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Performance Evaluation of LoRa 915 MHz for Health Monitoring with Adaptive Data Rate

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***Abstract*—One of the problem factors in transmitting LoRa data using a small bit rate (bytes) of a maximum of 125 kbps is the amount of packet loss. This is because many end nodes send data to the server simultaneously; transmitting data effectively needs to be done because this is a major thing. So one mechanism that can be done is to use the Adaptive Data Rate method on the LoRa module. This research discusses the Adaptive Data Rate shown explicitly by the way it works and the effect it gives if ADR is applied to transmitting LoRa data. And how much influence on packet Loss (bytes). Adaptive Data Rate on LoRa Transmission is essential for regulating power on LoRa in terms of battery power saving; LoRa runs in UHF, which is in the 300 MHz-3 GHz range; LoRa in this research works at 915 MHz-920 MHz depending on the type of devices used. LoRa works with power or supply voltage of 2.1-3.6 Volt DC, high sleep currents between 7.66 A up to 34 mA; in this research, LoRa is M2M between LoRa Transmitter and Receiver, which communicate alternately in sending sensor data with the delay method used for monitoring human health such as Pulse sensors, ECG sensors, and other sensors and these sensors' data is displayed in realtime using Thingspeak Application Server.**

***Keywords*—adaptive data rate, lora, lorawan, health monitoring, pulse, ECG, realtime**

I. INTRODUCTION

Health is an essential factor in all lines of human life today, and health is currently very flexible; it can be monitored through sophisticated devices of super small sizes that can be attached to the human body such as the arm or attached to the chest such as the ECG module. In previous studies, the author has researched how to detect pulse sensors with various devices such as ZigBee or Xbee, and LoRa modules, ZigBee and LoRa [1],[2] can send small bit rate sensor data for real- time monitoring, but these two devices have several weaknesses. One of the drawbacks is the ability to transmit data or different ranges. LoRa [3] is capable of >15 km in Line of Sight (LOS), while ZigBee is only capable of up to 120 meters, and ZigBee Pro is up to 1 km. This paper discusses specifically the LoRa [4]-[8] specifications at certain frequencies, e.g., 915 MHz and 920 MHz frequencies. Indonesia uses the 920 MHz frequency.

Some of the devices used in the process of transmitting data to Health monitoring patients are the AD8232 ECG module which is used to detect a heartbeat by looking at the type of ECG signal, whether it is the slow or fast movement of the ready segments such as PR, ST, and TP segments, which is called Arrhythmia. The previous experiments on sending sensors such as the pulse sensor using Zigbee with an additional Processing platform Arduino. This experiment was tested using XBee Internet Gateway and was able to transfer several bits of pulse data (bpm) to the internet. Next, the LoRa data transmission test was successfully carried out by making changes to the distance between the transmitter and receiver. The first experiment was conducted in the Tamalanrea area, Makassar, South Sulawesi, Indonesia, in the Hasanuddin University complex [9],[10],[11]. And it works up to 120 meters using XBee type 1. The pulse sensor can be placed on the human body on the hand and can detect the human heartbeat and classify it into major, minor, and normal or tachycardia, bradycardia, and normal.

This Arduino-based pulse module is developed by adding a GPS module to find out the location of the patient whose health is being monitored. Therefore, this case study was developed on the side of GPS technology which will find out the location of the Longitude and latitude of the patient being monitored in real-time for his health, and its application is given to the disaster emergency response team in finding or tracking victims. So that the community can use this system if conditions are not safe, such as earthquakes, volcanic eruptions, and tsunamis. This system must be installed in the human body to know specifically the heart rate and other elements that can be monitored in real-time. The end node

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sends heart rate data simultaneously to the Gateway, and then the gateway sends it back to the Internet server or Application server and can be monitored directly on a smartphone or laptop with a real-time internet connection. with the development of sophisticated devices that detect heart rate, SPO2, and IoT-based EEG, the LoRaWAN system [12],[13] in this article will be one of the hopes for the community by getting an affordable price, so that economically this tool can help the lower middle class. Finally, this research collaborates with researchers not only in the field of telecommunications but also in the field of economy, community economy, and also on the application of IoT-LoRa in addition to health, namely in Horticulture or agriculture.

