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ZigBee Test Performance with DHT11 Temperature sensor

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Abstract
This study aims to examine the ability and Performance or Quality of Services of the IEEE 802.15.4 or ZigBee Radio Frequency module on the sensor node ZigBee based. Furthermore, ZigBee's communication capabilities i.e., Tree, Star, and mesh networking were developed on the internet or Internet of Thing using RaspBerryPi 4 as the Internet Gateway. The sensors used e.g., Pulse sensor and temperature and Humidity Sensor. Moreover, the Spectrum Analyzer is used to measure the Radio Frequency Value (-dBm) per Channel (CH1 to CH12) on the Zigbee module (EDs and CN) communication at different distances, on the Mesh or Tree ZigBee Communication, ZR can be used, at Point to Point ZigBee, the role of ZR is neglected. Energy efficiency battery ZigBee sensor nodes need to be considered to obtain sensor nodes Long Life, moreover, RSSI (-dBm) is the key to the analysis of sensor node communication systems on different sensor node clustering, including Throughput, PacketLoss sensor data, and data analysis on Application Server.

Keywords: ZigBee, RSSI, Throughput, PacketLoss, Application Server

1. Introduction

Currently, Wireless Sensor Network is a popular topic, e.g., is the development of wireless sensor applications into application servers or the Internet of Things. WSNs Communication techniques are implemented in health monitoring [1]. Furthermore, the health monitoring application e.g. Blood Pressure monitoring uses a Blood Pressure sensor [2], heart rate monitoring using a pulse sensor [3], and Oxygen Level or SPO2 [4]. Moreover, the development of criteria WSNs seen in a lightweight, prototype size and power consumption, energy Management for Wireless Sensor Network sensor nodes to achieve long life on WSNs [5]. Furthermore, The Communication between Zigbee module Zigbee ED and Zigbee coordinator with e.g. topology. point-to-point, star, tree, or mesh communication analysis can be done [6]. Quality of Services from traffic communication e.g. Throughput, Packet Loss, and delay. moreover, ZD will be transmitting sensor data to the Coordinator node (ZC) and the internet via the Internet Gateway e.g. Digi XBee Internet Gateway or Raspberry Pi 4 [7], furthermore, Raspberry Pi 4 [9] stores data in the MySQL database using the Python 3 programming language. The final step is displaying output on a Web-based Graphical User Interface using PHP, JASON, Javascript, and HTML programming languages and code scripts, this is done to obtain a real-time display of data in graphical form. It is also possible, displaying sensor data can be displayed on

Smartphone devices. The development of the ZigBee or XBee communication system is an application to Artificial Intelligence (AI). [8], [10].

2. Literature Review

2.1 ZigBee Communication

Figure 1 is the design system of the ZigBee sensor node based on the Internet of Things, the points are the analysis of the ZigBee communication system, energy efficiency of sensor nodes, and packet data condition on the server (packetLoss, Throughput (byte)).

