

Patients' Heart Monitoring System Based on Wireless Sensor Network

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Abstract. Wireless sensor network (WSN) has been utilized to support the health field such as monitoring the patient's heartbeat. Heart health monitoring is essential in maintaining health, especially in the elderly. Such an arrangement is needed to understand the patient's heart characteristics. The increasing number of patients certainly will enhance the burdens of doctors or nurses in dealing with the condition of the patients. Therefore, required a solution that could help doctors or nurses in monitoring the progress of patients' health at a real time. This research proposes a design and application of a patient heart monitoring system based on WSN. This system with using electrocardiograph (ECG) mounted on the patients' body and sent to the server through the ZigBee. The results indicated that the retrieval of data for 15 seconds in male patients, with the age of 25 years was 17 times rate or equal to 68 bpm. For 884 data packets sent for 15 minutes using ZigBee produce a data as much as 4488 bytes, throughput of 2.39 Kbps, and 0.24486 seconds of average delay. The measurement of the communication coverage based on the open space conditions within 15 seconds through ZigBee resulting throughput value of 4.19 Kbps, packet loss of 0 %, and 6.667 seconds of average delay. While, the measurement of communication range based on closed space condition through ZigBee resulting throughput of 4.27 Kbps, packet loss of 0 %, and 6.55 seconds of average delay.

1. Introduction

The WSN-based communication system in the health field has shown a relatively rapid and positive development [1] and has applied to monitoring system applications. Implementation health control system, among others: supervision of the patient's heartbeat [2], the human health control system and the detection of the spread of toxic chemicals [3], and the monitoring of patients' rehabilitation process based on distance [4]. The system aims to provide ease in monitoring the patients' conditions, operational cost efficiencies, reducing diagnostic errors, and converting conventional systems into computer-based digital systems, as well as supporting professional practice of healthcare services involving multiple disciplines [5].

One of the problems that occurred at the moment is the increasing number of patients and limitations of medical personnel, the workload of doctors will increase in dealing with the patient's health condition. Furthermore, the equipment used in monitoring the patient's heartbeat is still using a cable connected to the computer. Therefore required a solution that can assist medical personnel in the follow-up to the patient's health real time.



One solution that can apply to a patient's heart health monitoring system is the design and implementation of a WSN-based heartbeat system using the ZigBee protocol as a transmission medium. This designed system will provide the following benefits: 1) reduce the workload of medical personnel, 2) reduce medical errors, because patient data can monitor in real time.

2. Review of Literature

2.1. Health Monitoring

Health monitoring is the monitoring of a person to identify changes in health status due to certain substances. Health monitoring may include: consultation, answering questions related to medical history or lifestyle such as smoking, alcoholic beverages, and related that affect health [6].

In creating the architecture design of a patient's health, there are at least three layers to perform its function [7]. The layers are: 1) Perception Layer, this layer is the bottom layer of e-health monitoring architecture. Perception this layer consists of sensors that take individual data, related to the patient's health, 2) Middleware and API's Layer, this layer is where the data processing place, and 3) E-Health Application and Service Layer, it is the top layer of e-health monitoring architecture. This layer is an interface to display supervision of the patient.

2.2. Wireless Sensor Network (WSN)

WSN is a collection of nodes organized into a partner network [8]. Each node has processing capabilities, has several types of memory (programs, data and flash memories), has RF transceivers (Radio Frequency), has resources (e.g., Batteries and solar cells), and accommodates various sensors, and the system can revolutionize the way work to live again [9].

