Implementation of Indoor Positioning Using Signal Strength from Infrastructures

Yuh-Chung Lin[1], Chin-Shiuh Shieh[2], Kun-Mu Tu[2,3], and Jeng-Shyang Pan[2]

[1] Department of Management Information Systems, Tajen University, 907 Pingtung, Taiwan
yuhchung@mail.tajen.edu.tw
[2] Department of Electronic Engineering, National Kaohsiung University of Applied Sciences, 807 Kauhsiung, Taiwan
{csshieh,jspan}@cc.kuas.edu.tw,
autoone@ms68.hinet.net

Abstract. Real time location system is not a brand new technology. The most typical approach is using global position system (GPS). However, GPS can only be used outdoors. It is unable to work completely indoors or in an environment with obstacles. Therefore, the development related to indoor position technology is quite important. In the system developed in this study, it makes use of Received Signal Strength Index value of low-power active RFID (Radio Frequency Identification) for movement detection. Besides, it adopts ZigBee wireless transmission technology as reference nodes for positioning detection. Information gathered by reference points is delivered to the server through the Internet. All positioning information is computed by the server. Positioning algorithm uses the average values of signals in its operation. The advantage is to compare many average values with the closing nodes in order to locate the closest position node for the mobile device and reduce the multi-path interference which is caused by other environmental factors. Positioning results can be accessed through the networked computer or mobile device with WiFi functionality. The experimental results are more stable than other positioning algorithms, and the installation of the system is more convenient.

Keywords: Position System, RFID, RSSI, ZigBee.

1 Introduction

Due to the advent of mobility requirement, the real time location positioning demand becomes a significant need in our daily life. The real time location system is not a brand new technology. Recently, the most well-known position system is the Global Position System (GPS) which is based on the signals transmitted by the satellites on the earth orbit. The GPS can locate the longitude and latitude of a place which is determined through triangulation of radio signals transmitted by satellites. In a travel navigation system, GPS users can track their positions depend on the moving velocity and the travel-time of signals transmitted in a line-of-sight propagation condition. In

J.-S. Pan, S.-M. Chen, N.T. Nguyen (Eds.): ACIIDS 2012, Part III, LNAI 7198, pp. 206–215, 2012.

addition to apply to the navigation of car traveling, there are a lot of applications based on the positioning function of GPS. However, the satellite signal can only be received outdoor without any obstacle. It can not be utilized directly for indoor positioning because of the failure of receiving satellite signals. Any obstruction between GPS users and satellites will cause significant errors in location estimation. Therefore, when entering a building or even in a heavy cloudy circumstance, without clear signals of satellites, the GPS will be failed to locate the user's position.

Because of the limitation of GPS, many researchers pay a lot of attentions on the indoor positioning system. There are many ways to implement the indoor positioning system. [1] A simple solution is to implement a network of cameras which is based on the image processing techniques. A network of sensors is also developed as an alternate method for indoor positioning. [2] Recently, Wi-Fi based positioning system becomes popular because it takes advantage of the rapid growth of wireless access point. [3,4] In this paper, we implement an indoor positioning system which makes use of Received Signal Strength Index value of low-power active RFID (Radio Frequency Identification) for movement detection. Besides, it adopts ZigBee wireless transmission technology as reference nodes for positioning detection. Information gathered by reference points is delivered to the server through the Internet. All positioning information is computed by the server.

The rest of paper is organized as follows. Section 2 represents the indoor positioning system implementation. Section 3 shows the experiment results. In section 4, we give a short conlusions.

2 Indoor Positioning System Implementation

2.1 System Architecture

There are different technologies developed for the positioning system, such as GPS, Infra-red, Supersonic, Image processing, RFID and ZigBee positioning. [1] Fig. 1 represents the system architecture in our implementation. The moving object will be equipped with a badge which is a low-power active RFID device as a signal transmitter for the position detection. When the position node receives the packets from the badge, it transmits the packets to the gateway by the ZigBee wireless communication technology. Then the information is delivered to the server through the Internet.