II. BASIC THEORY

A. Chirps Spread Spectrum (CSS)

Chirps Spread Spectrum (CSS) is the signal used in the Radar system, and LoRa was developed in this research. CSS LoRa consists of 3 types: Up-chirps, Down- chips, and signal modulation. this type contains the data of the signal. the chip signal shows the difference in the frequency of the LoRa signal considering that the LoRa Chips use the FSK modulation type [14]-[18]. FSK is frequency Shift Keying. FSK is formed from a sinusoidal signal with a certain sin, phi, and time values, forming a sine signal using Matlab software.

TABLE I. RELATIONSHIP BETWEEN SF, CHIPS, SNR LIMIT, TOA, AND BIT RATE OF LORA

Spreading Factor	Chips/Symbol	SNR Limit	Time on air (10- byte packet) (ms)	Bit Rate (bps)
7	128	-7.5	56	5469
8	256	-10	103	3125
9	512	-12.5	205	1758
10	1024	-15	371	977
11	2048	-17.5	741	5337
12	4096	-20	1483	293

More broadly and in detail, table 1 represents the relationship between SF, Chirp/symbol, and Bit Rate, it can be seen that the greater the SF value, the greater the value of the Chirps signal, and it also affects other parameters, i.e., SNR, ToA, and Bit Rate. This SF shows the distance from Tx to Rx; the greater the SF value, the farther the distance between the LoRa [19],[20] Transmitter to the LoRa Receiver is shown in the graph in the analysis and the results in this paper. Finally, the relationship between SF and the time required for Tx and Rx to successfully communicate with data as parameters, i.e., pulse sensor data or ECG sensor data.

Furthermore, the simulation results from CSS using MatLab, the greater the bandwidth value, the faster the travel time and the greater the bit rate (bps) value, and the more effective it is. it can be seen that the larger the SF, the longer the time required. Spreading Factor 7 (SF7) to Spreading Factor 12; the red line and yellow shadow are SF, while the time indicates the bandwidth capability used. The spreading factor 7 has a faster travel time than the larger factor SF 8, SF 9, SF 10, SF 11, and SF 12). from this statement, SF 12 is the slowest in sending data from Transmitter to Receiver.

B. Adaptive Data Rate

Adaptive Data Rate (ADR) is one of the mechanisms used for data rate efficiency and power consumption, ADR is used for static condition of end-node LoRa devices. Adaptive Data Rate (ADR) was created for communication systems using LoRaWAN, there are two terms, i.e., uplink and downlink, and the settings are on uplink and downlink data, where the end-node sending data at the gateway must go through the process of setting, scheduling, and delay time. The function of ADR is to save battery and reduce packet loss of data due to interference. The arrangement of data transmission is by sending sensor data at the closest distance, this allows for time efficiency or ToA. and also determine the RSSI value (-dBm) indicating signal strength.

