ZigBee and LoRa performances on RF Propagation on the *Snow Hills* area

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***Abstract*—In the research, the analysis of LoRa 915, 920 MHz, and ZigBee 2.4 GHz data transmission in an outdoor area with snow conditions and the transmitter and receiver position in the mountains full of Snow. Delivery conditions are sometimes hindered by heavy Snow; for this reason, in this research, ZigBee and LoRa Quality of Service calculations were carried out in severe snow conditions. They use the measurement method approach, i.e., two ray Ground reflection model, using the Free Space Path Loss (FSPL) approach between 2 Radio Frequency (RF) LoRa and ZigBee. A significant comparison is obtained from LoRa and ZigBee propagation regarding sending Tx to Rx data. The comparison between ZigBee and LoRa in this research is that the Transmitter (T_x) position is on a hill and the Receiver (R_x) is on a flat plane, with Transmitter Height (h_t) and Receiver Height (h_r) parameters, so that this allows signal reflection to occur. The difference between the standard ground layer and the snow-covered surface is also calculated in Attenuation during data transmission.**

Keywords—Propagation, Quality of Service, ZigBee, LoRa, Snow, Hills, Reflection Signal

I. Introduction

ZigBee and LoRa are Wireless Sensor Networks (WSN) devices, various WSN applications (agriculture) [21,29], victim and natural disaster [23], Underwater [28], and RSSI analysis [24,25,26,30,31] have been carried out by many researchers around the world, one of which is WSN QoS, WSN efficiency Power Consumption, etc. ZigBee and LoRa indeed have advantages and disadvantages from their respective sectors; for this reason, this research was appointed to analyze the advantages and disadvantages of ZigBee and LoRa. ZigBee is an abbreviation for Zig-Zag Bee compatible with mesh communication, while LoRa is an abbreviation for Long-Range. This research is beneficial for the development of applications based on Radio Frequency. ZigBee excels in transmitting data over short distances and indoors; ZigBee operates in the 2.4 GHz frequency value, while LoRa at 915 MHz frequency. LoRa also depends on the ISM Band in different regions. The core advantage of LoRa is Long-Range, the range of LoRa capabilities is up to 15 km on FSPL, but with a data rate (5.5 kbps), this is a low data rate. Unlike Bluetooth and WiFi, this capability is shown in table 1.

In research [2,3,17], researchers have analyzed ZigBee and LoRa using a pulse-sensor as data transmitted via Radio Frequency on an Ad-Hoc network. In a study [3], the BME280 temperature sensor was sent at a distance of 1 km and found attenuation sensors with forest obstacles and school or university buildings, signal strength at 1km is -140 dBm. ZigBee-IoT and LoRa-IoT have also been completed in research [3], i.e., communicating ZigBee with Raspberry Pi 3 as a server and building a MariaDB database [22]. Moreover, LoRa has also been developed into LoRa-IoT by communicating with the LG01 LoRa Dragino 915 MHz to send sensor data to the thingspeak application server. One example of using a server or Internet of Things (IoT) [19] server is MQTT [4,5], with an integrated sensor node device on the M5Stack Board. Research also leads to in-depth analysis using specific methods [33,34,35,36] to support platforms such as IoT servers and other parameters.

II. Theory

A. LoRa and ZigBee Parameters

LoRa and ZigBee have advantages and disadvantages; one of the advantages of ZigBee is that it can build a mesh network communication system. In comparison, LoRa's advantage is sending data further than ZigBee, reaching 15 km (FSPL). While the drawback of LoRa is that it has a low data rate (5.5

kbps). In general, it is stated in table 1. However, the value of the parameter changes slightly or is different.

