Personal Identification Based on Radio Signal Strength for Ubiquitous Healthcare Systems

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Abstract

Personal identification is essential for the automatic measurement of biosignal information in home healthcare systems. Personal identification is usually achieved with passive radio frequency identification (RFID), which does little more than store a unique identification number. However, passive RFID is not ideal for automatic identification. We present a user identification system based on radio signal strength indication (RSSI) using ZigBee for active RFID tags. Personal identification is achieved by finding the largest RSSI value from aggregated beacon messages that are periodically transmitted by active RFID tags carried by users. Obtaining reliable personal identification without restricting the orientation requires a certain distance between the closest active RFID tag from the ZED and the second closest tag. The results show that the closest active RFID tag from the ZED and the second closest tag must be at least 70 cm apart to achieve reliable personal identification.

Key words : healthcare, personal identification, active RFID, RSSI, ZigBee

I. INTRODUCTION

Healthcare is under pressure to improve the quality of care delivered to patients through effective prevention and postoperative care. However, there is also the need to curtail the growth in healthcare spending that has been fueled by aging populations, obesity, diabetes, cancer and chronic heart and lung diseases [1].

Miniaturized implantable and on-body wireless biosensors will change current clinical practices, especially in terminal illness, by monitoring the progression of chronic disease and assessing postoperative care and body reactions to complex therapeutic drug regimes. Ubiquitous healthcare systems monitor patients during normal everyday activities to warn the patients or healthcare workers of problems, as well as to collect data for trend analysis and medical research. The use of continuous monitoring circumvents the drawbacks of conventional diagnostics and monitoring, allowing both transient and progressive abnormalities to be reliably captured.

Nonintrusive biosignal acquisition techniques that do not restrict normal life activities are necessary for the ubiquitous healthcare environment [2]. Personal identification is essential for automatic gathering of biosignal information in healthcare systems. Active radio frequency identification (RFID)-based user ID tagging is less intrusive than barcode or passive RFID. Tags can be read automatically without disturbing users, enabling a fully automated solution for accurate personal identification with reduced labor costs and fewer manual errors.

II. RELATED WORK

RFID tags can be either passive or active [3]. Passive RFID tags do not require a battery. They reflect the RF signal transmitted to them from a reader and add information by modulating the reflected signal. Passive tags are mainly used to replace the traditional barcode technology and are much lighter and less expensive than active tags, with a virtually unlimited operational lifetime. However, the effective range is very limited. Active tags contain both a radio transceiver and a battery to power the transceiver. The onboard radio gives active tags a greater range than passive tags. Especially, active tags can be read automatically without disturbing users.

The attenuation of radio signal power with distance is an attractive property that could be used to estimate the distance of small transmitters. Radio signal strength indication (RSSI) has attracted a lot of attention in the recent literature for obvious reasons [4], [5], [6], [7], [8], [9]. RSSI eliminates the need for additional hardware in small wireless devices, and exhibits favorable properties with respect to power consumption and cost.

Existing methods are based on IEEE 802.11 stations with powerful 100 mW radio transmitters. These are a different class than the low-powered IEEE 802.15.4-compliant radios that have power levels ranging from 25 mW to 52 mW [10]. The wide availability of IEEE 802.15.4 radios has increased the interest in using signal strength in sensor networks.

Despite the popularity of IEEE 802.15.4 radios and signal strength localization, the development of personal identification systems using RSSI information has not been undertaken.

We created a ZigBee (IEEE 802.15.4)-based sensor network to acquire biosignals. Beacon nodes were used as active RFID tags to transmit periodical beacon messages, and a ZigBee End Device (ZED) was used to receive and collect biosignal information, and for use as a personal identification reader.

III. PERSONAL IDENTIFICATION

A. Personal Identification Overview

Figure 1 shows an overview of the personal identification for ubiquitous healthcare. RFID tags (ID1~ID4) continuously broadcast periodic beacon messages with the format <DeviceID, sourceID>. DeviceID represents a particular device used as a personal identifier beacon for healthcare purposes. SourceID is the unique identifier of the RFID tag. A medical device or instrument that uses the ZED to determine a user's identification listens for a period of time to acquire a signature consisting of a set of beacon messages. The ZED is connected to the medical device or instrument through a universal asynchronous receiver/transmitter (UART).

