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UNDERWATER COMMUNICATION USING LORA TECHNOLOGY

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ABSTRACT
The military, business, and scientific community are all very interested in underwater wireless information transfer because of its significant applications in offshore exploration, oil control and maintenance, pollution monitoring, oceanography research, and tactical surveillance. Unmanned vehicles and other underwater equipment are being deployed in greater numbers to support all of these operations, which calls for high bandwidth and high capacity information transport underwater. The science of underwater audio communication has advanced tremendously, yet bandwidth remains a constraint. Due to its ability to deliver better data rates than conventional acoustic communication systems with much lower power consumption and easier computational difficulties for short-range wireless networks, underwater optical wireless communication (UOWC) has become more and more popular. Applications for UOWC in deep seas and coastal waterways are many. Nevertheless, the primary obstacle to underwater wireless communication arises from the basic properties of ocean or seawater; overcoming these obstacles requires a deep comprehension of intricate physio-chemical biological systems. Understanding the viability and dependability of high data rate underwater optical communications in light of several propagation phenomena that affect system performance is the primary goal of this work. A comprehensive review of current developments in UOWC is given in this study. Discussed are several UOWC-specific noise sources, modulation strategies, coding approaches, and channel characterisation. This study intends to establish new concepts that will aid in the advancement of underwater communication in the future, in addition to providing comprehensive research on underwater optical communication. In order to supplement the current acoustic system, a hybrid approach to an acousto-optic communication system is described. This technique leads to high data rates, minimal latency, and an energy-efficient system.

Index Terms: Modulation and coding of underwater optical wireless, radio frequency, visible light, optical beam propagation, acoustic communication, hybrid optical-acoustic system.

I. INTRODUCTION

Marine research, environmental monitoring, and defense all depend on underwater communication, yet conventional techniques like acoustic transmissions confront several difficulties because of the water's high absorption, restricted bandwidth, and signal attenuation. A potential substitute is LoRa (Long Range) technology, which is renowned for its low power consumption and long-range capabilities. We can get around these problems by modifying LoRa for underwater usage using specific hardware and signal processing methods. This permits dependable, energy-saving communication between devices immersed in water. If LoRa is successfully deployed in underwater conditions, data transmission in the maritime sector may undergo a revolution, creating new avenues for study and innovation.

1. Attenuation limits communication range in water.
2. Interference from marine life and human activities disrupts signals.
3. Multipath signals cause distortion and delay.
4. Slow speed of sound affects latency underwater.
5. Power consumption is a concern for underwater devices.
6. Corrosion-resistant equipment is essential for harsh environments.
7. Scalable solutions are needed for varying network sizes.
8. Secure data transmission is crucial for underwater applications.
9. Water pressure is a significant challenge for deep-sea equipment.
10. Limited bandwidth affects data transfer rates underwater.

Using LoRa modules for underwater communication is a creative solution.

LoRa signals can travel long distances, but water absorption limits range.

Low power consumption makes LoRa suitable for battery-powered devices.

LoRa modules are relatively inexpensive, making them attractive.

However, LoRa signals suffer from interference and slow data transfer.

Underwater gateways and repeaters can extend range and improve coverage.

Adaptive frequency hopping minimizes interference and optimizes signals.

Data compression accommodates LoRa's slower data transfer rate.

LoRa is suitable for ocean monitoring, underwater exploration, and fishing.

With limitations addressed, LoRa can enable reliable underwater communication.

Here are the objectives and aims of using LoRa for underwater communication:

Objectives:

1. Reliable Data Transfer: Enable reliable data transfer between underwater devices and surface stations.
2. Long-Range Communication: Achieve long-range communication in water, overcoming attenuation limitations.
3. Low Power Consumption: Minimize power consumption for extended battery life in underwater devices.
4. Real-Time Monitoring: Enable real-time monitoring of underwater environments and applications.
5. Scalability: Develop scalable solutions for varying network sizes and topologies.

Aims:

1. Extend Communication Range: Extend LoRa's communication range in water to cover larger areas.
2. Improve Data Transfer Rate: Optimize LoRa's data transfer rate for underwater applications.
3. Enhance Network Reliability: Develop robust networks with minimal packet loss and error rates.
4. Reduce Power Consumption: Optimize LoRa modules for low

power consumption in underwater devices.