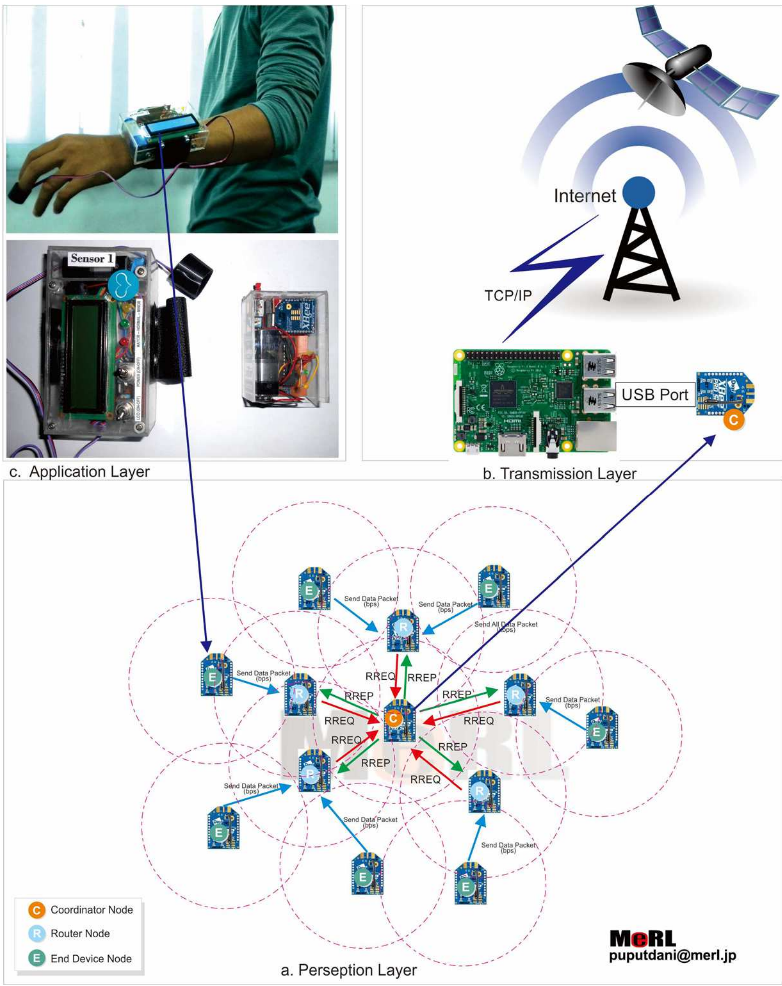

Figure 1. ZigBee communication IoT Based

ZigBee End Device (ZED) has a design as shown in Fig. 2, there are 3 important components; Arduino microcontroller, XBee Pro S1, and DHT11 Temperature and Humidity Sensor. The pin used by the Arduino Microcontroller is a 3.3 Volt DC voltage for voltage (Vcc) to XBee Pro S1 Pin 1. Whereas voltage (Vcc) 5 Volt DC Arduino Microcontroller leads to Vcc of DHT11 Temperature Sensor and Humidity.

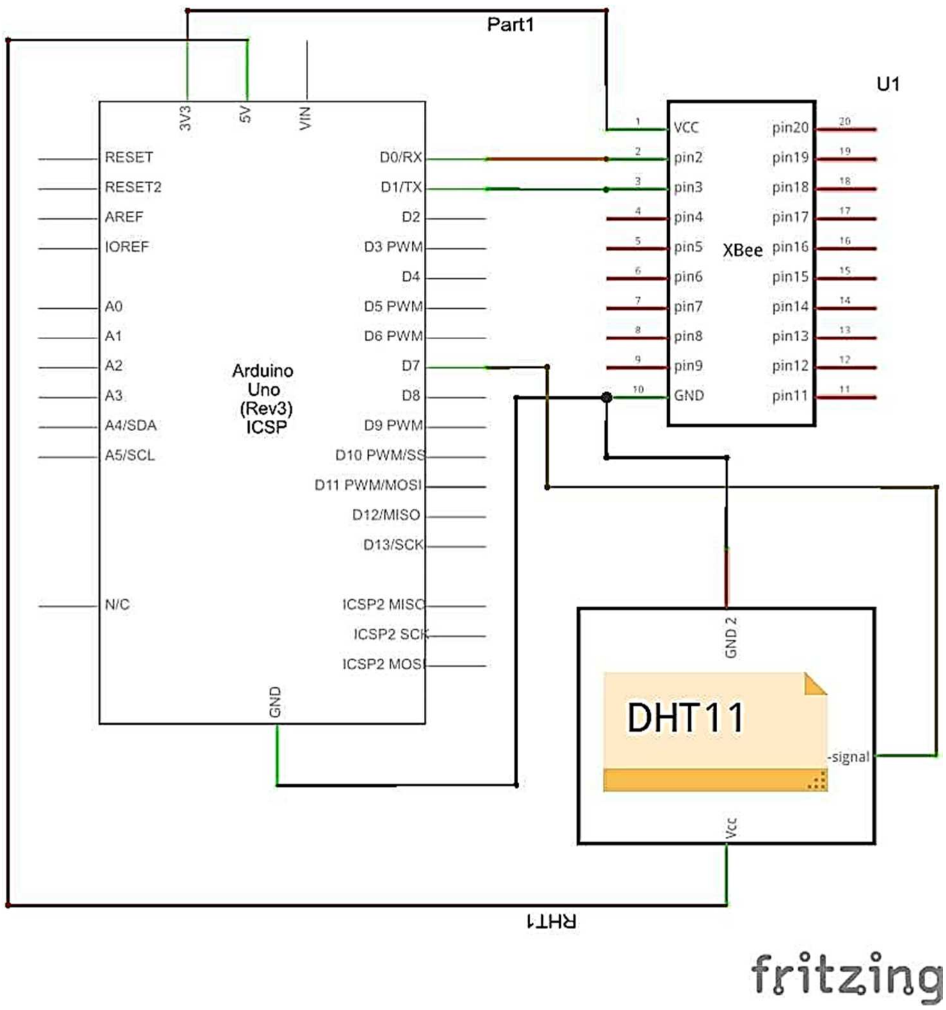

Figure 2. ZED Hardware Design

The Arduino Microcontroller is a Processor for DHT11 Temperature and humidity sensors, through Digital input (D7) being the port for DHT11 Temperature and humidity sensors and will generate digital signals from DHT11. Power TX and RX on XBee Pro S1 send temperature and humidity DHT11 sensor data to the ZC (ZigBee Coordinator) node. On Pins 2 and 3 on XBee Pro S1 uses Cross mode, which is the exchange between RX and TX from XBee ports with RX and TX at D0 and D1 Arduino. RX Xbee to TX D1 Arduino and TX Xbee to RX D0 Arduino. Moreover, the table for using hardware can be seen in Table 1.