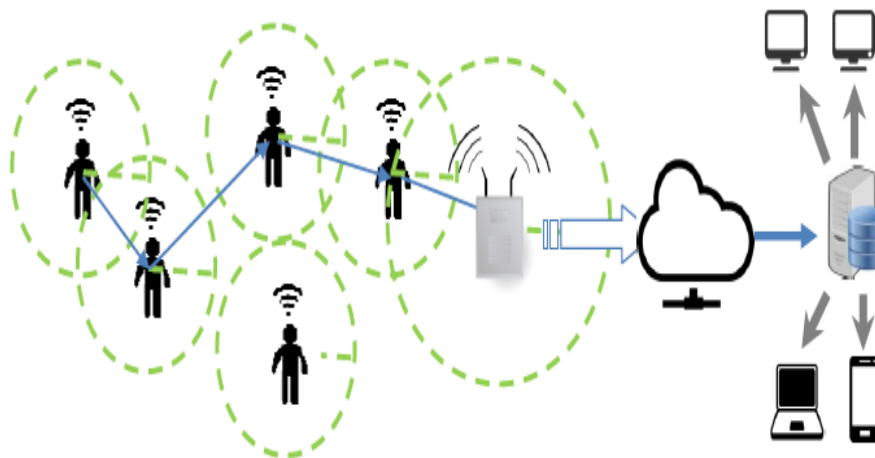


Figure 1. Topology wireless sensor network

2.3. Sensor Network

A sensor is a device used to detect or measure the value of a specified physical quantity. Sensors are a type of transducer used to convert mechanical, magnetic, heat, rays and chemical variations in voltage and electric current. Sensors play a critical role in the control of modern fabrication processes [10]. Meanwhile, according to [3], the sensor can be defined as a device that receives and responds to signals or stimulus.

The software that implemented on the network sensor is TinyOS. TinyOS is an open source operating system designed specifically for wireless sensor networks, which is responsive to sensory input and event-oriented [11], and TinyOS provides a relatively simple method of developing and

quickly implementing WSN [12]. TinyOS has a component-based architecture that supports the innovation and implementation of WSN by minimizing the required code size, as well as characteristics of sensor networks that have less memory.

2.4. Heart

The heart is the center of the human circulatory system [13]. The heart is a muscular organ that can push blood to various parts of the body. The human heart shape is like a cone and sized as an adult's fist, that's located in the left chest cavity and wrapped by a membrane called the pericardium. The heart is formed by muscular organs, apex, right and left atria, right and left ventricle. Heart size is about 12 cm long, 8 to 9 cm, wide as well as about 6 cm thick, heart weight is approximately 200 to 425 grams.

2.5. Electrocardiograph (ECG)

The electrocardiograph is a graph that depicts the electrical recording of the heart. The electrical activity of the heart in the body can be recorded and written by electrodes mounted on the body surface. An ECG sensor can detect signals at a frequency of 0.01 s / d 250 Hz. The main principle of the ECG is to identify the anatomy of the heart physiology and nerves. Thus it can be used to detect everything that occurs related to the performance of the heart. The signals issued by the ECG are analog signals of 0.5 mV up to 4 mV. The use of an optocoupler components needed in filtering ECG signals from sensor [14]. The physical form can see in Figure 2.

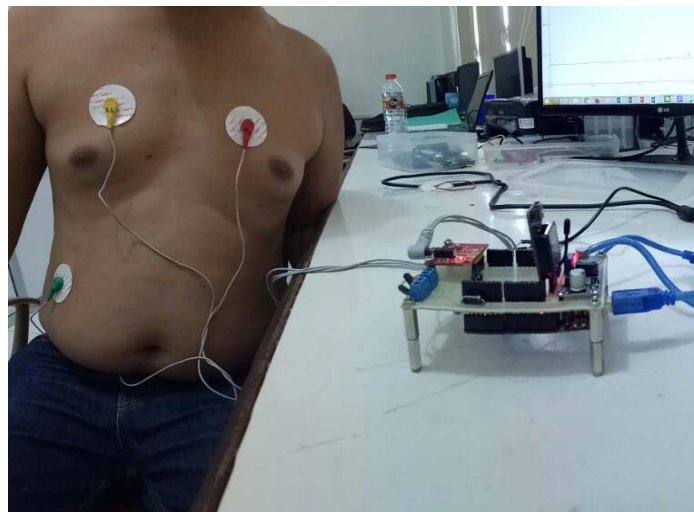


Figure 2. Electrode, lead cable and ECG sensor

The analog signals generated by the electrocardiogram are signals that interfered with other signals present in the body. Therefore, a sign is needed to separate it into two parts, i.e., a sign of the instrument (Signal Instrumentation Amplifier) and filter (low-pass filter and band reject filter).