The positioning method is based on the Received Signal Strength Index (RSSI). The system is composed of badges, positioning nodes, servers for location calculation and client PC or smart phone for representing position. The badge and the position node transmit location information to the gateway by wireless communications. The gateway and server are connected by the Internet. Once the location has been calculated, server will send the information to the monitor which is a client PC or handheld devices (ex. smart phone).

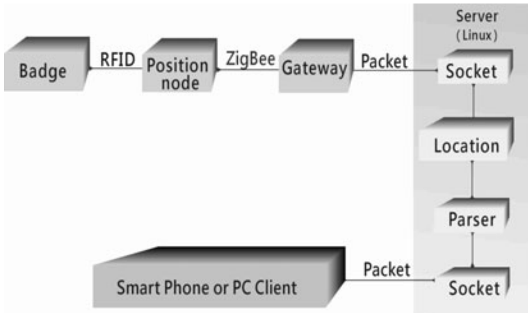


Fig. 1. The architecture of the indoor positioning system

2.2 Transmission Process

There are five steps for the positioning and transmission processes as shown in Fig. 2. At first, the badge will send information to the nearby position nodes. When the data is received, the position node will forward the data to the gateway by a ZigBee connection. Next, the gateway establishes a socket to the server for data transmission. According to the received data, the server will calculate the positioning result via the algorithm that will be described in the following section. Finally, positioning results can be accessed through the networked computer or mobile device with Wi-Fi.

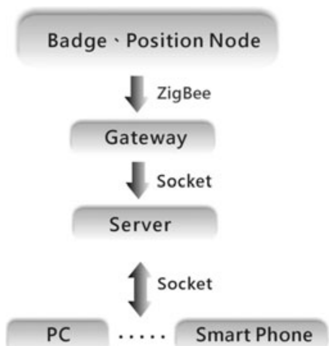


Fig. 2. The positioning and transmission process of the indoor positioning system

2.3 Operations of Server and Client

There are three main components in the server which are the socket program, packet parser and location engine. The socket program is for the connection to the gateway and clients. It opens a TCP socket to be the transmission channel. Once the server receives packets from the gateway, the packets will be delivered to the parser for further processing. The information in the packets will be disassembled to related data structure for the location engine. After a period of time, the location engine will execute a positioning algorithm to process the received information. Afterward the positioning result will be delivered to the client to show the position of the badge. The processing flow in the server is shown in Fig. 3.

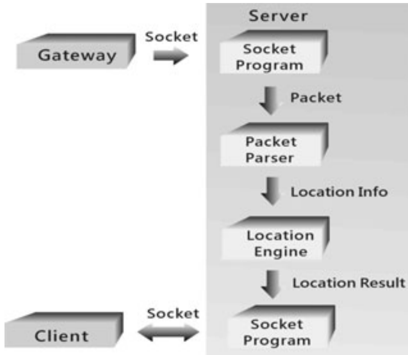


Fig. 3. The processing flow in the server

The client plays the role to display the location result on the end terminal such as PCs or mobile devices. By way of the socket program, the client receives the information from the server. Then it shows the result on the screen. The process is shown in Fig. 4.

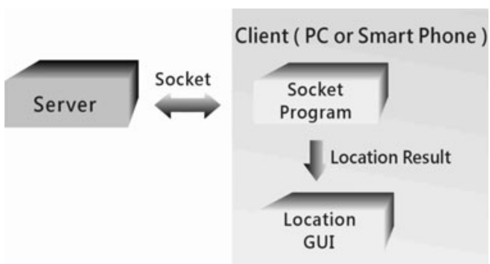


Fig. 4. The processing flow in the client

2.4 Packet Format

Fig. 5 is the data format of the badge and position node. Following is the descriptions of each field. The information sent by the badge includes the MAC address of the badge, the packet ID, the transmitting signal strength, the Link Quality Index (LQI) and RSSI, and the other attached message such as low voltage indication, body temperature, pulse, blood pressure, etc.