Table 1. Hardware Used

No	Hardware	Function
1	Microcontroller Arduino	Processor, ADC, Data Serial Communication With a Base Station
2	XBee Pro S1 End Device	Wireless sensor Network type to sending DHT11 sensor data to Coordinator node
3	XBee Pro S1 Coordinator	Wireless sensor Network type to receive DHT11 sensor data from ZED to Base Station
4	XBee USB Adapter	Setting Device to configuration the XBee Pro S1
5	DHT11 Humidity and Temperature Sensor	as Temperature and Humidity Sensor data
6	Pulse Sensor	Detect the Heart Beat data on the fingertips (beat per minute)
7	XBee S2	For tree and mesh communication (as the ZR Communication devices)

The flowchart in Figure 5 shows how this system works, there are 3 parts in the flowchart, ZED 1, ZED 2 and ZC that are interconnected.Moreover, Signal strength is an important factor in determining the parameters of the Received Signal Strength Indication (RSSI). Before measurement the RSSI recognize the parameters of the sending or transmit signal strength (P_{TX}) and signal strength of the P_{RX} or receiver. This parameter has a watt unit, accordingly in this study ZigBee Pro s1 has Transmit Power (P_{TX}) = 63 mW (18 dBm) this data from ZigBee Datasheet. according to the theory of reception signal, the strength of signal reception can be represented as P_{RX}.

$$Prx = Ptx.Gtx.Grx \left(\frac{\lambda}{4\pi d}\right)^2 \quad [1]$$

Furthermore, the RSSI (Receive Signal Strength Indicator) is the RF (Radio Frequency) signal strength value of ZigBee in dBm units. therefore The formula used is following equation 7. In this research, there are 2 RSSI that can be produced, namely Local RSSI (XBee A) and remote RSSI (XBee B), Local RSSI is the result of the signal strength received on XBee that is connected to the computer via a USB Adapter, while the RSSI remote XBee comes from the signal received from sending XBee A data to XBee B.

Table 2. Signal Strength Classification

Signal Level Range (dBm)	Classification	Score
-120 to -95	Extremely Bad	1
-95 to -85	Bad	2
-85 to -75	Average	3

-75 to -65	Good	4
-65 to -55	Very Good	5
-30 to -55	excellent	6

RSSI is the strength of the signal received, therefore the signal strength is classified in a certain range that shows the feasibility of a shipment in table II. Furthermore, Gain is a quantity produced by a comparison between the size of the output signal and the input signal in logarithmic number 10 with dB, where the exit signal is greater than the incoming signal. accordingly, Equation 2 is how to get the result G (dB) obtained from the results of the operation of a divide between Power Out (Watt) divided by the power input (Watt). e.g.,the Pin is 100 mW, Pout is 20 mW, accordingly G = 10 log (pout/ pin) dBi, G =10 log (20/100), G=-6.9 dBi. dBi is an isotropic decibel, called isotropic because of imaginary, this antenna calculation is done in theory and is used for measurement. According to the digi.com data references, that XBee has a gain of less than 13.8 dBi, for distances of around 20 cm, it is not recommended to use ZigBee with an antenna gain of less than 13.8 dBi. accordingly, In the embedded system a signal strength of the Received Signal Strength Indicator (RSSI) is defined by Pref, Pref is 1 mW. e.g., the ZigBee Pro transmitter (PTx) signal strength will be calculated with the power of Transmit Power (PTX) = 63 mW (18dB). Then the gain of 18 dB comes from combining equations 2 and 3. As follows: G (Tx) = 10.log PTx / Pref, then G(Tx) = 10.log (63/1)= 18 dB. So it can be concluded that ZigBee pro has a gain of 18 dB.

$$G\ (dB) = 10.\,Log\frac{Pout}{Pin} \qquad [2]$$

$$RSSI\ (-dBm) = 10\ log\frac{Prx}{Pref} \qquad [3]$$

$$[\mathrm{Pr}(d)] = [\mathrm{Pr}(d0)]\ dBm - 10Log\left(\frac{d}{d0}\right) + x\ dBm] \qquad [4]$$

$$[\mathrm{Pr}(d)] = [\mathrm{Pr}(d0)]\ dBm - 10n\ Log\left(\frac{d}{d0}\right) \qquad [5]$$

$$[\mathrm{RSSI}(dBm)] = [\mathrm{Pr}(d)]\ dBm \qquad [6]$$

$$[\mathrm{RSSI}(dBm)] = A - 10n.\,Log\ d \qquad [7]$$

$$d = 10^{\frac{A-RSSI}{10n}} \qquad [8]$$

the real distance and distance of the simulation can compare the percentage of the error rate (%). Therefore, the formula for finding the distance in a simulation can be seen in equation 8. Moreover, the Path Loss is the Power density reduction of a radio signal. and automatically can be known as the signal strength sent and received (dBm). equation 10 is the Mathematical Formula for the Path Loss Model. And the situation is n = 2 (Free Space), in accordance with Table 3.

