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LoRa-Enabled Inter-Ship Communication and Monitoring System

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Abstract: This project focuses on creating a ship-to-ship communication system using LoRa technology integrated with a mesh network architecture. The system is designed for three vessels, where one operates as the main gateway and the other two act as communication nodes. The gateway is responsible for gathering data from all connected ships and transmitting it to a cloud server for storage, supervision, and further analysis. LoRa technology is chosen because it enables long-distance communication while consuming very little power, making it highly suitable for marine environments where network infrastructure is often limited or unavailable. It supports the transfer of small but important information, such as alerts and short messages, across several kilometers. To improve communication reliability, a mesh networking approach is implemented. This allows ships to communicate directly with one another or indirectly through intermediate nodes when a direct connection to the gateway is not feasible. Such a setup ensures continuous data transmission even in challenging conditions. In addition to communication, the system incorporates safety features like humidity monitoring and an SOS emergency function with location tracking. These features help in detecting environmental changes and enable vessels to send immediate distress signals in case of emergencies. Moreover, the system is designed to be adaptable, allowing ships to send messages either to a specific vessel or broadcast them to all nodes within the network. Overall, this project presents an economical, power-efficient, and dependable communication solution specifically designed for maritime use, especially in remote areas where traditional communication systems are not accessible.

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I. INTRODUCTION

Communication between vessels is critical for safe navigation, coordination, and quick response during emergencies at sea. In numerous practical situations, commonly used communication systems such as satellite links and radio networks can be costly, power-intensive, or unreliable, especially in remote ocean areas where infrastructure is limited. These limitations highlight the need for a solution that is cost-productive, energy-effective, and capable of providing long-range communication without depending heavily on existing networks.

To overcome these challenges, this project presents a ship-to-ship communication system built using LoRa (Long Range) technology. LoRa is widely recognized for enabling long-distance wireless communication while consuming very little power, making it particularly suitable for marine applications where maintaining continuous connectivity is frequently difficult. Its ability to transmit data over several kilometers with minimal energy consumption makes it a strong candidate for such systems. The proposed setup connects three ships using LoRa modules, forming a small wireless network. Each ship is equipped with sensors to monitor environmental conditions such as temperature and humidity. The collected data is displayed in real time on an onboard LCD screen, allowing crew members to easily observe surrounding environmental conditions. Besides that to sensing capabilities, the system incorporates location tracking by transmitting latitude and longitude coordinates obtained from a positioning module. This feature enables basic tracking of each ship within the network, which can support navigation and enhance coordination among vessels. Among the three ships, one operates as a central gateway. This gateway gathers sensor readings and location data from the other ships and uploads the information to a cloud platform. By integrating cloud technology, the system allows users to monitor ship data remotely through a dashboard interface, even when they are not physically present onboard.

The system also includeincludees a messagi”g fe’ture controlled through an Arduino Bluetooth-based interface. This enables users to send text messages across the network. Messages can either be directed to a specific ship (unicast) or broadcasted to all ships simultaneously. Once received, the messages are displayed on the LCD screens of the respective ships and are also reflected on the cloud dashboard for centralized monitoring. For enhanced safety, an alert mechanism is incorporated into the system. Every incoming message is treated as a high-priority alert, triggering a buzzer to notify users immediately. This ensures that essential communications are not missed, especially during critical situations. In summary, this project demonstrates an productive implementation of a LoRa-based maritime communication network. By integrating environmental sensing, location tracking, cloud connectivity, and flexible messaging, the system offers a dependable, low-cost, and energy-effective solution to enhance communication and safety between ships.

