IMPLEMENTATION OF WIRELESS SENSOR NETWORK (WSN) IN OIL AND GAS SPECIFICALLY FOR PERSONNEL POSITIONING APPLICATION

by

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Approved:

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May 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MUHAMMAD AL AMIN AMALI BIN MAZLAN

ABSTRACT

The invention of WSN-based indoor positioning is to design effective personnel positioning system, monitor the personnel movement in oil and gas platform and alert the personnel if they entered a restricted area. Personnel tracking system in hazardous working environment such as in oil gas platform is very crucial due to GPS incapability inside a concrete building structure. Real-time monitoring of personnel health and condition is a top priority for immediate response in emergency situation. Communication device limitation in oil and gas platform will be hard for the supervisor to inform the personnel for an emergency evacuation. Personnel position application using WSN is determined based on RSSI values of multiple XBee multipoint RF modules consist of personnel node, fixed nodes and server node. A positioning algorithm will be used for the estimation of personnel location in the oil and gas platform.

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CHAPTER 1

PROJECT BACKROUND

1.1 Background Study

Wireless sensor network (WSN) is widely being used as a monitoring device to collect the data and information from the target location such as temperature, pressure, humidity and pressure. This project involves in using an IEEE 802.15.4 standard, a type of wireless personal area network which focuses on low cost and low powered device using the fundamental network layers and microcontroller board to triangulate the location of a personnel in oil and gas platform.

These wireless nodes are deployed over the specific region at a different distance between each node to cover all the monitoring area. By using IEEE 802.15.4 as a wireless sensor network, the receive signal strength indicator (RSSI) from each deployed nodes and personnel nodes can be monitored to measure the distance between the neighbouring nodes. Manipulating all the RSSI values from the entire wireless nodes over the monitoring area, the personnel location can be identified and monitored to keep the safety of the personnel in the working area especially in a hazardous workplace such as oil and gas well drilling platform.

1.2 Problem Statement

Effective personnel tracking system is very crucial especially in hazardous working environment such as in oil and gas platform and process plant. It is very hard to locate the personnel inside the plant during the emergency situation. The usage of GPS inside the indoor environment also not very reliable because of weaken signal due to the building structure.

The health of the personnel inside the plant also very difficult to monitor in case something had happen to the personnel. The personnel are easily exposed to the hazardous chemical, radiation and fire hazard inside the oil and gas plant. It is hard for them to report the situation immediately in emergency situation.

The usage of mobile phone inside the oil and gas platform is prohibited due to the safety procedure. This prohibition will limit the communication between the personnel and their supervisor in the platform. Without having an effective communication medium, it will be hard for the supervisor to inform the personnel to evacuate the area if something dangerous has happening.

1.3 Objectives

By implementing this project in oil and gas platform, many of the problems mentioned can be solved. However, due to the time constrain, this project will focus more on the listed objectives:

- Design effective personnel positioning system in oil and gas platform.
- Monitor the personnel movement in oil and gas platform.
- Alert the personnel if they entered a restricted area.

1.4 Scope of Study

The first scope of this project will be a wireless network sensor (WSN). WSN has been used for many monitoring applications such as home automation, environment monitoring, alert control, data logging and real-time monitoring.

The next study will be IEEE 802.15.4 based devices. This type of wireless personal area network (WPAN) will be used for indoor positioning because of its advantages in term of low power consumption, low cost and smaller module size.

The main study of this project is to develop a special algorithm for indoor positioning. Parameter from RF signal from WSN devices such as Received Signal Strength Indicator can be used to triangulate personnel location.

CHAPTER 2

LITERATURE REVIEW

2.1 Wireless Sensor Network (WSN)

Nowadays, wireless communication has been important in monitoring system for data collection and real-time monitoring system. A numbers of wireless sensors in a specific area at a different range was deployed to create a complete system of data transmission is known as wireless sensor network [1]. Distributed WSN with peripheral sensor will lead to many applications such as home automation, traffic control and environment monitoring [2]. Research fields on WSN has become the main topic due to its capability in term of cost, size and microcomputers [3].

2.2 IEEE 802.15.4

Currently in the market, there are various types of WSN devices being used such as ZigBee, IEE 802.15.4 and 6LoWPAN. ZigBee wireless network has become widen in the market because of its advantages such as low power consumption, self healing ability, high reliability and time saving [4]. However, this project will be focussed more on IEEE 802.15.4 as it is a basic architecture for WSN devices [5]. The IEEE 802.15.4 standards known as low-power communication devices which operate in the free 2.4 GHz Industrial, Scientific and Medical (ISM) frequency band [6].

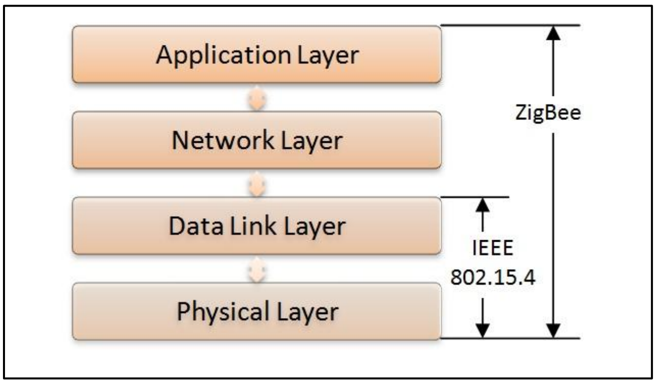

FIGURE 1: Fundamental Application of IEEE 802.15.4 network

FIGURE 1 shows the fundamental application of IEEE 802.15.4 network. IEEE 802.15.4 standard basic protocol consist of two different layers which is physical layer and medium access layer (MAC) [7]. Based on Open System Interconnection (OSI) seven layer network model, physical layer is located at the lowest part which provides basic networking hardware transmission technologies of a network [8] as shown in FIGURE 2. Meanwhile, the medium access layer (MAC) is located at the second level of OSI model as a sub-layer of data link layer which provides addressing and channel access control as an interface between logical link control (LLC) sub-layer of data link layer and physical layer of the network [8].

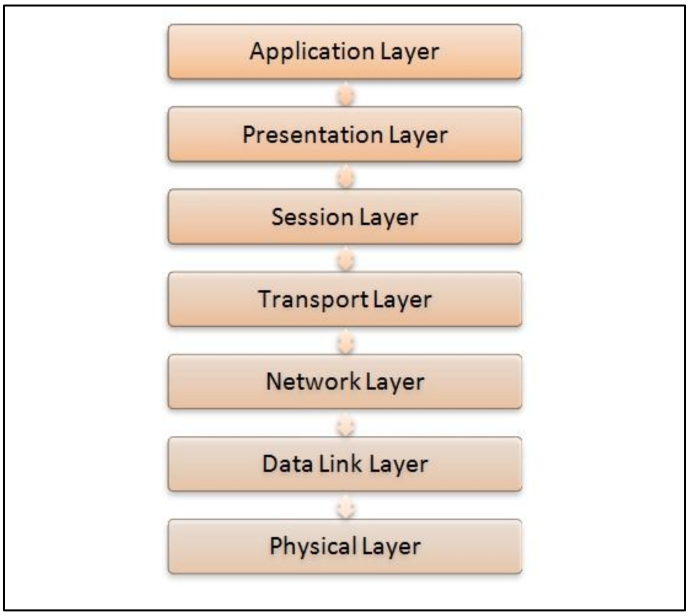

FIGURE 2: OSI Seven Layer Model

2.3 Indoor Positioning

Global Positioning System (GPS) is a satellite-based navigation system that provides real-time user's location. However, GPS cannot fully work for indoor environment because of a week signal inside the building structures [9]. Using GPS as a solution for indoor positioning also not a good choice due to cost and low power efficiency [10].

Parameter from WSN such as Received Signal Strength Indicator (RSSI), Link Quality Indication (LQI) and Packet Error Rate (PER) can be measured and analyzed to identify the indoor location of users [11]. Based on previous research, the positioning of the personnel node can be performed by using a few reference nodes as fixed nodes [10] as shown in FIGURE 3 The personnel node will calculate and manipulated the RSSI-based distance between the references nodes to locate the personnel location.

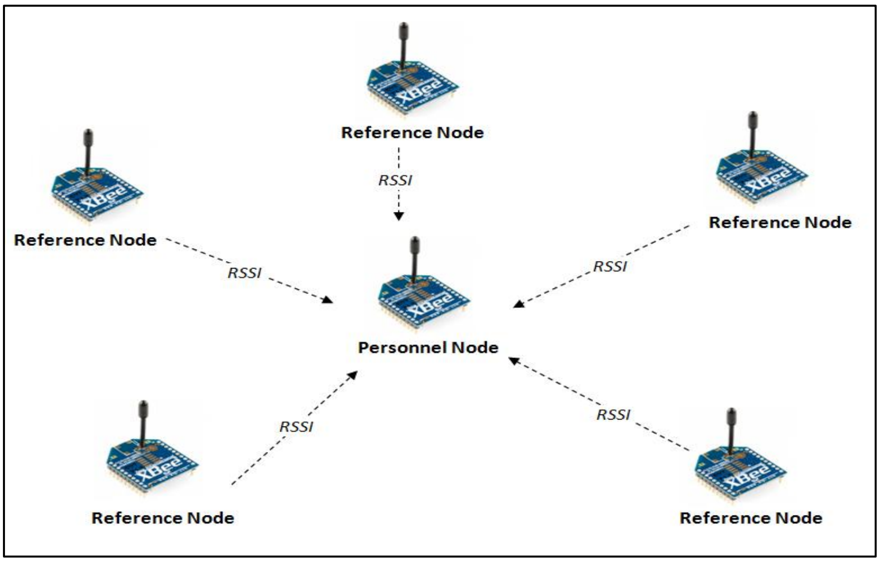

FIGURE 3: Indoor positioning using WSN

RSSI received from reference nodes will be recorded in decibel milliwatt (dBm) which can be used to locate the current position of personnel node [12]. When this personnel node received RSSI value from different source of reference node, a special algorithm will be used to triangulate the personnel location.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

