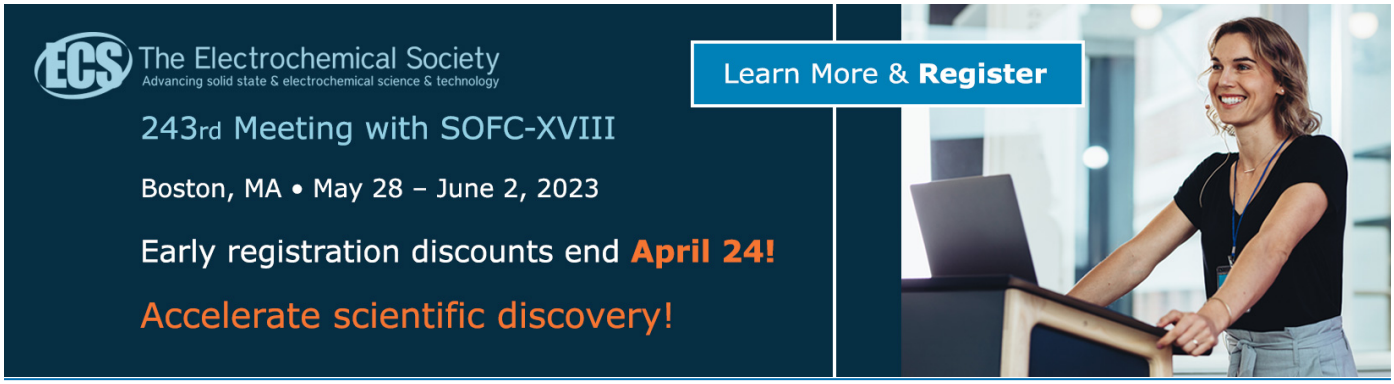
An LoRa based WSN for monitoring targeted Audience with Heart Diseases



An LoRa based WSN for monitoring targeted Audience with Heart Diseases

Narenthira Prasath D[1], Dushyant Kumar Singh[2*]
Lovely Professional University, Phagwara, Punjab, 144411

Orcid ID author 1: https://orcid.org/0000-0002-9762-1545
Orcid ID author 2: https://orcid.org/0000-0003-1859-9122
Email*: dushyant.kumar@lpu.co.in

Abstract
Health 5.0, health digitization is growing rapidly with the help of Internet of Things (IoT) and Internet of Medical Things (IoMT). The growth in this sector motivated us in learning the loopholes in the advancements. The various communication technologies and strategies are discussed based on the power consumption, speed and range. The LoRa is seen to work on low power, high range with less data transmission. Investigating the fields of Wireless Sensor Network, LoRa is seen as a reliable protocol that can best fit for Wireless sensor Network. The applications based on the capability of the system is reviewed considering the wide scale properties of each component. The best fit processing unit based on cost with the transmission protocols is discussed to give a clear vision on the technologies. Various transmission protocols are reviewed and LoRa is taken ahead in exploring and enhancing the features considering the knowledge gap. The speed of LoRa is simulated using Pothos, and the range is tested on the real ground. The data distribution based on heavy data transmission is discussed. The role of IoT and IoMT in the growth of the sector is visualized as the major contribution is given by the technologies. The Future scope of research in healthcare is concluded motivating the researchers giving a wide range opportunity to work on.

Keywords: Health 5.0; Internet of Things (IoT); Internet of Medical Things (IoMT); Wireless Sensor Network (WSN); Sustainable Development; LoRa; Pothos.

1. Introduction

If Wealth is lost, nothing is lost; If health is lost, everything is lost. This shows the significance of health sector in the daily life. the advancements in this sector are seen to be comparatively high with other sectors. The growth of the sector is due to the demanding need of the advancements to serve better. The healthcare infrastructure stays in the competitive phase between countries as the sector has the potential researchers in every corner of the world. A continuous data monitoring is done digitally to collect a wide range of dataset to automate the working mechanism. The Machine Learning (ML) and Artificial Intelligence (AI) brought a hike in the sector but demands a proper dataset from user. The Wireless Sensor Network is a solution technology provided to collect data in an efficient way. The different communication systems are available. The Bluetooth, BLE, Wi-Fi, Zigbee, LoRa has their own standards. The capabilities and shortages in the self, made them application specific. The brief about IoMT, WSN, Comparison of various networking technologies, Literature survey based on LoRa technology is detailed in the article.