II. LITERATURE REVIEW

The proposed system builds upon earlier developments in wireless communication and marine monitoring technologies. Traditional communication methods such as GSM, Wi-Fi, and Bluetooth have been widely used for transmitting data, but they suffer from several limitations, including short communication range, higher operational costs, and dependence on network infrastructure. These drawbacks become more critical in ocean environments where connectivity is frequently unavailable. Recent studies indicate that LoRa (Long Range) technology offers a more suitable alternative, as it supports long-distance communication with very low power consumption and does not rely on continuous internet access. Despite these advantages, numerous existing implementations are limited to sending data from remote nodes to a central base station, without enabling direct interaction between multiple ships or providing dedicated emergency alert mechanisms. This gap highlights the need for a more thorough and independent system. The proposed project addresses these issues by establishing communication among Ship 1, Ship 2, and a Gateway, while also supporting real-time data exchange, messaging functionality, and SOS-based alert features.

From Paper [1], the authors introduced a LoRa-based vessel tracking solution intended to serve as an alternative to conventional AIS systems. In this approach, LoRa modules are used to transmit location data of ships to a central gateway for monitoring. The study demonstrated that the system performs reliably for real-time tracking and is economically feasible for practical deployment. However, it was observed that communication performance decreases with increasing distance. In some configurations, signal strength dropped significantly beyond approximately 1000 meters, suggesting that further optimization is required to extend coverage in marine environments. From Paper [2], a LoRa-based monitoring and safety system designed for fishermen was presented to enhance communication and security at sea. The system leverages LoRa technology to achieve long-range connectivity with minimal power consumption, making it suitable for utilize in remote ocean regions. It provides real-time alerts along with environmental monitoring, thereby enhancing safety and reducing potential risks during fishing operations. The study highlights that LoRa is capable of supporting both communication and sensing tasks effectively, including the monitoring of environmental parameters. From Paper [3], a hybrid communication system combining LoRa and ZigBee technologies was proposed for tourist boat management. This system enables continuous tracking of boats along with regular updates of environmental data. The results showed that integrating multiple communication technologies improves reliability, especially in areas lacking proper network infrastructure. However, a limitation noted was the relatively low data rate of LoRa, which may restrict the speed of information updates in time-critical applications. From Paper [4], a LoRa-based emergency beacon system was developed to enhance safety during maritime rescue operations. The system is capable of detecting emergency situations and transmitting distress signals along with location information. It also includes alert mechanisms and supports long-range communication. The findings confirm that LoRa technology is highly productive for implementing SOS-based safety systems in marine environments. From Paper [5], the behavior of LoRa signals in water-dominated environments, such as estuaries, was analyzed. The study revealed that environmental factors like water level variations and antenna positioning significantly influence signal strength. It also pointed out differences in performance between ship-to-ship communication and other types of wireless links. These insights are worthwhile for designing more stable and effective maritime communication systems. From Paper [6], the application of LoRaWAN in environmental monitoring was examined. The study demonstrated that LoRa can transmit parameters such as temperature and humidity over long distances while maintaining low energy consumption. It also supports real-time monitoring and analysis, although challenges such as scalability and data reliability still need further improvement. From Paper [7], experimental investigations confirmed that LoRa is a practical solution for communication between mobile units, such as vehicles. The results showed that LoRa maintains stable communication even under challenging conditions and remains cost-productive due to its straightforward hardware requirements. These characteristics suggest its suitability for comparable applications, including ship-to-ship communication systems. From Paper [8], distinct LoRaWAN network configurations, including star and mesh topologies, were studied. The results indicated that combining these topologies can enhance communication range and reliability without introducing significant delays. Additionally, it enables multi-hop communication, which is beneficial in scenarios where multiple nodes, such as ships, need to exchange data through a central gateway.