5. Enable IoT Applications: Enable IoT applications in underwater environments, such as ocean monitoring and underwater exploration.

By achieving these objectives and aims, LoRa can become a viable solution for underwater communication, enabling various applications and revolutionizing our understanding of underwater environments.

II. LITERATURE SURVEY

Recent Studies:

1. "Underwater Communication using LoRa: A Feasibility Study" (2022) - Explores LoRa's potential for underwater communication, highlighting its advantages and challenges.
2. "LoRa-based Underwater Sensor Networks: A Survey" (2021) - Surveys existing LoRa-based underwater sensor network architectures, protocols, and applications.
3. "Experimental Evaluation of LoRa for Underwater Communication" (2020) - Presents experimental results on LoRa's performance in underwater environments, including range and data transfer rate.

Key Findings:

1. LoRa's low frequency and low power consumption make it suitable for underwater communication.
2. LoRa's range in water is limited due to attenuation, but can be extended using repeaters or gateways.
3. LoRa's data transfer rate is slower than other wireless technologies, but sufficient for many underwater applications.
4. LoRa-based underwater sensor networks can enable real-time monitoring and IoT applications.

Research Gaps:

1. Developing efficient modulation techniques to improve LoRa's underwater performance.
2. Investigating LoRa's performance in various water environments (e.g., freshwater, saltwater, murky water).
3. Designing optimized network architectures for large-scale LoRa-based underwater sensor networks.

Future Directions:

1. Integrating LoRa with other underwater communication technologies (e.g., acoustic, optical).
2. Exploring LoRa's potential for underwater machine-to-machine (M2M) communication.
3. Developing practical solutions for real-world underwater applications using LoRa.

This brief survey highlights the growing interest in LoRa for underwater communication and identifies areas for future research and development.

III. BLOCK DIAGRAM

The system design consists of a transmitter (TX) module, receiver (RX) module, and underwater antenna. The TX and RX modules are equipped with LoRa modules, microcontrollers, power sources, and water-resistant enclosures. The underwater antenna is designed for optimal performance in water. During implementation, the LoRa module is configured for underwater communication, and the antenna is attached

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to the TX and RX modules. The modules are then deployed underwater, and a communication protocol is developed and implemented for data transmission.

Challenges and considerations include water absorption, interference, power consumption, corrosion, and scalability. To address these, repeaters or gateways can be used to extend range, and interference can be avoided by using specific frequencies. Power consumption can be optimized for extended battery life, and corrosion-resistant materials can be used. The system should be designed for scalability and adaptability to varying network sizes and topologies.

Future enhancements include integrating LoRa with acoustic or optical communication, improving antenna design, implementing advanced error correction techniques, and enabling real-time monitoring and IoT applications. Key components include LoRa modules, microcontrollers, power sources, water-resistant enclosures, and underwater antennas. Configuration settings include frequency, bandwidth, spreading factor, and coding rate. Performance metrics include range, data transfer rate, power consumption, and battery life. Applications include ocean monitoring, underwater exploration, aquaculture monitoring, and offshore oil and gas monitoring. Advantages include low power consumption, long range, low cost, and easy integration, while limitations including.

BLOCK DIAGRAM

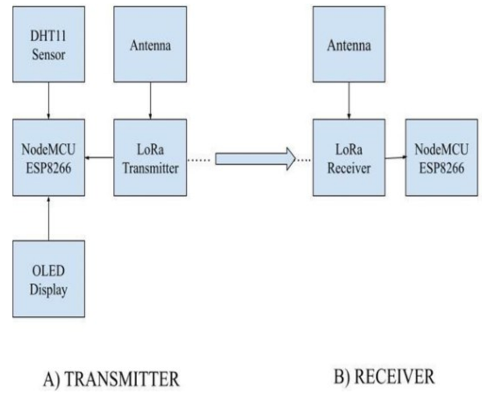

Figure.1: Block Diagram of Communication Using LoRa Technology

To implement communication in a black spot using LoRa technology, several steps are undertaken. Figure 3.1 shows the block diagram of the system Initially, two LoRa modules are chosen, one configured as a transmitter and the other as a receiver, each equipped with antennas to enable long-range communication.