From the results, the signal selected will be only the heartbeat signal. This weak signal will then be amplified by Instrumentation Amplifier and will scale. Once the signal processed at the signal processing and scaling level has performed, the data will be inserted into the ADC (Analog to Digital Conversion), or utilize the internal ADC in the Arduino module.

3. Research Methods

Figure 3 shows the stages of research that have done, including stages literature studies, tool design, and making heartbeat signal monitoring device, hardware testing, software preparation of heartbeat monitoring system, and analysis of test results.

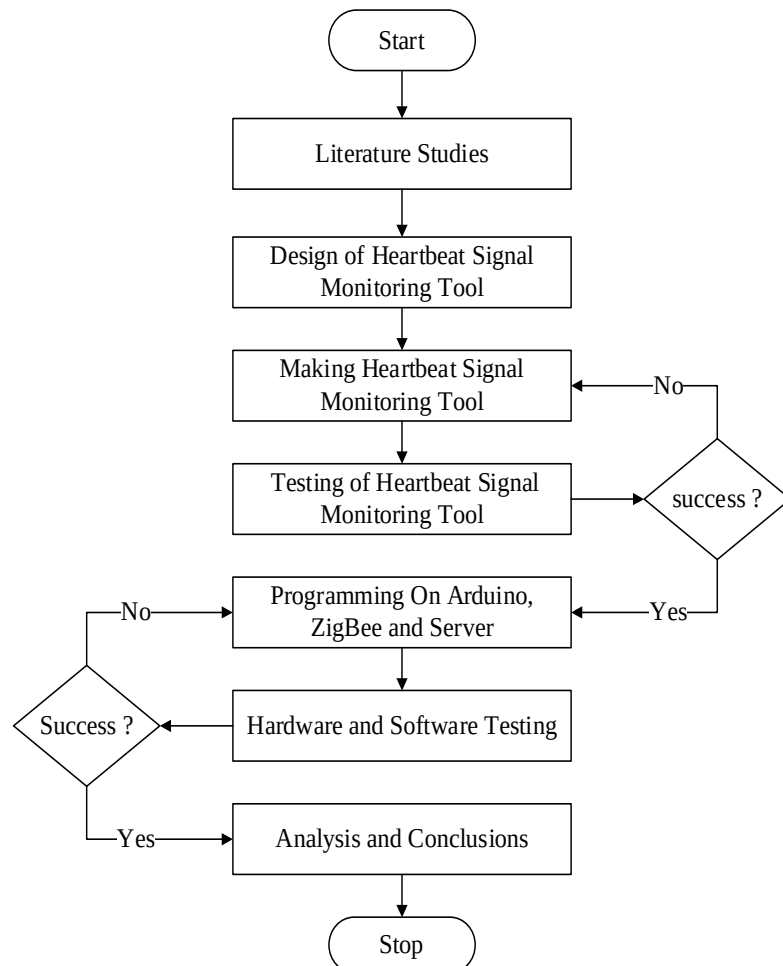


Figure 3. Flowchart of research

3.1. Literature Studies

In the literature study phase, a reference search will be made by the problem to be considered, especially about the heartbeat signal monitoring system. The target at this stage is to support the hypothesis in the design of a patient heartbeat monitoring system based on WSN.

3.2. Designing and Making Tools

Stage of the design and making of the heartbeat signal control system using hardware and software devices. The device consists of: sensor-board AD8232 is an ECG sensor, Arduino is the processing of ECG sensor data, XBee is a transmission medium, and the power supply is a voltage source. While the software consists of Integrated Development Environment (IDE) application program for Arduino, a XCTU application program for XBee, and node.js application program for the server.