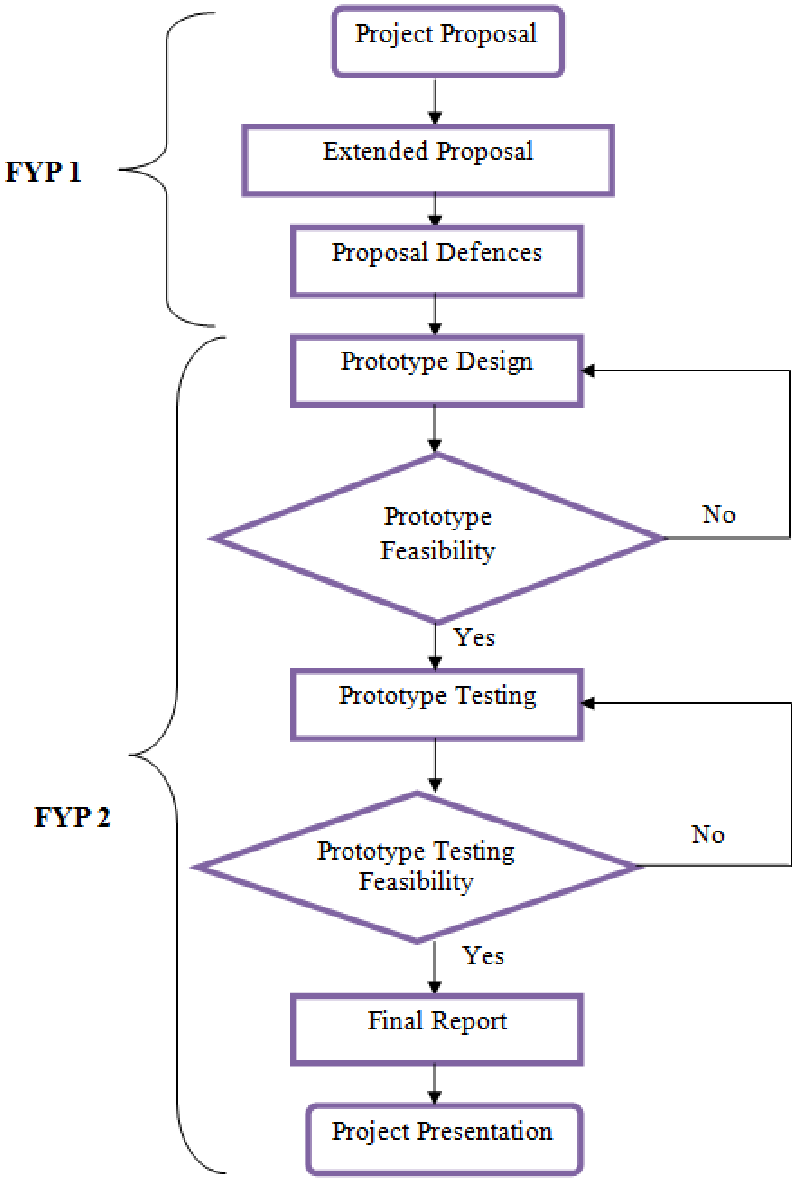

FIGURE 4: Flow Chart of the Project

3.2 Project Activities

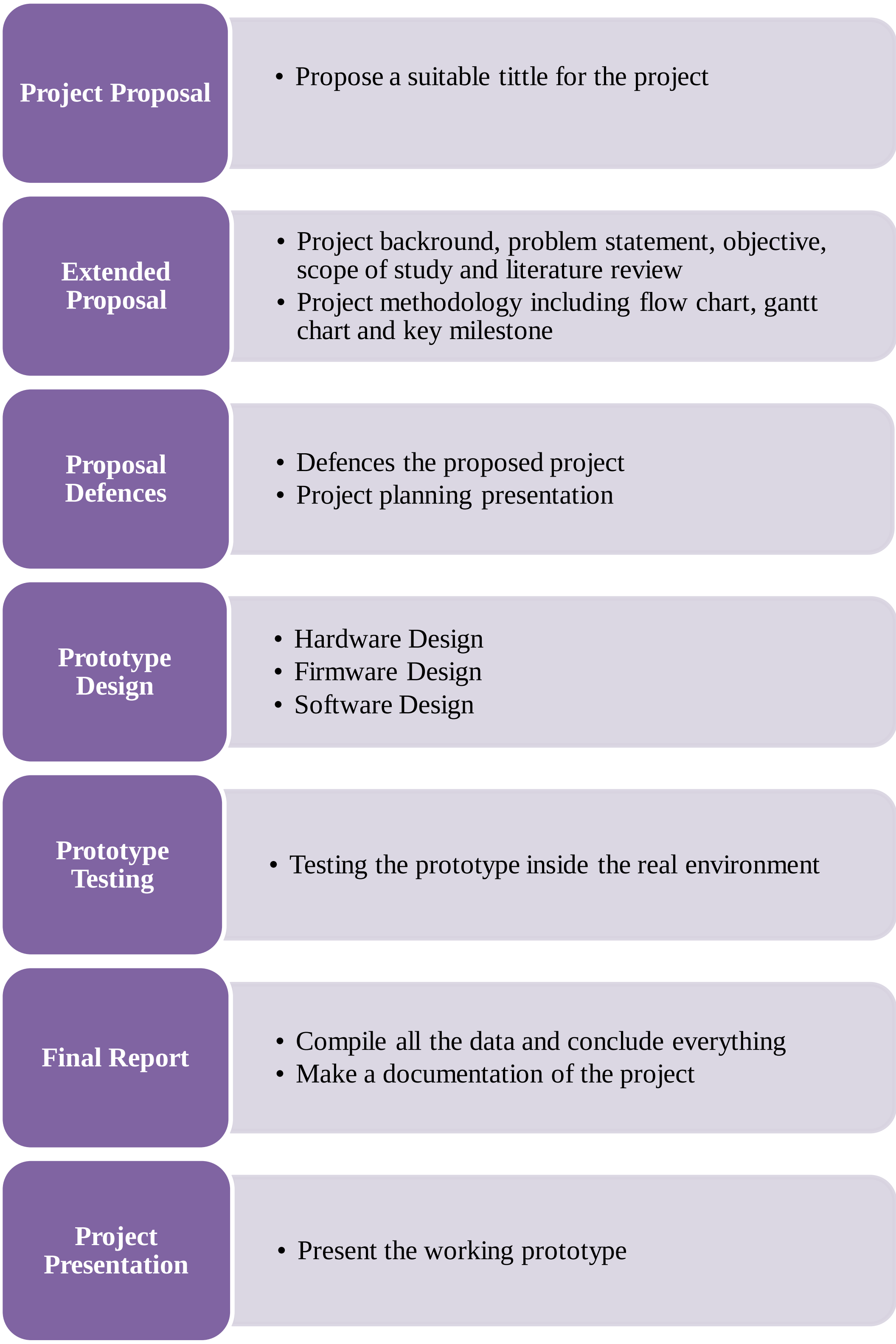

FIGURE 5: Description of Project Activities

3.2.1 Prototype Design

Hardware Design

<u>XBee 802.15.4 (Series 1)</u>

FIGURE 6: XBee 802.15.4 (Series 1) RF Modules Standard Version

FIGURE 7: XBee 802.15.4 (Series 1) RF Modules Pro Version

The WSN module that will be used in this project is XBee Multipoint RF Modules. The specific model will be XBee 802.15.4 (Series 1) which uses IEEE 802.15.4 as basic network topologies and 2.4 GHz frequency band which is adaptable for worldwide deployment as shown in FIGURE 6 for a standard version and FIGURE 7 for a Pro Version. This embedded RF modules manufactured by DIGI International Inc is very ideal for application that requiring low latency and predictable communication timing.

TABLE 1: ZigBee/IEEE 802.15.4 network comparison

	ZigBee™ 802.15.4	Bluetooth™ 802.15.1	Wi-Fi™ 802.11b	GPRS/GSM 1XRTT/CDMA
Application Focus	Monitoring & Control	Cable Replacement	Web, Video, Email	WAN, Voice/Data
System Resource	4KB-32KB	250KB+	1MB+	16MB+
Battery Life (days)	100-1000+	1-7	.1-5	1-7
Nodes Per Network	255/65K+	7	30	1,000
Bandwidth (kbps)	20-250	720	11,000+	64-128
Range (meters)	1-75+	1-10+	1-100	1,000+
Key Attributes	Reliable, Low Power, Cost Effective	Cost, Convenience	Speed, Flexibility	Reach, Quality

This multipoint RF module normally used as pure cable replacement for simple serial communication and as hub-and-spoke network of sensors which maximize wireless performance and ease of development. Standard XBee 802.15.4 (Series 1) module with 1mW transmits power has a 30 meter range for indoor and 100 meter range for outdoor. Meanwhile for Pro version with 60mW transmits power, has a range of 100 meter for indoor and 1.6 km for outdoor. TABLE 2 shows a full specification of XBee IEEE 802.15.4 modules and TABLE 3 pin assignment of XBee modules.

TABLE 2: Specification of XBee and XBee-Pro IEEE 802.15.4 modules

Specification	XBee	XBee-PRO
Performance		
Indoor/Urban Range	Up to 100 ft (30 m)	Up to 300 ft. (90 m), up to 200 ft (60 m) International variant
Outdoor RF line-of-sight Range	Up to 300 ft (90 m)	Up to 1 mile (1600 m), up to 2500 ft (750 m) international variant
Transmit Power Output (software selectable)	1mW (0 dBm)	63mW (18dBm)* 10mW (10 dBm) for International variant
RF Data Rate	250,000 bps	250,000 bps
Serial Interface Data Rate (software selectable)	1200 bps - 250 kbps (non-standard baud rates also supported)	1200 bps - 250 kbps (non-standard baud rates also supported)
Receiver Sensitivity	-92 dBm (1% packet error rate)	-100 dBm (1% packet error rate)
Power Requirements		
Supply Voltage	2.8 – 3.4 V	2.8 – 3.4 V
Transmit Current (typical)	45mA (@ 3.3 V)	250mA (@3.3 V) (150mA for international variant) RPSMA module only: 340mA (@3.3 V) (180mA for international variant)
Idle / Receive Current (typical)	50mA (@ 3.3 V)	55mA (@ 3.3 V)
Power-down Current	< 10 µA	< 10 µA
General		
Operating Frequency	ISM 2.4 GHz	ISM 2.4 GHz
Dimensions	0.960" x 1.087" (2.438cm x 2.761cm)	0.960" x 1.297" (2.438cm x 3.294cm)
Operating Temperature	-40 to 85° C (industrial)	-40 to 85° C (industrial)
Antenna Options	Integrated Whip, Chip or U.FL Connector, RPSMA Connector	Integrated Whip, Chip or U.FL Connector, RPSMA Connector
Networking & Security		
Supported Network Topologies	Point-to-point, Point-to-multipoint & Peer-to-peer	
Number of Channels (software selectable)	16 Direct Sequence Channels	12 Direct Sequence Channels
Addressing Options	PAN ID, Channel and Addresses	PAN ID, Channel and Addresses
Agency Approvals		
United States (FCC Part 15.247)	OUR-XBEE	OUR-XBEEPRO
Industry Canada (IC)	4214A XBEE	4214A XBEEPRO
Europe (CE)	ETSI	ETSI (Max. 10 dBm transmit power output)*
Japan	R201WW07215214	R201WW08215111 (Max. 10 dBm transmit power output)*
Austraila	C-Tick	C-Tick