The research study is done to identify the practical range of the transmission LoRa device for an application for Wireless Sensor Network implementation of health band for a selected group of people. The study also covers the data transmission techniques for heavy data transmission using Lora for long distance transmission. The study is proposed for places where the lack of cellular network or the need of special network for limited access is seen.

1.1. Motivation of this paper

Humans can never afford to ignore their health. A better lesson has been taught by this pandemic regarding the healthcare sector. It showed both the potential of the healthcare sector as well as the demanding improvements in the field. This gained the attention of many researchers. The need of advancement in the healthcare sector motivated the authors in learning the existing technologies to propose a solution for the modern problem statement. The authors found LoRa to be the efficient way to send data for long ranges without the physical interference. But the deficiency in the data transmission rate is seen and the research to enhance the speed is proposed. The problem in the forests and rural region where the lack of network is seen for effective health data communication is hard. One of the major problems in developing countries in the villages is the lack of a comprehensive system capable

of both health data transmission and heavy data transmission for a long range. Authors developed the system to deal with a major problem encountered by the country.

1.2. IoMT in Healthcare

Internet of Medical Things came up bringing the solutions in medical field using Internet of Things. Solutions on smart health monitoring, pandemic detection, smart elderly people guidance, social unity based on healthcare are proposed and advancements are going on. The IoMT mainly focuses on digitization of data which includes collection of data from sensor data, data segmentation, data storage and data analyzing. The smartness in IoMT requires smart communication technologies which enables higher range and less power. The low power consumption and high-range covering helps in enabling the feature of smartness in the system. The Figure 1 shows the comparison of data rate and distance coverage, and power consumption. The figure shows the NFC, WLAN, Bluetooth which has increasing data rate and less distance coverage. Zigbee and 6LoWPAN has a bit less data rate with more distance coverage. Cellular communication has the highest data rate with highest coverage. On the other hand, LoRa and Sigfox has lowest data rate with highest distance coverage. The power consumption increases with the data range is clearly seen. The LoRa is selected as the power consumption is less and data coverage is more despite less data range. In case low data rate sensors LoRa will be the advanced solution. Further, based on applications, the network technology can be decided.

Every Network Technology requires a specific topology for serving better the purpose. The frequency is another major role-playing character to decide a networking technology [1]–[4]. The networking technology with their corresponding frequency and Topology is stated in Table 1. The data collected shows the LoRa as a satisfying technology which has a wide range of operating frequency and could be built on star or mesh topology. The diverse opportunities in the advanced technology opens a path to the researchers to select the technology based on the application requirement. A vital signal-based Health monitoring system using IoT is developed using three different networking technologies and the study concluded saying the LoRa to be the advanced one [5]. The results are compared between GSM, Wi-Fi and BLE. The Lora is proved to have better reliability.

Table 1. Topology and frequency of the communication technologies

Network Technologies	Topology	Radio Frequency (MHz)
LoRa	Star/Mesh	433, 860-1020 MHz
Wi-Fi	Star	2.4 GHz
BLE	Adhoc	2.4 GHz
ZigBee	Mesh	868.3 MHz, 902-928 MHz, 2.4GHz
SigFox	Star	862-928 MHz

1.3. Communication Technologies for Remote Data

Various researches are reviewed critically to highlight the key notes. The literature work is studied on various networking technologies. The LoRa is selected to the further research as it had a good scope in application point of view. Considering the Wireless Sensor Network, the relay nodes are to be placed for efficient data collection[6]. The relay positioning is done through Optical Relay Placement Algorithm (OPRA) is proposed by the author. Authentication stands next as the privacy is concerned. The health data could govern the country if it is mishandled. The three-way authentication system is proposed to ensure the privacy of data[7]. The WSN on scattered nodes is detailed to collect data precisely. The efficient use of WSN on cattle health monitoring system is focused and the benefits are proposed by the author[8].