$$PL = Ptx - Rrx = -10nlog(d) + A\ (dBm) \qquad [9]$$

Table 3. Pathloss exponent value from different Environment

No	Environment	PathLoss Exponent, n
1	Free Space	2
2	Urban area cellular radio	2.75 to 3.5
3	Shadowed urban cellular radio	3 to 5
4	In Building line of Sight	1.6 to 1.8
5	Obstructed in building	4 to 6
6	Obstructed in factories	2 to 3

ZigBee or the Wireless Sensor Network Protocol IEEE 802.15.4 (Figure. 3) operate within the ISM 2.4 GHz Frequency band, ZigBee has several types and types of antennas, accordingly, ZigBee consists of 2 series, i.e. ZigBee S1 and ZigBee S2, it has an RF power of 1 mW (0 dBm), while those with more RF Power large, 63 mW (18 dBm) is the type of ZigBee Pro S1 and ZigBee Pro S2 which means that with the difference in Power RF making the range capabilities wider [12], [13].

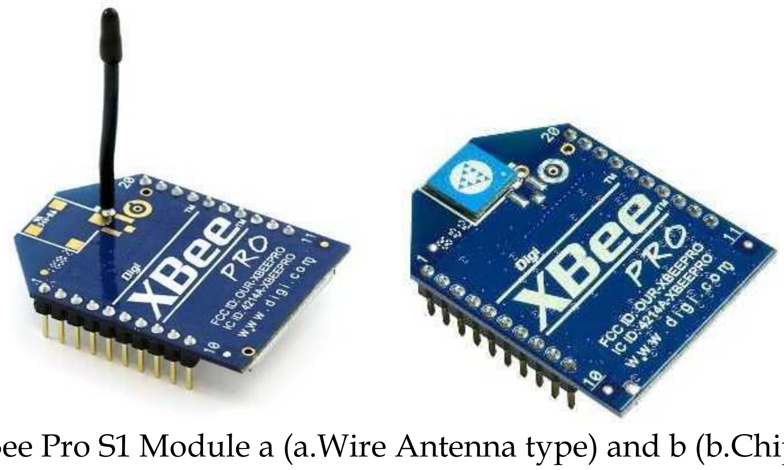

Figure.3 ZigBee Pro S1 Module a (a.Wire Antenna type) and b (b.Chip Antenna type) Antenna type RF Power 63mW / 18 dBm

From the measurement, the specifications of the 3.7 Volt Battery node 1000 mAh, and load calculations e.g. XBee = 27 mA (TX Mode), LCD 8x2 = 2 mA, Arduino Pro mini 40 mA, FTDI232 is 50 mA and Pulse 5 mA, then total load is 124 mA. With a 5 Volt Voltage, then the Power is Voltage x Current = 5x0.124 is 0.62

Watt. Furthermore, I = 0.62 W / 3.7 Volt = 0.167 Ampere. Therefore, the power Consumption is 1000 mAH or 1AH / 0.167 A = 6 hours.

Moreover, The difference of ZigBee Communication is on the JV Channel settings on the router, Coordinator, or end device of ZigBee, moreover, on the tree and mesh cluster of ZigBee, JV Channel Enable, vice versa, at the point to point and stare, JV Channel Disabled. Moreover, XBee Point to point on the Figure 4. In addition to the Zigbee communication system, the cluster method is known as the k-mean cluster method [11].

