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A Study on the Development of User Location Based Home Automation Service Technology

Sun-Yeob Kim

Dept. Information-Communication Engineering, 91 Daehak-ro Seonghwan-eup Sebuk-gu Cheonan-si Chungcheongnam-do, Korea. ahinlove0821@gmail.com

Abstract

With the evolution of IoT technology, there is a growing demand for location based services to identify mobility and identity of users. The initial LBS system was mainly used to measure position information by measuring the phase of a signal sent from a GPS (Global Positioning System) satellite or by tracking the code of a carrier signal and measuring the distance to the satellite. However, the use of GPS satellites is ineffective indoors because it is difficult to receive satellite signals. Therefore, researches on wireless communication systems such as UWB, RFID, and Zig-bee are being actively carried out for location recognition technology that can be utilized in indoor environment. For this the paper produced an LBS system including the 2.45GHz band for CSS and the 3.1~10.6GHz band and the 250-750MHz band for UWB using IEEE 802.15.4a standard for location recognition based on low power. TOA, TDOA, and AOA algorithms are used in location tracking, and in TOA, the propagation time between the mobile device and the fixed device is measured to determine the distance. TDOA is a method of measuring the relative difference in propagation time of a signal sent from a plurality of receivers to a transmitter, and AOA is a method of locating the direction of the fixed antenna, that is, where the cell site overlaps the signal source, with the signal sent from the antenna. The position recognition algorithm used in the designed LBS system uses a method of calculating the angle of arrival of the radio waves using two or more array antennas in two dimensional position, in order to overcome the disadvantages of increasing size and cost while improving resolution for phased array antennas meeting spatial sampling requirements. In this way, phase alignment and gain calibration with incomplete measurement error, and improper coupling between antenna elements were avoided. As a result, the 2.45GHz ISM RF transceiver and the ranging function were implemented in hardware and it was confirmed to have an output power of 0dBm, and the LBS system designed in this paper is thought to be useful for realizing the location based recognition system at low price.

Key Words: Location based system, position, recognition, wireless, communication.

1. Introduction

Recently, due to miniaturization of semiconductor and development of wireless communication technology, research on ubiquitous computing that can provide users with desired information and services regardless of place and environment is being actively carried out. Among them, wireless location recognition technology for user convenience and stability improvement has been applied in various fields such as navigation, home automation, parking management, logistics management, exhibition hall guidance and prevention of lost children[1].

Like this, GPS (Global Positioning System), which uses satellite signals and trilateration method, can find the location of moving objects in real time, and thus it is widely used in fields requiring location tracking service. However, it is less useful indoors where reception of satellite signals is difficult. Therefore, researches on wireless communication systems such as UWB, Zigbee, RFID, and Criket are being actively carried out [2-4]. By applying error suppression algorithm to IEEE 802.15.4a Chirp signal and SDS-TWR method, the position error of Zigbee-RSSI which is used in existing indoor location recognition technology was reduced. However, the experiment is conducted only in an environment of 6m width and 3m length without obstacle, and it is disadvantageous that it is not reliable for errors from various environmental disturbances[5-8].

In order to locate users in Indoors, it is necessary to develop a system that operates in the two base technologies of IEEE 802.15.4a, the CSS frequency band and the UWB frequency band, based on low power. For this the study developed location recognition service technology based on IEEE 802.15.4a for low power based location based service.

IEEE 802.15.4a is a standard that includes Chirp Spread Spectrum (CSS) and Impulse Radio-Ultra Wide Band (IR-UWB), and the band includes the 2.45 GHz band for CSS and the 3.1 to 10.6 GHz band and the 250-750 MHz band for UWB.

2. Wireless Modulation Technique

CSS in IEEE 802.15.4a provides up to 2Mb/s at 250kb/s and 842kb/s in IR-UWB. Figure 1 shows the frequency band of IEEE 802.15.4a.

