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Research Article

Design of a modern communication system with high quality using LoRa technology

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Abstract:

Along the time and the increase in demands on modern communications networks, it has been observed that the number of the Internet of Things IoT devices has increased in countries around the world as they support subscriber services. The number of these devices increases every year, and there is a statistic that the number of devices will reach 60 billion devices in 2030.The research aims to obtain high-quality and secure communications from eavesdropping and reduce the corruption of received data due to its large numbers and within a certain period of time. We noticed the effect of this case reducing the bit error rate BER Through the practical experiments we conducted.

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In this research, we designed a communications system using modern communications technology LoRa, which supports IoT devices using sensors of the type SX1276 and a software-defined radio device SDR, Through conducting several laboratory experiments, we concluded that the best case is when Spreading factor SF=9 is at a constant bandwidth B.W=250kHz and the code rate CR=3, this case represents practically the lowest Bit Error Rate BER= 0.56dB, SNR=8 dB, While the theoretical reading was BER=0.6dB, SNR=11.6dB for a communications system that works with modern LoRa technology that supports internet of thing IoT applications.

Keywords: Spreading factor (SF), Bit error rate (BER), Signal to Noise ratio (SNR), Chirps.

1. Introduction

The Strategy for Flow and Agricultural Administration (SFA) need a wide range of environmental data, including hailstorms, down humidity, heat, pressure, and river water levels. Approximately 130 remote weather stations have been erected across Azuay, and Chimborazo. SFA has two initiatives involving limn graphic sensors. The first is early flood warning, and the second is flow forecast using modern communication neural networks (Ye, Z., Yang, J., Zhong, N., Tu, X., Jia, J., & Wang, J.,2020:699). Our research team is focused on designing and implementing a wireless network to collect sensor data and transmit it to the SFA data hub. The idea is to use wireless technology to lessen the displacement of those in charge of downloading data. As a result, this will increase the availability of limn graphic information in hourly transmissions. Lower the danger of data loss, and reduce mobilization costs that can be used for maintenance.

LPWANs are a new trend in the development of wireless communication technology. This communication technique is able to connect and control a large number of sensors, spanning huge areas at minimal energy costs (Sharma, S., &Verma, V. K., 2021: 4778-4812). One of the most modern approaches to this innovation is long-range LoRa(Benkhelifa, F.,Bouazizi, Y., & McCann, J. A. 2022: 19928-19944). The LoRa Network developed the medium access control layer, or LoRaWAN. It focuses on the Internet of Things IoT architecture and builds networks using the benefits of LoRa modulation, shown figure. 5Singh, (Singh, R., Birajdar, G. S., Rashid, M., Gehlot, A., Akram, S. V., AlGhamdi, A. S., &Alshamrani, S. S. 2021: 13238).

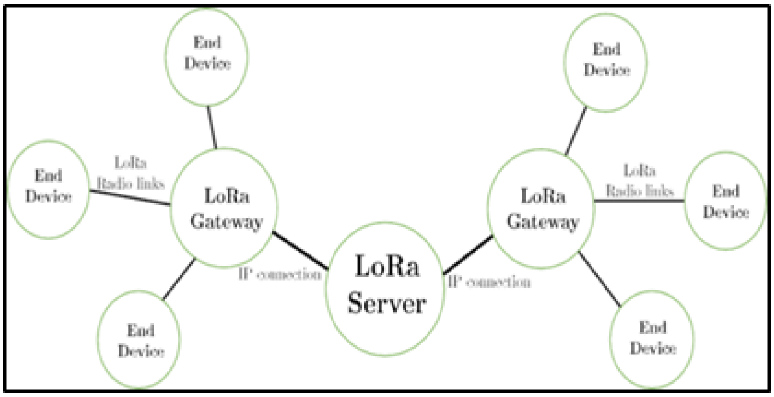

Figure 1.LoRaWAN Architecture (Suomi, H. 2024).

2. LoRa And PropagationModels

Spread spectrum modulation, which is the foundation of LoRa, was developed using Chirp Spread Spectrum CSS technology.It was created by Cycleo, a French company based in Grenoble,and was purchased bysmtc.

a founder of the LoRa Alliance, in 2012. In Europe, LoRa can be used in the license-free band between 863 and 870 MHz, and in the USA, between 902 and 928 MHz.Different combinations of the following characteristics define LoRa effective radio network coverage: Bandwidth BW, Spreading Factor SF, Transmission Power TP, Carrier Frequency CF, and Coding Rate CR (Ingabire, W., Larijani, H., & Gibson, R. M. 2020:1-6).