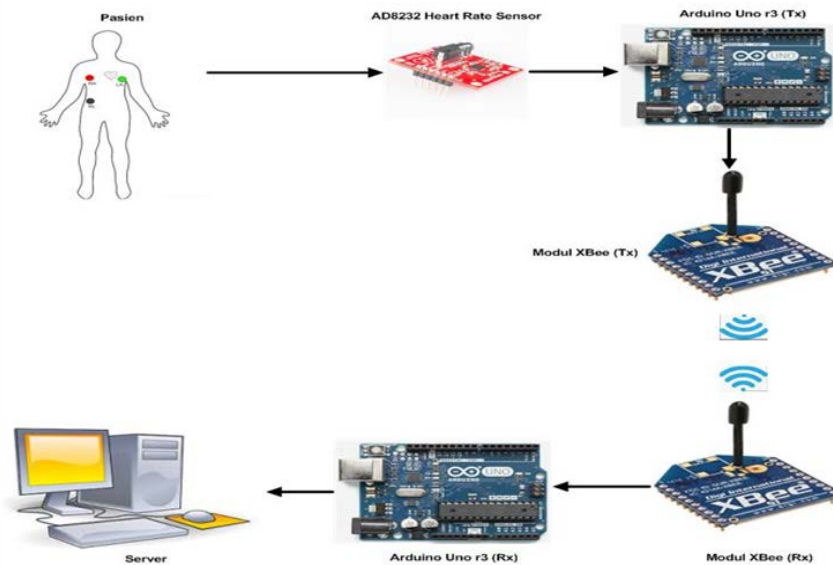


Figure 4. Block Diagram of the Patient's Heartbeat Pulse Monitoring System Based WSN

Figure 4 shows the block diagram of a patient's heartbeat pulse monitoring system. On this policy will be attached an AD8232 sensor-sensor (ECG sensor) on the patient's body. treated ECG sensor data results will be processed and treated by Arduino. Further, the data handled by the Arduino module will send to the server computer via the XBee module, and the patient ECG data will be visible on the server.

3.2.1 Design Hardware. Figure 5 shows the block diagram hardware, where the heartbeat signal is a weak analog signal. Therefore, the heartbeat signal to be connected to the AD8232 sensor-board pin will be amplified and filtered. Connect the ECG sensor, the signal conditioned according to the AD8232 sensor board specification. The sensor board AD8232 and Arduino are configurations from a sensor node. The sensor nodes are tasked to report analog to digital converter (ADC) readings to the server via XBee transmission media. At a later stage, the system test will be done entering the heartbeat signal into the Arduino and the result processed heartbeat data by Arduino will be forwarded to the server via XBee.

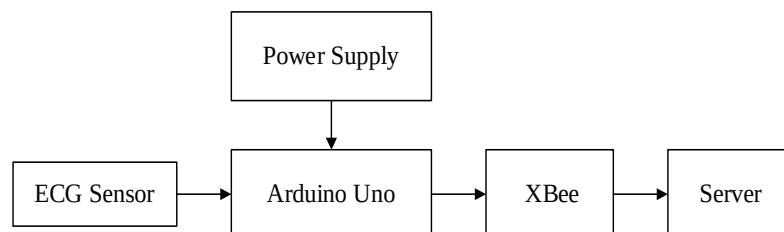


Figure 5. Block Diagram Hardware

3.2.2 Design Software. The application program used in software design consists of the IDE application program for Arduino by using C programming language, a XCTU application program which will be used to manage XBee module, and node.js application program used to run server

computer. The XCTU program implemented on a patient's heartbeat monitoring system using the JavaScript language.

4. Results and Discussion

4.1. Sensor Reading Validation

The voltage test results on the AD8232 board sensor shows that the observed value of the AD8232 sensor is 3.3 volts and the measurement value is 3,286 volts.

4.2. The Measurement of Heartbeat Signals Using Serial Plotter

Testing of heartbeat signals originating from the AD8232 sensor board output is not transmitted using XBee, but the output of the AD8232 sensor board connected to the Arduino will be linked directly to the server. In testing of heart rate test of male patients with age 25 years for 15 seconds resulted in 68 bpm heart signal period, the average delay of 0.245 seconds, and received data of 4,888 bytes. For a maximum voltage of 3.25 volts and a minimum voltage of 0 volts. The results of measurement of male heart signals using serial plotter could see in Figure 6.