ZigBee based solutions on health monitoring is widely seen, the Transmission range is a drawback which is again highlighted. The ECG and heart rate monitoring of 17 males of 25 years old is taken into consideration for transmitting data through WSN[9]. The data transfer speed to the server is critically reviewed by the author the prove the advantages of ZigBee technology. More than the technology on transmission, the technology on the outfit and data collection is reviewed. The wearables-based sensor is widely suggested by researchers as it is user friendly and can be a plug and play system[10], [11]. The human posture detection and the ECG, EMG, temperature is detected across WSN.

The LoRa is widely used than Bluetooth is reviewed by the author and is stated in his work[12]. LoRa in the field of Air Quality monitoring from different nodes is also widely seen as the advantage[13]. Implementation of similar technology replacing the sensors based on the counterfeit action would help the society better. The

motivation and suggestion of other researchers in moving on to the advanced technology forces us to move on with LoRa. The LoRa is used nowadays by various sectors. The topologies and the various sensors that are capable to work on is the knowledge gap identified[14]. The need to know the combination of technological to bring it in action with better efficiency is stated as a result of critical research. LoRa is best fit with Star and Mesh topology and has a wide range of operating frequency. The energy efficiency is stated to be very less when compared with ZigBee and BLE[15]. The research concludes saying the demerits of the BLE and ZigBee providing a solution with the advancements.

The Fog computing based WSN on Health monitoring is reviewed to check the computational speed and the efficiency of the system[16]. The fog computing enables the components of edge computing to make it work efficiently. Elderly monitoring in a smart city is reviewed[17], [18]. The LoRa in the sector of health enables the smart city which makes it a good go to the technology. The Elderly monitoring for the specific problem statement taken can be addressed only by LoRa as it has the lower power and high range specifications. LoRa is user friendly and beneficiary module to serve the future.

The workers' health monitoring in a construction site by monitoring both the atmosphere and the body health using LoRa based network is reviewed[19]. The System proves the efficiency of LoRa based system showing the capability of the system. The connected safety and interconnection are proposed by the Wireless Sensor Network. The communication between the sensor nodes is to taken care by the LoRa for better efficiency is viewed reviewing multiple research papers. Table 2 shows the application areas of different reviewed Networking technologies.

Table 2: Applications based on Networking Technologies is explained

Networking Technology	Application	Paper
BLE, Wi-Fi, GSM	Temperature and Blood Pressure monitoring	[5]
ZigBee	ECG and Heart Rate	[9]
LoRa	System energy efficiency detection based on LoRa	[15]
LoRa	Bolted Joints Health monitoring	[18]
LoRa	Cattle health monitoring	[8]
LoRa	Air Quality Monitoring	[13]
LoRa	Connected safety and healthcare monitoring	[19]
LoRa	Wearable IoT sensor-based health monitoring	[11]
LoRa	Walk stick-based elders monitoring	[17]

As the result of various researches reviewed critically, the LoRa module is the advanced technology module with low power consumption and high distance coverage. The networking technology is a major part of any IoT enabled system. The decision has to be wise considering the applications usage. The healthcare is a growing sector which needs attention when the IoT is considered. The modern solutions are proposed on IoT, but the applications that comes to market is less due to the lack of awareness of the communication protocol. For example, if a prototype is designed working with Bluetooth, bringing into the application major of BLE must be used. The protocols used till date in the healthcare sector has smaller communication space. The wireless transmission protocols used in the ages are limited to communication range and data rate. The security of data transmission is another major issue seen in the technologies. Troubleshooting all the issues with a compatible protocol to serve the health sector is seen in LoRa. The application-oriented prototyping would help in marketing the technology. The research lag is found in the technology areas where the data rate of transmission is less. The parallel synchronization of bigger data (EMG, CT scan, MRI) through different LoRa modules to sync could help better. No research is found stating the synchronization. The data rate is found to be a drawback in LoRa as less data can be transmitted at a moment. The alter of combing two networking technologies to improvise system can also be carried on research. The advancements in the LoRa are open in health sector which has a bright market value.

