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AQUA TRACE -Marine Tracking and Communication Based On LoRa Network

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Abstract:
This project presents a comprehensive marine tracking and communication system named AQUA TRACE, designed specifically to enhance the safety and operational efficiency of fishermen operating in deep-sea environments. The system utilizes LoRa (Long Range) communication technology, which enables reliable data transmission over long distances with minimal power consumption. This work introduces a safety and monitoring system for fishermen aimed at improving security at sea through the integration of communication and sensing technologies. The system utilizes GPS for continuous position tracking, LoRa for long-distance communication, and a land-based control unit for real-time monitoring. Its main features include detection of maritime boundary crossing, identification of sudden boat movements using motion sensors, and water level assessment through ultrasonic sensing. An emergency notification system supports quick rescue actions, and a mobile application enables data logging and visualization. The design emphasizes cost-effectiveness, dependability, and suitability for small-scale fishing activities.

Keywords: *LoRa module,GPS module,maritime safety,low cost solution*

I. INTRODUCTION

Marine tracking has become a crucial domain within oceanographic and environmental science. The ability to track the movements, diving behaviors, provides scientists with critical insights into ocean health, ecosystem balance, and the impacts of human activities. Traditional approaches for tracking rely heavily on satellite telemetry and bio-logging devices. Although effective, these systems are often characterized by their high cost, complex deployment requirements, and dependence on proprietary technology. This process can be unreliable, especially for deep-sea or those inhabiting remote regions. Biotelemetry systems, on the other hand, transmit data in real time but consume significant power and rely on costly satellite links, which limits deployment duration and scalability. An innovative solution has been developed to address this urgent problem and protect the lives of these fishermen. With the use of cutting-edge technologies, this project intends to prevent such mishaps and notify fishermen in real time when they are getting close to border regions. The invention provides fishing boats with the means to keep track of their geographic positions in relation to the border lines by fusing the power of GPS. A GPS module, which precisely tracks the location of the boat, and LoRa communication technology, which is renowned for its long range capabilities and low power consumption, are crucial elements of the project. These elements guarantee dependable data transmission in maritime situations. This reliable system allows for the transmission of critical information between fishing boats and the navy, permitting prompt reactions to emergencies or probable border.

Due to unreliable cell network coverage, fishermen working in deep-sea and offshore environments frequently encounter serious communication and safety issues. Even though they work well, conventional maritime communication systems like satellite-based solutions or VHF radios can be costly, power-intensive, or have a restricted range for small-scale fishing vessels. Because of this, emergency reaction times are often delayed, and it becomes challenging to track boats in real time, which raises the possibility of collisions, unauthorized border crossings, and fatalities under unfavorable circumstances. The development of low-cost, energy-efficient, long- 1 1 range communication networks appropriate for distant areas has been made possible in recent years. LoRa (Long Range) is one of these technologies that has shown promise since it can send little data packets over many kilometers while using very little power. Even in locations well beyond the reach of cellular infrastructure, LoRa-based networks may establish dependable communication linkages between vessels and shore stations when combined with microcontrollers and GPS devices.

II. RELATED WORKS

A. Existing Systems

Current safety solutions for fishermen primarily depend on communication methods like GSM and VHF to share location data and emergency alerts. While they offer fundamental tracking functions, their performance is restricted by poor connectivity in offshore areas and relatively higher expenses. Moreover, these systems generally do not include advanced sensing features such as motion-based fall detection or water level sensing, which are crucial for improved safety. Their reliance on uninterrupted network access makes them less dependable in isolated sea regions.

GSM-Based Tracking System

Uses GSM networks to send location and alert messages to predefined contacts. It is simple and widely used but becomes ineffective in deep-sea areas due to poor network coverage.

VHF Communication System

Employs VHF radio signals for communication between boats and coastal stations. It provides reliable short-range communication but is limited by distance and requires manual operation.

AIS (Automatic Identification System)

A tracking system used in ships to broadcast location, speed, and identity information. It is effective for monitoring large vessels but is expensive and not suitable for small-scale fishermen.

Satellite Communication System:

Uses satellites for global coverage and reliable communication in remote ocean regions. Although highly effective, it is costly and requires complex infrastructure.