Personal identification works as follow. When a user attempts to access a medical device or instrument, the ZED starts to aggregate periodic beacon messages from active
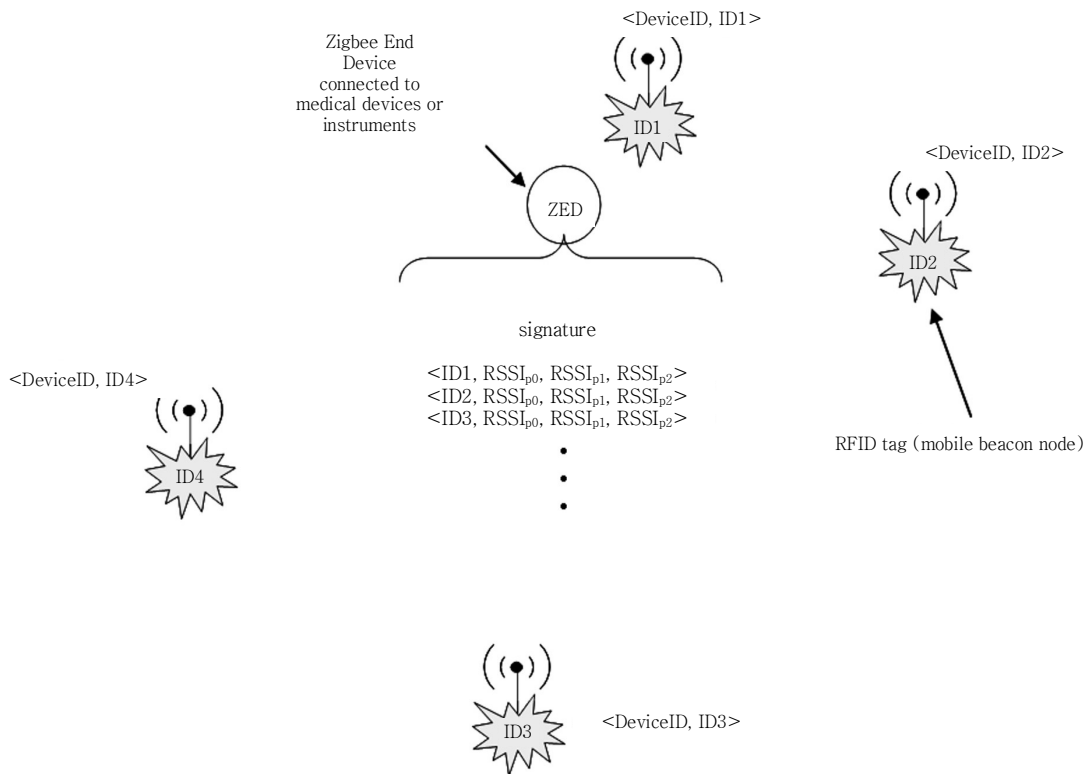

Fig. 1. The personal identification system. ID1, ID2, ID3 and ID4 are active RFIDs (beacon nodes) that broadcast beacon messages at regular time intervals. The ZED is connected to medical devices or other instruments using a UART, which can receive from some active RFIDs. It aggregates beacon messages received over 1s periods into signatures.
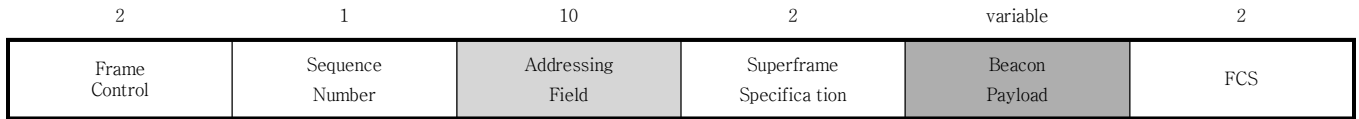
2	1	10	2	variable	2
Frame Control	Sequence Number	Addressing Field	Superframe Specifica tion	Beacon Payload	FCS

Fig. 2. Beacon frame format.