The Badge will transmit packets that mentioned above periodically. When the position nodes receive the packet, each position node will append their own ZigBee MAC address to the head of the packet (Fig. 5b) and transmit to the Gateway. Then the gateway transmits all packets that might be received from different position nodes to the server.

In order to measure the signal strength of wireless communication, we utilize the Received Signal Strength Index (RSSI) as a metric to judge the condition of wireless connection. It is widely used in the applications based on the signal strength. The value of RSSI is negative. Therefore, the smaller the RSSI value, the stronger the signal. We also utilize the Link Quality Index (LQI) to represent the link quality of the transmission. The range of LQI is from 0x00 to 0xFF. The higher the LQI value, the stronger the signal.

S	N	T	L	R	M

(a)

D	S	N	T	L	R	M

(b)

Fig. 5. The packet format of the badge (a) and the position node (b)

D: Position Node's MAC address.
S: Badge's MAC address
N: Packet ID
T: Transmitting Signal Strength of Badge
L: Link Quality Indicator
R: Received Signal Strength Index
M: Other attached messages

The relation of RSSI and transmission distance is shown in the following equation (1).

$$RSSI = -(10n \log 10d + A) \tag{1}$$

where n is the signal propagation constant, d is the transmission distance, and A is the signal strength within 1 meter.

From equation (1), because *n* and *A* are constants, RSSI will be decreasing when the distance of two nodes is increasing. Therefore, the distance can be represented as the equation (2).

$$d = 10 \wedge ((|RSSI| - A)/(10 \times n)) \tag{2}$$

Next, equation (3) shows the conversion between RSSI and LQI.

$$RSSI = -(81 - (LQI \times 91)/255) \tag{3}$$

2.5 Positioning Algorithm

In the subsection, we will introduce the positioning algorithm which is used in our implementation. In order to reduce the interference which is caused by other environmental factors, we utilize the average value of RSSIs in the positioning algorithm. The received information will be classified according to the badge's and the position node's MAC address. Based on the pair of (badge, position node), the server will calculate the average RSSI periodically. Then, the smallest average RSSI will be selected and subtract the second small average RSSI. The result will be compared with a threshold. If it is less than the threshold, that means the badge is located between two position nodes. It is hard to determine which position node the badge should belong to. Therefore, the previous position will be maintained. Otherwise, it will compare the received packets' RSSI separately as shown in Fig. 6.

Next, we use an example to explain how the algorithm works. We consider a scenario in which there are three position nodes and one badge. Their IDs are D1=0001, D2=0002, D3=0003 and S=1001. Assume the data received in a period is shown as follows.

D=0001 S=1001 N=FC T=FF L=17 R=40
D=0002 S=1001 N=FC T=FF L=38 R=49
D=0003 S=1001 N=FC T=FF L=3B R=45
D=0001 S=1001 N=FD T=FF L=1E R=40
D=0002 S=1001 N=FD T=FF L=2A R=4C
D=0003 S=1001 N=FD T=FF L=28 R=43
D=0001 S=1001 N=FE T=FF L=17 R=40
D=0002 S=1001 N=FE T=FF L=2C R=4A
D=0003 S=1001 N=FE T=FF L=20 R=45
D=0001 S=1001 N=FF T=FF L=1F R=40
D=0002 S=1001 N=FF T=FF L=31 R=4A
D=0003 S=1001 N=FF T=FF L=37 R=43

Firstly, the server will classify these data into three groups:
D1:
D=0001 S=1001 N=FC T=FF L=17 R=40
D=0001 S=1001 N=FD T=FF L=1E R=40
D=0001 S=1001 N=FE T=FF L=17 R=40
D=0001 S=1001 N=FF T=FF L=1F R=40
D2:
D=0002 S=1001 N=FC T=FF L=38 R=49
D=0002 S=1001 N=FD T=FF L=2A R=4C
D=0002 S=1001 N=FE T=FF L=2C R=4A
D=0002 S=1001 N=FF T=FF L=31 R=4A
D3:
D=0003 S=1001 N=FC T=FF L=3B R=45
D=0003 S=1001 N=FD T=FF L=28 R=43
D=0003 S=1001 N=FE T=FF L=20 R=45
D=0003 S=1001 N=FF T=FF L=37 R=43

Next, the server will calculate the average RSSI of these three groups which are listed as follows.