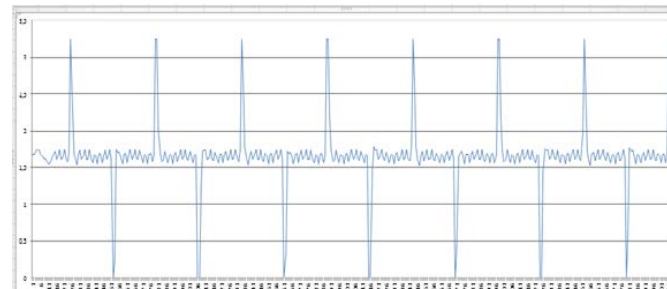


Figure 6. Heartbeat Signals Using Serial Plotter

4.3. Heart Signal Measurement with XBee

Testing the patient's heartbeat signal transmitted using XBee in males with age of 25 years, obtained a maximum voltage value of 3.25 volts and a minimum voltage value of 0 volts. While the delivery of 884 data packets conducted for 15 minutes through XBee able to receive data as much as 4488 bytes, a throughput of 2.39 Kbps and an average delay of 0.24486 seconds. The result of packet transmission of the heartbeat signal received through XBee can see in Figures 7 and 8.

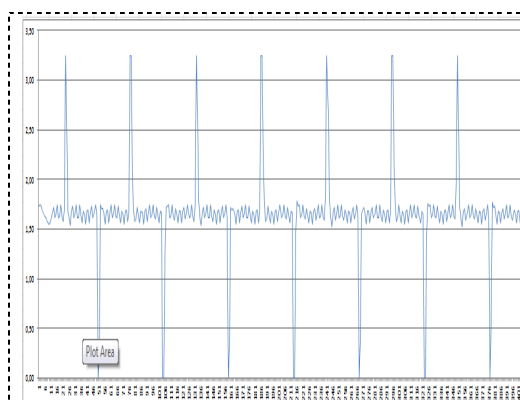


Figure 7. Results of heartbeat using XBee

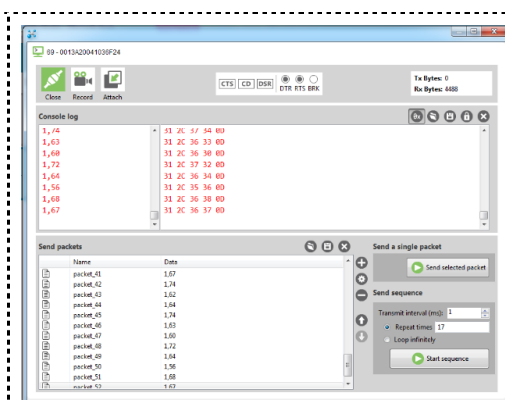


Figure 8. Display of Console XBee results

4.4. Communication Coverage Measurement

The measurement of XBee signal coverage done in two scenarios, namely the condition of enclosed space and open space conditions. In closed space conditions, the position between the first XBee and the second XBee placed along 23 meters with a height of 50 to 200 cm. While the status of open space, a position between the first XBee and XBee second positioned in the 38 meters with a height of 50 to 200 cm.

4.4.1 Closed Space Scenario. Table 1 shows the testing of the coverage of the communication signal using XBee in a closed space scenario with a height of 50 cm to 200 cm, send data of 80 bytes for 60 seconds.

Table 1. Closed space communication test results

XBee Position (cm)	Tx Data (byte)	Tx Packet	Rx Packet	Time (s)
50	19280	249	239	60
100	20080	251	251	60
125	30880	386	386	60
150	31200	390	390	60
200	31440	393	393	60

The test results show, the XBee module placement based on the height, very influential on the throughput generated. The result of throughput can see in Figure 9.