RFID tags as signatures for a given time duration. A signature consists of a set of messages of the form <sourceID, RSSIp1, RSSIp2, RSSIp3>. SourceID is the unique identifier of the RFID tag, and the RSSI of a given transmission power level is the mean received signal strength indication of a set of received beacon messages for the active RFID tag. User identification is achieved by finding sourceID with the largest RSSI value from the signature pool.
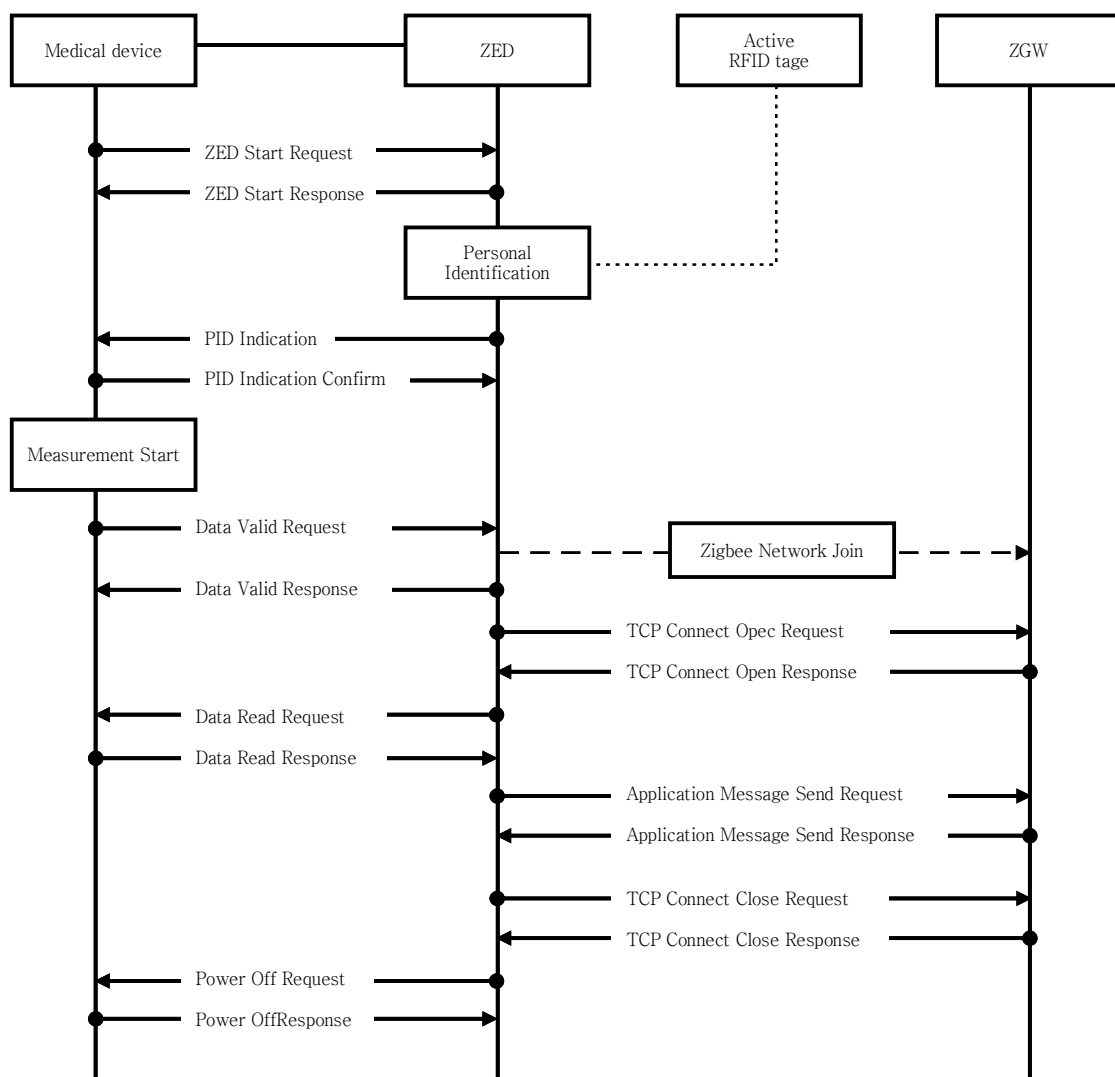