TABLE I. ZIGBEE AND LORA PARAMETERS

RF (λ)	Parameters			
	Data rate (bps)	*Comm. type*	*Current (mA)*	*Range (meters)*
ZigBee 2.4 GHz (12.5m)	250 kbps	Mesh	100 mW	1-120 meter
LoRa 915 MHz (32.8 m)	5.5-27 kbps	Peer to Peer	24-44 mA[Tx], 12 mA [Rx]	3000-15000 meter [FSPL]

B. Free Space Path Loss (FSPL)

Free Space Path Loss (FSPL) is when there is no obstacle or obstacle-free Radio Frequency transmission between Transmitter and receiver [1, 6, 7]. ZigBee doesn't have the capability of LoRa RF, ZigBee is only capable of transmitting a few meters of data, with the X-Bee pro capable of up to 1 km at Free Space Path Loss. While LoRa is capable of transmitting sensor data as far as 3-15 km on the FSPL. The formula used for calculating snow [1] height and transmitting ZigBee and LoRa data can follow equation 1. Equation 1 is the general formula for sending ZigBee and LoRa data under FSPL conditions.

$$L_{FSPL}[\mathrm{dB}]=20\log_{10}(4\pi d/\lambda) \quad (1)$$

$$L_{GR}[\mathrm{dB}]=20\log_{10}(d^2/h_t.h_r) \quad (2)$$

Furthermore, equation 2 is the formula if it involves Transmitter Height (h_t) and Receiver Height (h_r); accordingly, h_t *and* h_r are the height of Transmitter and receiver Radio node, in a condition without any obstacles. However in radio Propagation [8,9,10,32], FSPL conditions that can occur are rain and Snow, which affect ZigBee and LoRa communication systems outdoor and FSPL. An illustration of the snowfall is shown in Fig.1. In addition to bad weather, it is also affected by 2 Ray Reflected Ground because the receiver's position is in a lower plane Fig.2 and Fig.3). The Transmitter (T_x) is in a hill area; this will allow this to happen. Signal reflection before arriving at the receiver. It takes a signal analyzer (-dB) to know this signal communication, and a data packet analyzer (bps) is also needed, as a comparison tool, between data transmission on a ZigBee at *Tx* and *Rx* conditions on a flat plane and *Rx* and *Tx* positions in the hills.

C. The Reflection model [2-ray Ground]

Ground Reflection 2-ray model is a model that is used to predict packet loss on radio transmitters and radio receivers in conditions of reflection due to the position of Tx and Rx which form a certain angle due to different altitude positions with different T_x and R_x positions, so that signal reflection occurs.

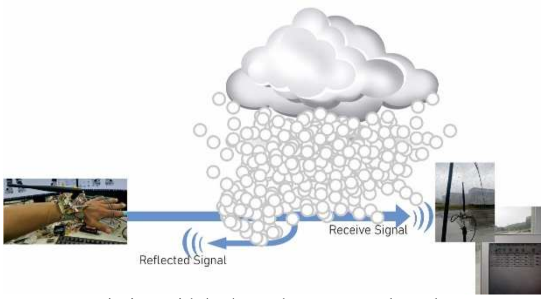

Fig 1. Data transmission with bad weather 'snow' obstacle

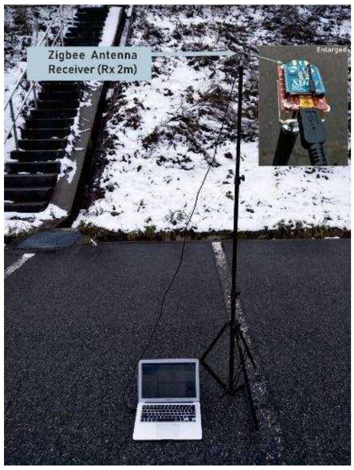

Fig 2. A Zigbee Antenna receiver

In general, both antennas have different heights (h_t and h_r). *ht* is the height of the transmitter antenna in meter (m), and *Hr* is the height of the receiving antenna in meter (*m*). consequently, a signal has reflected the ground before the signal is received by the receiving antenna (*Rx*). At the same time, the *d* (distance) is the distance between the sending and receiving antennas in meters (*m*). In the hills area, the signal transmitting from the T_x antenna is far above the hill. Therefore, the theory of ground signal reflection can occur. The 2-Ray Ground reflected model has several parameters, including the Fresnel coefficient value is 1, and there is a reflection value between the transmitter and receiver. then the value of the wave reflection coefficient is shown as equation 3.