III. METHOD

A. Develop of Adaptive Data Rate (ADR)

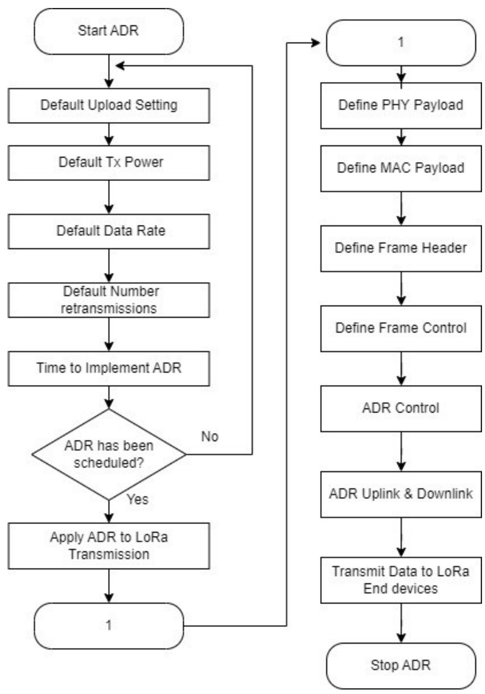


Fig.1. ADR Mechanism

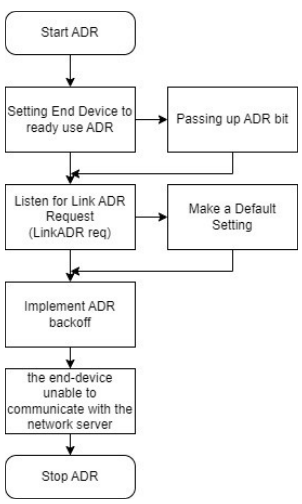


Fig.2. ADR Setting for End-node

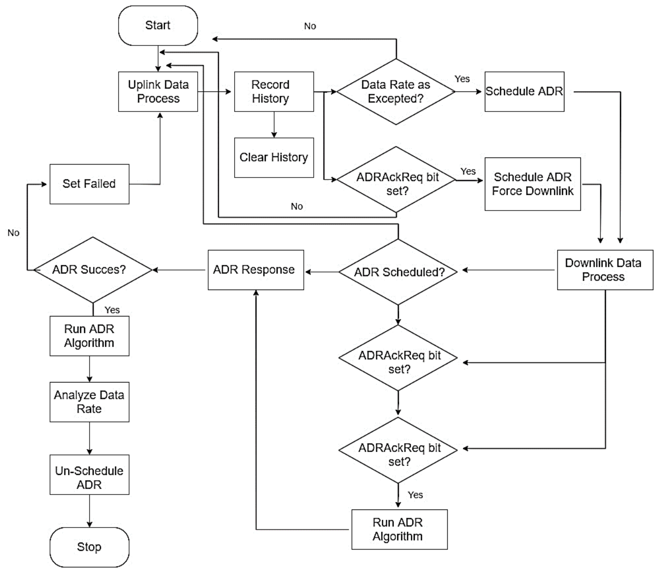


Fig. 3. ADR Scheduling

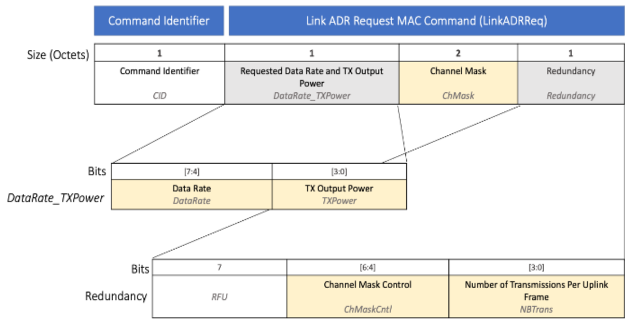


Fig.4. ADR Request MAC Command

The Adaptive Data Rate method [Fig.1],[Fig.2],[Fig.3],[Fig.4] are the right method to produce efficient power consumption when transmitting LoRa data and also functions in reducing packet loss. The complete flowchart is shown in the following flowchart at Fig.3. Moreover, Equation 1 is a formula for calculating the time symbol, while equation 2 is a carrier frequency calculation, equation 3 is the time of LoRa transmission, equation 4 is t preamble, and t payload is in equation 5, and the P symbol is in equation 6. Et is Energy consumption when transmitting data, while t is time, Pt is transmitting power, Eb is Energy per useful bit, Rs is data rate, while Es is the energy consumption of LoRa, while PLx is Packet data length. All of which are described in Equations 7-10. LoRa equation can be seen in the following formulas:

$$x(t)=sqrt(2Ex/Tx) . cos [2phi fct \pm phi(u(t/Tx)-w(t/Tx)^2)] \qquad (1)$$

where x(t) is a time symbol, Ex is energy x, Tx and fc are a frequency carrier.