Fig. 3. Communication command and operation flow. As a user attempts to access a medical device or instrument, the ZED in sleep mode wakes up. The ZED then aggregates beacon messages from active RFIDs for personal identification. The medical device begins to acquire data from the user. Acquired data is then sent to a server through the ZigBee gateway (ZGW).

B. Beacon Generation

ZigBee networks can use beacon or nonbeacon environments [10]. Beacons are used to synchronize the network devices, identify the Home Area Network (HAN) and describe the structure of the superframe. The beacon intervals are set by the network coordinator and vary from 15 ms to 252 s. Sixteen equal time slots are allocated between beacons for message delivery. The beacon mode is a mechanism for controlling power consumption in an extended network such as a cluster tree or mesh. It enables all clients to know when to communicate with each other. The two-way radio network has a central dispatcher that manages the channel and arranges the calls. The primary value of the beacon mode is that it reduces the system's power consumption. Beacon mode is more suitable when the network coordinator is battery operated. The client units listen for the network coordinator's beacon. A client registers with the coordinator and looks for any messages directed to it. If no messages are pending, the client returns to sleep mode, awaking on a schedule specified by the coordinator. Once the client communications are completed, the coordinator itself returns to sleep. The beacon signal is generated by beacon nodes with described characteristics.

Figure 2 shows the beacon frame format for the ZigBee we used. 0xCAFE was the value used in addressing a field as a unique <DeviceID> to distinguish it from other ZigBee devices. It indicated that it was a personal identifier for healthcare purposes. <sourceID> and transmission power level were assigned in the beacon payload area.

The Chipcon CC2420 IEEE 802.15.4 supports eight discrete power levels, 0 dBm, -1 dBm, -3 dBm, -5 dBm, -7 dBm, -10 dBm, -15 dBm and -25 dBm, with power consumption varying from 25 mW to 52 mW [11]. Personal identification for biosignal measurements is usually done within a 1 m radius, and we used the three weakest transmission power levels available (-10 dBm, -15 dBm and -25 dBm). Multiple transmission power levels cause a signal to propagate at various levels and exhibit different characteristics at the receiver. Therefore, varying the transmission power diversifies the set of measurements obtained by receiving nodes and increases the accuracy of personal identification.

C. Communication Command and Operation Flow

When a biosignal measurement user approaches a medical device or instrument, the device sends a <ZED Start Request> signal to wake up the ZED. When the ZED receives the start signal, it begins to aggregate beacon messages from active RFID tags for a given time period and performs personal identification using received signal strength values. When

personal identification has been made, the medical device acquires the biosignal and notifies the ZED that it has pending data to transfer. The acquired data is then transferred to a server through the ZigBee gateway.

D. Identification Based on RSSI

The most widely used signal propagation model is the log-normal shadowing model [12]:

$$RSSI(d) = P_T - PL(d_0) - 10\eta\log_{10}\frac{d}{d_0} + X_\sigma \qquad (1)$$

where P_t is the transmission power, $PL(d_0)$ is the path loss for a reference distance d_0, η is the path loss exponent, X_σ is a Gaussian random variable with zero mean and δ^2 is the variance. This models the random variation of the RSSI value.