A network protocol stack known as LoRaWAN connects the wide-area network of LoRa and provides a model of LoRa technology on the MAC. stratum. Moreover, information is sent by LoRa motes or endpoints to a LoRaWAN gateway, which then forwards it to a network server, forming the LoRaWAN network (Tapparel, J., Afisiadis, O., Mayoraz, P., Balatsoukas-Stimming, A., & Burg, A.,2020: 1-5), On the other hand, end devices connect directly (to a small number of gateways in a star topology using a single-hop method. The LoRaWAN network architecture is assessed and confirmed by the authors (Kannan, B. M., Solainayagi, P., Azath, H.,Murugan, S., & Srinivasan, C. 2023:1385-1389),(Guevara, N. E., Bolaños, Y. H.,Diago, J. P., & Segura, J. M.,2022) in order to facilitate low-cost long-range transmissions. In order to provide dependable communication for mobile devices, the LoRaWAN protocol utilizes less power than previous LPWAN technologies based on the LoRaWAN architecture (Sadri, A.A., Rahmani, A. M., Saberikamarposhti, M., Hosseinzadeh, M.,2022). BER generally reduces as SNR rises. This is so that the receiver can more easily differentiate the transmitted signal from the noise because a higher SNR indicates that the signal power is stronger in comparison to the noise power.

As a result, there are less mistakes in the received data (Ahmed, Y.,2023: 85-98)a commonly used approximation for therelationshipbetween SNR and BER is given by Shannon's capacity formula or the Shannon-Hartley theorem:

$C = B.log_2\,(1+ \text{SNR})$ ……..(1)

Where:

C is the channel capacity in bits per second (bps), B is the bandwidth of the channel in Hertz (Hz), The BER (P_b) can be related to SNR is the signal-to-noise ratio.

$P_b = Q\left(\sqrt{\frac{2.c}{B}}\right)$……..(2)

Q(x) is the Q-function, representing the tail probability of a standard normal distribution, C/B is the SNR expressed in terms of the bandwidth B normalized SNR (Huang, J., Gheorghe, A., Handley, H., Pazos, P., Pinto, A., Kovacic, S., Daniels, C., 2020: 234-261).

2.1 End to end specifications for LoRa

By taking use of a coding gain derived from the spread spectrum modulation approach, LoRa is able to establish long-range connectivity. More precisely, symbols are modulated across a defined bandwidth using chirp spread spectrum CSS Chirps. The number of chirps is determined by the spreading factor SF. Increasing the SF will increase the range. Table 1 provides a summary of the related gains for each spreading component. An increase in SF results in a decrease in data rate and an increase in time on air, which raises energy usage (Wong, A. W. L., Goh, S. L., Hasan, M. K., Fattah, S.,2024:1-43),(Ahmad, F., Mariyam, S., Ahamad, F.,2025: 161-171).

Spreading Factor	RSS (dBm)	SNR (dB)
SF6	-118	-5
SF7	-123	-7.5
SF8	-126	-10
SF9	-129	-12.5
SF10	-132	-15
SF11	-133	-17.5
SF12	-136	-20

*TABLE 1. Sensitivity of the LoRa demodulator (BW125 kHz) expressed in received signal strength (RSS) and signal-to-noise ratio (SNR) for the used LoRa*chip (Huang, J., Gheorghe, A., Handley, H., Pazos, P., Pinto, A., Kovacic, S., ... & Daniels, C. 2020: 234-261).

3. Network design and practical experiments

We designed a communications system that uses the Internet of Things (IoT) communication technology, where we used three computers, two of which were programmed in the Linux language, and one in the Windows language and used to program the Arduino type Uno. Sensors of type SX1276 were used connected to the transmitter side, with a connection Software-defined radio device SDR, which is considered signal processing part, and the transmitted signals are detected by One of the computers used in our laboratory experiments.The design that we conducted our practical experiments on in the laboratory consisted of three computers, two of which were programmed with Linux software and the third with Windows software. We used an Arduino Uno type and it was connected to the third computer. We also used number three type SX1276 sensors, and the software-defined radio device SDR was connected to the two computers working with the Linux program, where the SDR device is considered the operations center for digital signal processing and we used an antenna of the type ROHDE SCHWARZ which has frequency range 200MHz-500MHz and this is shown in Figures 3,4.

Figure3. Antenna type ROHDE SCHWARZ.