$$Tx = (2^{SF}) / BW \qquad (2)$$

where Tx is a frequency carrier, SF is a Spreading Factor (6-12), and BW is a Bandwidth. Furthermore, the time required by the LoRa transmitter to reach the receiver is denoted by the t-value. Where t is the sum of t preamble and t payload. As in the following equation:

$$t = tpr + t pay \qquad (3)$$

$$tpr = (4.25 + Np) * (2^{SF})/BW \qquad (4)$$

$$tpl = Psy*(2^{SF})/BW \qquad (5)$$

$$Psy=8+max(ceil((8PL-4SF+44-20H)/4*(SF-2DE))*(CR+4),0) \qquad (6)$$

$$E(t) = Pt*t \qquad (7)$$

$$Eb = E(t)/ 8*PL \qquad (8)$$

$$Rs=SF*(CR/2^{SF})*BW*1000 \qquad (9)$$

$$Es=(PLx/Rs)*V*I \qquad (10)$$

Furthermore, Fig.6 is a LoRa transceiver type 920 MHz, ES920LR, used in Japan; this type LoRa can be combined with Leafony Board LoRa. Trial data transmission is at the time of LoS and Non-LoS, and Fig.6 is LoS with different distances, so it can be calculated in the signal reflection formula. The results of the calculation of signal reflection with different distances are shown in the results and analyzed in this research.

B. Sensor Position

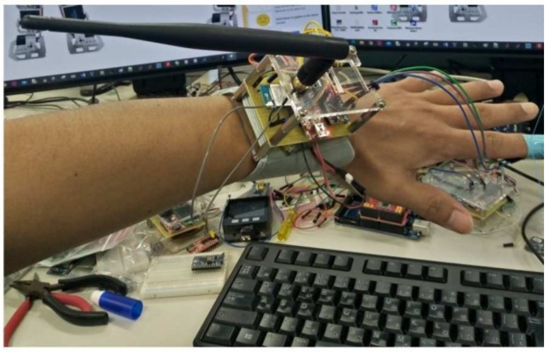


Fig.5. Fingertip Pulse sensor position

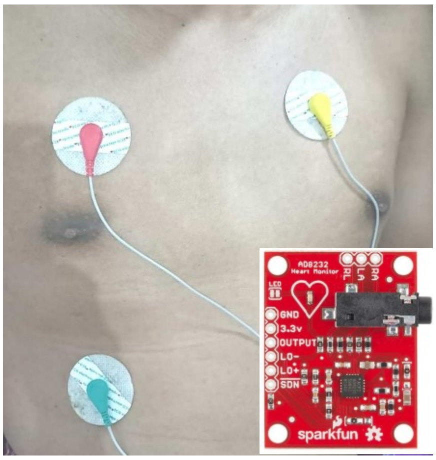


Fig.6. Electrode of AD8232 ECG position on the body

The position sensor type Electrode of AD8232 ECG Module [Fig.6] and Fingertip Pulse sensor [Fig.5] are examples of sensors built in this paper. the sensor data has been analyzed from the process of transmitting data LoRa dragino type LoRa 915 MHz and LoRa type ES920LR 920 MHz.

IV. Result and Analyze

This analysis in the subsection of this analysis is the result of the real-time analysis of this research. Fig.7, Fig.8, and Fig.9 are measurement results using a Tektronix LoRa signal analyzer at a frequency of 915 MHz and are shown in real-time.