As shown in Equation 1, if path loss and noise is minimal, the shorter the distance, the larger the RSSI value. However, ubiquitous healthcare is usually an indoor activity, with significant path loss and noise levels. Therefore, varying transmission power levels increases the accuracy of personal identification. Personal identification is achieved by finding the sourceID with the largest RSSI at all transmission power levels. This is represented in code as:

```
for(PowerLevel=0; PowerLevel<3; PowerLevel++){
    for(i=0;i<the total number of beacon nodes;i++){
        if(MAX_RSSI< RSSIPowerLevel_IDi){
            MAX_RSSI= RSSIPowerLevel_IDi;
            PIDPowerLevel=IDi;
        }
    }
    MAX_RSSI=MIN_RSSI;
}
if(PID0= =PID1= =PID2)
    PID=PID0
else ErrorMessage("Personal Identification is failed");
```

PowerLevel 0,1,2 represents each transmission power level of -10 dBm, -15 dBm and -25 dBm and ID ($PID_{PowerLevel}$) with the maximum RSSI (MAX_RSSI) is searched for each transmission power level. When a single ID with the maximum RSSI at all levels is found, personal identification has been successful.

IV. EXPERIMENTAL RESULTS

Our active RFID tags and ZED are based on ZigBee, a low power, embedded wireless device. These devices incorporate a Chipcon CC2420 radio and an 8 MHz ATmega 128L

processor. The Chipcon CC2420 IEEE 802.15.4 radio transceiver operates in the 2.4 GHz ISM band and includes a digital direct sequence spread spectrum (DSSS) modem providing a spreading gain of 9 dBm and an effective data rate of 250 Kbps. It was specifically designed for low power wireless applications. The inverted-F antenna is used as a monopole antenna for our sensor node. The height of the antenna is 17.61 mm and the length is 6.55 mm. Therefore the physical size of the antenna is 24.16 mm(17.61 mm + 6.55 mm) [10]. Figure 4 shows an operational ZigBee sensor node as implemented.
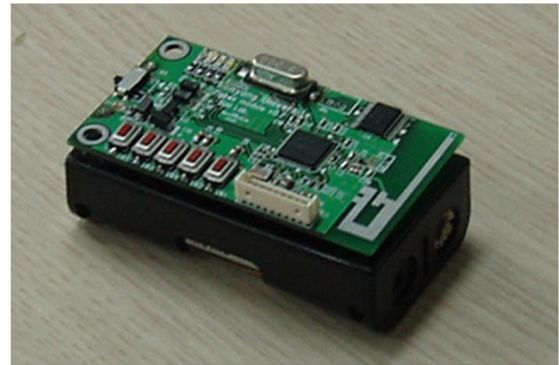
Each active RFID tag has a nonuniform radiation pattern.

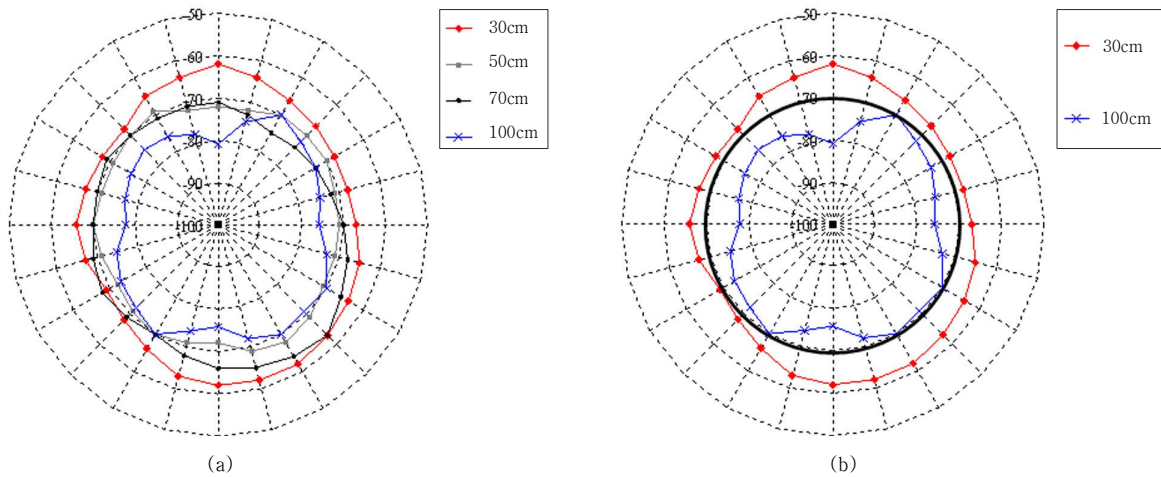**Fig. 4.** The sensor node used in our experiments.