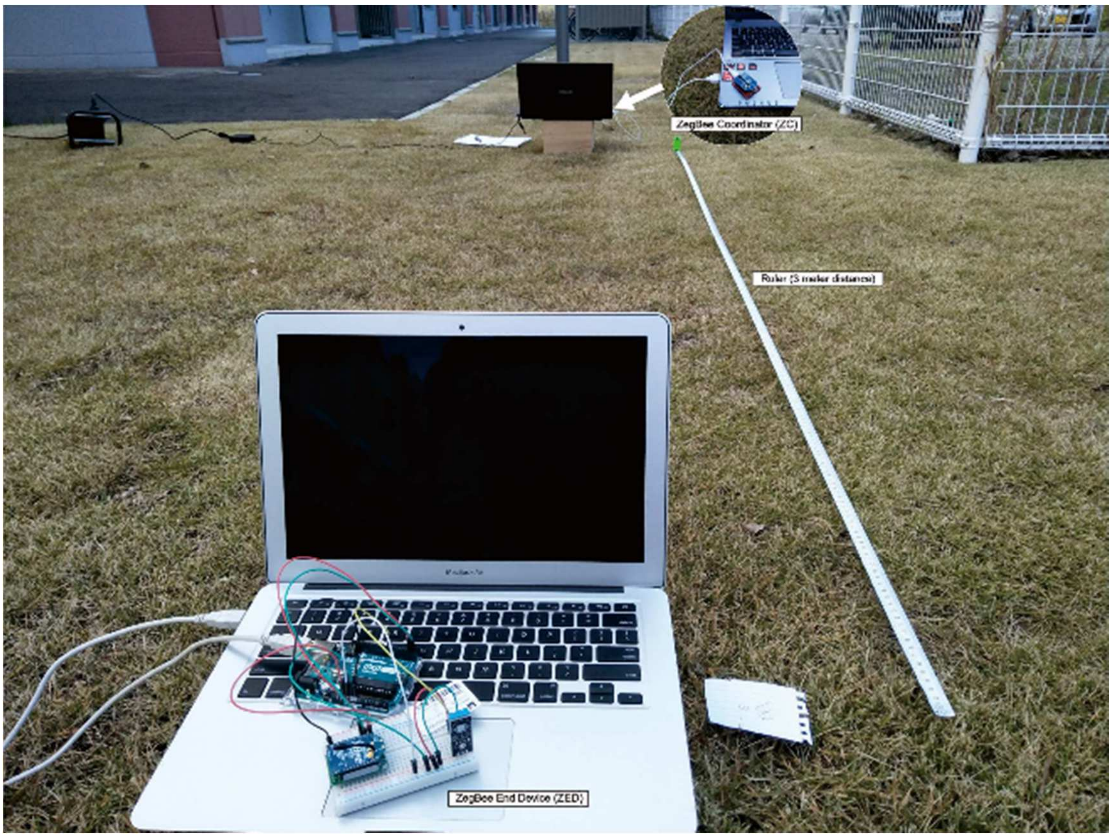

Figure 4. ZigBee Communication with difference distance

The development of point to point communication is a tree, star, and mesh, some of these types of communication occur because of the large number of scattered sensor nodes with different conditions, different positions, whose purpose is to the transmission layer, internet gateway, and application server. One of the analysis results from the comparison of communication systems above is the battery level and the byte data analysis.The ZigBee Coordinator (ZC) on the Internet gateway is connected using a USB port.