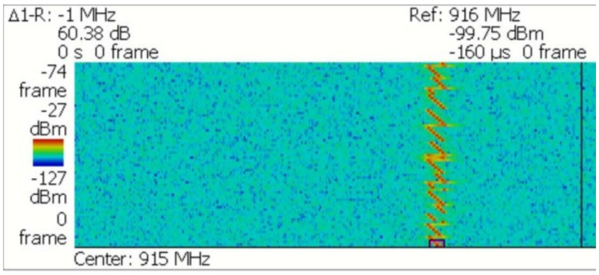


Fig. 7. CSS LoRa 915 MHz realtime

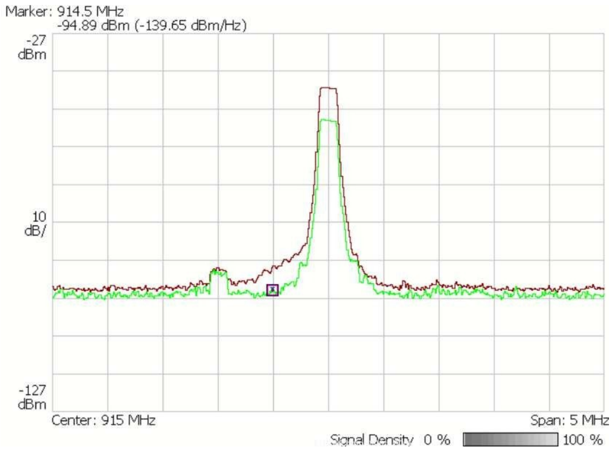


Fig.8. LoRa signal strength 915 MHz

While Fig.13 & Fig.14 are a real-time heart rate in BPM, the normal is 60-100. The graph shows a normal beat of 70; to be more specific, it can be distinguished when running, tense, relaxed, or sleeping to get different heart rates. Furthermore, in Fig.11 is the PRR (%) which was tested at a distance of 1 km. And produces above 90% receive packet ratio; this condition is still good when compared to PRR (%) on an obstacle or Non-Line of Sight (N-LoS).

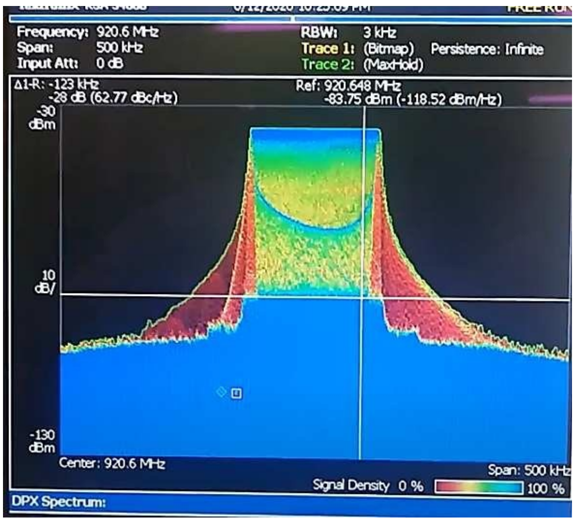


Fig.9. LoRa signal strength 920 MHz realtime with signal analyzer

Fig.10 shows LoRa's real condition RSSI when measuring LoRa in mixed conditions, e.g., Line of Sight and Non-Line of Sight. So it shows a graph that goes up, down, even flat. This graph was taken in the measurement area in the mountains in Japan. While in more detail on the situation or character of the diffraction, scattering LoRa signal is a reflection with an approach to the antenna height and LoRa Frequency, the results obtained are graphs as shown in Fig.8.