TABLE 3: Pin Assignment of XBee and XBee-Pro IEEE 802.15.4 modules

Pin #	Name	Direction	Description
1	VCC	-	Power supply
2	DOUT	Output	UART Data Out
3	DIN / **CONFIG**	Input	UART Data In
4	DO8*	Output	Digital Output 8
5	**RESET**	Input	Module Reset (reset pulse must be at least 200 ns)
6	PWM0 / RSSI	Output	PWM Output 0 / RX Signal Strength Indicator
7	PWM1	Output	PWM Output 1
8	[reserved]	-	Do not connect
9	DTR / SLEEP_RQ / DI8	Input	Pin Sleep Control Line or Digital Input 8
10	GND	-	Ground
11	AD4 / DIO4	Either	Analog Input 4 or Digital I/O 4
12	**CTS** / DIO7	Either	Clear-to-Send Flow Control or Digital I/O 7
13	ON / **SLEEP**	Output	Module Status Indicator
14	VREF	Input	Voltage Reference for A/D Inputs
15	Associate / AD5 / DIO5	Either	Associated Indicator, Analog Input 5 or Digital I/O 5
16	**RTS** / AD6 / DIO6	Either	Request-to-Send Flow Control, Analog Input 6 or Digital I/O 6
17	AD3 / DIO3	Either	Analog Input 3 or Digital I/O 3
18	AD2 / DIO2	Either	Analog Input 2 or Digital I/O 2
19	AD1 / DIO1	Either	Analog Input 1 or Digital I/O 1
20	AD0 / DIO0	Either	Analog Input 0 or Digital I/O 0

<u>Arduino Pro Mini 328 – 5V/16MHz</u>

Designing WSN module as a personnel positioning application, a single-board microcontroller is used to communicate with the XBee 802.15.4 RF module. Microcontroller board will be responsible as an additional application layer of XBee RF module which manages the communication between RF module and the user interface.

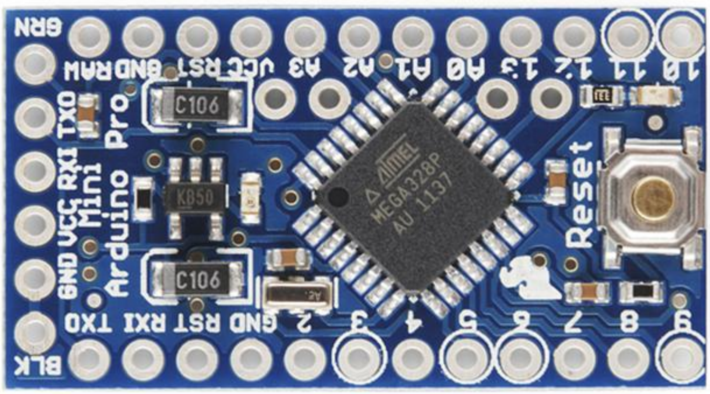

FIGURE 8: Arduino Pro Mini 328 – 5V/16MHz

Arduino has been chosen as a microcontroller platform for personnel positioning application as it is an open-source electronics prototyping platform and a lot easier to interact with various types of sensors and environments. A tiny and thin Arduino Pro Mini 328 board has been selected in order to compress the design and keep it mobile as shown in FIGURE 8. Arduino Pro Mini uses Atmel 8-bit AVR RISC-based microcontroller running at 16MHz with external resonator as shown in TABLE 4. TABLE 5 shows a pin assignment of Arduino Pro Mini 328 and FIGURE 9 show a schematic circuit of Arduino Pro Mini 328 board.

TABLE 4: Arduino Pro Mini 328 – 5V/16MHz Specification

Specification	**Detail**
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage	5V - 12V
Digital I/O Pins	14 (6 PWM output)
Analog Input Pins	6
DC Current per I/O Pins	40 mA
Flash Memory	32KB (2KB used by bootloader)
SRAM	2KB
EEPROM	1KB
Clock Speed	16 MHz
Dimension	18x33mm

TABLE 5: Pin Assignment of Arduino Pro Mini 328 – 5V/16MHz

Pin	Detail
RAW	For supplying a raw voltage to the board
VCC	Regulated 5V
GND	Ground
RX	Receiver for UART communication
TX	Transmitter for UART communication
2 and 3	40 mA
3,5,6,9,10,11	Digital I/O and PWM pins
10,11,12,13	Digital I/O and SPI pins (10-SS, 11-MOSI, 12-MISO, and 13-SCK)
A0,A1,A2,A3,A6,A7	Analog input pins
A4 and A5	Analog input and IIC pins (A4-SDA and A5-SCL)
Reset	Reset the board

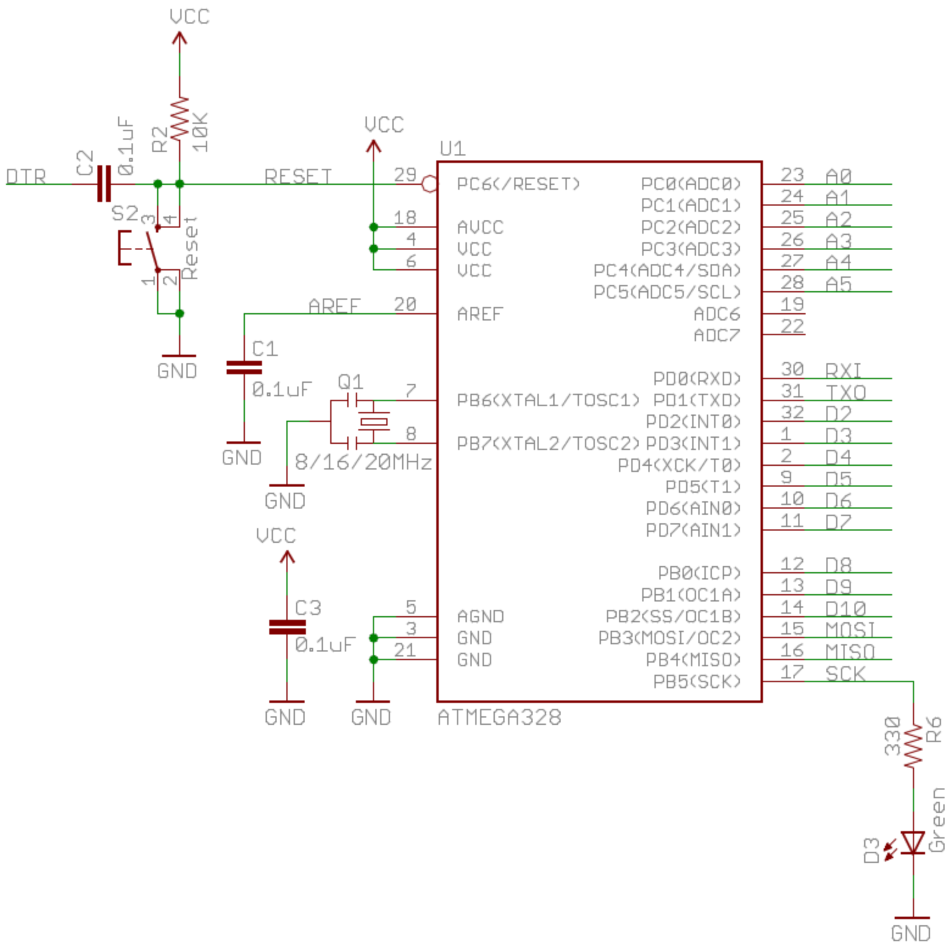

FIGURE 9: Schematic circuit of Arduino Pro Mini 328 – 5V/16MHz board

<u>XBee Starter Kit</u>

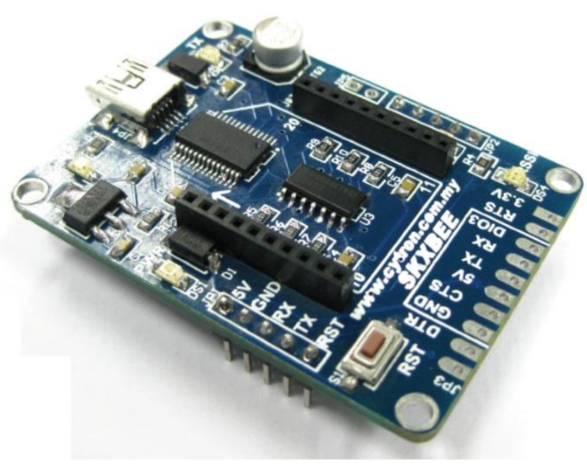

FIGURE 10: XBee Starter Kit

XBee module is designed using 3.3V system while Arduino Pro Mini 328 board is using 5V system. Thus, XBee starter kit is used to convert the 3.3V XBee system to 5V system before communicating with the 5V microcontroller system as shown in FIGURE 10. This board will regulate the supply voltage and translate the 3.3V XBee serial signals (TX/RX) to 5V serial signal. TABLE 6 shows the pin layout of XBee starter kit.

TABLE 6: XBee Starter Kit board pin layout

Label	Detail
5V	Input voltage
GND	Ground
RX	UART receiver signal
TX	UART transmit signal
RST	Reset

Firmware Design

Firmware is a program code that etched permanently into a hardware device. For this project, a permanent Arduino coding is programmed into a designated hardware which consists of Arduino Pro Mini and wireless XBee module to give permanent instruction. This permanent instruction will allow the hardware to perform basic function like input/output task, communicate each other and interface with the graphical user interface (GUI). Without a firmware, the hardware of positioning device would be non-functional.