$$\Gamma_i = \frac{\cos\theta_i - q\sqrt{\varepsilon_c - \sin^2\theta_i}}{\cos\theta_i + q\sqrt{\varepsilon_c - \sin^2\theta_i}} \quad (3)$$

Path loss (PL) (dBm) value [11, 12, 13, 14, 15, 16, 18, 20, 27], Next it is necessary to determine the power of the receiver (Pr), according to equation 4.

$$P_r = P_t + G_t + G_r - PL \quad (4)$$

as stated in the previous statement, 2 ray reflection models are shown with different positions of the transmitter and receiver from the height side until the signal reaches the ground level. so that x and x' reflection occurs, so the Power receiver equation (Pr), is shown in equation 5.

$$Pr\ (dBm) = \frac{\lambda^2}{(4\,\pi\,d)^2}\left[2\sin\frac{2\,\pi}{\lambda}\,\frac{ht.hr}{d}\right] G_t.G_r.P_t \quad (5)$$

On the Ground Reflection Model, Path Difference (Capital Delta) Δ is the result of a reduction of *d* in reflection or (d'') and d in Line Of Sight (LOS) or (d'). Therefore, the formula from the Path Difference is shown in equation 6.

$$\Delta = d'' - d' = \sqrt{(h_t + h_r)^2 + d^2} - \sqrt{(h_t - h_r)^2 + d^2} = \frac{2h_t h_r}{d} \tag{6}$$

from combining some of the previous equations, the Power Receiver is described in equation 7.

$$P_r = P_t G_t G_r \left(\frac{h_t h_r}{d^2}\right)^2 \tag{7}$$

Fig 3. 2-ray ground reflection propagation in snow hills

D. Signal interference from snow γ_{snow}

Signal interference from snow also has an attenuation effect on signal propagation in units (dB/km). if with the attenuation approach from snow, more details can be seen in table 2 and and use the formula according to equation 8.

$$\gamma_{snow} = \alpha . S^b \tag{8}$$

III. Method

This flowchart in Fig.4 shows how the system in this research works, namely by calculating how each node works according to capacity. The node is the end device, router, and coordinator node. Zigbee end devices function as senders of pulse sensor data to routers and coordinator nodes. ZigBee end device will function when Destination High and Low (DH and DL), and (SH and SL) High and Low Communication Serials settings are already adjusted according to end device functions, as well as routers and Node coordinators. The Zigbee router function using JV Channel. The JV Channel as a router function is needed when the JV Channel ON position means the node function is as a router node.

The task of the node coordinator is as a base station and manages the network with a clustering system such as the LEACH Algorithm. Some types of communication, such as star-type communication, will cause a heavy load on one receiver. The star communication type will is likely cause BottleNeck. in this case, ZigBee networks use the TDMA (Time Division Multiple Access) systems; TDMA is one of the multiplexing methods sending multi-nodes to the coordinator node. Furthermore, the coordinator node sends pulse sensor data to the internet through its connection with Raspberry Pi 3 Model B as IoT Devices. in this case, the Python Language and MySQL databases and Maria DB are entirely used to support IoT.

TABLE II. Attenuation value caused by snow

Snow Shape	***A [Alpha]***	***b***
Wet snow	0.000102 λ + 3.79	0.72
Dry snow	0.0000542 λ + 5.50	1.38