III. PROPOSED WORK OVERVIEW

The proposed LoRa-based Ship Communication and Monitoring System is designed to offer dependable long-range wireless connectivity between vessels operating in regions where cellular networks and internet access are unavailable. The system enables ships to exchange critical information such as environmental conditions, location coordinates, and emergency alerts through LoRa communication technology. The overall setup consists of two ships (Ship 1 and Ship 2) along with a central Gateway unit. Each ship is equipped with

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sensing components, a GPS module for positioning, a LoRa transceiver for communication, an LCD display for data visualization, a buzzer for alerts, and an SOS switch for emergency signaling. The Gateway serves as the central hub, collecting data from both ships and displaying the combined information on a connected laptop for monitoring and control purposes. This arrangement supports uninterrupted communication between ships, continuous tracking of vessel positions, real-time monitoring of environmental parameters, and rapid transmission of emergency alerts. Due to its low power requirements and cost-effectiveness, the system is well suited for applications such as fishing boats, small marine vessels, and rescue operations.

A. System Architecture

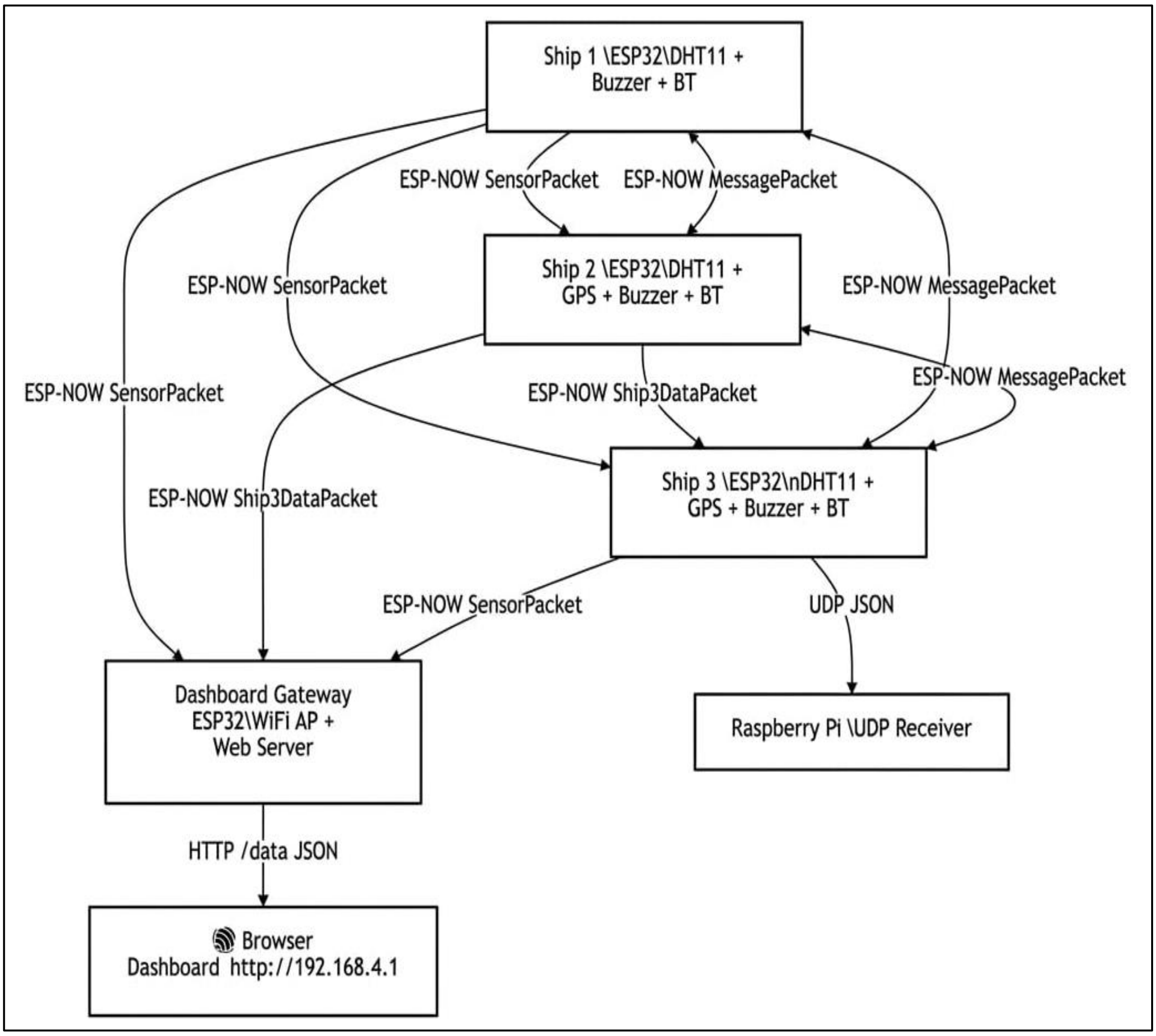

Fig 1 Flow Chart

➢ *System Initialization Module*

- The system is powered ON to begin operation
- All major components, including the LoRa module, GPS unit, sensors, and display, are initialized
- A check is performed to ensure proper functioning of each component before proceeding

➢ *Data Acquisition Module*

- Current geographic coordinates (latitude and longitude) are obtained from the GPS module
- If a valid GPS signal is not available, the system continues attempting until accurate data is received
- Environmental data such as temperature and humidity is collected from the sensors

➢ *Display Module*

- Sensor readings and location details are shown on the LCD screen
- System status and communication activity are also indicated for user awareness

➢ *LoRa Communication Module*

- The collected sensor data and GPS information are transmitted using LoRa technology

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- Communication is established among Ship 1, Ship 2, and the Gateway
- Incoming data from other nodes is received and processed
- Two-way communication is supported, allowing message exchange between all units

➢ *Data Processing Module*

- Received data, including sensor values, location details, and messages, is decoded and interpreted
- The system continuously updates and maintains the latest data records
- The Gateway stores received information for monitoring and reference

➢ *Emergency Alert Module*

- The system constantly checks for activation of the SOS switch