Designing a firmware for personnel positioning purpose will require a combination of wireless sensor module (XBee) and microcontroller board that can communicate each other in order to perform a single instruction. A state machine mathematical model is used to design the firmware of the device that can operate based on the input to change the status of the devices.

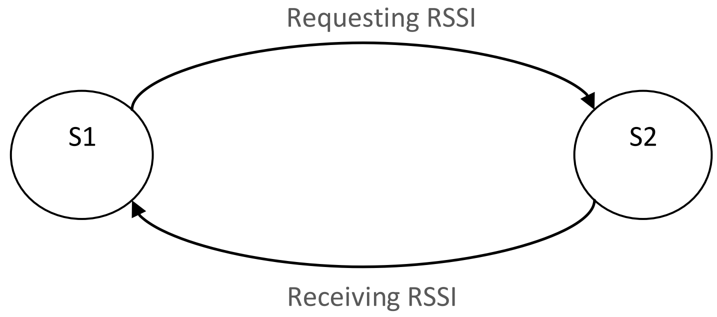

FIGURE 11: State Machine model of the firmware

Based on FIGURE 11, the device is separated into two different states. The first state is an idle state which will only change its state to waiting mode (State 2) when the user has request RSSI as an input. After receiving the requested RSSI, the current state, S2 will turn back into S1to wait for the next instruction. This continuous loop is known as finite state machine model that purposely designed to store permanent instruction as a firmware of the device.

Software Design

Considering usability and scalability with current industries software trend, Windows platform is used as a graphical user interface (GUI) design platform in order to keep this positioning software adaptable with most of the users and industries. Monitoring personnel movement will require a lot of data processing and complex algorithm in order to compute accurate indoor positioning-based system. Thus, a computer with Windows operating system will be used as a main operating system.

Microsoft Visual Studio Express is a freeware integrated development environment (IDE) developed by Microsoft especially for its Windows OS. Visual studio has a collection of tools and services for developing desktop application which capable to support many languages such as C#, VB.NET, C++, HTML, JavaScript and many more. FIGURE 12 shows a screenshot of Microsoft Visual Studio Express 2012.

This IDE will be used to design the GUI that capable to compute and process the complex algorithm for indoor distance estimation. User friendly interface will be a main priority in designing GUI in order to keep this software adaptable with any type of individual or industries.

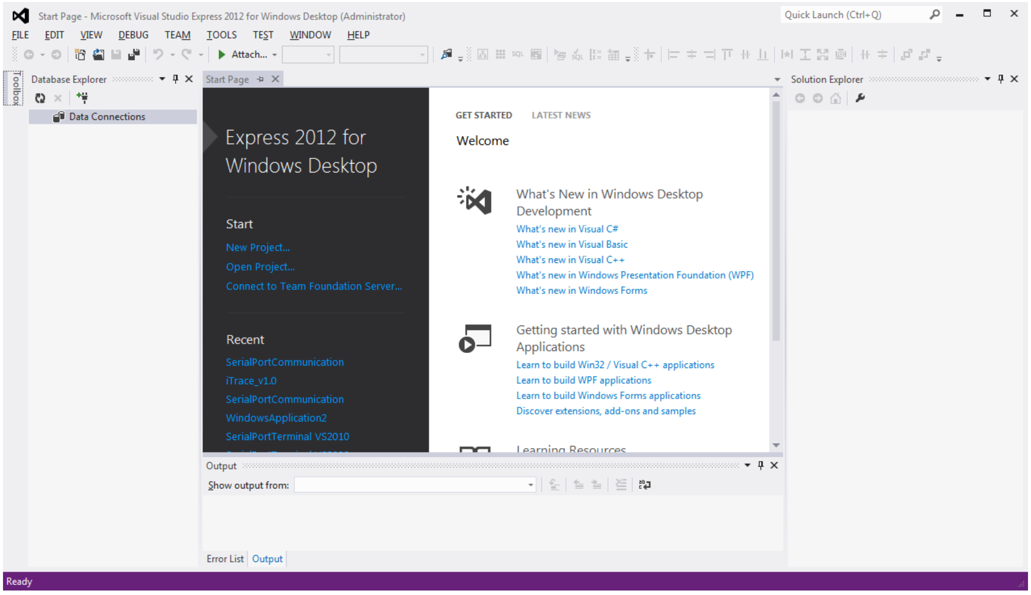

FIGURE 12: Microsoft Visual Studio Express 2012

3.3 Key Milestones

TABLE 7: Key Milestones of the Project

No.	Milestones	Target
FYP 1		
1	Project Proposal	Week 2
2	Extended Proposal	Week 6
3	Proposal Defences	Week 9
4	Interim Draft Report	Week 13
5	Interim Final Report	Week 14
FYP 2		
6	Prototype Design	Week 19
7	Prototype Testing	Week 23
8	Final Report	Week 26
9	Project Presentation	Week 27

3.5 Gantt Chart

TABLE 8: Gantt chart of the Project

Task	Date/Week																											
	January			February				March					April				May				Jun					July		
	13	20	27	3	10	17	24	3	10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	7	14	21
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
Project Proposal																												
Extended Proposal																												
Proposal Defences																												
Interim Draft Report																												
Interim Final Report																												
Prototype Design																												
Hardware Design																												
Firmware Design																												
Software Design																												
Prototype Testing																												
Open Space Indoor Environment																												
Close Space Indoor Environment																												
Indoor Positioning System																												
Restricted Area Testing																												
Final Report																												
Project Presentation																												

CHAPTER 4

RESULT AND DISCUSSION

4.1 Prototype Design

Prototype of WSN indoor positioning system consists of three different nodes which is Personnel Node, Server Node and Fixed Nodes.

First Prototype

The first prototypes of the device require a lot of space because of the battery size. From left are a Server Node, Personnel Node and Fixed Node as shown in FIGURE 13.

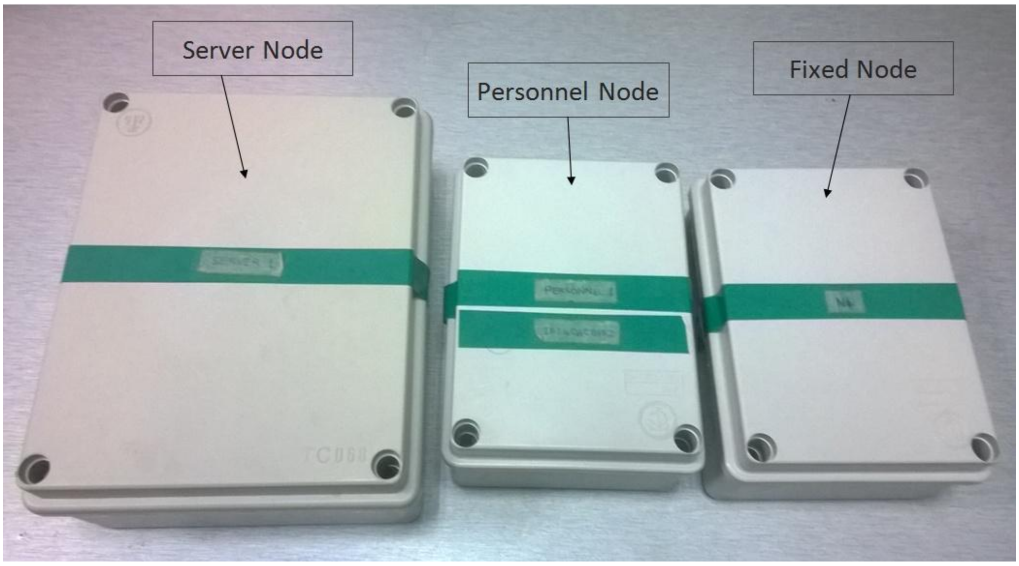

FIGURE 13: First Prototype Packaging

FIGURE 14: Extracting RSSI Value from WSN Module

Second Prototype

FIGURE 16 shows the component assembly of a Fixed Node while FIGURE 15 shows the packaging of the second prototype. From left are Server Node wit USB cable, Fixed Node and Personnel Nodes.

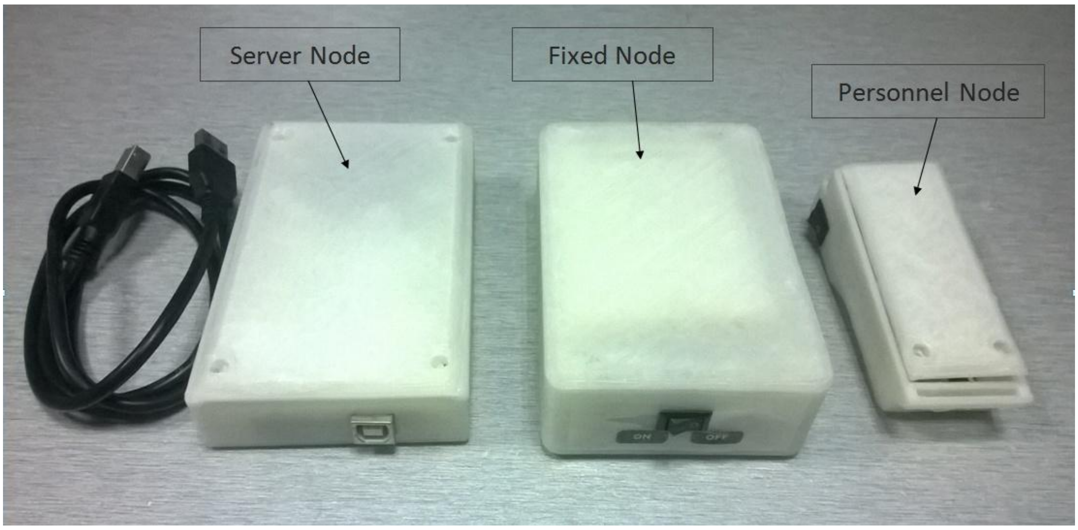

FIGURE 15: Second Prototype Packaging using 3D Printer

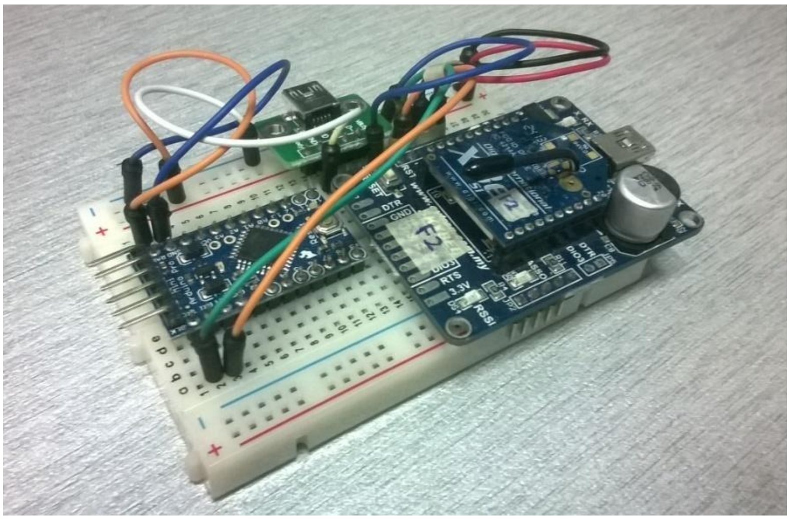

FIGURE 16: Component Assembly of Fixed Node

4.1.1 Personnel Node

Personnel Node is a mobile device that will be attached to the personnel. It is consisting of microcontroller, XBee IEEE 802.15.4 WSN module, switches and buzzer. FIGURE 17 shows the block diagram of Personnel Node's component.