The average RSSI of D1 is $R1_{avg}$=(40+40+40+40) /4=40
The average RSSI of D2 is $R2_{avg}$= (49+4C+4A+4A)/4= 4A
The average RSSI of D3 is $R3_{avg}$= (45+43+45+43)/ 4= 44

If there is no previous positioning information for the badge, we select the D1 and D3 which average RSSIs are the smallest of the top two. Then the information of the last two packets will be compared as shown in following.

N=FF: D=0001 S=1001 N=FF T=FF L=1F R=40
D=0003 S=1001 N=FF T=FF L=37 R=43
N=FE: D=0001 S=1001 N=FE T=FF L=17 R=40
D=0003 S=1001 N=FE T=FF L=20 R=45

The values of R of D1 are smaller than the one of D3. Then the positioning result will be D1. Otherwise, the next comparison will be proceeded as follows.

N=FF: D=0001 S=1001 N=FF T=FF L=1F R=40
D=0003 S=1001 N=FF T=FF L=37 R=43
N=FD: D=0001 S=1001 N=FD T=FF L=1E R=40
D=0003 S=1001 N=FD T=FF L=28 R=43

If the R of D1 is smaller than the one of D3, D1 will be the positioning result. If not, the final comparison will be proceeded as follows.

N=FE: D=0001 S=1001 N=FE T=FF L=17 R=40
D=0003 S=1001 N=FE T=FF L=20 R=45
N=FD: D=0001 S=1001 N=FD T=FF L=1E R=40
D=0003 S=1001 N=FD T=FF L=28 R=43

If the R of D1 is smaller than the one of D3, D1 will be the positioning result; otherwise the D3 will be the positioning result. The detail of processing flow is shown in Fig. 6.

3 Experiment

The devices that utilized in our experiment are self developed equipments. The wireless communication chip CC2500 [5] of TI is utilized for the transmission of RFID. The badge adopts MSP430F2274 microcontroller of TI to control the CC2500. The communication for ZigBee uses the chip CC2530 [6] of TI which includes the enhanced 8051 microcontroller. We use the MSP430F247 microcontroller of TI as the position node to manipulate the data transmission between CC2500 and CC2530. The Gateway utilizes AX11015 to be the network controller. Fig. 7 is the hardware pictures that are used in our experiment.