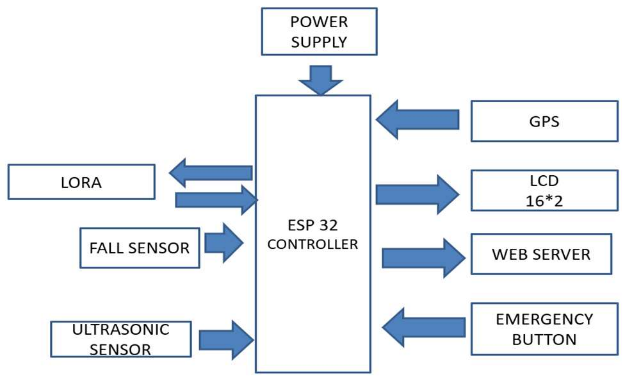
Disadvantages of existing system

Existing fisherman safety systems face several limitations, particularly in terms of cost and affordability. Many advanced solutions, such as satellite-based and AIS systems, involve high installation and maintenance expenses, making them unsuitable for small-scale fishermen. Even commonly used systems like GSM and VHF are constrained by limited range and dependence on network availability, especially in deep-sea regions. Additionally, these systems often provide only basic functionalities without integrated safety features, reducing their overall effectiveness. The combination of high cost, limited coverage, and lack of advanced capabilities makes existing systems less accessible and impractical for economically constrained fishing communities.

III. METHODOLOGY

The proposed system is developed by integrating GPS, LoRa communication, and multiple sensors to ensure effective fisherman safety and tracking. The GPS module continuously acquires the location of the boat, which is transmitted to the shore station using LoRa for long-range communication. Sensors such as a fall detection sensor and an ultrasonic sensor are used to monitor sudden movements and water levels, respectively. A predefined marine boundary is set to detect unauthorized crossing. In case of abnormal conditions, an emergency alert is generated and sent to the control station for immediate action. The collected data is also stored and monitored through a mobile application for real-time tracking and analysis.

A. Block diagram



ESP 32 Controller

The ESP32 microcontroller is a low-cost, high-performance embedded system widely used in IoT applications. It features a dual-core processor, built-in Wi-Fi and Bluetooth connectivity, and multiple GPIO pins for interfacing with sensors and modules. The ESP32 supports various communication protocols such as UART, SPI, and I2C, making it highly versatile for real-time data acquisition and control. Its low power consumption, compact design, and high processing capability make it suitable for applications like smart monitoring and wireless communication systems.

LoRa module

The LoRa module is a long-range wireless communication device designed for low-power data transmission in IoT applications. It operates on the LoRa (Long Range) technology, enabling communication over several kilometers with minimal energy consumption. The module is ideal for remote monitoring systems as it provides reliable data transfer even in areas with limited or no network coverage. Its ability to support low data rates while maintaining long-distance connectivity makes it suitable for applications like environmental monitoring and fisherman tracking systems.

GPS module

The GPS module is a satellite-based navigation device used to determine the precise location of an object in terms of latitude and longitude. It receives signals from multiple satellites to provide real-time positioning, speed, and time information. The module is widely used in tracking and navigation applications due to its accuracy and global coverage. Its integration with microcontrollers enables continuous location monitoring, making it suitable for systems like vehicle tracking and maritime safety applications.

Fall Sensor

A fall sensor is used to detect sudden movements, tilts, or impacts that may indicate a fall or abnormal condition. It typically works using accelerometer or tilt-based sensing to monitor changes in orientation and motion. When a sudden deviation is detected, it triggers an alert signal. This sensor is useful in safety systems to identify accidents or unstable conditions in real time.

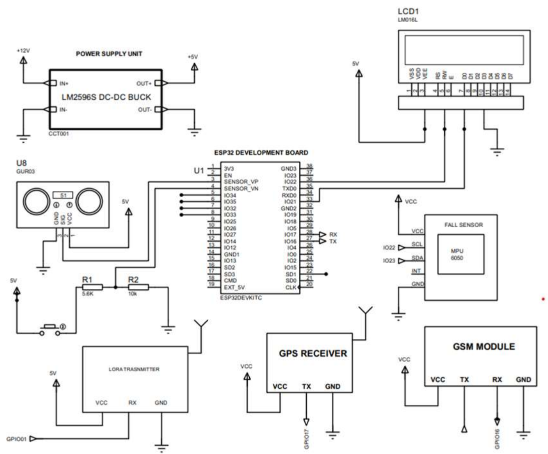
Ultrasonic Sensor:

An ultrasonic sensor is used to measure distance or detect object levels by emitting ultrasonic sound waves and calculating the time taken for the echo to return. It is commonly used for water level monitoring and obstacle detection. The sensor provides accurate and non-contact measurement, making it suitable for applications in marine environments and safety systems.