Additionally, two ESP8266 microcontrollers are utilized, with one interfaced with a transmitter and a temperature sensor to gather temperature data. The transmitter then packages this data along with humidity information into packets, which are sent using LoRa communication. On the receiving end, the other ESP8266 microcontroller is linked to the LoRa receiver to capture the transmitted data.

An OLED display is integrated with this receiving microcontroller to visualize the temperature and humidity readings. The implementation involves hardware setup, ensuring proper connections between components following appropriate pin configurations. Software development follows, where the ESP8266 microcontrollers are programmed to manage data transmission and reception.

FLOW CHART OF COMMUNICATION

USING LoRa TECHNOLOGY

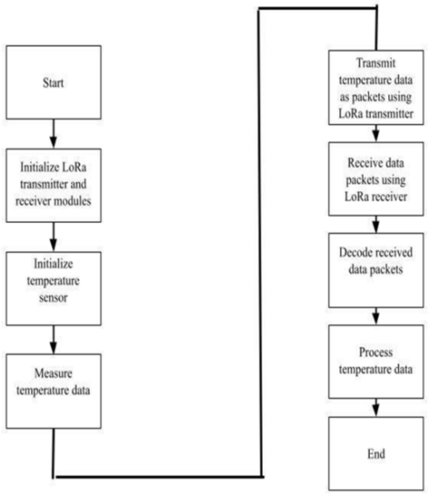

Figure.2: Flow Chart of Communication Using LoRa Technology

The transmitter ESP8266 collects sensor data, packages it, and transmits it via LoRa, while the receiver ESP8266 retrieves and interprets the transmitted data before displaying it on the OLED screen. Figure 3.2 shows the flow chart of the system. Error handling mechanisms are embedded within the software to ensure communication and data integrity. Finally, collected temperature and humidity data are analyzed to identify any patterns or anomalies, completing the implementation of communication in the black spot using LoRa technology for real-time environmental monitoring. Two LoRa modules are employed, one configured as a transmitter and the other as a receiver. Additionally, two ESP8266 microcontrollers are utilized, with one connected to a transmitter and a temperature sensor. The temperature sensor connected to the ESP8266 measures the temperature in its surroundings [14]. The ESP8266 collects temperature data from the sensor and packages it along with humidity data. The transmitter ESP8266 then sends this data as packets using LoRa communication. On the receiving end, the other ESP8266 microcontroller, connected to the LoRa receiver, receives the transmitted data packets from the transmitter ESP8266. The receiving ESP8266 extracts the temperature and humidity data from the received packets.

The extracted temperature and humidity data are then displayed on an OLED screen connected to the receiving ESP8266, allowing users to visualize the environmental conditions in real-time. The LoRa technology enables long-range communication between the transmitter and receiver, ensuring reliable data transmission even in areas with limited traditional network coverage. Both the ESP8266 microcontrollers and the LoRa modules operate with low power consumption, ensuring long battery life and enabling continuous monitoring of environmental conditions without frequent maintenance.

Error handling mechanisms may be implemented to ensure the reliability of communication and data integrity, such as error-checking protocols or retransmission strategies in case of packet loss.

IV. HARDWARE COMPONENTS

4.1 NodeMCU :

The NodeMCU ESP8266 is a powerful and versatile platform designed for Internet of Things (IoT) development. The ESP8266 is a cost-effective Wi-Fi microchip known for connected solutions efficiently. Overall, NodeMCU stands as a versatile and powerful microcontroller platform, driving innovation in the IoT space and enabling the realization of creative and impactful projects.