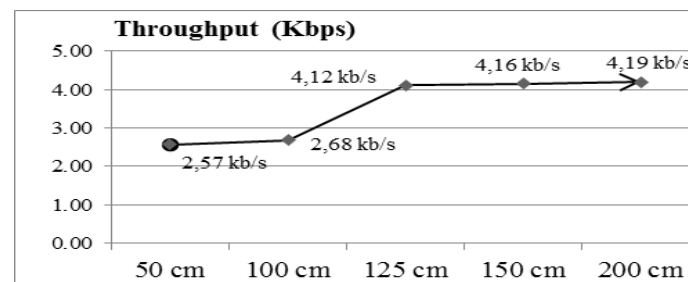


Figure 9. Throughput results in closed space scenarios

Figure 9 shows, the placement of XBee modules from 50 cm to 125 cm by throughput value increased from 2.57 Kbps to 4.12 Kbps. The location of the XBee module from 125 cm to 200 cm, throughput value increased by 0.07 Kbps. However, the placement of XBee modules 200 cm, the throughput value will experience a constant position of 4.19 Kbps.

For the test results, the amount of packet loss during the two XBee modules to communicate can see in Figure 10.

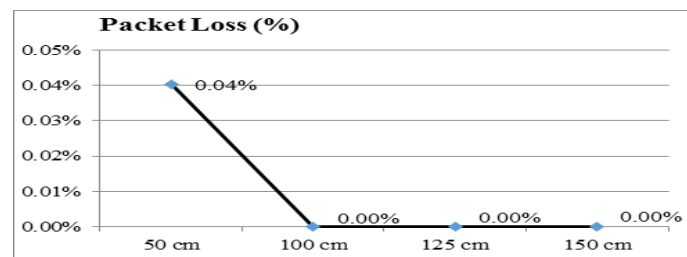


Figure 10. Packet loss occurs in closed space scenarios

Figure 10 shows, the placement of the XBee module at an altitude of 0 to 50 cm increased packet loss by 0.04%. However, the location of the XBee module at the height of 50 cm to 100 cm a packet loss decrease of 0%. Packet loss experiences a constant position at the height of 100 cm to 200 cm, with a packet loss value of 0%.

The average delay obtained when the two XBee modules communicate, can be seen in Figure 11.

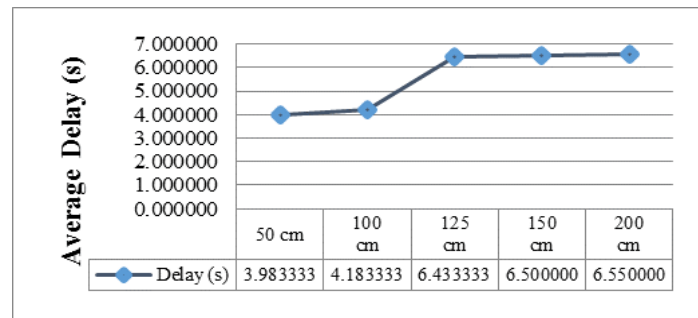


Figure 11. Average delay results in closed space scenarios

Figure 11 shows, the placement of the XBee module at an altitude of 50 cm to 200 cm has an average delay increase of 3.983 seconds to 6.55 seconds. The average delay experiences a constant position at the height of at 200 cm height, with a mean delay value of 6.55 seconds.

4.4.2 Open Space Scenario. Table 2 shows, the testing of the coverage of the communication signal using XBee in an open space scenario with a height of 50 cm to 200 cm, send data of 80 bytes for 15 seconds.

Table 2. Open space communication test results

ZigBee Position (cm)	Tx Data (byte)	Tx Packet	Rx Packet	Time (s)
50	6160	100	77	15
100	8000	100	100	15
125	8000	100	100	15
150	8000	100	100	15
200	8000	100	100	15

The test results show, the XBee module placement based on the height, very influential on the throughput generated. The result of throughput can see in Figure 12.