- When triggered, an emergency alert is immediately transmitted to all connected nodes via LoRa
- A buzzer is activated to indicate an emergency situation
- Alert messages are displayed on the monitoring interface

➢ *Monitoring Module*

- The Gateway displays complete system data on a connected laptop
- Environmental parameters and location information of all ships are shown
- Messages and emergency alerts are also visible for centralized monitoring

➢ *Continuous Operation Module*

- A short delay is introduced using a timer before the next cycle begins
- The system continuously repeats the processes of data collection, transmission, and reception

➢ *Workflow:*

System Start → Component Initialization → GPS Data Acquisition → Sensor Data Collection → Data Display → LoRa Transmission → Data Reception & Processing → Gateway Monitoring → Emergency Alert Handling → Continuous Loop Execution.

IV. RESULTS

The LoRa-based Ship Communication and Monitoring System was implemented and evaluated under real-time operating conditions to analyze its overall performance. During testing, a stable wireless link was successfully established between Ship 1, Ship 2, and the central gateway using LoRa technology. Throughout the experimental phase, each unit accurately captured environmental parameters, including temperature and humidity, along with location information obtained from the GPS module. This data was transmitted across the LoRa network and received by the respective nodes with minimal delay, demonstrating the system's effectiveness in supporting long-range communication. The messaging feature operated efficiently, allowing seamless bidirectional communication between the ships. Users were able to exchange text messages without interruption, which proved beneficial for maintaining coordination and information sharing between vessels. The emergency alert mechanism was also tested by activating the SOS feature. Upon activation, an alert message was immediately transmitted to the connected nodes, including the gateway. Simultaneously, a buzzer was triggered, and the alert notification was displayed on the monitoring interface. This ensured that emergency signals were promptly recognized and acted upon. The gateway unit functioned as intended by gathering data from both ships and presenting it in a structured format. It displayed sensor readings, positional information, and received messages, thereby serving as a centralized monitoring and control point. In summary, the system demonstrated dependable performance in terms of energy efficiency, communication stability over long distances, real-time data transmission, and rapid emergency response. These results indicate that the proposed system is a practical and productive solution for ship-to-ship communication, particularly in remote marine environments where conventional communication infrastructure is limited.