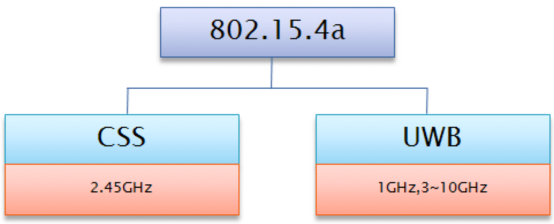

Fig. 1: 802.15.4a Base Band

Characteristics of Signal

It is a CSS PHY using 2.45 GHz band, and DBO-CSK (Differential Bi-Orthogonal Chirp Shift Keying) modulation scheme using chirp pulse is used unlike the existing IEEE 802.15.4. The characteristic of the chirp signal is a signal whose frequency varies with time, and expression as equation is as follows[9-10].

$$S_{ch} = Exp\left[j\left(\omega_s + \frac{\omega BW}{T_{ch}}\right)t + \theta_0 * [u(t) - u(t - T_{ch}]\right] \quad (1)$$

Equation (1) is the rectangular linear chirp signal among the chirp signals, and each configuration is as follows.

As shown in equation (1), over time, the Schirp (chirp signal) changes frequency with a constant slope. And it can be seen that phase changes more and more quickly over time.

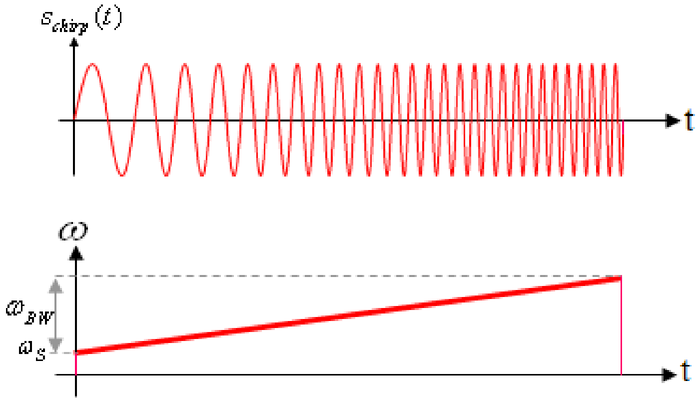

Fig. 2: Pulse and Frequency variation of Chirp Signal

Figure 2 shows the change of pulse and frequency according to chirp signal. Fig2. Pulse and Frequency variation of Chirp Signal. As the modulation method of CSS, DBO (Differential Bi-Orthogonal Shift Keying) method is used, which transmits data by applying Phase Modulation to a specific linear chirp. The phase modulation method can operate in binary and quadrature phase modes.

Quadrature Phase Shift Keying

If the existing Chirp signal is formulated by separating the signals by phase difference of π, it is like the following, and two signals are generated[11].

By separating the signal by phase difference of 1/4, the signal is modulated by transiting π/2, π, 3π/2 signal to the existing Chirp signal.

Differential Bi-Orthogonal method is used for Encoding method, and there are 8-ary and 64-ary methods. 8-ary scheme receives 3 bits and encodes them into 4 Bi-orthogonal codes.

Data transmission mode uses Differential Detection mode, which is less efficient than Coherent Detection, and this is because Coherent Detection increases the complexity of the hardware when the slope of the Chirp and the start frequency are different for SOP (Simultaneously Operating Piconet). To compensate for performance, 3/4 Bi-Orthogonal coding is used**.**

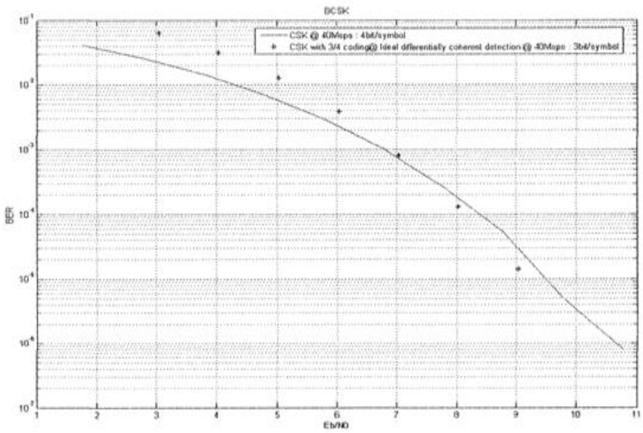

Fig. 3: Coherent Detection and 3/4 Bi-Orthogonal Coding Comparison

As shown Fig. 3, the dotted line shows the bit error rate when receiving 3/4 coding by Differential Detection, and the solid line shows Coherent Detection. It can be seen that as the time passes, the BER characteristics becomes better. Ranging is a type of synchronizing to distinguish the first arriving signals for location based, and the way to find the signal is as follows.