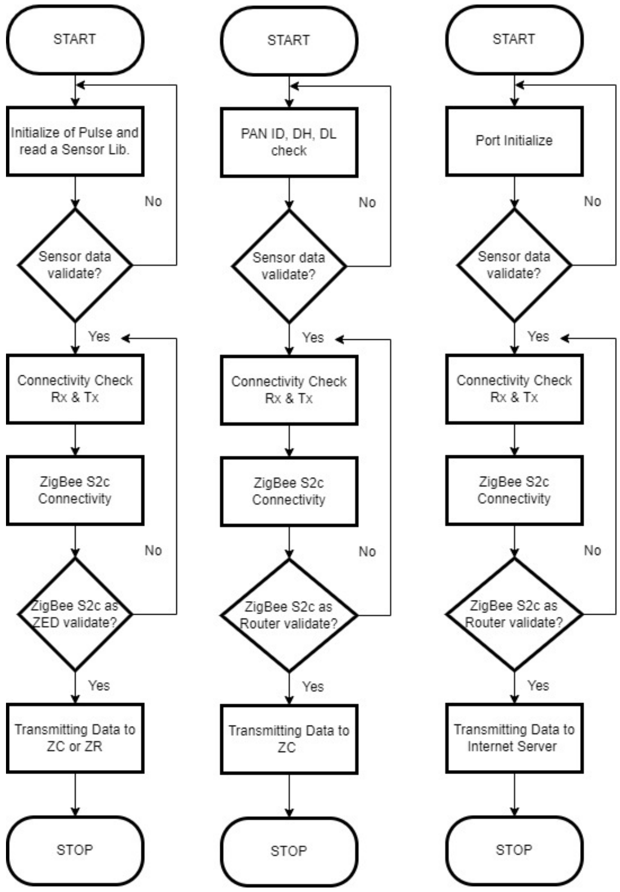

Fig 4. A flowchart system

IV. Result and Discussion

By looking at the characteristics of ZigBee, in equation (3), the analysis in Fig.5 can be generated, i.e., ZigBee PathLoss at condition (FSPL). Moreover, equation 5, compared with the PathLoss graph (-dBm) in Fig.6. Please note, the path loss value is affected by the location of the Transmitter. In the experiment on the hill, the Transmitter is placed in a different position, which has an impact on attenuation and packet loss factors on the receiver side, as shown in Figure 5, if the position of the transmitter is higher, it is likely that the value of the signal strength at the receiver will be greater, this is influenced by the absence of significant obstacles such as if the transmitter is in a low position.