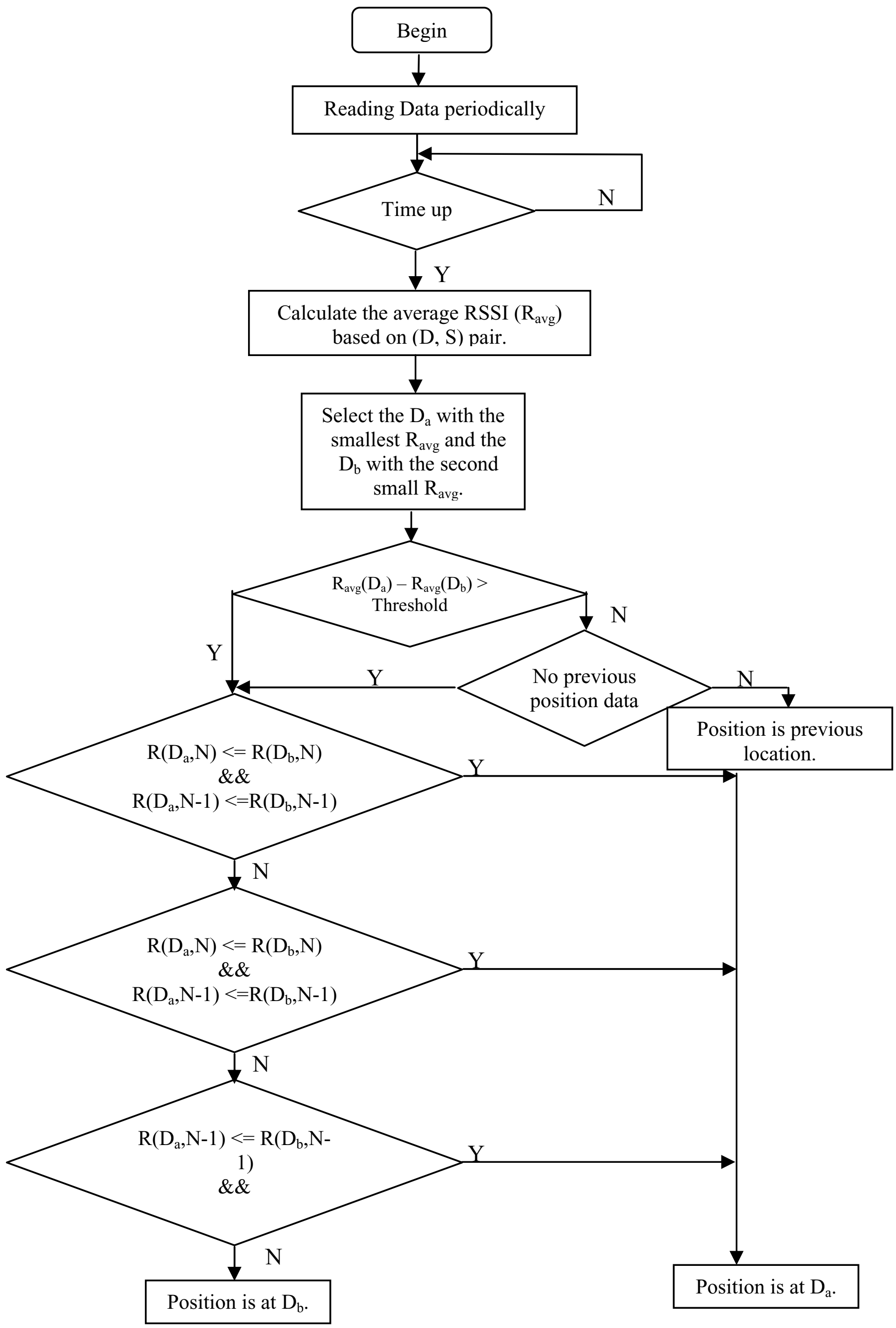
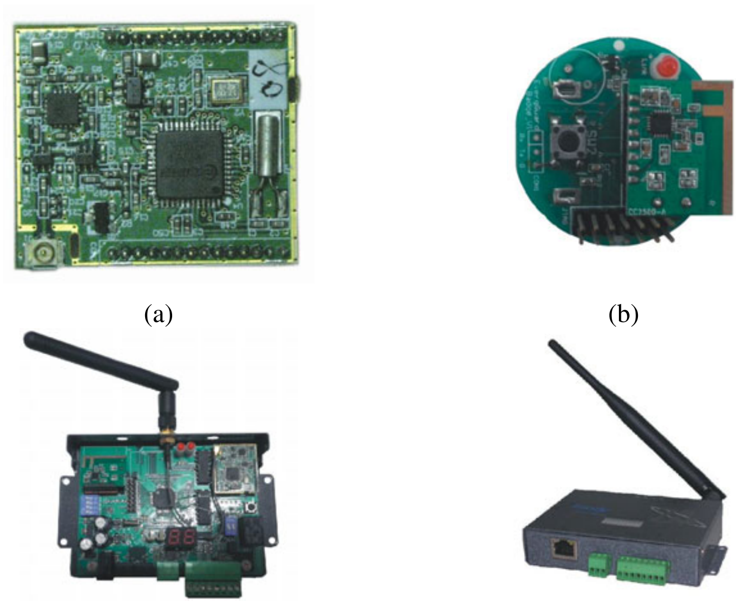