Implementation

Hardware design

The ESP32 microcontroller acts as the central unit to which all modules and sensors are connected. The GPS module is interfaced using UART communication, where its TX and RX pins are connected to the ESP32's RX and TX pins respectively for location data transfer. The LoRa module is connected using SPI communication, involving pins such as MISO, MOSI, SCK, and NSS for long-range data transmission. The fall sensor is connected to a digital GPIO pin to detect sudden motion or tilt changes. The ultrasonic sensor is interfaced using two pins: TRIG (output from ESP32) and ECHO (input to ESP32) for distance measurement. All components share a common power supply and ground to ensure proper operation and reliable communication between devices.

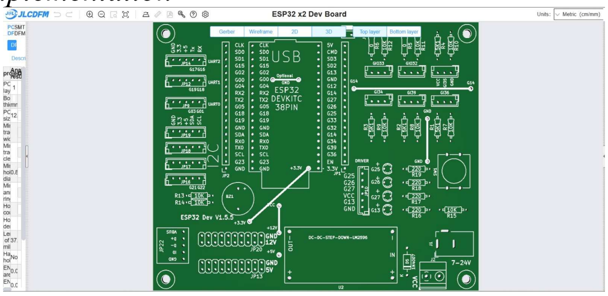


circuit diagram

Network routing

Network routing in the proposed system involves the transmission of data from the fisherman's device to the shore-based monitoring station using LoRa communication. The ESP32 collects data from the GPS and sensors and sends it through the LoRa module, which acts as a long-range wireless transmitter. The transmitted data is received by a LoRa receiver at the base station, where it is processed and monitored. The routing process is designed to ensure reliable and efficient data delivery over long distances with minimal power consumption. This setup avoids dependence on conventional networks and enables communication even in remote sea regions.

Implementation



The hardware implementation is carried out by designing a compact and efficient Printed Circuit Board (PCB) that integrates the ESP32 microcontroller, LoRa module, GPS module, and sensor interfaces. The PCB is designed to ensure proper routing of power and signal lines, minimizing noise and interference. Appropriate voltage regulation and decoupling capacitors are included to provide stable power supply to all components. Connectors and headers are provided for sensors like the fall sensor and ultrasonic sensor to enable easy interfacing. The layout is optimized for compactness, durability, and suitability for marine environments, ensuring reliable performance of the system in real-time applications.

Software requirement

EMBEDDED C

It is an extension of the C programming language specifically designed for microcontrollers and hardware-based applications. an Embedded C program acts as the "brain" of a wearable or boat-mounted device, coordinating hardware to ensure safety and location monitoring.

GPS Data Processing:

The program uses libraries to read and parse NMEA sentences from a GPS module (like the NEO-6M GPS Receiver) .

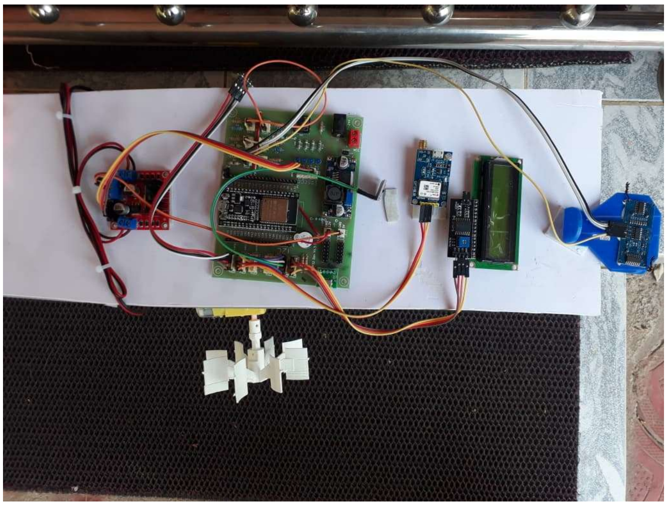
Geofencing & Alerts:

Developers define specific coordinate boundaries in the code. The program constantly compares current GPS coordinates with these "danger zones" to trigger buzzer alarms or LED indicators if a fisherman nears a maritime border.