Fig. 5. RSSI values for various distances and directions at a transmission power level of -25 dBm: (a) RSSI values at various distances (30 cm, 50 cm, 70 cm and 100 cm) and changes in direction, and (b) RSSI values at various distances (30 cm and 100 cm) and changes in direction. The circle in (b) emphasizes that RSSI values at 30 cm are always larger than the values at 100 cm.

Fig. 6. RSSI values for various distances and directions at a transmission power level of -15 dBm: (a) RSSI values at various distances (30 cm, 50 cm, 70 cm and 100 cm) and changes in direction, and (b) RSSI values at various distances (30 cm and 100 cm) and changes in directions. The circle in (b) emphasizes that RSSI values at 30 cm are always larger than the values at 100 cm.
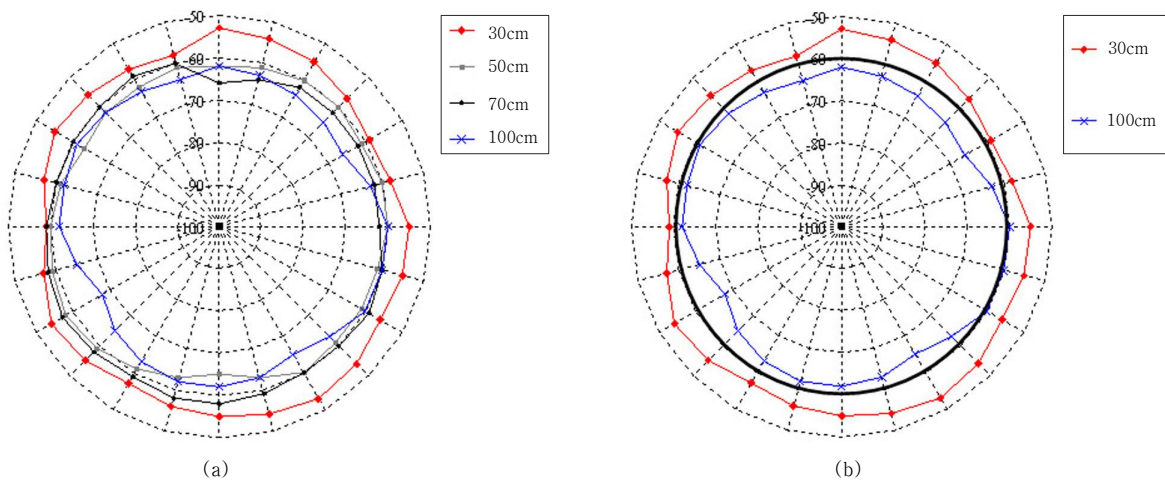
(a)   (b)

