and λ (i.e. $\lambda = 1$/frequency: 2.4 GHz). The path loss coefficient n is set to 3 because this system is assumed to be indoors [4].

By using Eq. (1) to Eq. (3), plots of the transmission power (P_t) and sensor data volume (c) versus the radius of the communication area r are obtained, as shown in Fig. 1 (d). The unit "dBm" is converted to "mW" Fig. 1 (d) for better understanding.

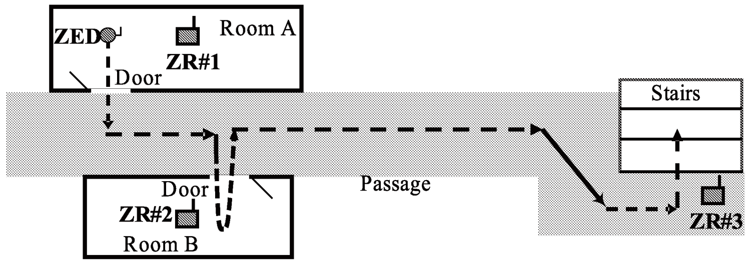
We assumed the amount of transmission data to be 300 KB in one communication ZR area. In Fig. 1 (d), this situation corresponds to a communication area radius of 5 m. Under this condition, the transmission power is 0.01 mW, and hence, P_t is controlled by this value.

3 effectiveness of proposed scheme by experiments

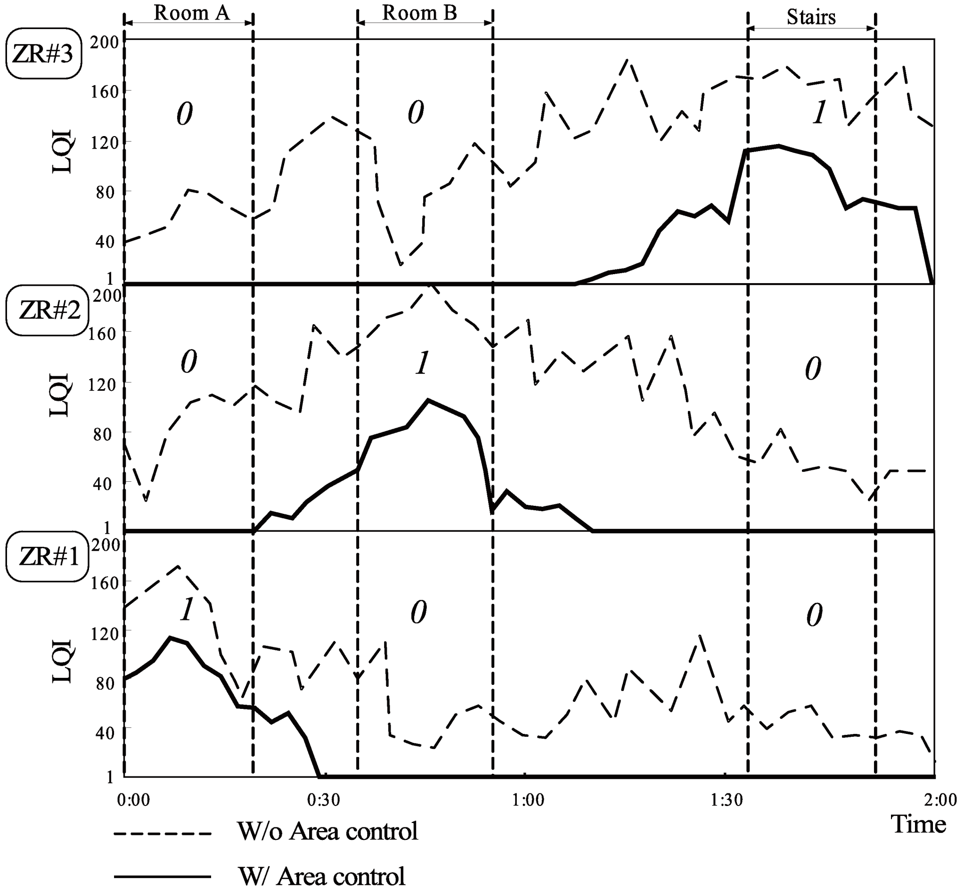
The performance of the proposed scheme was demonstrated by experiments. The experimental setup consisted of three ZRs and a ZED terminal that was moved. The route of the ZED is shown in Fig. 2 (a). The specification of ZigBee module (IMI-Z-M-001) [5] is shown in Table I. The ZED holder was moved in Room A, in Room B, and along the stairs as shown in Fig. 2 (a). ZR#1, ZR#2 were located inside Room A and Room B, respectively. ZR#3 was positioned in front of the stairs. The ZED holder entered Room B after leaving Room A. Next, the ZED holder moved to the stairs. The value of LQI measured in the experiment is denoted in Fig. 2 (b). The solid lines in the figure represent the measurement results with area control versus the time. The dotted lines indicate the results obtained by using a default value of transmitting power (1 mW) without area control. The power transmitted by the proposed scheme became 0.01 mW, except at the target point, using area control. In Fig. 2 (b), first, the decision of ZR#1 was set to "1" because the LQI of ZR#1 is higher than the LQI of the other ZR. Next, the decision was set to "1" because the LQI of ZR#2 became a large value. For