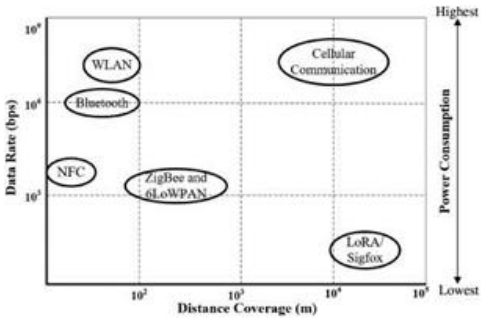


Fig. 1. The communication technologies classified based on data rate, distance coverage and power consumption

2. Lora in Healthcare

Chirp is a dump in frequency. The chirp is of two types. High to Low or Low to High. The high to low chirp states the frequency dump in which the frequency dumps from higher frequency to lower frequency. The low to high chirp states the increase in frequency from low frequency to high. Spreading Factor (SF) helps in deciding the performance of the LoRa system. The SF of system always lies between 7-12. Larger SF increases the communication range with more power communication with less data and vice versa. The pothos application is taken in simulating the LoRa system to check for the characteristics of data transmission. The chirp is given as the input data to the simulated system and the power spectrum is seen on the graph on the graph. The output data in the continuous natural number is seen as the transmitted signal through the LoRa module. The loss in the signal can be found in the output box. The demodulated Frequency and dechirped demodulated frequency are seen on two different graphs as output. The Fig.2 shows the Pothos application window with the above prescribed functionalities.

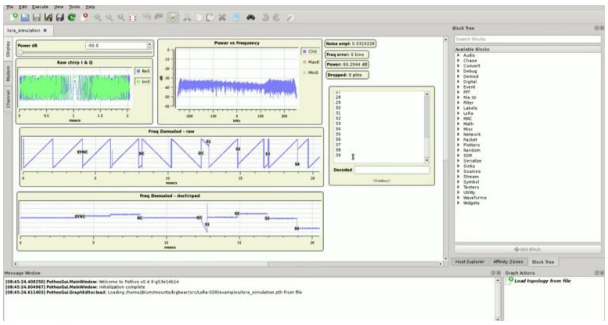


Fig. 2. The Pothos application window with the functionalities.

2.1. Pothos simulation for LoRa test

On the platform, several tests are performed to assess the LoRa modem's ability to transmit high data rates in a shorter amount of time. The authors began by lowering the Spread Factor for any given time instance, the chirps are doubled half the number of samples; achieving a greater data transfer in less time. When the SF is reduced, the data transmission rate is increased by means of faster chirps. The results of the lowering the SF is seen in Fig 3a. The second test is done on increasing the Spread factor for the same instance of time. The samples are doubled for the half the number of chirps which significances the lower data transfer in more time. The increase in SF reduces the data transmission rate with the high active time in air which leads to better performance in case of transmission range. The results of higher SF are seen in the Fig 3b. In terms of data transmission rate and range, the Spread factor has a major impact. If Higher data rate is needed, SF has to be reduced; which apparently the range is reduced. If higher range is needed, SF have to be increased; which significantly reduces the data rate.

