Revolutionizing Satellite Communications: A Comprehensive Exploration Of Lora Technology For Enhanced Data Acceleration

Madhavi Mallam[1*], Yashaswini M P [2], G. Reddy Hemantha [3], M.K. Linga Murthy [4], and Jami Venkata Suman [5]

[*1]Professor, Department of E&CE,
PES Institution of Technology and Management Shimoga, Karnataka, India
gurumadhu432@gmail.com

[2]Department of E&CE, PES Institution of Technology and Management Shimoga, Karnataka, India
yashaswiniyashu300@gmail.com

[3]Assistant Professor, Department of ECE
Madanapalle Institute of Technology & Science Madanapalle, Andhra Pradesh, India
hemanthag75@gmail.com

[4]Department of ECE, Lakkireddy Bali Reddy College of Engineering, Mylavaram, Andhra Pradesh, India
lingamurthy413@gmail.com

[5]Assistant Professor, Department of ECE, GMR Institute of Technology, Rajam Andhra Pradesh, India
venkatasuman.j@gmrit.edu.in

Abstract: Recent years have seen major developments in satellite communications, with the goal of increasing overall performance, decreasing latency, and increasing data transfer efficiency. extended-range (LoRa) technology, which is well-known for its low power consumption, extended range, and applicability to Internet of Things (IoT) applications, is one of the technologies leading this revolution. With an emphasis on improved data speeding, this article offers a thorough investigation of LoRa technology's potential to completely transform satellite communications. The first section of the article provides an outline of the difficulties that satellite communications is now facing, such as latency problems, bandwidth constraints, and power consumption issues. After that, it explores the core ideas of LoRa technology, emphasizing its energy-efficient design, spectrum usage, and modulation methods. The integration of LoRa technology into satellite communication networks for improved data acceleration is demonstrated in detail in the following analysis. Talks about how LoRa can optimize data payloads, how it can modify data rates, and how well-suited it is for a range of uses, including asset tracking, environmental monitoring, and remote sensing, are included.

Keywords: Satellite Communication, LoRaWAN, Uplink, Downlink, Data Acceleration.

1 Introduction

In the contemporary era, where visual information is integral to various sectors, ranging from emergency response to environmental monitoring, the requirement for dependable and quick data transfer via satellite communication is paramount. Conventional communication systems often encounter challenges in delivering large data files efficiently. To address this, we investigate the integration of LoRa technology, known

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for its long-range communication capabilities and energy efficiency, into satellite communication systems.

The difficulties with traditional ground sensor nodes are their large size, increased power requirements, and high cost of operation. Besides being too costly to monitor wide areas, expensive sensor nodes should not be placed remotely and frequently needs human intervention for routine maintenance. The data transmission components of these sensor nodes are the ones that use the most power, which includes selecting the appropriate data rate and modulation type. Data transmission and transmission power are frequently trade-offs that must be made, which limits the amount of data that can be sent from the remote stations.

Satellite communication systems, which provide communication links for a variety of applications including disaster management, agriculture, environmental sensing, and weather monitoring, have long been used to establish global connectivity. However, LoRaWAN integration has added a level of flexibility and efficiency to these systems. LoRaWAN can be deployed in locations lacking traditional communication infrastructure since it operates in unlicensed frequency bands and allows long-distance connection with low-power devices.

This paper's primary goal is to suggest the LoRaWAN protocol, which will allow us to take use of LoRa's adaptability to increase the efficiency while lowering the latency of satellite image transmission. It will provide a summary of the exciting opportunities for utilizing LoRaWAN technology in LEO applications. A swift response is necessary in emergency situations where accessibility is limited due to human involvement in war, infrastructure destruction, and mobility accidents. In some cases, a system for interacting with entities might be required for the exchange of critical data.

This integration requires the widely used programming and simulation platform MATLAB, which provides tools for building, modeling, and evaluating communication networks. With MATLAB, researchers and engineers may model the combined satellite and LoRaWAN communication system, simulate data transmission scenarios, and adjust parameters for optimal performance.