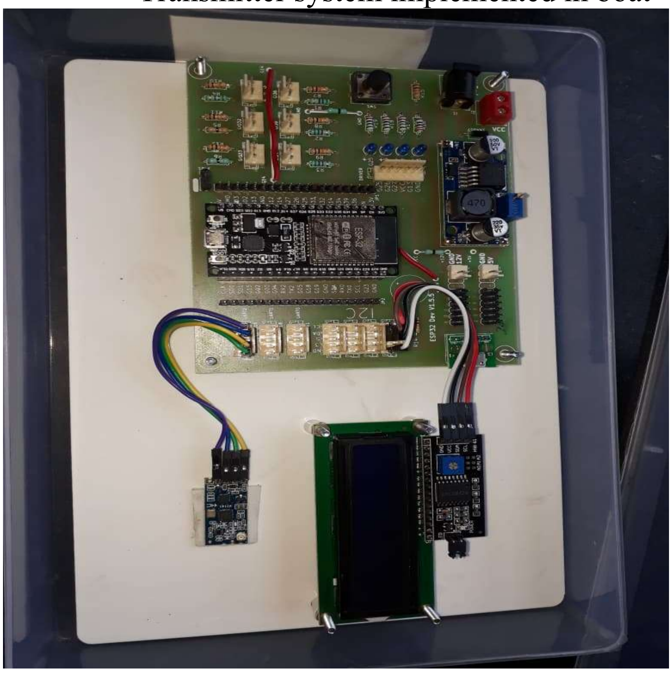
Transmission & Communication: GSM/IoT:

It can send the boat's location and distress signals to coastal guards via a GSM module or upload data to an IoT cloud using Wi-Fi

Result



Transmitter system implemented in boat

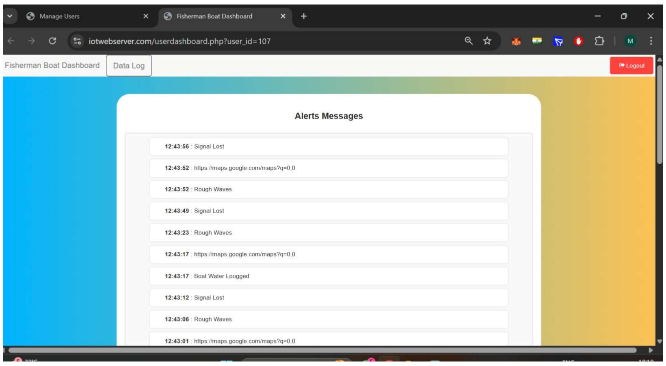


Receiver in base station

Output analysis

- The LCD display shows real-time location coordinates and boat movement status for easy on-site monitoring.

- A buzzer alert is activated during emergency conditions to provide immediate audible warning to the user.



a) The website provides a dynamically updating Google Maps link to display the current location in real time.

- When the boat reaches predefined marine boundaries, a signal loss or boundary alert messageis indicated on the website.

Future scope

The future scope of the proposed system includes the integration of advanced technologies to further enhance safety, reliability, and usability. Features such as satellite communication can be incorporated to ensure connectivity even in extremely remote ocean regions. The system can be upgraded with AI-based prediction models for early detection of potential hazards and weather conditions. Additional sensors can be included to monitor environmental parameters like temperature and pressure for improved decision-making. The development of a more user-friendly mobile application with real-time analytics and cloud storage can enhance data accessibility. Furthermore, the system can be expanded to support large-scale fleet monitoring and integrated with government rescue systems for faster emergency response and improved maritime safety.

Conclusion

The proposed fisherman tracking and safety system provides an effective solution to enhance security and monitoring in marine environments. By integrating GPS, LoRa communication, and essential sensors, the system ensures real-time location tracking, emergency detection, and reliable data transmission over long distances. It addresses the limitations of existing systems by offering a cost-effective, low-power, and user-friendly approach suitable for small-scale fishermen. The overall implementation demonstrates improved safety, timely alert mechanisms, and efficient monitoring, making it a practical and scalable solution for real-world maritime applications.

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