FIGURE 17: Block Diagram of Personnel Node

4.1.2 Server Node

Server Node is a main control unit that manage all the communication between all nodes. It is consisting of microcontroller, XBee IEEE 802.15.4 WSN module and USB port. Server node is USB connected devices that communicate with the computer interface so that all the personnel activities and location can be monitored. FIGURE 18 shows the block diagram of Server Node's component.

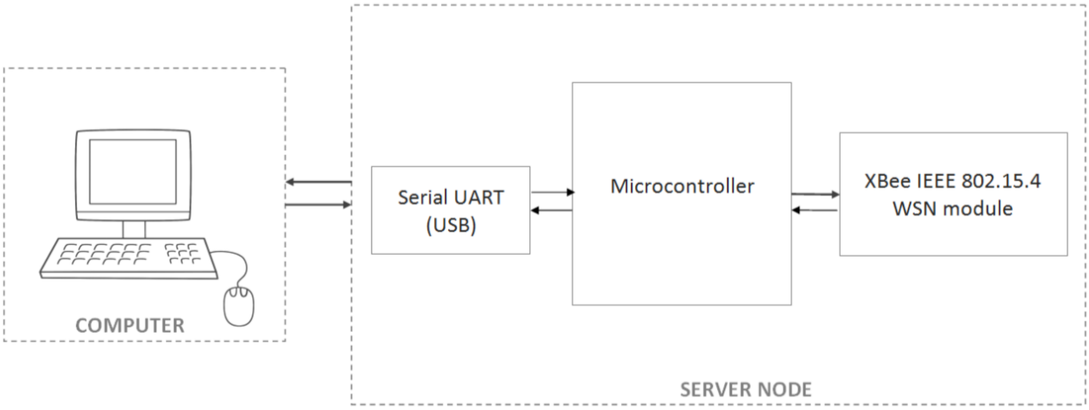

FIGURE 18: Block Diagram of Server Node

4.1.3 Fixed Node

Fixed Node is a several reference nodes that will be placed at a specific place within a certain range. It is consisting of microcontroller and XBee IEEE 802.15.4 WSN module only. FIGURE 19 shows the block diagram of Server Node's component.

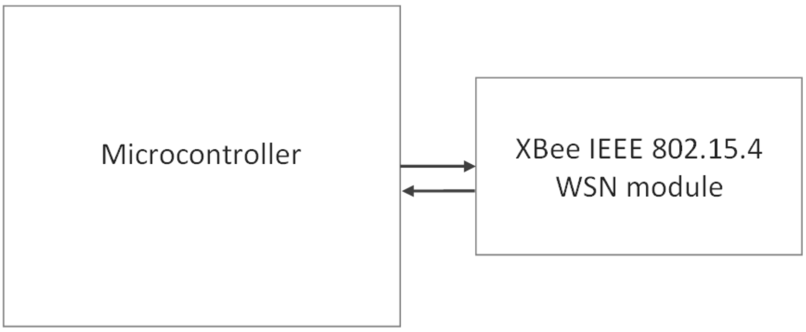

FIGURE 19: Block Diagram of Fixed Node

4.2 Prototype Testing

Measurement of signal strength against distance was observed and recorded to study the behaviour of XBee IEEE 802.15.4 module over various condition of indoor environment.

4.2.1 Open Space Indoor Environment

Open space indoor environment is a condition where there is not much obstacle inside the building and will have a better Line of Sight (LOS) freedom. However, the reading still can be inaccurate due to reflection and refraction of wireless signal inside the concrete building and surrounding condition. TABLE 9 shows the measurement result inside the concrete building with a lesser obstacle as shown in FIGURE 20.

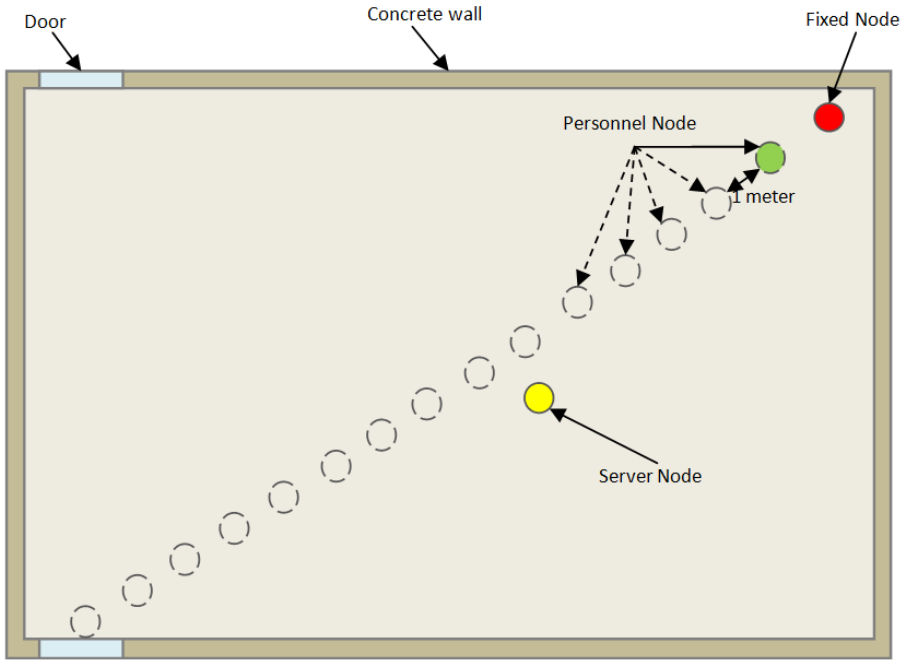

FIGURE 20: Top View of Open Space Indoor Environment

TABLE 9: Signal Strength VS Distance (Open Space Indoor Environment)

Distance (meter)	**Signal strength (-dBm)**			
	1st Reading	**2nd Reading**	**3rd Reading**	**Average**
0	47	40	42	41
1	52	51	54	52
2	59	56	63	59
3	63	64	57	61
4	58	59	60	59
5	56	53	61	57
6	62	60	62	61
7	65	67	64	65
8	62	62	64	63
9	65	63	68	65
10	67	68	70	68
11	70	72	74	72
12	64	67	66	66
13	66	69	69	68
14	76	77	79	77

Based on FIGURE 21, the maximum distance of between the Personnel Node and Fixed Node can achieved up to 14 meter. The higher the value of signal strength (-dBm), the stronger the signal strength. However, the signal strength reading of XBee IEE 802.15.4 still not very stable due to surrounding condition of the indoor environment.

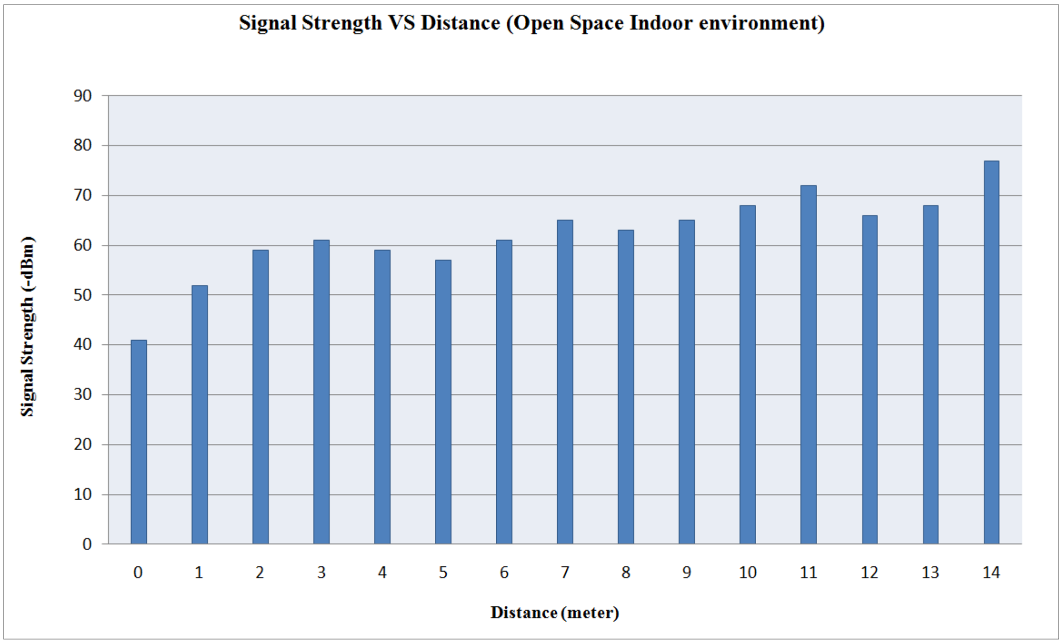

FIGURE 21: Signal Strength VS Distance (Open Space Indoor Environment)

4.2.2 Close Space Indoor Environment

Close space indoor environment as shown in FIGURE 22 is a confined space which has more obstacles such as concrete walls and wooden door. The reading will be less accurate due to restrict accessibility of LOS freedom as shown in TABLE 10.