2 Literature Review

There will be over 75 billion internet of things (IoT) devices online by 2025, according to recent study. For such massive IoT networks to continue operating seamlessly, we will need effective communications technology. While the medium access control (MAC) protocol is used by default in LoRa wide area networking, or LoRaWAN, new study suggests that LoRaWAN may not be the ideal choice for certain types of low-power widearea networking applications, including via peer-to- and networked devices [1]. The goal of this paper is to determine whether a low-cost, low-power wireless communications system for data gathered by marine sensors is feasible. More precisely, they conduct an experimental assessment of the Azorean Long Range Wide Area Network's coverage (LoRaWAN). To demonstrate the communication capabilities of LoRaWAN transmissions, measurements of the lines of sight (LOS), signal-to-noise ratio (SNR), and received signal strength indicator (RSSI) were made. These findings highlight LoRaWAN's enormous potential for trustworthy long-distance data transport for marine sensing [2]. The LoRa-based methods for achieving scalable and energy-efficient DtS-IoT are presented in this paper. They specifically suggested uplink transmission strategies that make use of satellite trajectory data. Devices may transfer buffered data to Low-Earth orbit (LEO) satellites, which can act as IoT gateways while they are passing by. But because of the extremely limited devices on the ground along with the transmission distances and channel dynamics, DtS-IoT is a very difficult problem [3]. The chirp spread spectrum (CSS) modulation is evolved for long-range, low-power applications, is the fundamental element of LoRa. LoRa signals are especially prone to synchronization problems during decoding due to their nature. They suggest differential CSS (DCSS), to overcome this limitation, a special synchronization technique combined with a modification of the LoRa physical layer is used. Because of this adjustment, they are able to demodulate the incoming signals while accepting some timing synchronization flaws and avoiding full frequency synchronization. Because the receiver does not have a maximum carrier frequency offset limit, unlike deployed LoRa receivers, it can therefore handle ultra-narrow band LoRa-like transmissions [4].

3 Block Diagram

As we can see that, there are two primary sections in this project: Transmitter and Receiver. Which contains main components such as LoRa and Microcontroller in it.

3.1 Transmitter part:

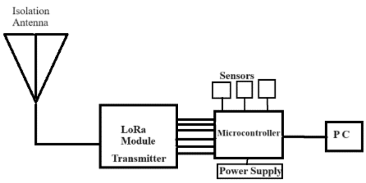

Fig.1. Block schematic for Transmitter component

The transmitter portion is depicted in Figure 1; here, datagrams are used to transmit the signals. Datagram will be processed through the Arduino IDE and then uploaded to the payload using MATLAB.

3.2 Receiver part:

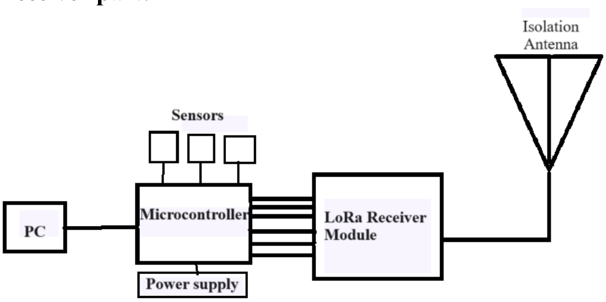

Fig.2. Block schematic for Receiver component

As seen in Figure 2, the receiver portion of the satellite communication system employing the LoRa module receives data via a reception antenna.

LoRa PART:

LoRaWAN, the LoRa module we are utilizing, can transfer data payloads up to a maximum size over long distances. The transmission signal's breadth is indicated by the bandwidth value. It is available solely in three different frequencies: 125 kHz, 250 kHz, or 500 kHz. A 500 kHz value is preferable if a speedy transmission is necessary. However, to get a high reach, a 125 kHz value needs to be set up. This indicates that selecting a narrower bandwidth will result in a lower transfer rate but an increased range. With LoRa, the chirp spread spectrum technique is used to distribute each payload bit over a number of symbols. To assess system performance in various scenarios, we can simulate the integration of LoRaWAN with satellite communication using MATLAB.