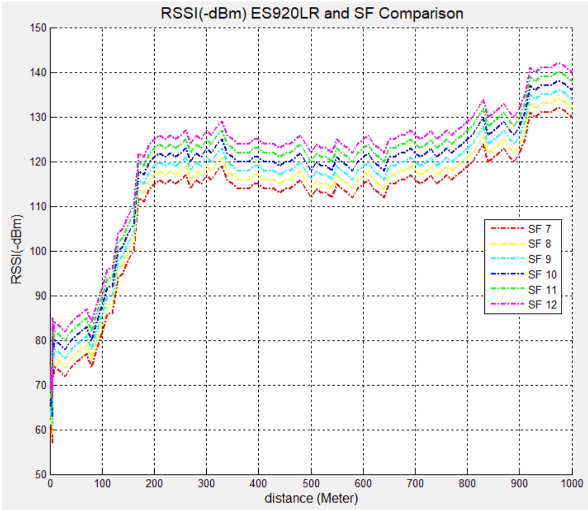


Fig.10. RSSI of LoRa with difference SF

The display in Fig 13 and Fig 14 are a real-time example of a health monitoring signal output, i.e., a pulse sensor, and the picture shows real-time normal human BPM at 72.90 and an average of 65 BPM. This display is obtained from real-time measurements on the Arduino Serial monitor IDE. The next is the approach to power consumption, where the formula is

$$EE\ (bit/mAH) = (data\ rate\ (bits/s))/Energy\ Consump = (data\ rate\ (bits/s))/(Iavg\ (mA).Ttime(hours)) \quad (11)$$

Therefore, a small mA on LoRa, it can increase LoRa energy (bit/mAH), which is shown in Fig 15. Furthermore, it can be calculated on age or battery life as in Fig.16 using a 1000 mAH 3.7-volt battery, its age in hours can be calculated as in Fig 16. If the data is tried to throw the data from Tx on the drone, then the RSSI and SNR approach conditions are as in Fig.17 and Fig.18. From the Figure it can be concluded that LoS and NLoS conditions have different results, and of course LoS is better in terms of getting a signal (-dBm) because there is no diffraction, scattering, or obstruction that gets in the Communication between Tx and Rx.

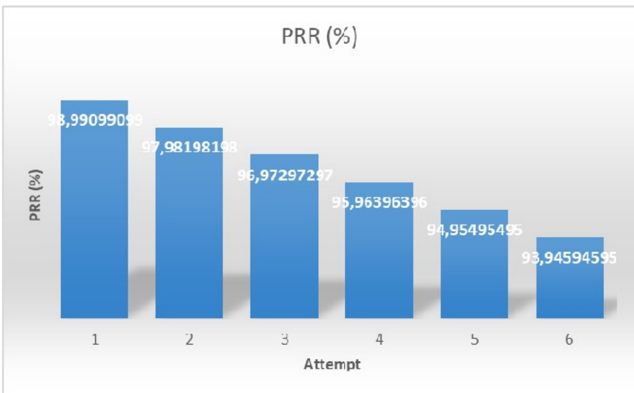


Fig.11. PRR (%) LoRa

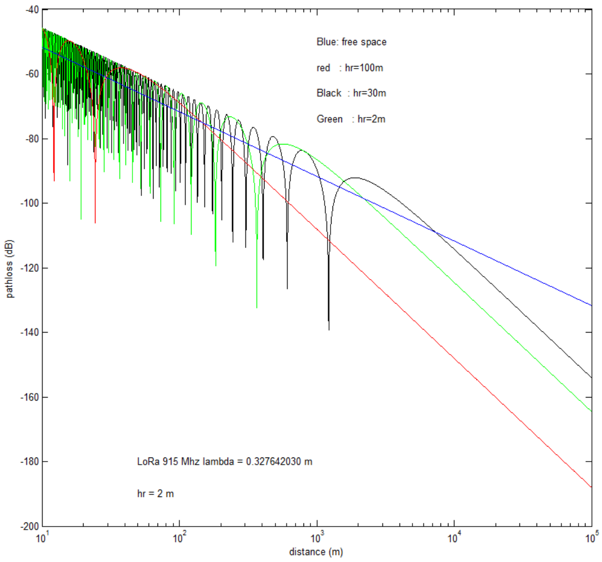
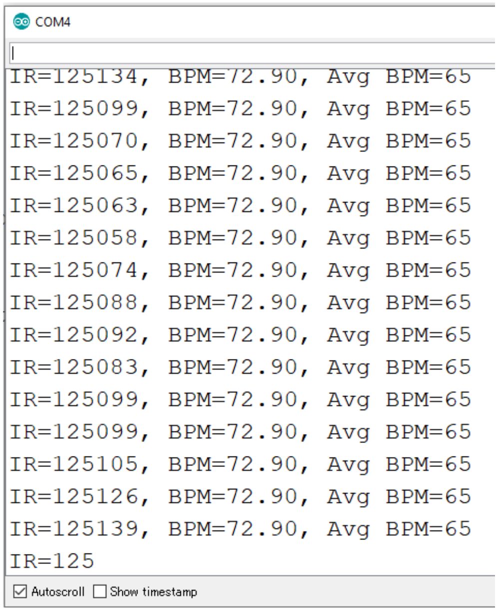