In Fig. 3, the straight line in red in the single Chirp of the received signal is the time reference that conjugated the Chirp signal, and the black is the transmitted Chirp signal, and when the two chirp signals thus shifted are multiplied, they have the square frequency component. The same is true for multipath, which produces a signal proportional to the time difference. Therefore, the receiver can find the component that arrives first by reversing it and can track the position using this time.

SOP of DBO-CSK

In the system used in W-PAN, SOP (Simultaneously Operating PICONET) is specified for simultaneous multiple group communication, and it distinguishes PICONET by using policy using up/down chirp and different time-gap. The up / down chirp method divides the frequency change in the time domain into four types and distinguishes each PICONET[12].

As shown Fig. 4, the method using up/down chirp can distinguish the PICONET by dividing the signal in the same band by varying the frequency change.

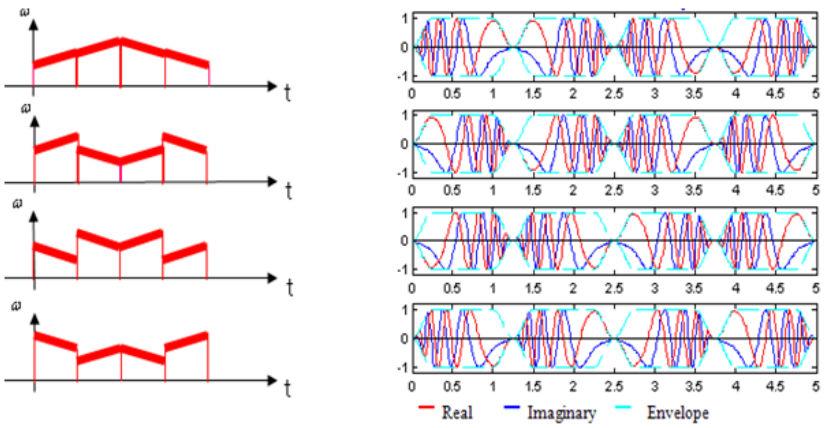

Fig. 4: SOP Using Up and Down Chirp Pulses

As shown Fig. 5, This is a way to distinguish PICONET by using different time intervals between different frequencies, which is possible because of the use of difference encoding method. It distinguishes the signal by setting the time-gap to be the same for both symbols and by varying the symbol interval for each PICONET.

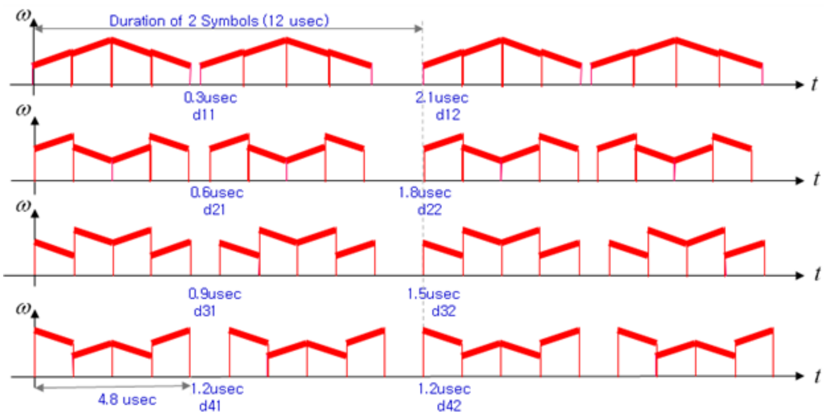

Fig. 5: SOP Using Time-gap and up/down Chirp

3. Location Recognition Algorithm

The basic algorithms used for location tracking include TOA, TDOA, and AOA. For TOA, once two terminals are synchronized to a common clock, TOF information can be obtained directly from a simple OWR transaction[13]. A direct approach to calculating the location of a mobile device terminal based on TOA uses a geometric interpretation of the intersection of the three circles in the TOA-based algorithm. In practice, if three TOAs are measured between a mobile terminal and three or more separate anchors, the position of the mobile can be readily calculated in a two-dimensional plane. This solution is consistent with the detection method by conventional radio detectors. Figure 6 shows the position recognition method using TOA.