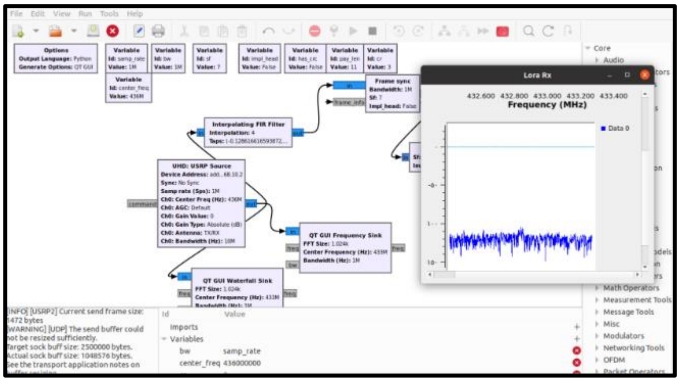

Figure 4. The Network construction designed by using technique LoRa type SX1276.

3. Discussion

In this research, we discuss connecting the Internet of Things network using a specific design previously mentioned in Figure 4, and how to use these designs to facilitate the task of huge devices by reaching the lowest bit error rate and highest signal to noise ratio through the practical experiments mentioned above in paragraph2.1 of this research to accomplish its necessary tasks in various fields and according to the requirements we need, and this is explained below:

LoRa (Long Range) communication networks connected have a complementary relationship, particularly in applications requiring long-range, low-power, and efficient data transmission. Here's how they are interconnected:

LoRa technology enables devices to communicate over long distances (up to several kilometers in rural areas and a few kilometers in urban environments) with minimal power consumption. This is particularly useful for beyond-visual-line-of-sight (BVLOS) operations, where drones need to transmit data or receive commands over extended ranges.

Devices equipped with LoRa modules can act as mobile nodes in IoT (Internet of Things) networks. They can collect data from ground-based LoRa sensors (e.g., environmental monitoring, agriculture, or infrastructure inspection) and relay it to a central gateway or cloud platform. This LoRa's low-power characteristics make it ideal for drones that need to conserve battery life while maintaining communication. This is especially important for long-duration missions or when drones are deployed in remote areas where recharging or replacing batteries is challenging.

Communication networks can provide real-time telemetry data (e.g., location, altitude, speed, and sensor readings) from drones to groundstations. This enables operators to monitor and control drones effectively, even in areas with limited cellular or Wi-Fi coverage.In devices swarm operations, LoRa can facilitate communication between multiple drones, enabling coordinated tasks such as search and rescue, precision agriculture, or surveillance. Its ability to handle many devices with low interference makes it suitable for such applications.

LoRa networks are relatively inexpensive to deploy compared to traditional cellular networks, making them an attractive option for drone operators who need affordable, reliable communication solutions.

Agriculture: Drones with LoRa can monitor crop health, soil conditions, and irrigation systems over large farms.

Environmental Monitoring: They can track air quality, water levels, or wildlife in remote areas.

Disaster Management: Drones can use LoRa to relay critical information during emergencies when traditional communication infrastructure is down.

Smart Cities: Drones can assist in traffic monitoring, infrastructure inspection, and public safety using LoRa networks.

The most Challenges are:

Bandwidth Limitations: LoRais designed for low-data-rate applications, so it may not support high-bandwidth tasks like live video streaming.

Interference and Range Variability: Environmental factors and network congestion can affect LoRa's performance.

In summary, LoRa communication networks enhance the capabilities of drones by providing long-range, low-power connectivity, enabling innovative applications across various industries. However, the choice of communication technology depends on the specific requirements of the mission, such as data rate, range, and power consumption.

4. Results

The design of the communications system was built and we used the modern communications technology LoRa, where we installed the values of B.W=250kHz and CR=3, and changed SF, according to the clear design blocks in Figure 4, where in the beginning several signals were generated from the sensors used and we received The chirp were transmitted through the antenna shown in Figure No.3 previously.We detected those chirp through a spectrum analyzer device type RSA6100 A, where the received chirp accumulated and according to a certain period of time, and this is shown in Figure 5.

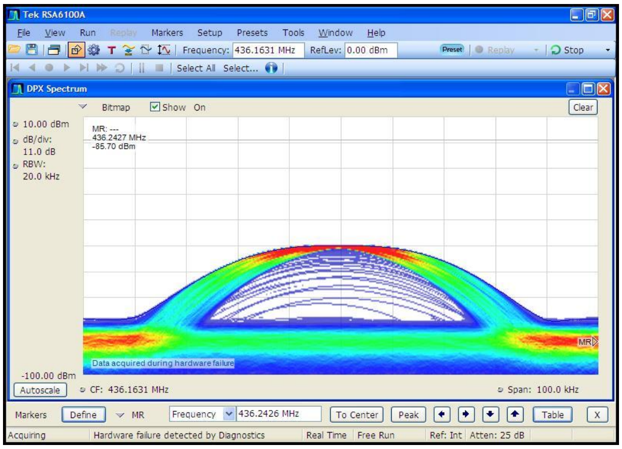

Figure 5. Shape of several Chirps received.