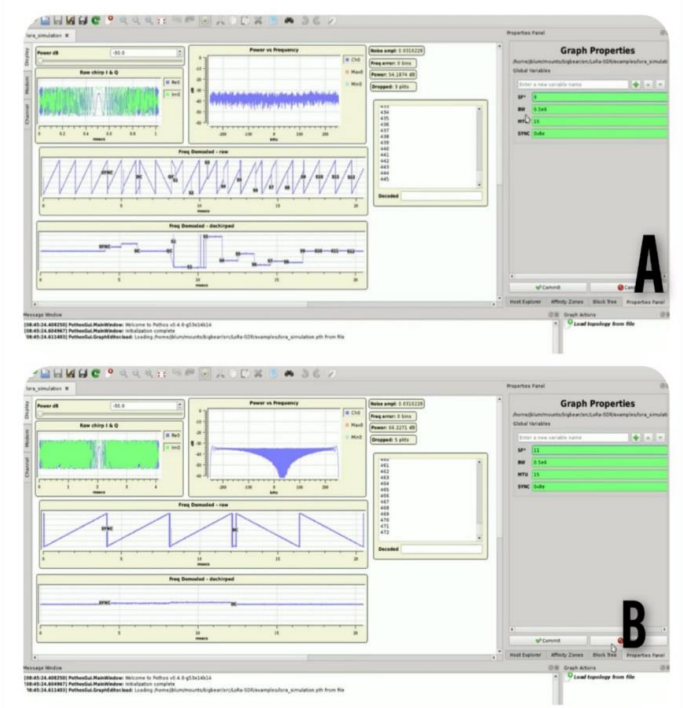


Fig. 3. (a) Simulation in Pothos with reduced Spread Factor. (b) Simulation in Pothos with increased Spread Factor.

Noise, an environmental disturbance that affects the transmission of signal is simulated to check the system efficiency. Simulating the idle system performance does not provide a full understanding. So, the application where the noise is fed in the environment to detect the change in the data rate and range is checked. The system is simulated with a considerable amount of minimum noise. The waveform is smeared still the data packets are received. The flat edges of the frequency wave are seen in Fig 4. Further increasing the noise, decreases the power of the signal which can be seen over frequency power graph. The loss of signal is also seen. The Fig 5a shows the significances of increase in noise simulated condition. When the SF is increased in the heavy noise environment, the data packet losses are avoided. The role of spread factor during the noisy environment can be seen in the simulation in Fig 5b.

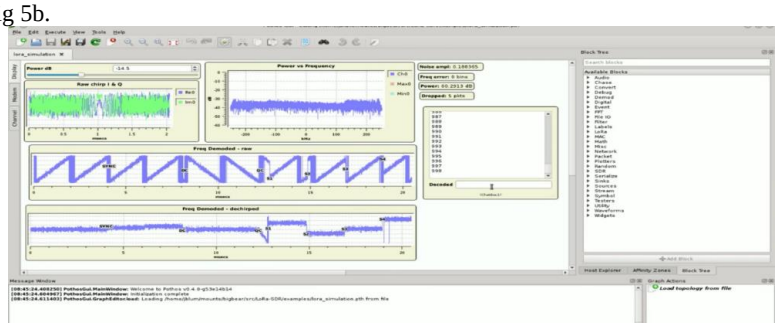


Fig. 4. System incorporated with Noise

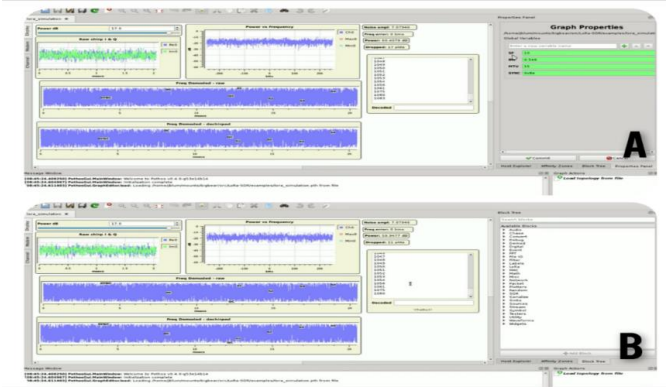


Fig. 5. (a) Effects of heavy noise in the Frequency vs Power graph and data losses in the system. (b) The data loss is reduced in increasing the SF.