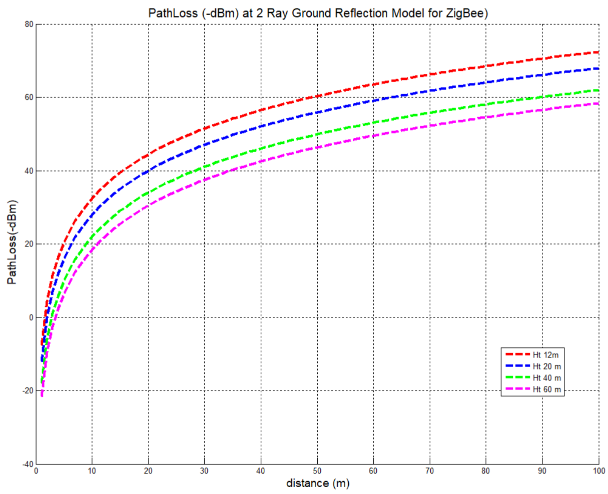

Fig 5. ZigBee PathLoss (-dBm) with FSPL Model

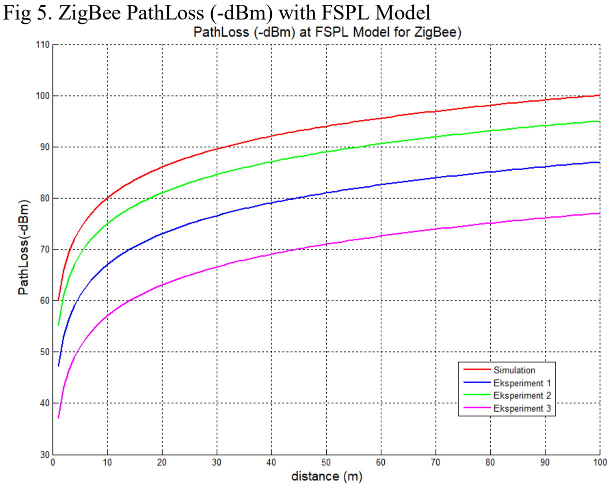

Fig 6. 2 ray reflected model pathloss result with h_r 2 meters

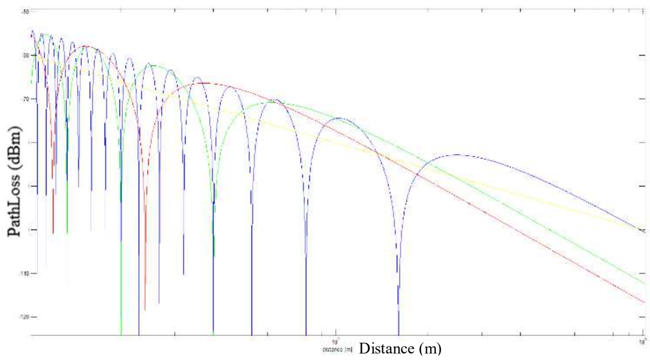

Fig 7. 2-ray reflected pathloss model with h_{t1} 5m, h_{t2} 20m, h_{t3} 40m, and h_r 0.5.m

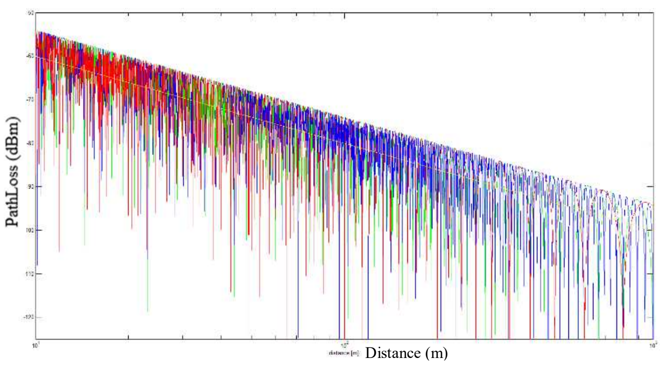

Fig 8. 2-ray reflected pathloss model with h_{t1} 5m, h_{t2} 20m, h_{t3} 40m, and h_r 50 m

From Matlab simulation, with lambda parameter is 0.125 m, with transmitter height values (ht1, ht2, and ht3, respectively 5m, 20m, and 40m), with receiver height value (hr) is 0.5 meters and 50 meters, has the results are as shown in Figure 8. This simulation experiment was made to obtain the path loss analysis value with the difference in the height of the receiver. From Figure 8, it can be seen that the signal density is higher if the receiver height is higher. From the simulation, the signal strength value of the receiver at a receiver height of 0.5 meters is -54.3 dBm with a distance of 10 meters, while with HT 20 meters it has a signal strength of -54.46 dBm, while at a transmitter height of 40 meters and a distance of 10 meters, the signal strength is -122.64 dBm.

The h_t and h_r approach concludes that the height of the sender and receiver affects PathLoss, the greater the Pathloss because the comparison between h_t and h_r is too far. This signal strength comparison is the same for LoRa and ZigBee, but ZigBee is more specific at a distance of <=120 meters. Therefore, the comparison between ZigBee and LoRa must be <=120 meters, and only look at the signal transmission factor, using the same sensor, namely the Pulse Sensor.

V. CONCLUSION

From the experiment using ZigBee module 2.4GHz or 0.125 meter wavelength, with the simulation of the difference in distance, the results are as follows; at a distance of 100 meters, the signal strength value is 100.04 dBm. whereas if you use a 2-ray reflected model with a different height of the transmitter (Ht) and the height of the receiver (Hr) as well as the distance between the transmitter and receiver, the resulting power receiver value (Pr) is different. For example, at a height of 5 meters the transmitter produces a Power receiver (Pr) of -54.3 dBm. at a distance of 10 m, h_t 20 m with a Power Receiver of -54.46 dBm, while h_t = 40m is -122.64 dBm at a distance of 10 m.

Remember that the comparison between ZigBee and LoRa is not based on the distance traveled from transmitting data from Transmitter to a receiver; if this is a comparison, it is particular that LoRa will be far superior. However, the ZigBee and LoRa comparison is in the signal reflection state if the data is sent from a hill position, which means several parameters such as h_t and h_r affect the signal in the reflected condition.

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