To maximize the efficiency of the integrated system, variables including data rate, interference, and signal strength can be changed.

Benefits of LoRa:

Increased Coverage and Range: By combining LoRaWAN with satellite communication, data transfer in inaccessible and distant locations is made possible.

Low-power consumption: LoRaWAN's minimal power needs allow it to be used with battery-operated devices, guaranteeing long-term and sustainable field operation.

Application versatility: This integrated system is utilized in asset tracking, disaster response, agriculture, and environmental monitoring, among other areas.

Cost-effective solution: Energy-efficient LoRaWAN technology and the utilization of current satellite infrastructure allow for the deployment of cost-effective solutions across a range of industries.
Electromagnetic waves are sent and received by antennas. The Isotropic antenna, which is ideal for mobile satellite communications, is what we use. It is widely used to provide a broad angle, that has equal intensity and radiation in all directions, both horizontally and vertically. These extra antennas are specifically used by us to boost the signals from the antennas inside the LoRa module. Fig. 3 below displays the designed antenna's reflection coefficient (S_{11} parameter):

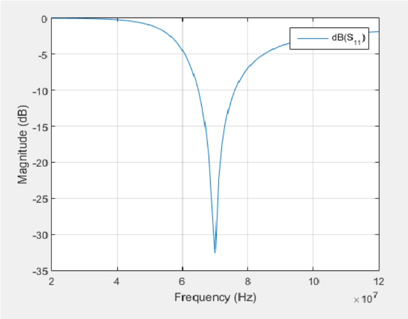

Fig. 3. The designed antenna’s reflection coefficient

It is anticipated that the GST will be dispersed throughout several isolated areas encompassing a big area. While defining the structure of the data packets that are broadcast from the GST, it is essential that each GST be allocated a unique ID. The packet structure of LoRa is seen in Figure 4.

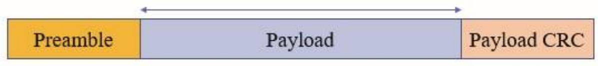

Fig.4. LoRa packet structure

To transfer the data which is in the form of datagrams, an antenna is attached to the LoRa. We process the data to be sent and received one using MATLAB. We process the payload and Uplinks through MATLAB. We get data in the text format. Antenna contains a servo motor for rotation, ADXL for orientation control, LM35 to detect the noise and to check the temperature, Solar panel to supply power, and an antenna disk, DHT 11/ DHT 12 to check the humidity.

MICROCONTROLLER PART:

Using a microcontroller like Arduino in satellite communication with LoRa (Long Range) technology involves adapting hardware as well as software for efficient data transmission. Arduino can serve as the interface between sensors, communication modules, and LoRa transceivers, enabling satellite communication in remote or challenging environments. Implementing LoRa in this context allows for long-range, low-power communication suitable for satellite-based applications. Integration involves coding for LoRa communication, handling sensor data, and ensuring compatibility with satellite communication protocols. Careful power management is crucial for prolonged operation in satellite setups.

In order to integrate LoRa (Long Range) technology with satellite communication, we employ the IPv4 protocol. This protocol is essential for creating scalable and effective communication networks for Internet of Things (IoT) applications. It a fundamental part of internet communication, facilitates the integration by providing a standardized addressing scheme. A widely adopted networking protocol, enables global connectivity. When integrated with LoRa technology, which provides long-range and low-power communication, it allows IoT devices in remote areas to communicate over satellite networks using IPv4 addresses.

4 Methodology

The technique or flowchart is displayed in Fig.5. We first activate the circuit by providing the power supply. The LoRaWAN connection is then created, managed by sensors that are connected to the Arduino UNO microcontroller board. After connecting to satellite, the collection and recording of data after reading it will be done. The required data can be fetched and displayed.
The primary objective is:

i. To create a reliable, small, inexpensive, stand-alone remote station that requires the least amount of complexity for data collecting and
ii. To show the use of LoRa modulation for efficient sensor data transfer.