Fig. 7. RSSI values for various distances and directions at a transmission power level of -10 dBm: (a) RSSI values at various distances (30 cm, 50 cm, 70 cm and 100 cm) and changes in direction, and (b) RSSI values at various distances (30 cm and 100 cm) and changes in direction. The circle in (b) emphasizes that RSSI values at 30 cm are always larger than the values at 100 cm.
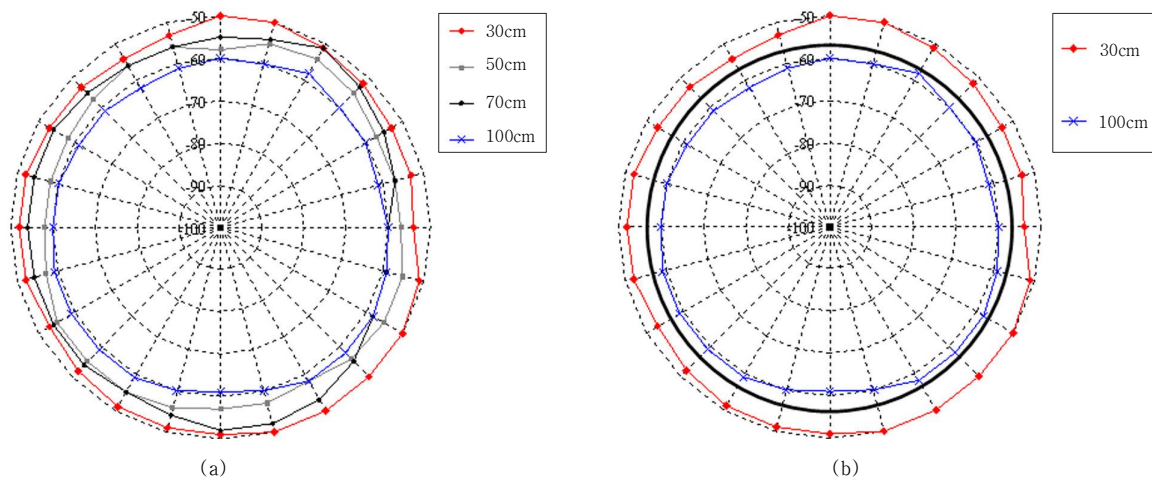
The RSSI value recorded at the receiver for a given pair of communication nodes and over a given distance separating them varies as the antenna orientation of the transmitter and the receiver are changed. Obtaining reliable personal identification without restricting the orientation requires a certain distance between the closest active RFID tag from the ZED and the second closest tag. The experiment was to determine how the RSSI changes with different directions and distances, and to determine the preferred distance for stable, personal identification. We have performed the experiment at three transmission power levels (-25 dBm, -15 dBm and -10 dBm). The RSSI value shown is the mean value from five different active RFID tags.

Figure 5 shows the changes in RSSI values for various distances and orientations with a transmission power level at -25 dBm. At short distances, RSSI values are not uniform for each of the directions tested. Figure 5(b) shows that stable personal identification for all orientations requires that the closest active RFID tag from the ZED and the second closest tag must be at least 70 cm apart.

Experimental results at the transmission power levels -15 dBm and -10 dBm are shown in Figures 6 and 7.

The results show that the RSSI increases as the transmission power level increases. It also shows that the closest active RFID tag from the ZED and the second closest tag must be at least 70 cm apart to achieve reliable personal identification.

Six active RFID tags were used to test the identification rate by varying the distance (D) between the closest active RFID tag from the ZED and the second closest tag, and four other tags that were randomly distributed. The beacon time interval for the

active RFID tag was 60 ms (about 16 beacons per second).

When the ZED receives a <ZED Start Request> signal from a medical device or instrument, it aggregates beacon messages from active RFID tags for 1 s and performs personal identification based on RSSI values at each power level. Table 1 shows identification rates with various distances. The result shows that stable identification is achieved when D is larger than 70 cm.

Table 1. Identification rate with a varying distance (D) between the closest active RFID tag from the ZED and the second closest tag

D（cm）	30	50	70	80	90
Identification rate Successful ID/total （%）	11/20 （55）	10/20 （50）	20/20 （100）	20/20 （100）	20/20 （100）

V. CONCLUSION

A ZigBee (IEEE 802.15.4)-based sensor network was set up for a ubiquitous healthcare system using beacon nodes as active RFID tags for personal identification. This method has minimal restrictions for automatic personal identification. With this system, medical devices can be used for both bioinformation transfer and personal identification.

The actual user to be identified must be at least 70 cm from other users to obtain stable identification with our ZigBee personal identification system.

To achieve more reliable personal identification, an improved antenna design for acquiring uniform RSSI values for all directions is needed. A RF module that can provide

more stable RSSI is also required.

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