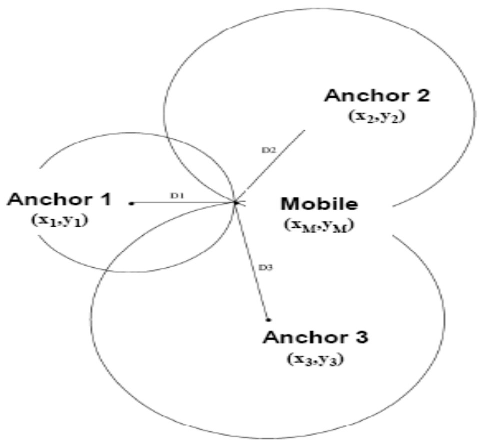

Fig. 6: Location Positioning Using TOA

TDOA and DOA are positioning methods that determine the position by measuring the relative difference of the propagation time of the signal sent from the transmitter in several receivers. TDOA relates to what is used to calculate the TOA position due to the time difference between the already synchronized reference fixture and the terminal. TDOA is traditionally obtained through an OWR transaction, as shown in the figure below. In this scheme, a pair of isochronous fixture terminals can detect a TOA in association with a packet emitted by a mobile device.

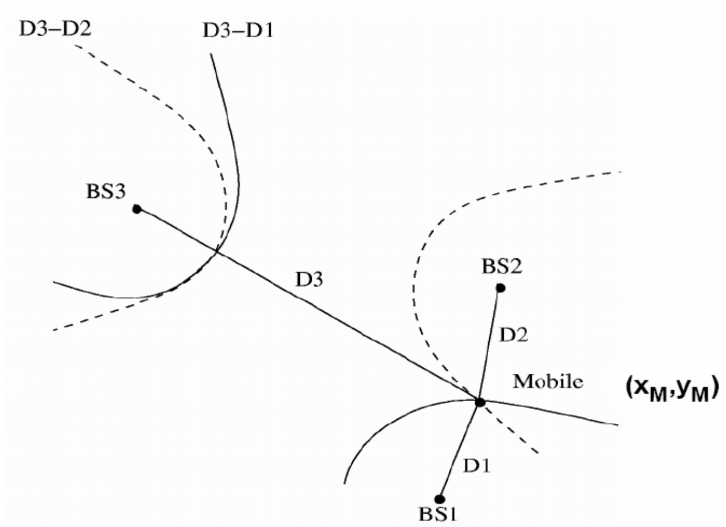

Fig. 7: Location Positioning Using TDOA

Figure 7 shows the location recognition method using TDOA.

In AAOA, 4~12 antennas are arranged for each direction in one fixed device, and the transmitted signal is received at each of the antennas, and the direction of each fixed antenna, that is, the position where the signal source overlaps with the cell site (cover region), is determined as a position.

TDOA has many advantages over other positioning algorithms. In particular, since the device does not require additional components (such as a GPS module), it is less expensive than positioning at the intersection using GPS and does not require knowing the absolute time of the signal transmitted from the mobile device, such as TOA measurement. In addition, since it does not require special antennas, it is cheaper than using AOA and can reduce time errors due to multipath.

The study developed a position recognition algorithm that can be applied to LBS system based on TDOA as shown in Figure 8.