2.2 Range Test

The Lora module with titled version "E32 433T30D (TTL 1W)" with the antenna is used in the complete research work. Fig 6 shows the LoRa transmitter and receiver module. The module is tested for range and the data transfer rate. Most of the times, the basic (temperature, BP, sugar, oxygen level) health data is really small and the advanced (MRI, CT images) health data is really huge. Two applications are developed considering the need of the system. The similarities in the solutions are totally different but the range and data rate plays a major role. Complete research on considering the different applications based on different mandatory functionalities is discussed.

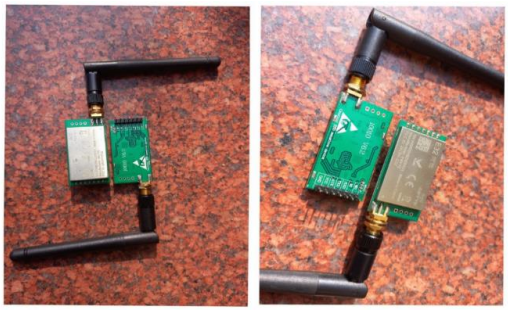


Fig. 6. LoRa module "E32 433T30D (TTL 1W)" is displayed

The climatic conditions play a major role in wireless communication system as the radio waves are often affected with the environmental conditions, to make the study transparent the climatic conditions at which the tests are performed is shown in Fig 7. The Lora setup is seen in Fig 8. Fig 8a shows the Transmitter system, 8c shows the receiver system and 8b shows the data received.

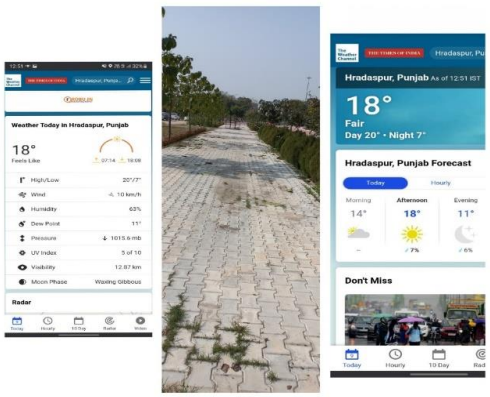


Fig. 7. The climatic conditions including temperature, humidity, wind, pressure, UV index, dew point, visibility.

Fig. 8. (a) Transmitter System (b) Received Signal (c) Receiver System

The authors went on with the first test in the open field, The ground in Lovely Professional University is selected for the test. The ground is mostly clear with few trees in the sides. The Fig 9a shows the range of around 1000 mts from “block 26” to block “30 parking”. Fig 9c shows the range of approx. 1500 mts from “Law gate” till “block 14”. Fig 9b shows the receiver setup. The images are taken from the WhatsApp location calculating the distance between two centers. The results were really satisfactory that the system gave perfect results in the locations with same altitude. The authors went on with the further test on higher altitude. The Transmitter system is set on the 9th floor of the building (approx. 85ft) and the receiver system is set to move far in the lower altitude. The range is seen for around 3000 mts considering the buildings on the way. The location indication is seen near the “Uni hospital” and the “Block 56”. The Fig 10a shows the google map image of the receiver and transmitter whereas the 10c indicates the WhatsApp location of the system. The area with the buildings is shown in Fig 10b in which the test was held.

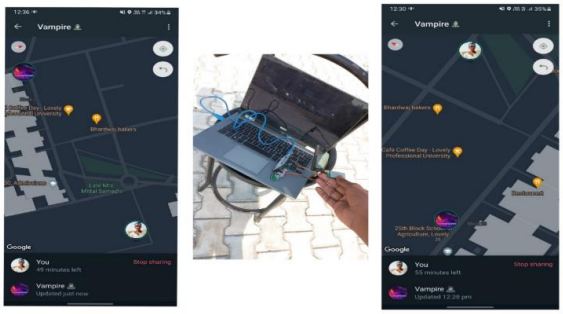


Fig. 9. (a) Covering range of over 1000 mts (b) receiver system in the ground (c) Covering range of approx. 1500 mts.