4.1 The Impact of diverge chirps on the efficiency system

During the many experiments that we conducted in the laboratory. We took the value of SF=7 as a measure of the performance of the communications system represented by the use of modern communications technology LoRa, as it was observed when using less SF, represented by the value of SF=7. The signal spacing by detecting it by one of the computers connected to the design circuit.It is prepared by us, and whenever we increase SF. This leads to the convergence of those signals until reaching the value of SF=9, where the convergence of these signals is greater leads to Reduce the value of bit error rate BER, whereas the value of B.W=250kHz and CR=3, figure 6.

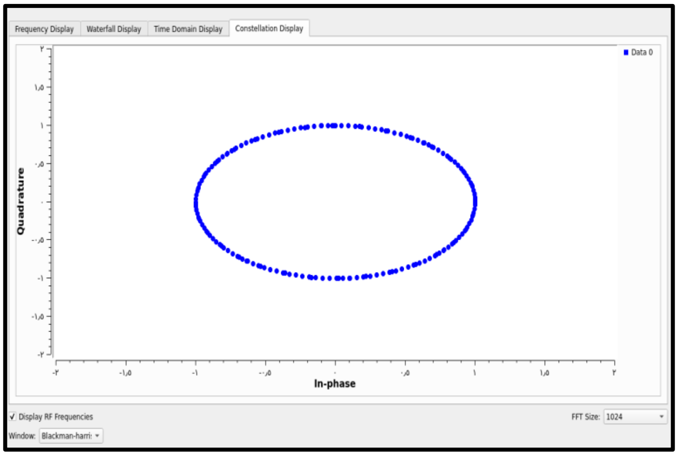

Figure 6. Constellation display of chirps.

4.2The impact BER & SNR chirps on system performance

We can see from Figure 6 of the received chirps that were detected by the spectrum analyzer , the realistic practical design value of BER and the theoretical value, as the continuous curved line represents the theoretical value and its reading was 11.6 dB, while the realistic practical (the squiggly line at the end reading) was close to The theoretical reading is also the best reading of BER obtained through practical laboratory experiments that were conducted. As for the magnitude of 0.56dB dB, it was under the AWGN equal to 1 dB, which represents the best value of BER it was obtained practically through experiments conducted in the laboratory.

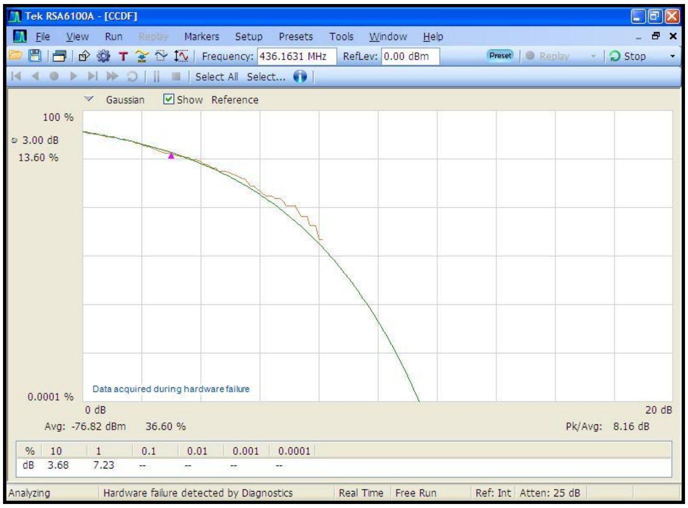

Figure6. The impact BER Chirps on system performance.

5. Conclusion

These results obtained in the laboratory showed that the spreading factor SF has a significant impact on choosing the best case. Which makes the modern communications system that supports IoT applications highly efficient. We found the most efficient case when SF=9 with constant CR=3 and B.W=250kHz, because the chirps is converge to each other, meaning the magnitude of BER is as small as possible, as the theoretical reading 0.6 dB and the practical reading were 0.56 dB, So the signal to noise ratio theoretical is 11.6 dB while the practical signal to noise ratio is 8dB. Meaning the magnitude of the two readings is converge. This is the most accurate and efficient communications system designed using modern communications technology that supports Internet of Things devices at the present time and in the future, especially using in customer services for requirements to smart cities and Communication devices used in the field of global media in the future.

We notice the great development has included the modern communications system,especially in the field of using drones and how to control and direct them to achieve the required goals, it includes all human facilitates to serve all of humanity in the future, as it is possible to connect the Internet of Things networksIoT to a group of drones through secure , fast communications protocols by using the above data, to achieve reliable communication and control of work with the least electrical energy used and with high quality.

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