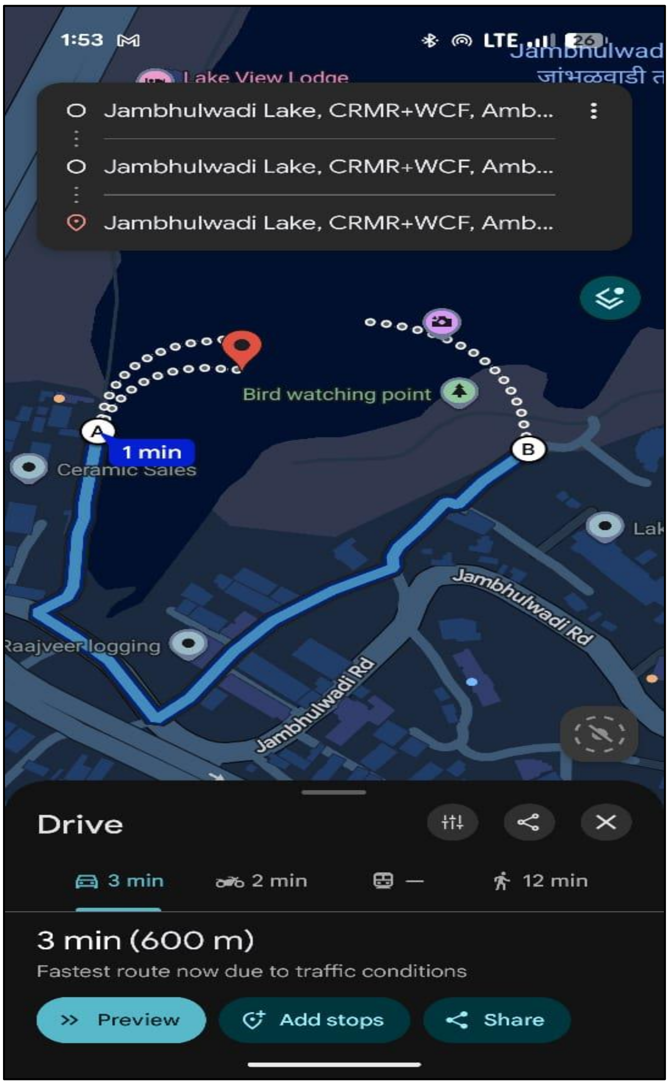

Fig 2 System Implementation Test Location (Google Map)