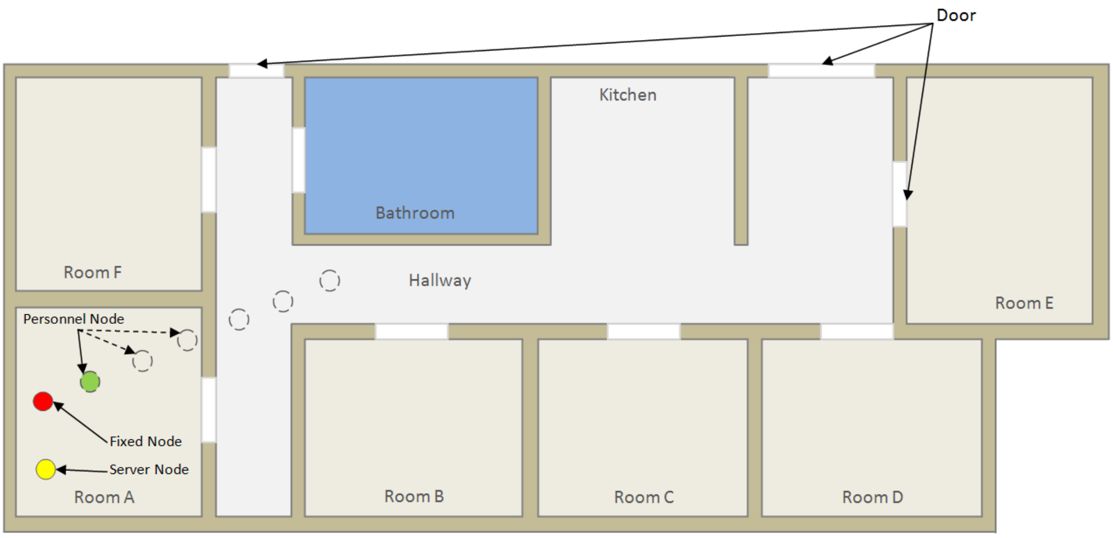

FIGURE 22: Top View of Close Space Indoor Environment

TABLE 10: Signal Strength VS Distance (Close Space Indoor Environment)

Distance (meter)	Signal strength (-dBm)			
	1st Reading	2nd Reading	3rd Reading	Average
0	44	43	45	44
1	51	51	53	52
2	56	54	58	56
3	58	57	59	58
4	73	71	70	71

Based on the plotted graph in FIGURE 23, the maximum distance can be achieved is four meter only. The concrete wall has reduced the signal strength of the WSN. The range for 3 meter and below was inside the room which is less than -60dBM while at 4 meter the signal strength is already more than -70dBm which can be considered as a weak signal already.

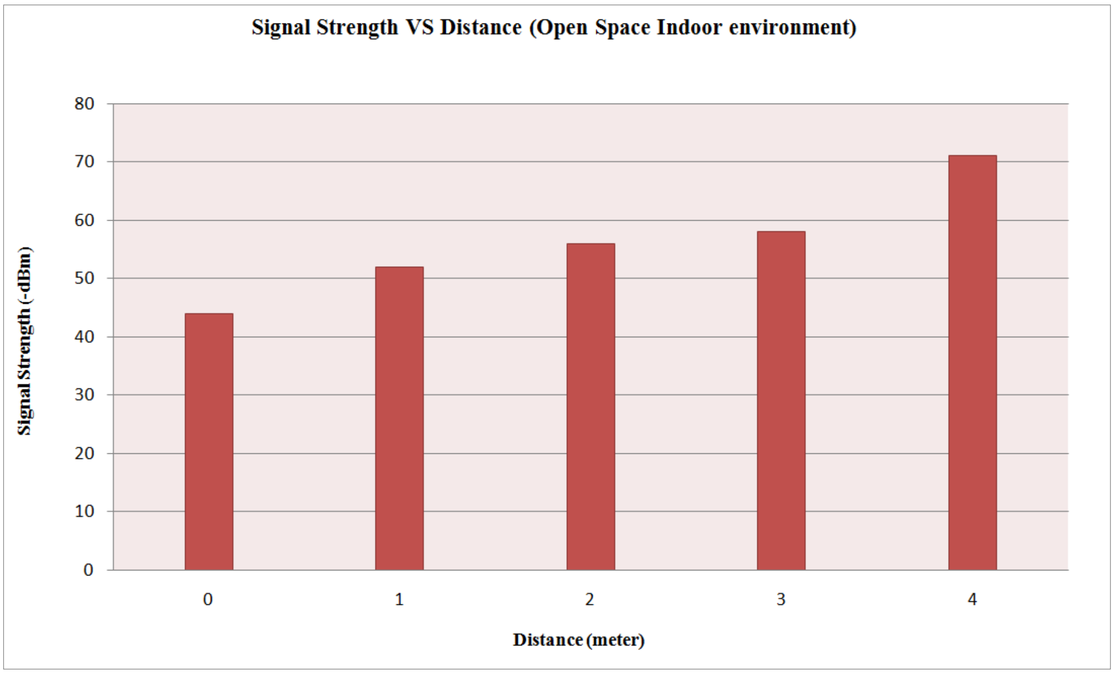

FIGURE 23: Signal Strength VS Distance (Close Space Indoor Environment)

4.3 Indoor Positioning System Design

Designing indoor positioning using WSN will require an efficient triangulation method. Most of the research nowadays, they were using trilateration method which will be measured based on the intersection of three defined circular signal strength of the WSN. The reading of signal strength for outdoor environment is quite reliable due to Line of Sight (LOS) access. However, since there are too many obstacles, LOS become restricted which will cause the trilateration method become inaccurate due to unreliable reading of signal strength. Thus the triangulation by sectioning method is preferable compared to the trilateration method.

4.3.1 Indoor Positioning Testing

In order to simulate the sectioning method of indoor positioning, the testing was done inside the apartment house with a close space indoor environment. Personnel Node, Server node and three Fixed Nodes were used to validate the exact location of the personnel with the triangulate location of the personnel.

Based on the prototype testing in the closed space indoor environment, the maximum four meter distance range of signal strength is used as reference to set up the nodes placemen. This is to make sure all the studied areas were covered with the WSN circular range. The server node was placed in the middle so that it can have maximum coverage. The placement of Fixed Nodes and Server Node is shown in FIGURE 24.

The Personnel Node will be place at five different location which is at Room A, Room B, Room C, Center Hallway and Junction Hallway. All the nodes placementr at five different location are shown from FIGURE 25 until FIGURE 29.