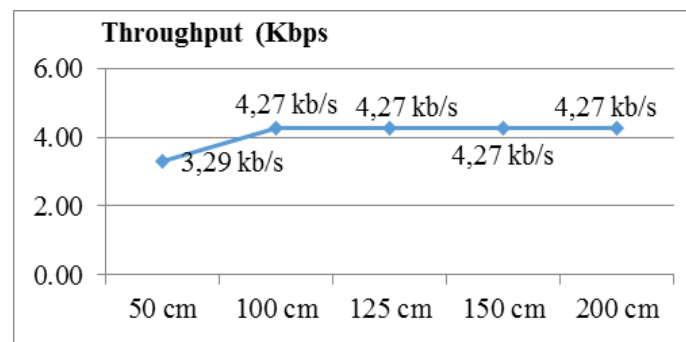


Figure 12. Throughput results in open space scenarios

Figure 12 shows, the placement of the XBee module at an altitude of 50 cm to 100 cm, the throughput value increased from 3.29 Kbps to 4.27 Kbps. The throughput value will be constant at a height of 100 cm to 200 cm, with a throughput value of 4.27 Kbps.

The test results in the amount of packet loss during the two XBee modules to communicate can see in Figure 13.

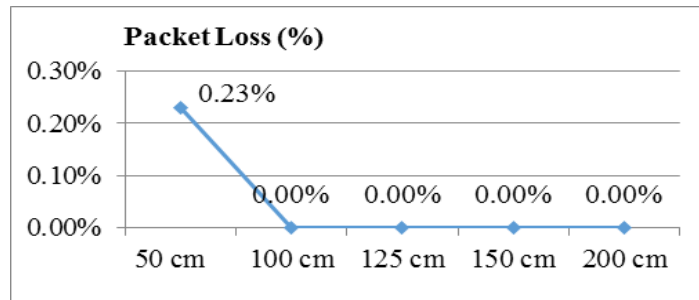


Figure 13. Packet loss results in open space scenarios

Figure 13 shows, the placement of the XBee module at an altitude of 0 to 50 cm increased packet loss of 0.23%. However, the location of the XBee module at the height of 50 cm to 100 cm a packet loss decrease of 0%. Packet loss experiences a constant position at the height of 100 cm to 200 cm, with a packet loss value of 0%.

The average delay obtained when the two XBee modules communicate, can be seen in Figure 14.

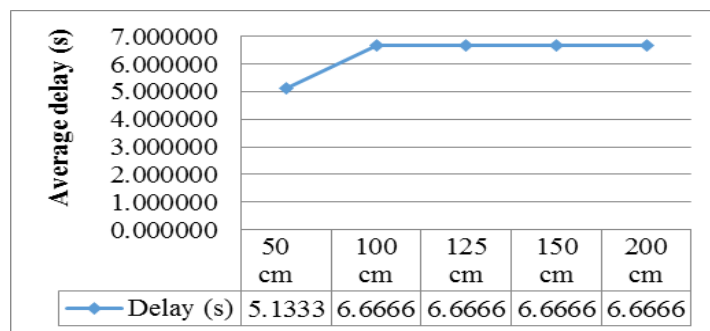


Figure 14. Average delay results in open space scenarios

Figure 14 shows, the placement of the XBee module at an altitude of 50 cm to 200 cm has an average delay increase of 5.133 seconds to 6.666 seconds. The average delay experiences a constant position at the height of at 200 cm height, with a mean delay value of 6.666 seconds.

5. Conclusion

Testing of heart signal sensor data which is done using a serial plotter for 15 seconds in men with the age of 25 years, resulted in a heart signal period of 68 bpm, received data of 4888 bytes, a throughput of 2.39 kbps and an average delay of 0.24486 seconds. The maximum voltage value is 3.25 volts, and the minimum voltage value is 0 volts.

The results of tests conducted on the XBee module based on the height of 50 cm - 200 cm and the distance of 23 meters within 60 seconds in the closed space, obtained the data transmission will be stable at an altitude of 100 to 200 cm. The higher the position of the module placed, it will result in a significant throughput value, and the resulting packet loss is decreasing. The test conducted on the XBee module based on the height of 50 to 200 cm and the distance of 38 meters within 15 seconds in the open space obtained that the data transmission will be stable at an altitude of 100 to 200 cm. The

higher the position of the module placed, it will produce a significant throughput value and the resulting packet loss is decreasing.

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