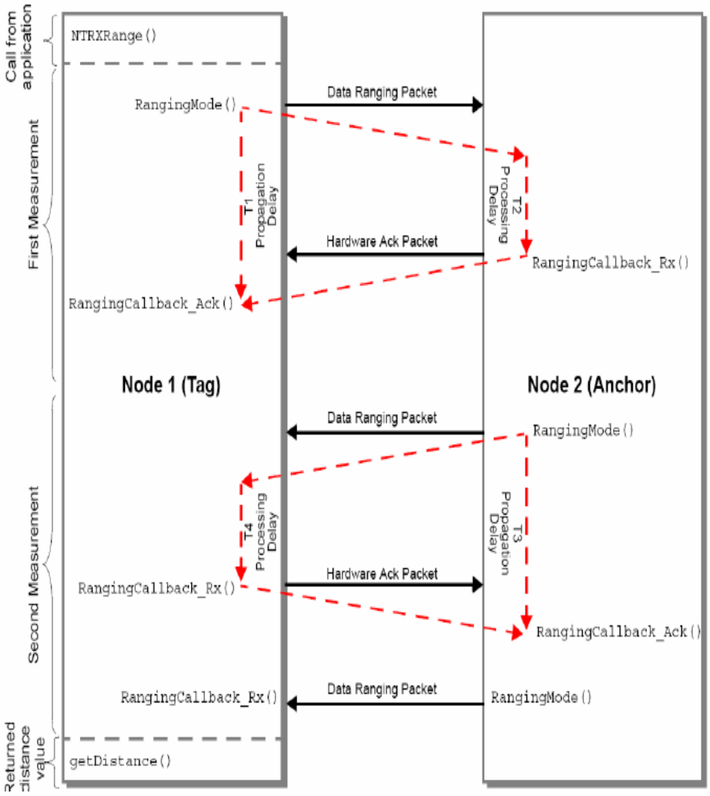

Fig. 8: Proposed Algorithm

When InitApplication() is called by initializing the board for position recognition, the address value of the destination and the source is set, and the initial value for the position recognition for ranging is set. Then NTRXRange returns the Ranging value as a distance value.

Figure 9 shows the Ranging state displacement diagram for position recognition. Initially in the state diagram, it is in READY(0) and it transitions to START(1) by calling the NTRXRange function. The distance value is calculated through two transmission and reception to measure the position and the distance, and the distance value is finally obtained through the Distance calc.done.