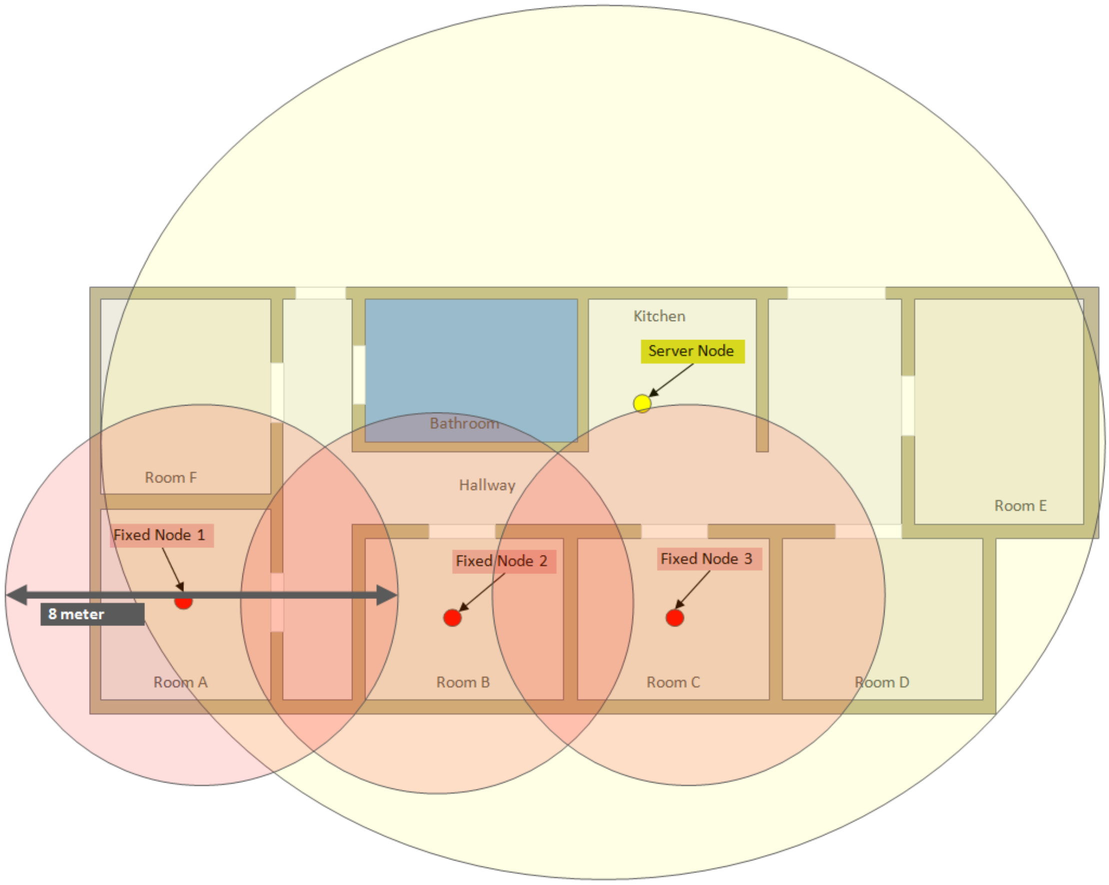

FIGURE 24: WSN Nodes Placement

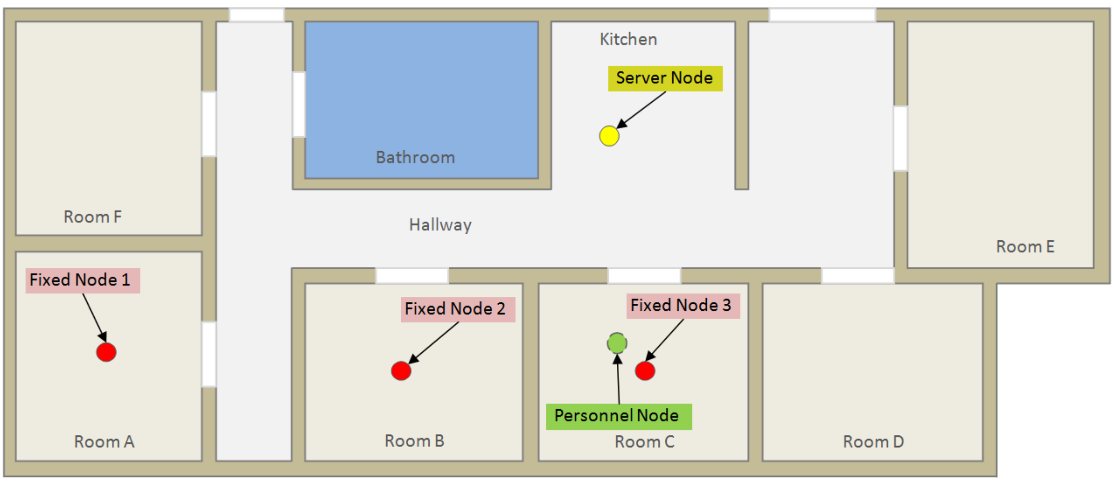

FIGURE 25: Personnel Node at Room C

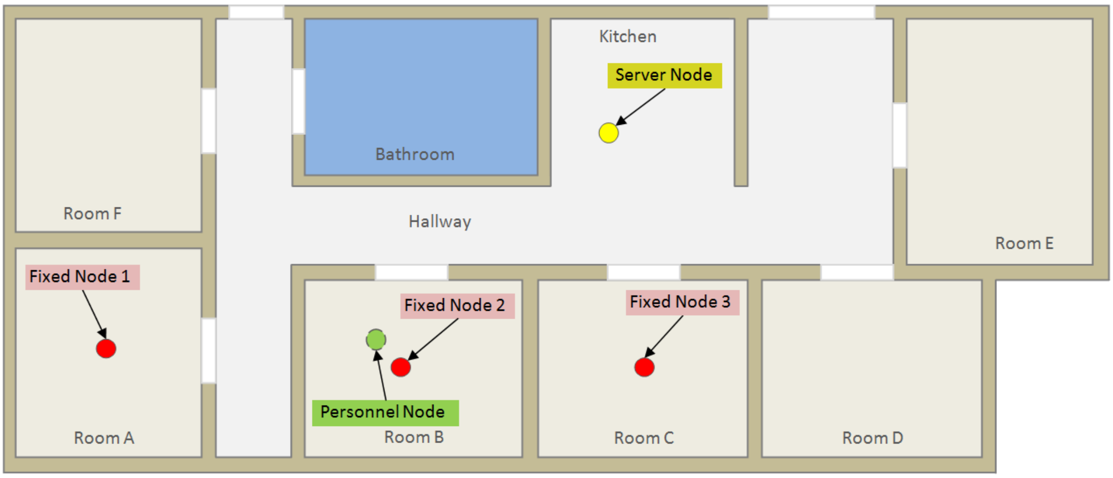

FIGURE 26: Personnel Node at Room B

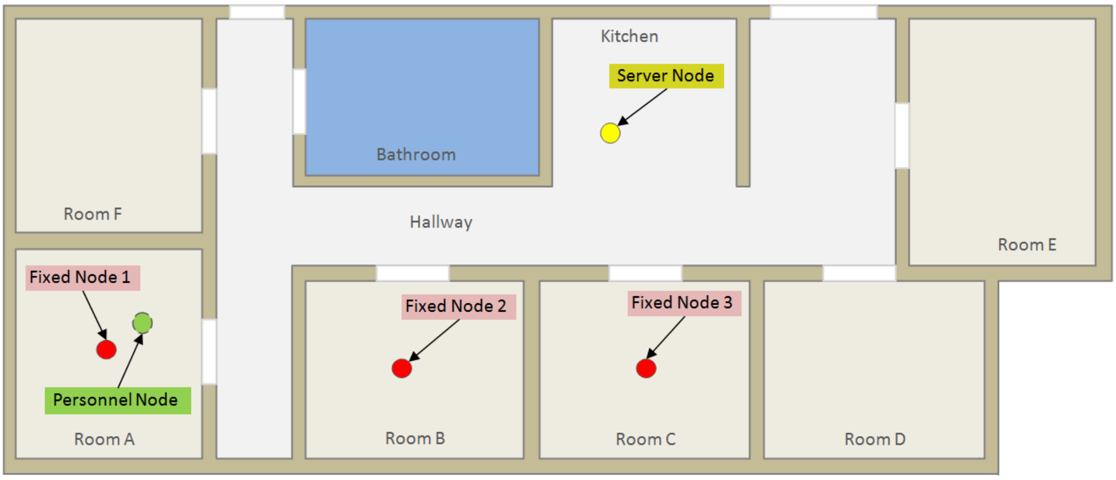

FIGURE 27: Personnel Node at Room A

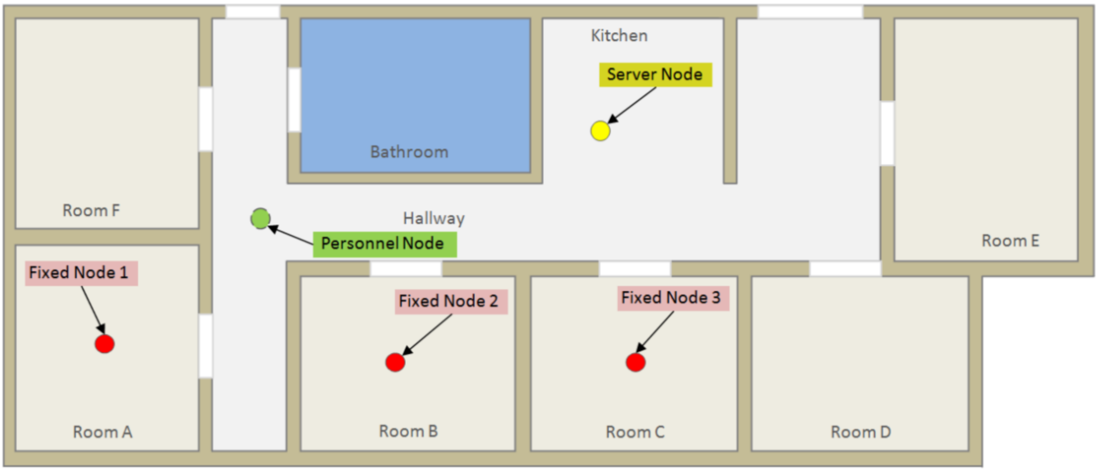

FIGURE 28: Personnel Node at Junction Hallway

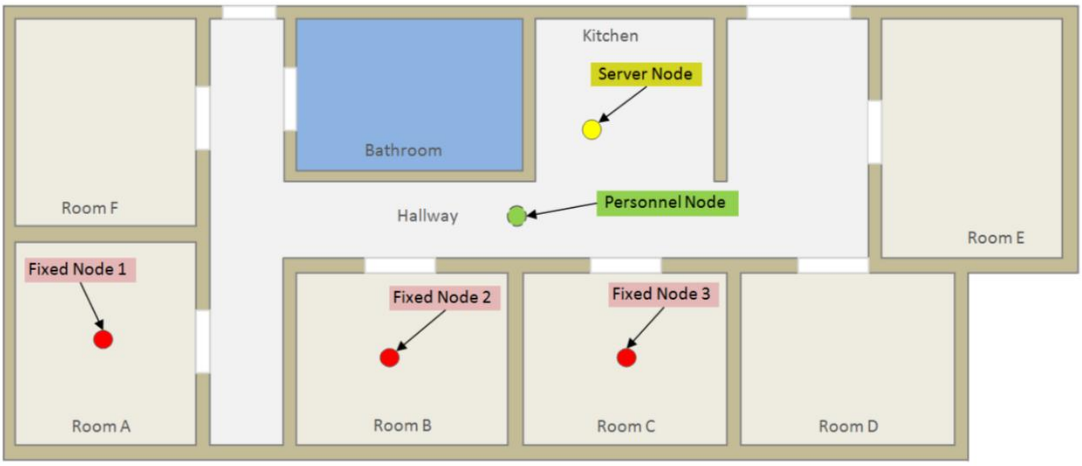

FIGURE 29: Personnel Node at Center Hallway

TABLE 11: Signal Strength (-dBm) VS Triangulate Location

Exact Location	Signal Strength (-dBm)			Triangulated location
	Fixed Node1	Fixed Node2	Fixed Node3	
Room C	-	-	52	Room C
Room B	-	48	-	Room B
Room A	45	-	-	Room A
Junction Hallway	67	63	-	Junction Hallway
Center Hallway	-	66	67	Center Hallway
Room C	-	71	48	Room C
Room B	69	44	73	Room B
Room A	51	71	-	Room A
Junction Hallway	65	64	-	Junction Hallway
Center Hallway	-	70	64	Center Hallway

All the measurement location were repeated for two times so thatvarious combination of signal strength can be observed and analyzed. TABLE 11 shows that the triangulate location will have the strongest signal strength reading of its own Fixed node. This can be show through the first measurement of Room Cwith its own Fixed node 3 which has the strongest signal strength reading while the other two fixed nodes have no reading at all since they are not in range. For Juntion Hallway and Center Hallway the triagulate location can be decided using the two weakest signal. For example, the Junction Hallway can be decided using the two weakest signal strength of Fixed Node 1 and Fixed Node two since the Junction Hallway is located in the middle of Fixed Node 1 and Fixed Node 2.