3. Method, Data, and Analysis

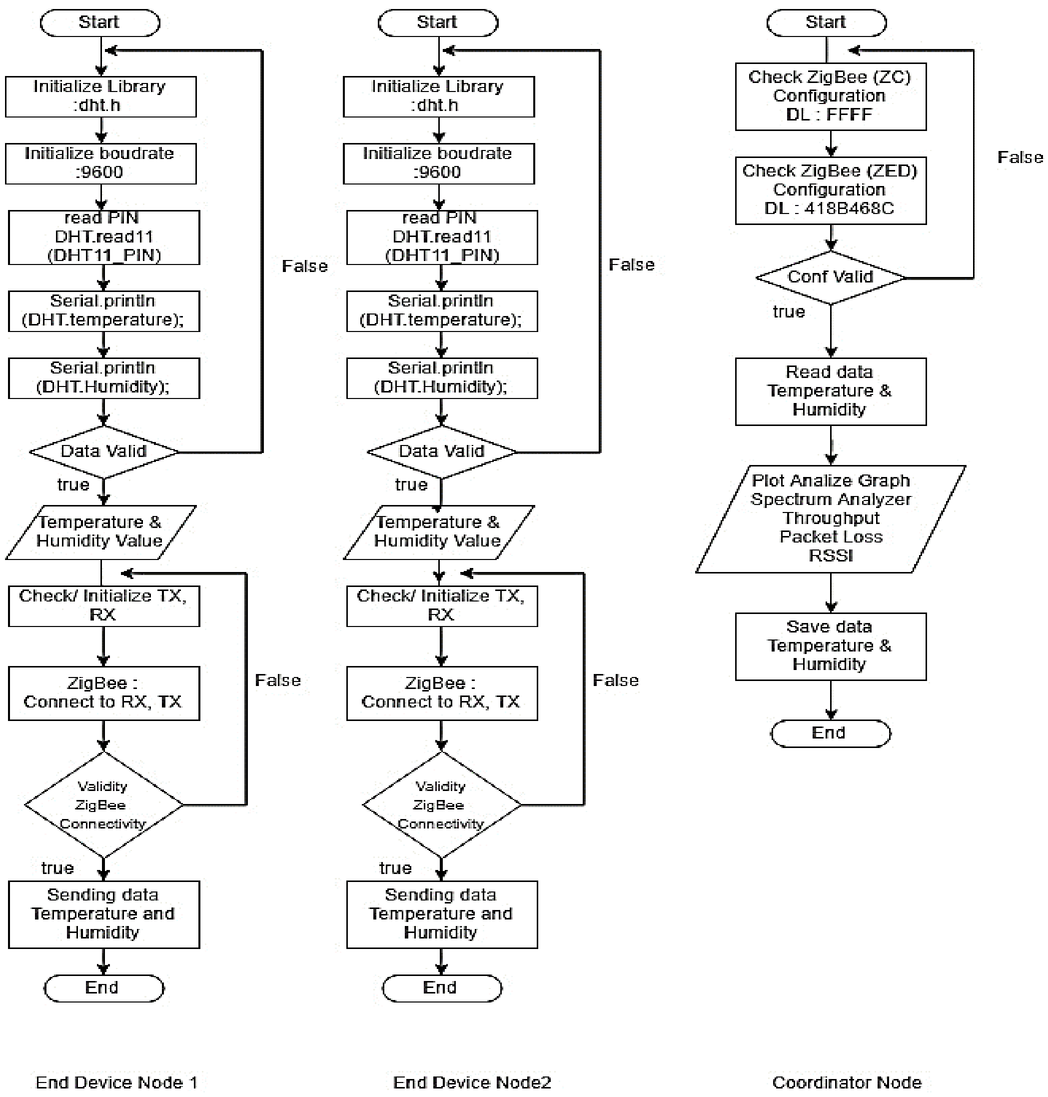

Figure 5. Flowchart in this research

The method used can be seen in the flowchart in figure 5.The method used is experimental by monitoring data on the Arduino serial monitor and X-CTU Software

4. Results

ZigBee transmission data from 3 meters to 33 meters, a software used is X-CTU type 6.4.2 and selecting the Radio range test section and obtain the RSSI data realtime on the Fig. 9. the average Local RSSI at a distance of 3-33 meters is -68,8 dBm, the average remote RSSI at a distance of 3-33 meters is -67,8 dBm and the average RSSI Local RSSI and Remote RSSI from a distance of 3-33 meters is - 68,3 dBm in Figure 6.