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Fig 3 Node

Fig 4 Gateway

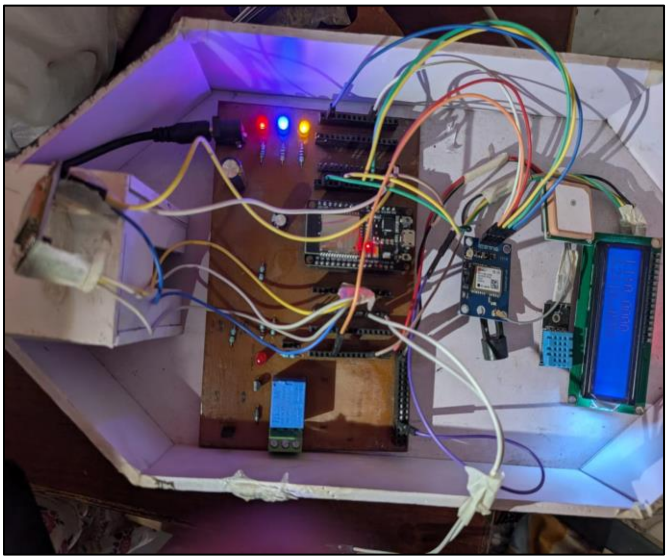

Fig 5 Display at Node 1

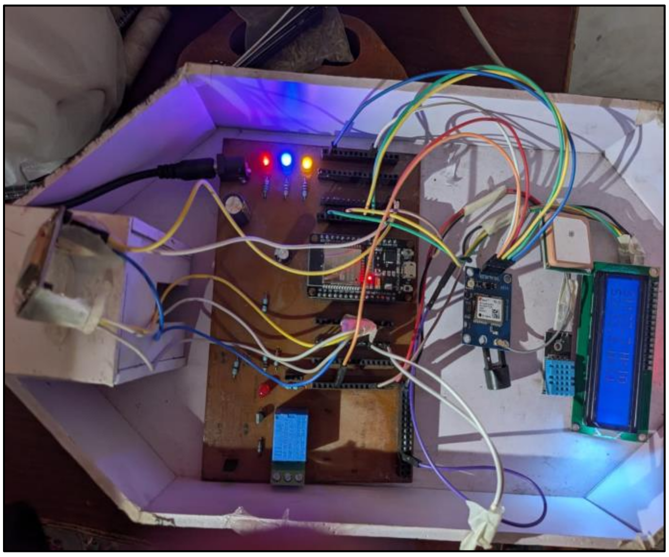

Fig 6 Display at Node 2

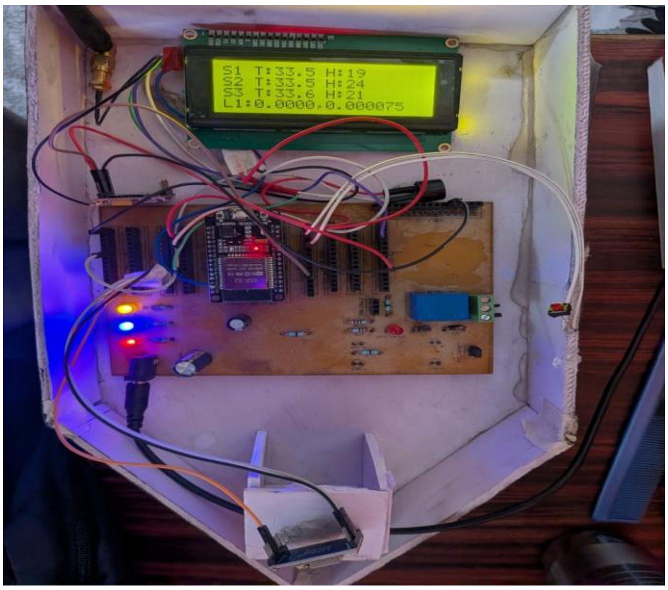

Fig 7 Display at Gateway

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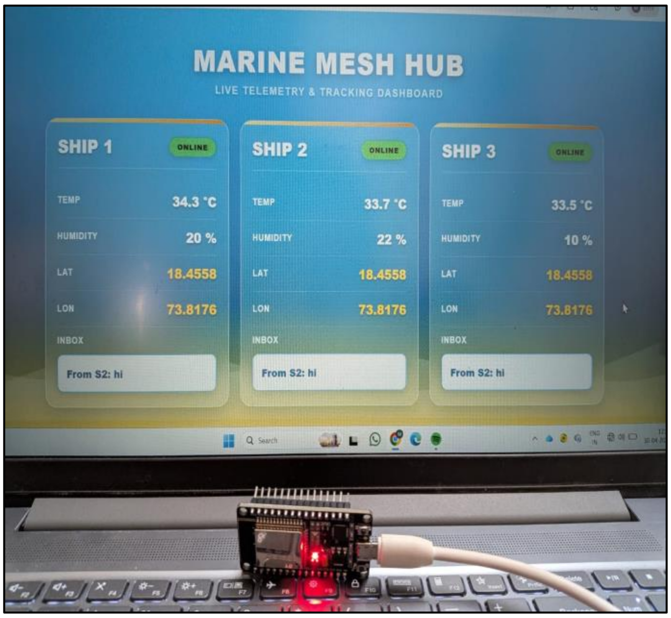