Based on the measurement result from TABLE 12, the reading is converted into percentage form. The signal strength of the XBee IEEE 802.15.4 will be from -40dBm until -80dBm with 40dBm range. All of the conversion is shown in TABLE. The percentage form of the signal strength can be converted using the following equation:

$$\text{Percentage of Signal Strength } (\%) = x$$

$$\text{Signal Strength}(-\text{dBm}) = S$$

$$x = \frac{80 - S}{40} \times 100\% \quad \textbf{(4.1)}$$

TABLE 12: Percentage of Signal Strength (%) VS Triangulate Location

Exact Location	Percentage of Signal Strength (%)			Triangulated location
	Fixed Node1	Fixed Node2	Fixed Node3	
Room C	0	0	70	Room C
Room B	0	80	0	Room B
Room A	88	0	0	Room A
Junction Hallway	33	43	0	Junction Hallway
Center Hallway	0	35	33	Center Hallway
Room C	0	23	80	Room C
Room B	28	90	18	Room B
Room A	73	23	0	Room A
Junction Hallway	38	40	0	Junction Hallway
Center Hallway	0	25	40	Center Hallway

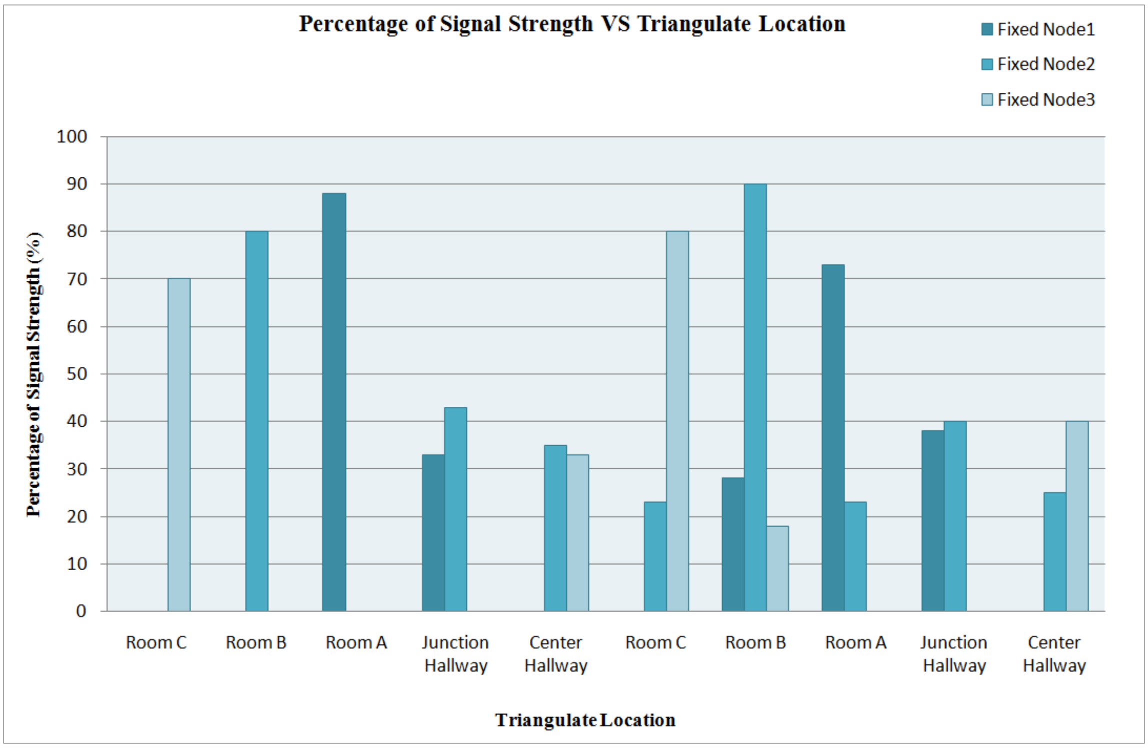

FIGURE 30: Percentage of Signal Strength VS Triangulate Location

FIGURE 30 shows the graph of percentage of signal strength against the triagulate location of the personnel. All the the triangulate location of the personnel can be decided based on the highest percentage and the two lower percentage of signal strength.

4.3.2 Restricted Area Alert System Testing

Each Personnel Node will be equiped with the small buzzer and emergency switch so that any ugernt alert can be send to the personnel as soon as possible without interupting other personnels. This individual alert system can increase the the working efficiency since they are personnelly attached and less interupting so that only that personnel will receive the alert if they had entered a restricted area.

The simulation of restricted area was done in the same location which is apartment house with Room C as a restricted area as shown in FIGURE 31.

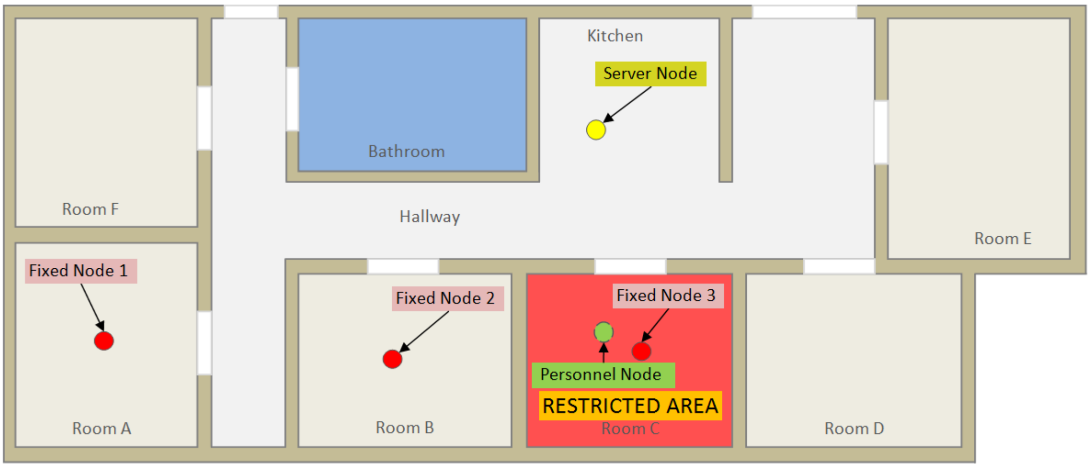

FIGURE 31: Close space Indoor Environment with a Restricted Area

TABLE 13: Buzzer Mode at the Different Location of Personnel

Personnel Location	Signal Strength (-dBm)			Buzzer
	Fixed Node1	Fixed Node2	Fixed Node3	
Room C	-	-	52	ON
Room B	-	48	-	OFF
Room A	45	-	-	OFF
Junction Hallway	67	63	-	OFF
Center Hallway	-	66	67	OFF

The alarm or buzzer will only activate when the personnel had entered the Room C as shown in TABLE 13. When the alarm is triggered, the Personnel Nodes also will send a signal to the Server Node to notify the administrator that someone already had entered the restricted area. This buzzer will immediately turn off when that personnel leave the the restristed area without disturbing any other personnels.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the result, an effective indoor positioning using WSN can be triangulate using sectioning method which is more reliable than the trilateration method because of inconsistent reading of signal strength due to the weak signal inside a concrete building. Since the range of signal strength of the XBee IEEE 802.15.4 is ranged from -40dBm up to -80dBm, the signal strength reading can be separated into two different groups of signal state which are strong signal and weak signal as shown in TABLE 14.

TABLE 14: Signal State Grouping of Signal Strength

Signal Strength (-dBm)	Signal State
40-59	Strong
60-80	Weak
No data	Weak

Restricted area alert system which can be setup from the Server Node also fully working as the alarm is triggered when the personnel had entered the restricted area. Thus the entire objectives of this project which are to design effective personnel positioning system, monitoring the personnel and alert the personnel if they had entered the restricted area are achieved.

5.2 Recommendation

In order to increase the reliability of this WSN indoor positioning system some recommendation is suggested as below:

- Using higher receiver sensitivity and transmit power of WSN module.
- Design a more compact Personnel Node so that it will be easier to attach.
- Design a low power consumption of Personnel Node so that it can last longer.

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APPENDICES

FIGURE 32: First Prototype Packaging Assembly

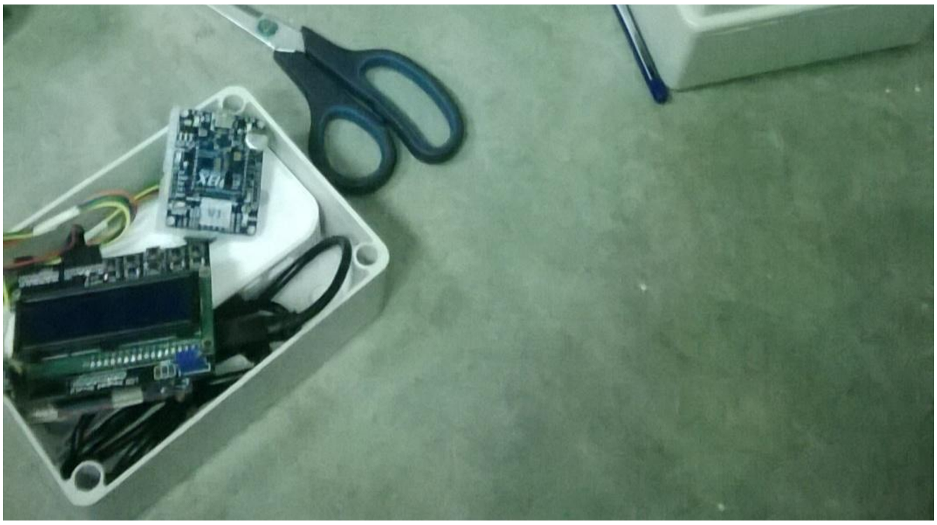

FIGURE 33: Component Assembling Inside the Packaging

Figure 34: Complete Set of First Prototype of WSN Position System Devices

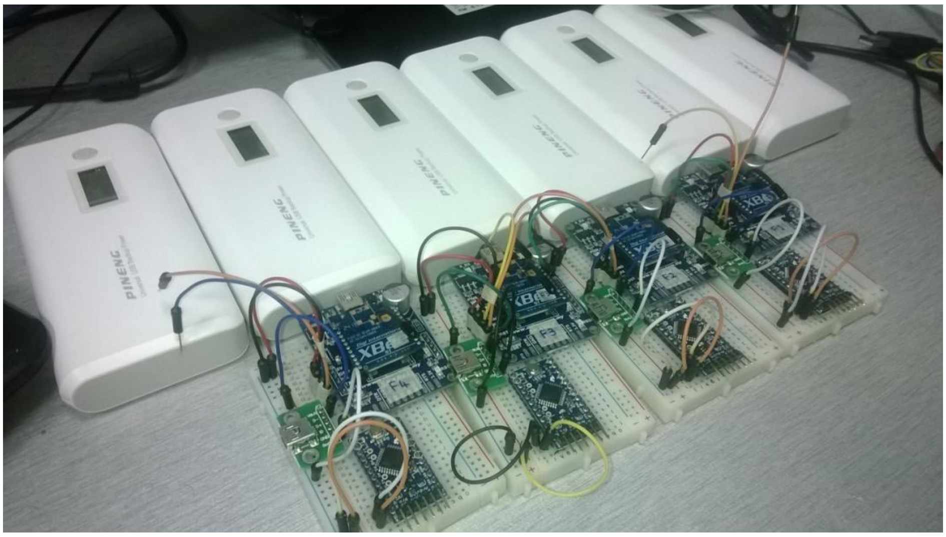

Figure 35: Latest Prototype of WSN Positioning System Devices