DOI: 10.1587/comex.1.72
Received June 06, 2012
Accepted June 20, 2012
Published July 10, 2012

IEICE Communications Express, Vol.1, No.2, 72–77



(a) Route of ZED



(b) LQI value versus time line

Fig. 2. Route of ZED and evaluation result in experiment

Table I. IMI-Z-M-001 Module specification

Reception sensitivity	−97 dBm
Transmission power	1 mW (Default) 0.01 mW (w/ Area control)
Link rate	250 kbps
Frequency	2.4 GHz

these evaluation results, the determined pattern indicates that the ZED terminal holder moved from Room A to Room B. Finally, the LQI of ZR#3 increased, and the decision was set to "1". When the values "1" or "0" in ZR#1, ZR#2, and ZR#3 were recorded, the pattern [100], [010], and [001] is obtained in the proposed scheme. This pattern represents a route

DOI: 10.1587/comex.1.72
Received June 06, 2012
Accepted June 20, 2012
Published July 10, 2012

IEICE Communications Express, Vol.1, No.2, 72–77

from Room A to Room B, and Room B to the stairs. If some patterns are pre-generated, the system administrator may easily determine the route via pattern matching.

However, when a default value of transmitting power is used without area control, it is difficult to obtain accurate location information because the change in the value of LQI is unclear. Moreover, in the scheme without any area control, it may not be possible to specify the ZR nearest to the ZED owing to the ZED being connected to multiple ZRs. On the other hand, when the area control is used, the change in the value of LQI is clear, although the level is lower. From the experimental results, it was confirmed that the proposed scheme provided more accurate operation when the best area radius was selected.

In the proposed scheme, ZED can clearly detect only the ZR of the line-of-sight in order to limit he transmission power of the ZED. The multipath signal from the ZED barely transmits to the ZR beyond the line-of-sight. The results in Fig. 2 (b) are reliable because the same results are obtained when this experiment is repeated 10 times.

However, in Eq. (1) of the theoretical calculation, the sensor data volume was estimated when the ZR passed the center of the communication area. In the real application environment, a different route that does not pass the center may be taken. This issue will be clarified in near future, because an evaluation based on the theoretical analysis has been employed [6]. In Ref. [6], the data volume of about 50% is transmitted, when theZED runs though one ZR. Moreover, the transmission probability of data volume will be able to be improved, if the ZED passed two or more the ZR like the network configuration in this paper. Our future work will involve the evaluation and experiment regarding this issue.

4 Conclusion

In this letter, we proposed a system and scheme that obtains location information and vital health information using a ZigBee system. The experimental results showed that the proposed scheme operates accurately when the best area radius is selected.

DOI: 10.1587/comex.1.72
Received June 06, 2012
Accepted June 20, 2012
Published July 10, 2012