Fig. 6. The flow chart of positioning algorithm



(a) (b)

(c) (d)

Fig. 7. The pictures of hardware: (a) ZBM_CC2530 Module, (b) Badge Module, (c) Position Node and (d) Gateway

Fig. 8. The experiment environment

Fig. 8 represents the experiment environment. We deploy 10 position nodes and 1 badge. The distance among the position nodes is about 10 meters. The position nodes are the reference points in the positioning system. Therefore, the accuracy of positioning will depend on the density of the position nodes. The signal strength of badge is 0 dbm. The signal will be transmitted once a second. A examiner with the badge walks around all the offices. The positioning algorithm will process data every three seconds.

The examiner carries the badge and monitors the positioning result in the mobile devices (as shown in Fig. 9). When the badge is close to the position node about 3.5

meters, the monitor will show that the badge is approaching to the position node. If the examiner stops about 3 meters away from the position node, within 3 minutes 60 positioning results are obtained. All of them represent the correct position.

Next, the examiner walks around the test environment without stop. The 60 positioning results also are acquired. Some results are not correct. The successful ratio of positioning is about 95%. Then, the examiner increases his walking speed. This will cause the decrement of the successful ratio of positioning which is 60%.

As we can know from the experiment, the moving speed will affect the correctness of positioning. The refresh rate of the positioning algorithm is about 3 seconds. If the transfer time between two position nodes is less than 3 seconds, some data will be viewed as a noise and be ignored. Therefore, the successful ratio of positioning will be reduced. Furthermore, the deployment of more position nodes can raise the accuracy of positioning, but it also reduces the distance among position nodes. This will cause the system is even more sensitive to the moving speed. More frequent transfers among position nodes make the successful ratio of positioning drop dramatically as shown in the experiment. Even though the successful ratio is dropped, it won't affect the accuracy of positioning.

4 Conclusion

In this paper, we implement an indoor positioning system using signal strength from infrastructures. A simple but effective positioning algorithm is proposed. In our experiment, the system can provide a high accurate positioning function. According to our experiment, we know that the density of deployment of the positioning nodes will affect the accuracy of positioning. The experimental results are more stable than other positioning algorithms, and the installation of the system is more convenient.

Acknowledgments. This work is partially supported by the National Science Council, Taiwan, under the grant No. NSC 100-2221-E-151-041-.

References

1. Bejuri, W.M.Y.W., Mohamad, M.M., Sapri, M.: Ubiquitous Positioning: A Taxonomy for Location Determination on Mobile Navigation System. Signal & Image Processing 2, 24–34 (2011)
2. Chang, N., Rashidzadeh, R., Ahmadi M.: Differential Access Points for Indoor Location Estimation. In: IEEE International Conference on Electro/Information Technology, EIT 2009 (2009)
3. Mahtab Hossain, A.K.M., Van, H.N., Jin, Y., Soh, W.-S.: Indoor Localization using Multiple Wireless Technologies. In: IEEE Internatonal Conference on Mobile Adhoc and Sensor Systems, MASS 2007 (2007)
4. Chen, Y., Kobayashi, H.: Signal strength based indoor geolocation. In: Proceedings of the IEEE International Conference on Communications (ICC 2002), New York, NY, USA, vol. 1, pp. 436–439 (April-May 2002)
5. Texas Instruments, CC2500 Datasheet, `http://www.ti.com/lit/ds/symlink/cc2500.pdf`
6. Texas Instruments, CC2530 Datasheet, `http://www.ti.com/lit/ds/symlink/cc2530.pdf`