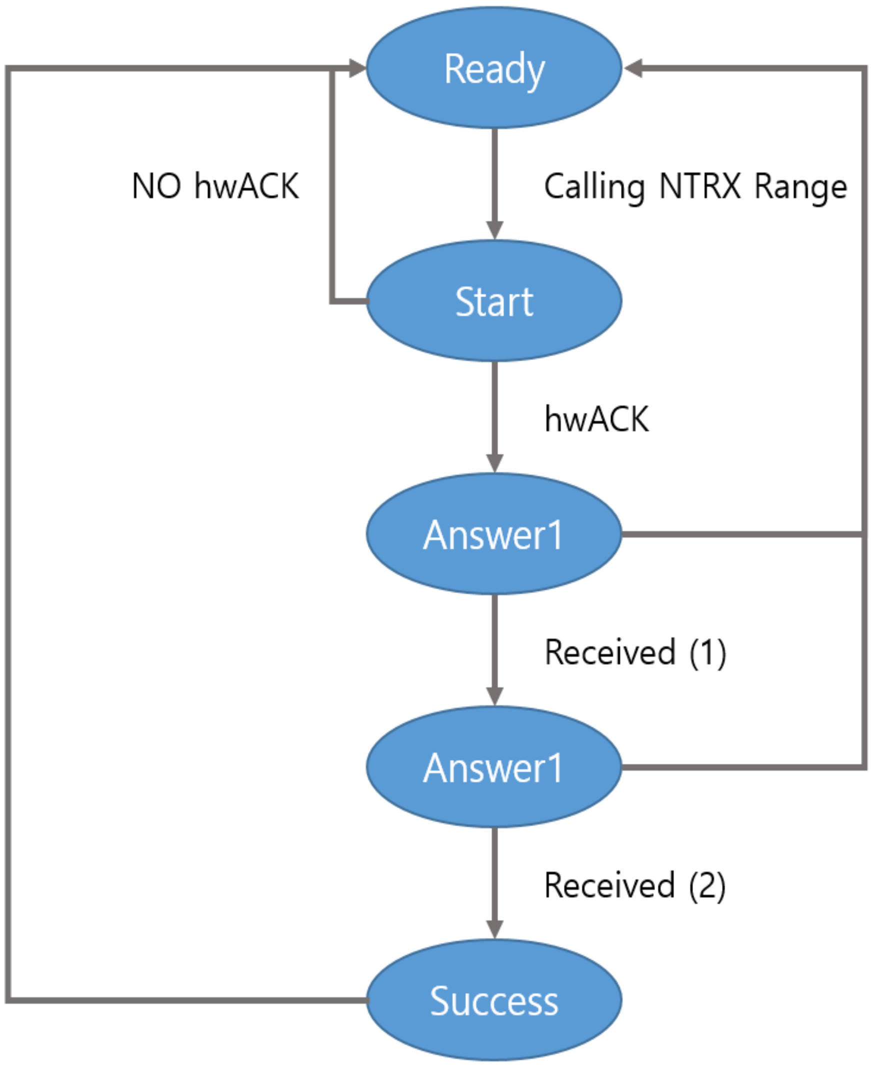

Fig. 9: Algorithm Flow Chart

NTRXRange() is a function that calls RangingMode, waits for a timeout or response, and calculates the distance value.

NTRXRange() waits for a response or timeout, using NTRXStartBasebandTimer(RANGING_TIMEOUT);.

NTRXReceive(Actor) performs the following functions. It measures the distance between the normal packet and the ranging packet, ragning packet is processed automatically, and the normal packet calls the ApplCallback function. After the ranging process, two ranging values are expected.

NTRXReceive(Remote) responds twice after receiving the initial ranging packet.

4. LBS System Production

The operation of each block shown in Figure 10 is as follows.

De-multiplexer (DEMUX) receives binary data values and maps them to I Path and Q Path, and mapping is done divided into 3-bit unit and 6-bit unit. This is a task for mapping to Bi-orthogonal symbols. 3 bit mapping is as follows.

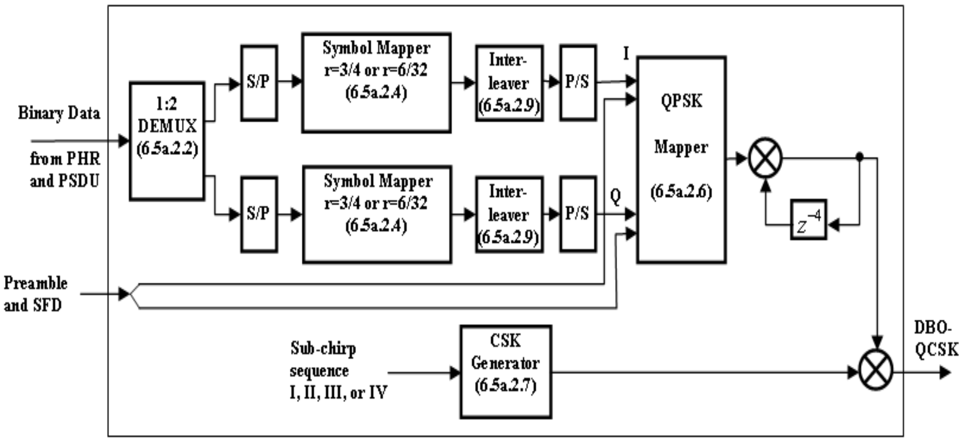

Fig. 10: Block Diagram of System

Serial-to-parallel mapping (S/P) transforms the serial signal into a parallel signal, converts it into I path and Q path, and sends it to the symbol mapping device bundled in 3-bit units. The form of the signal sent is as follows.

Data symbol to bi-orthogonal code word mapping block is a device that maps a signal divided into 3 bits or 6 bits into Bi-orthogonal symbol form. A signal mapped to 3 bits has a speed of 1 Mbps and is mapped to 4 signals, and a signal mapped to 6 bits is mapped to a Bi-orthogonal symbol with 32 signals. In the case of 3 bits, the mapping type is as follows.

The parallel-to-serial converter (P/S) and QPSK symbol mapping block converts the parallel signal back into a serial signal for QPSK modulation and QPSK modulates the serial signal.

Figure 11 shows a block diagram of the developed position recognition board.

The operation of the developed system is as follows.

The transceiver performs TX, RX, and basic digital operations to filter the external noise signal by filtering through the ISM bandpass filter and antenna.