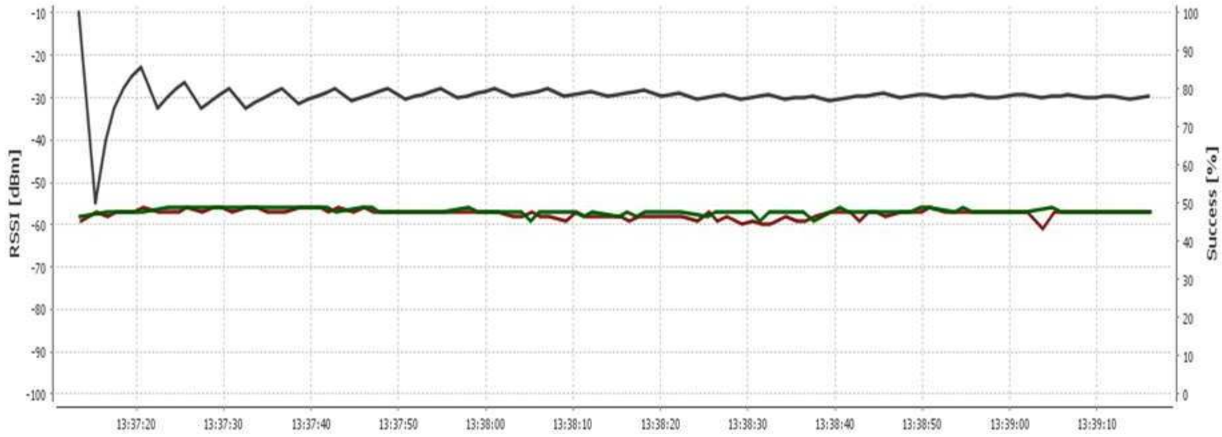

Figure 6. RSSI data from ZED to ZC at 3 meter distance

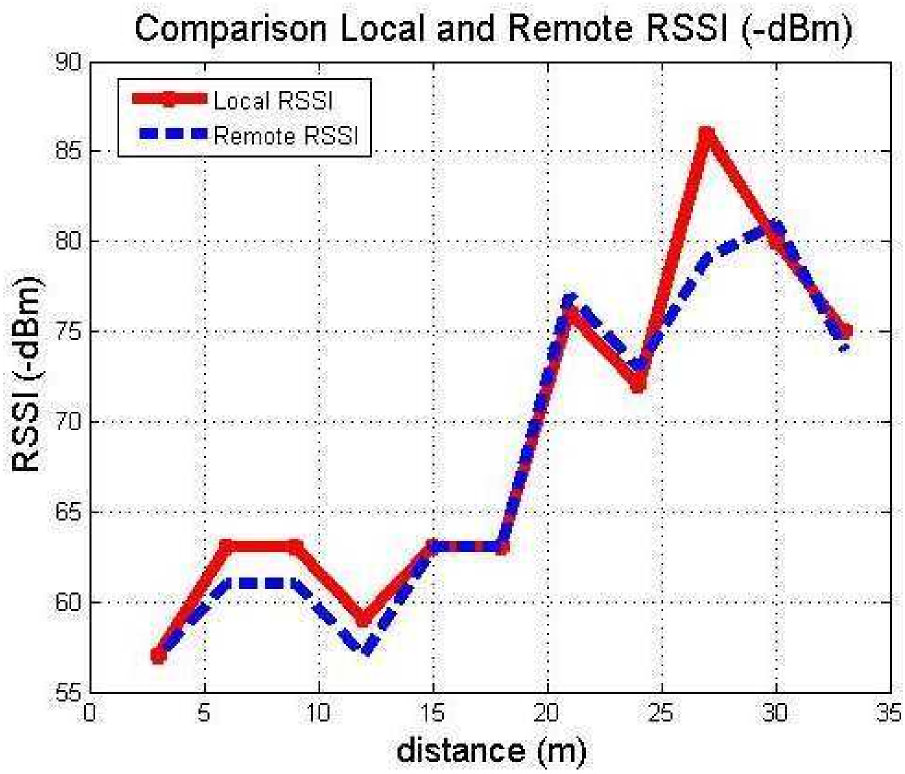

Figure 7. Comparison Local and Remote RSSI (-dBm)

Packet loss is expressed in percent, which is the number of packets sent divided by the number of packets received and the result multiplied by 100%. The Graph shows a drastic decrease, this was due to a transmitter (TX) error, the analyzer shows the TX error and the error value was quite large, 13, at 27 meters, conversely after a distance of 30 meters and 33 meters, the graph showed a normal even though there are errors of 3 and 4. See on the circled part in Figure 7. Percentage of loss decreased by 64%.

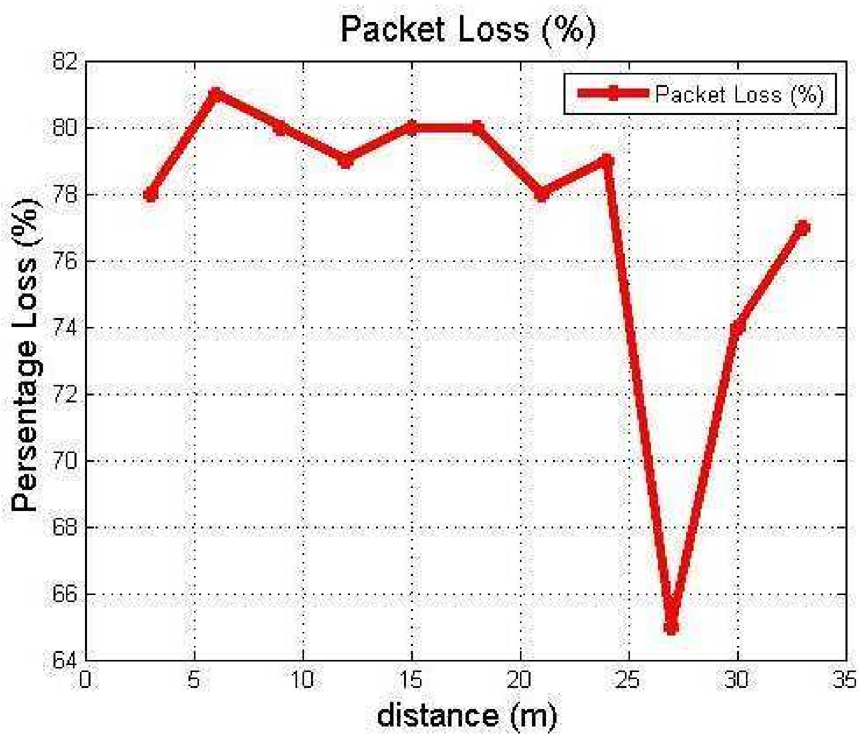

Figure 8. Packet Loss (%) when sending the data from ZED to ZC with distance 3-33 meter

Tx error occurs at a distance of 27 meters, where packet data loss due to transmitter error and eliminating 13 data packets, see in Figure 9. And the average of the transfer ratio (kbps) can be seen in Figure 10.