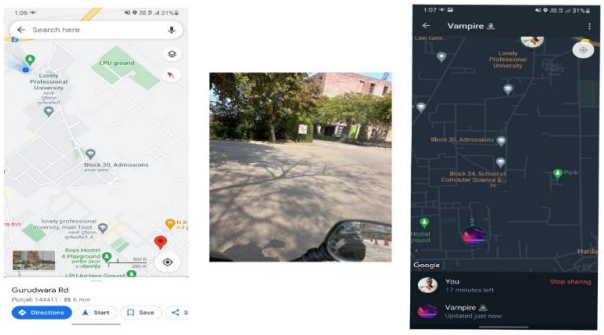


Fig. 10. (a) Google map imaging of System (b) The Scenery at which the test was conducted (c) WhatsApp imaging of Transmitter and Receiver

2.3 Data Rate Test

The LoRa module has 4 modes in which the communication between the LoRa and controller is established. The modes are enabled used 2 dedicated pins Mo and M1. The Mode 0 states the Transmission Mode. The UART communication is enabled all time to send and receive data. When user sends a data, module sends using UART protocol and in idle state wireless receiving is enabled to receive data. During configuration mode, Data can be received normally, using the same receiving function as in mode 0. In WOR mode, an automatic preamble is added before transmitting when a party is defined as a transmitting party. Data can be received normally; the receiving function is the same as mode 0. In Deep Sleep Mode, wireless receiving and transmitting is disabled. The module will configure when the mode is switched from Deep sleep mode to any other mode. The functionality of LoRa module is detailed in Table 3.

Table 3: The different modes of the LoRa module

S. No	M0	M1	Status
1	0	0	Transmission Mode
2	0	1	Configuration Mode
3	1	0	WOR mode
4	1	1	Deep Sleep Mode

The official tool by LoRa named “LoRa Modem Calculator Tool” helps in determining the bitrate based on the predefined background formulas. Various tests are performed to see the bitrate difference. First authors kept SF as 12 and CR as 1 is seen in Fig 11. The bitrate was found to be 732.42 bits per second with preamble duration of 83 ms. The time on air was 215 ms. The transmit mode timing is 299 ms and receiver mode timing is 215 ms with sleep time of 3156 ms. Transmit Charge Consumption is seen really high 26910 micro-Columb. Fig 12 shows the results for SF 10 with CR 2. The bitrate is found to be 3255 bits per second with the time on air as 61.95 ms. The permeable duration is 20.99 ms and symbol time is 2 ms. The transmit mode time is 70.7ms and receiver mode timing is 62 ms with sleep time of 3412 ms. The transmit charge consumption is seen to be less around 6359 micro-Columb as compared to the previous scenario. Comparing both the situation gives an idea of the CR and SF on the system. The increase in CR significantly reduces the data rate and the decrease in SF increases the data rate with the significant power loss and the time on air.

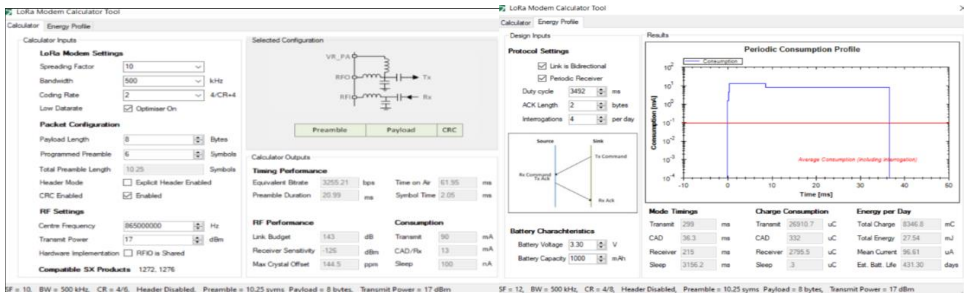


Fig. 11. The bitrate and other data based on SF 12 and CR 1.