Fig.12. Ray-Reflected model


COM4

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IR=125099, BPM=72.90, Avg BPM=65
IR=125070, BPM=72.90, Avg BPM=65
IR=125065, BPM=72.90, Avg BPM=65
IR=125063, BPM=72.90, Avg BPM=65
IR=125058, BPM=72.90, Avg BPM=65
IR=125074, BPM=72.90, Avg BPM=65
IR=125088, BPM=72.90, Avg BPM=65
IR=125092, BPM=72.90, Avg BPM=65
IR=125083, BPM=72.90, Avg BPM=65
IR=125099, BPM=72.90, Avg BPM=65
IR=125099, BPM=72.90, Avg BPM=65
IR=125105, BPM=72.90, Avg BPM=65
IR=125126, BPM=72.90, Avg BPM=65
IR=125139, BPM=72.90, Avg BPM=65
IR=125
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Autoscroll Show timestamp

Fig.13. The output of Bit Per minute (bpm) pulse

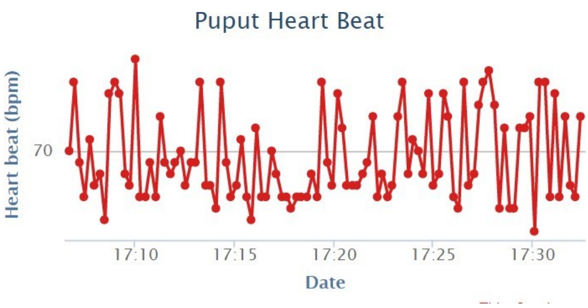

Fig. 14. Heartbeat on Thingspeak IoT

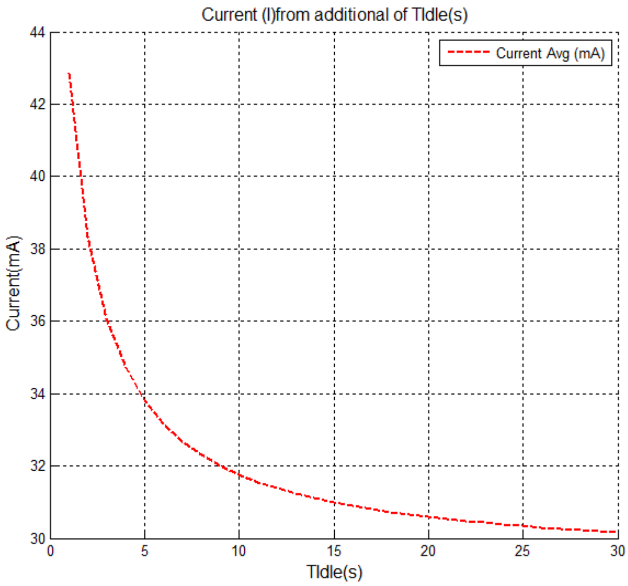

Fig.15. Current (mA) of LoRa

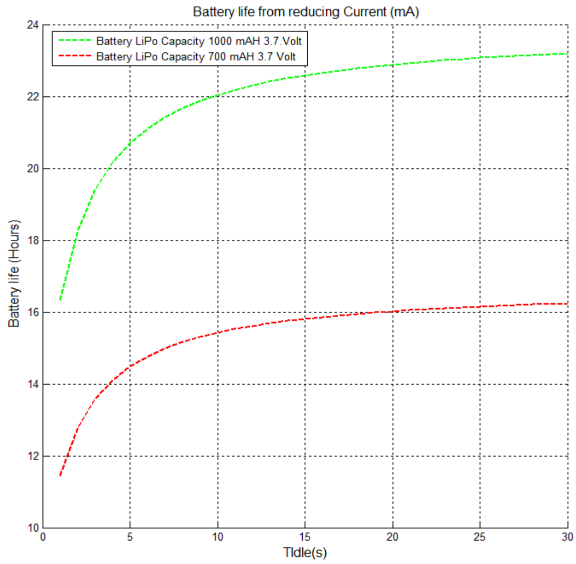

Fig.16. Battery life of LoRa

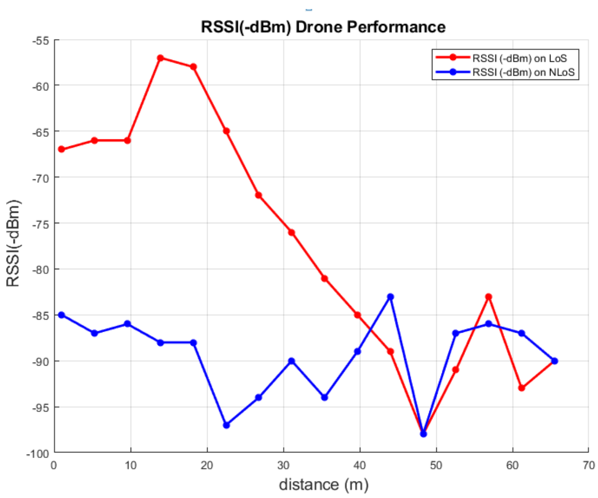

Fig.17. RSSI LoRa on Drones with 2 conditions LoS and NLoS

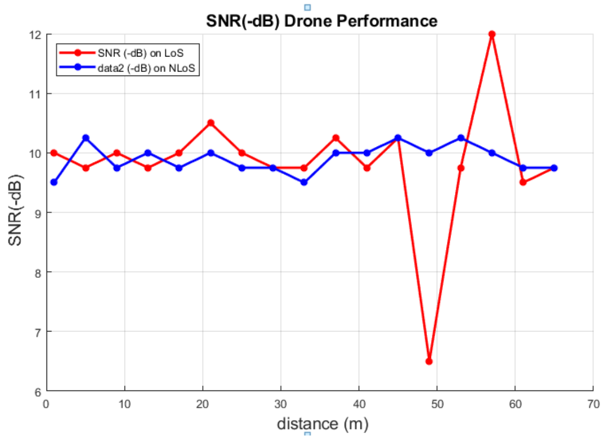

Fig.18. SNR LoRa on Drones with 2 conditions LoS and NLoS

V. CONCLUSION

Health monitoring has been carried out successfully with an accuracy rate of 90%, including pulse sensors, SPO2 sensors, and ECG sensors; these sensors have different specifications, and different devices in the process of sending data using LoRa 915 MHz and 920 MHz also have different results in terms of data rate (bytes), this is because each sensor has different specifications and different values, e.g., pulse uses BPM and SPO2 sensor uses mmHg value. And the next thing is attenuation (dB) when sending sensor data, with obstacle conditions and Non-Line of Sight, which causes the RSSI value (-dBm) to have different values. While ADR is very effectively used to reduce or reduce the effectiveness of Power consumption and, on the other hand, affects the battery life of sensor nodes, ADR is also able to reduce packet loss, so it is very effective if applied to LoRa and LoRaWAN based systems.

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