Fig 8 Dashboard

V. FUTURE SCOPE

The current LoRa-based ship-to-ship communication system, consisting of three ships and a central gateway, successfully provides features such as environmental monitoring, position tracking, and SOS-based messaging. While the system performs well, several enhancements can be introduced to create it more robust and suitable for real-world marine operations. One key improvement involves smarter message management. Instead of relying on manual selection for message transmission, the system can be designed to automatically classify and prioritize messages. For instance, emergency alerts can be immediately broadcast to all connected ships, while routine messages can be directed only to selected nodes, thereby improving communication efficiency and reducing unnecessary traffic. Another area for enhancement is data storage. At present, the system mainly focuses on real-time display of information. By incorporating a data logging mechanism, it would be possible to store historical records such as ship movement paths, environmental conditions, and communication logs. This stored data could be worthwhile for future analysis, reporting, and decision-making. Security is also an essential aspect that can be strengthened. Implementing encryption techniques and authentication mechanisms would assist protect the communication network from unauthorized access and ensure that transmitted data remains safe and dependable. The alert system can be further improved by introducing multiple types of notifications. Distinct indicators—such as distinct buzzer patterns or visual signals—can be used to differentiate between emergency alerts, general messages, and warning conditions, making it easier for users to respond appropriately. Besides that, the system can be enhanced with basic automation features. For instance, alerts can be generated automatically when sensor readings exceed predefined thresholds or when a ship moves into restricted or unsafe zones. This would reduce dependency on manual monitoring and boost system responsiveness. Ultimately, the scalability of the system can be improved by extending support to a larger number of ships. Expanding the network would create the system more applicable for fleet-level communication and coordination, thereby increasing its practical usability in maritime operations.

VI. LIMITATIONS

➢ *Very Low Data Speed*

- LoRa can send only small amounts of data

Not suitable for voice, video, or large data. Only useful for sensor data (temperature, humidity).

➢ *Affected by Environment (Water, Weather)*

- Sea water reflects signals Rain, fog, storms reduce signal strength.Communication becomes unstable

➢ *Requires Extra Infrastructure for Internet*

- Cannot connect to internet directly.Needs gateway or network setup.

➢ *Lack of Reliability for Critical Communication*

- LoRa communication is not fully reliable
- *Messages can:*

✓ Be lost (packet loss)
✓ Be delayed

VII. CONCLUSION

This project demonstrates a LoRa-based ship communication system designed to enhance coordination and data exchange among multiple vessels in a straightforward and effective manner. By utilizing LoRa technology, the system achieves long-distance wireless communication while maintaining low power consumption, making it highly suitable for marine environments where conventional communication methods may be expensive or unreliable. The system interconnects three ships, each equipped to monitor environmental parameters such as temperature and humidity. Besides that, it enables location sharing through latitude and longitude coordinates, allowing continuous tracking of each vessel's position. All collected information is displayed locally on an LCD screen, ensuring simple accessibility for onboard users. A central gateway ship plays a crucial role by gathering data from the other ships and transmitting it to a cloud-based dashboard. This feature allows real-time monitoring of all system parameters on a computer, providing a centralized view of the network. The inclusion of a messaging system further improves communication, enabling both targeted (unicast) and group (broadcast) message transmission. These messages are displayed on onboard LCDs and updated on the cloud interface for complete visibility. To enhance safety, an SOS alert mechanism is integrated into the system. Whenever a message is received, a buzzer is triggered to ensure

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immediate attention, especially during emergency situations. To wrap up, the proposed system offers a dependable, energy-effective, and cost-productive solution for ship-to-ship communication. By integrating environmental monitoring, location tracking, cloud connectivity, and messaging capabilities into a single platform, it significantly improves communication and safety for maritime operations.

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