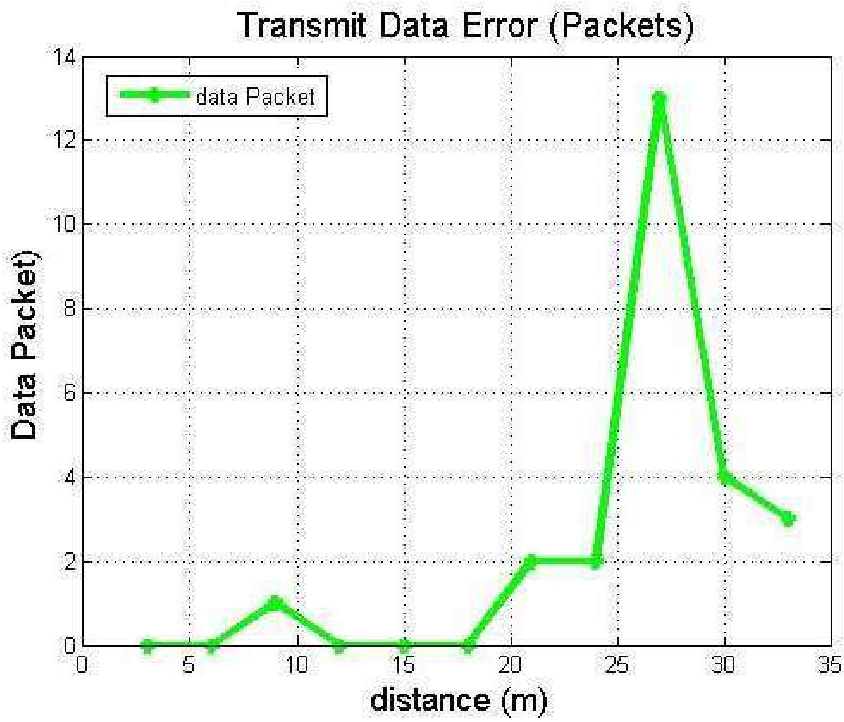

Figure 9. Tx Error (Packet) significant error at 27 meters

The lowest throughput value is obtained at 30 meters, the throughput value obtained is only 3.4 kbps. furthermore, sampling is done for 10 seconds. So that the total data received is 3400 bits per second (bps) or the total data in 10 seconds is 34000 bits or 4,250 bytes. Throughput testing is done for 10 seconds. moreover, delivery of sensor data from Zigbee cluster is 3 meters distances. Furthermore, the Power consumption of Zigbee use simulator. This is a data Power Consumption on the Edge router Zigbee or Zigbee router.

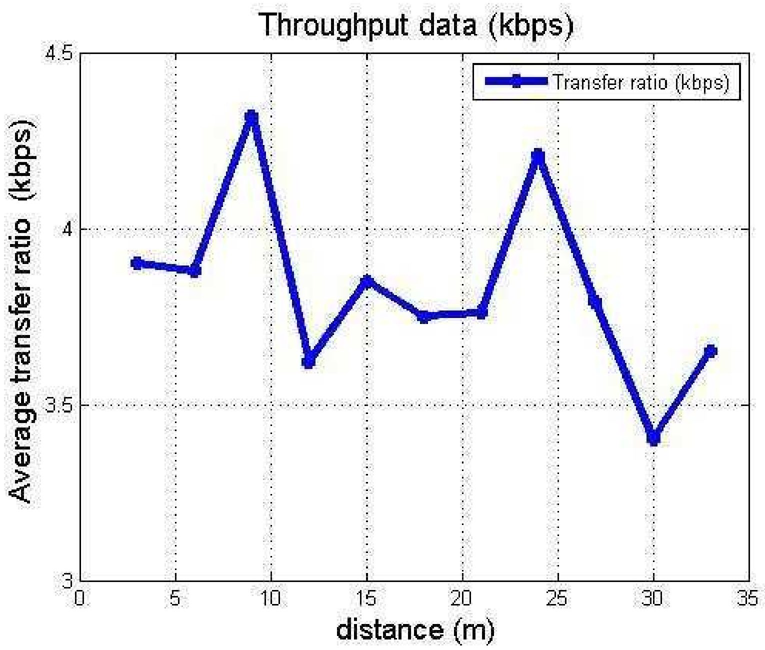

Figure 10. Average Throughput (kbps) when sending the data from ZED to ZC with distance 3-33 meter

Finally, the various sensor data can produce realtime on the application server. e.g., thingspeak, use a record of the channel from the End device or ZED, the data. moreover, in Table IV, The highest RF Channels noise at CH6 is -34 dBm and the average is -76 dBm, then CH7 with Maximum RF Value is -35 dBm and an average of -77 dBm.

Table 4. Noise Level on All Channels of Zigbee Radio Frequency

Chan nels	**Maximum RF values (-dBm)**	**Minimum RF values (-dBm)**	**Average RF Value (-dBm)**
CH1	47	91	83
CH2	47	93	84
CH3	78	93	87
CH4	45	93	85
CH5	69	93	80
CH6	34	90	76
CH7	47	90	78
CH8	50	92	79
CH9	48	95	88
CH10	47	91	79
CH11	61	88	80

CH12	35	89	77

5. Conclusion

The average of XBee data transmission power of -67.8 dBm seen from the remote RSSI at ZED up to a distance of 33 meters, Furthermore, In Packet Loss, there is a decrease in the percentage of data reception due to the transmitter error (TX error), a decrease that occurs up to 64%. Tx error occurs at a distance of 27 meters, where the packet data loss due to transmitter errors and consequently eliminating 13 data packets. Moreover, The highest RF Channels noise at CH6 is -34 dBm and the average is -76 dBm, then CH7 with Maximum RF Value is -35 dBm and an average of -77 dBm.moreover, the byte data of the communication zigbee i.e. point to point comm 3.74 kbps, star comm 4.kbps, tree comm 4.93kbps, and mesh comm 5.42 kbps. Finally, the sensors data realtime on the IoT application server.

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