RS-232 communication is used for connection to the board for position recognition and PC, and Hypertermial software is used for PC.

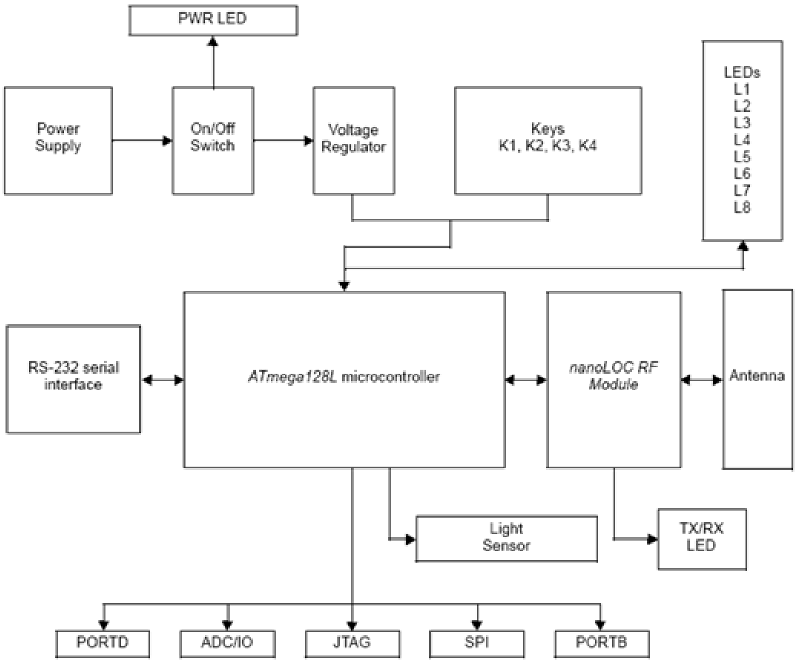

Fig. 11: Block Diagram of Developed Board

Fusing or debugging of the location recognition software firmware is done through the JTAG interface. The ISP interface serves as an interface for fusing the program to the board for location recognition. Using AVR ISP tool, AVR source code executable is generated using the WINAVR program.

Figure 12 shows an executed server program for location positioning.

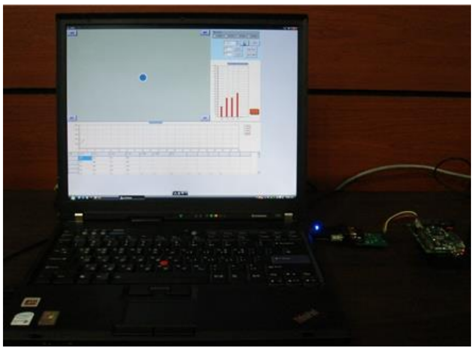

Fig. 12: Screen of the Running Server Program

5. Conclusion

In the study, IEEE 802.15.4a proposed for low power based location recognition is a standard that includes Chirp Spread Spectrum (CSS) and Impulse Radio-Ultra Wide Band (IR-UWB), and the band includes the 2.45 GHz band for CSS and the 3.1 to 10.6 GHz band and the 250-750 MHz band for UWB. In the frequency band of CSS, it provides up to 2Mb/s at 250kb/s and 842kb/s in IR-

UWB. Figure 1 shows the frequency band of IEEE 802.15.4a. This is a CSS PHY that uses the 2.45 GHz band and uses DBO-CSK (Differential Bi-Orthogonal Chirp Shift Keying) modulation scheme using chirp pulse unlike the existing IEEE 802.15.4. As the modulation method of CSS, DBO (Differential Bi-Orthogonal Shift Keying) method is used, which transmits data by applying Phase Modulation to a specific linear chirp. The phase modulation method can operate in binary and quadrature phase modes. The algorithm of the constructed LBS system is based on TDOA for ease of implementation, and an algorithm was developed and applied to the developed system.

Therefore, it is considered that if the 2.45GHz ISM RF transceiver and the ranging function are implemented through hardware and designed to have a nominal output power of 0 dBm for position recognition as in the result of this study, it will be possible to conduct location based recognition based at low cost.

Acknowledgment

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