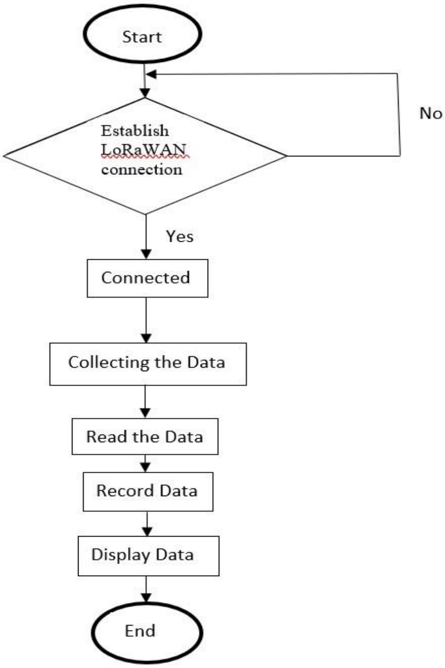

Fig.5. Methodology of data processing

5 Results

The satellite orbit is measured as a Geo-orbits distance in kilometers, and open space loss of path at 10°, 30°, 60°, and 80° elevations are utilized to compute the link budget in orbit. Cable transmission loss, antenna pointing losses, loss due to polarizations, and loss in atmosphere and ionosphere are all taken into account on the ground station. Antenna aiming loss and loss due to cable are taken into account at the satellite side. The computations have not taken the satellite's internal noise into account. The table below displays the link budget calculation with the help of following equations:

Pt – Transmitter power = Ps + PL
G – Gain of the antenna
PL – Path Loss = Pt – Pr
Ps – Power at the satellite
Pr – Received Power
Preq – Required Power
LM – Link Margin = Pr – Preq

Table: Table of Calculation

Parameter in dB	Angle in degree			
	10°	30°	60°	80°
Pt(dBm)	12	12	12	12
G(dBi)	0.2	2.5	3.4	3.9
Losses*(dB)	2.5	2.5	2.5	2.5
PL(dB)	151.4	142.7	137.5	136.1
Ps(dBm)	-138.5	-132.7	-128.6	-127.4
Losses**(dB)	3.2	3.2	3.2	3.2
Pr(dBm)	-139.4	-130.7	-125.5	-124.1
Preq(dBm)	-133.2	-133.2	-133.2	-133.2
LM(dB)	-6.2	2.5	7.7	9.1

Losses*: Cable transmission loss, Antenna pointing loss, Loss due to polarization, Loss in atmosphere and ionosphere,

Losses**: Antenna aiming loss, Loss due to cable

Table indicates that, in the event that the elevation is greater than 20°, data transmitted from the GST under its current configuration may be received by satellite. If the elevation is more than 60°, the satellite's reception possibilities increase.

6 Conclusion and Future Scope

To sum up, a thorough investigation into LoRa technology in satellite communications has shown how revolutionary it may be in terms of data acceleration in space-based networks. The research highlights the advantages of LoRa as a cost-effective, dependable, efficient, and adaptable way to improve communication networks in difficult and distant locations. Potential avenues for future research include optimizing AI integration, strengthening security protocols, facilitating better interaction with other technologies, investigating sophisticated modulation methods, and creating standardized protocols. Through these initiatives, LoRa's place in satellite communications is expected to grow, opening the door for improved connection and data acceleration in space-based applications.

Future research on transforming satellite communications by thoroughly examining LoRa technology for improved data acceleration may concentrate on a number of important topics. Adaptive modulation schemes, which dynamically alter based on channel circumstances to enhance data throughput, are one example of how LoRa modulation techniques for satellite applications might be further optimized. Furthermore, to enhance data robustness against interference and reliability, research could explore the development of sophisticated error correction and coding techniques specifically designed for LoRa-based satellite communication systems. Improved coverage and performance of communications could also result from investigating novel antenna designs tailored for LoRa satellite terminals. Moreover, LoRa-enabled satellite communication networks may be far more efficient and scalable if machine learning algorithms for adaptive networking protocols and intelligent resource management were integrated.

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