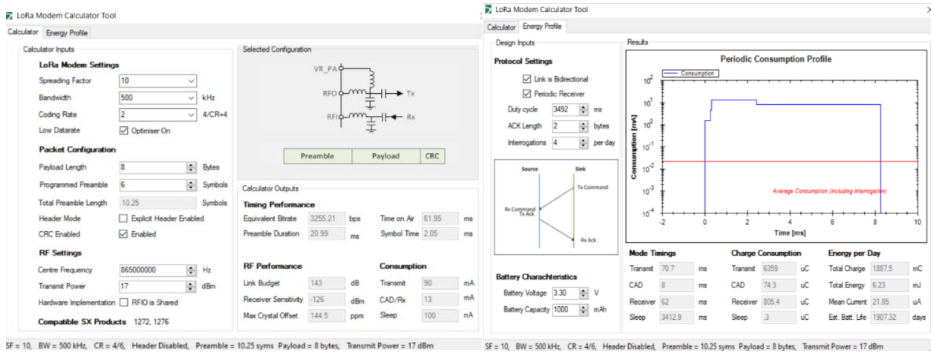


Fig. 12. The bitrate and other data based on SF 10 and CR 2.

3. Wireless Sensor Network in an open network with targeted audience of ECG monitoring

The ECG band is enabled with the controller system holding the LoRa module as the transmission node. Heart attack is a kind of disease that cannot be diagnosed in prior notice. The diagnosis can be done few hours before the affect. The system would help in regular monitoring of patient remotely in the areas where the network is limited or the need of private network is needed. The rural area people with the poor health condition can have the device to remotely and timely monitor of the heart. The fig 13 shows the transmitter and receiver setup for the enabling of targeted audience monitoring for the specific data using IoT Technologies. The system is capable to livestream the data to the distant doctor. People with heart diseases needs a regular monitoring of heart using Electro Cardiogram. This system would help in fetching the data from sensor and send through Lora transmitter. The doctor on the other end can receive the signal using LoRa and decode it in the controller and display the ECG data on the monitor. Series of data is sent through LoRa, which is procured from the sensor setup. Moreover, the basic health data such as body temperature, Blood Pressure, Heart rate are also transferred to the distant doctor using the system.

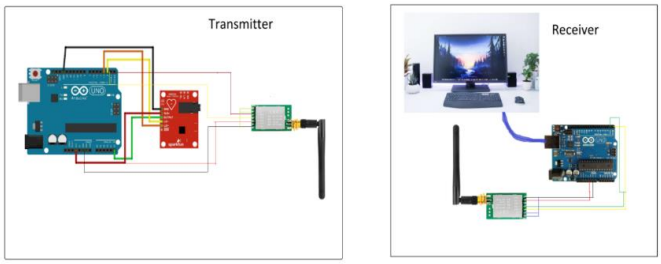


Fig. 13. The receiver and transmitter system with the sensor setup.

4. Conclusion

The various communication technologies existing on various health domain literature is reviewed and the LoRa is found to be a better device for the targeted group monitoring in the remote areas. The range and data rate can be managed to develop an application for healthcare sector. The simulation of LoRa is performed to check the noise deviation and data rate. Another simulation is done to determine the bitrate, power losses, transmit mode timing and various other parameters. The lora is developed for the transmission of ECG signal using LoRa for distant doctor. The results of using LoRa in the remote monitoring and for the specific purpose is appreciable. The advancements in the technology with Machine Learning and Artificial Intelligent techniques would help us in building the intelligent system with capabilities to serve the health domain. The early prediction of heart attack and other deadly diseases with the dataset developed by testing on thousands of people would help in achieving the further goal. The system to ensure the health of heart from a remote distance and to analyze the data with enhanced techniques to ensure the good health of the human is a demanding need and can be achieved using the system.

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