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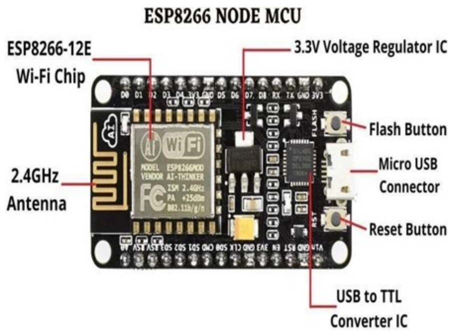

Figure 3: NodeMCU Parts

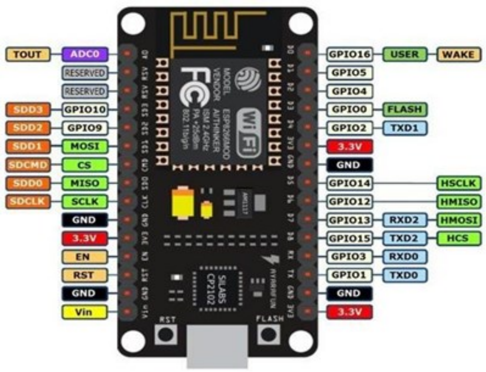

Figure 4: NodeMCU ESP8266 Pinout The NodeMCU ESP8266 development board typically has GPIO General Purpose

4.2 Arduino software:

NodeMCU (ESP8266) microcontrollers are programmed using the Arduino IDE (Integrated Development Environment). Arduino programs, called "sketches", are written in a programming language similar to C and C++. Every sketch must have a setup () function (executed just once) followed by a loop () function (potentially executed many times); add "comments" to code to make it easier to read [19] .

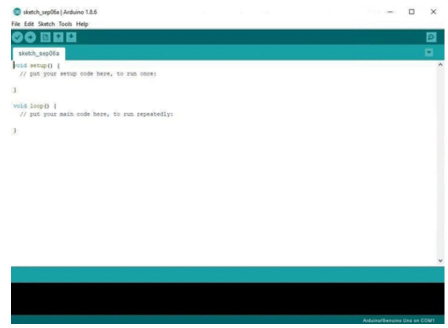

Figure5: Arduino IDE

4.3 LoRa MODULE (LoRa Ra-02 SX1278) :

The LoRa Ra-02 SX1278 module, based on the Semtech SX1278 chip, is a versatile and reliable transceiver module renowned for its long-range communication capabilities and as 433MHz, 868MHz, and 915MHz, it offers flexibility to adapt to different regional regulatory requirements. With its programmable output power ranging from +20 dBm to -1 dBm, the module allows for optimization of transmission range and power consumption, catering to diverse application needs. Its high receiver sensitivity ensures reliable reception even in challenging RF environments, while the SPI interface facilitates seamless integration with microcontrollers and embedded systems.

The module's compact size makes it suitable for space-constrained applications, and its wide operating temperature range from -40°C to +85°C ensures reliability in harsh environmental conditions. Commonly used in wireless sensor networks, smart city infrastructure, asset tracking systems, and IoT devices, the LoRa Ra-02 SX1278 module continues to be a preferred choice for long-range wireless communication across various industries and applications [21].

LoRa Module (LoRa Ra-02 SX1278) as a Receiver :

The LoRa Ra-02 SX1278 module is a

popular choice for long-range wireless communication. Utilizing the SX1278 chipset, it operates on the LoRa (Long Range) modulation technique, enabling communication over extended distances with low power consumption. As a receiver, the Ra-02 module offers sensitivity down to -148dBm, ensuring reliable reception even in challenging environments [22].

Figure 6: LoRa Module

4.4 OLED Display:

OLED (Organic Light-Emitting Diode) displays are advanced display technologies that offer numerous advantages over traditional LCD (Liquid Crystal Display) screens. These displays are constructed using organic materials that emit light when an electric current is applied, eliminating the need for a separate backlight. OLED displays are inherently thin and flexible, allowing for the creation of curved or flexible screens. This feature enables innovative designs for various electronic devices, including smartphones, wearables, and televisions.

OLED displays have fast response times, virtually eliminating motion blur and ghosting, which enhances the viewing experience, especially in applications such as gaming and video playback. OLED displays offer wide viewing angles, maintaining consistent brightness and color accuracy even when viewed from extreme angles. This characteristic makes OLED displays suitable for large-screen applications like televisions and digital signage. OLED displays consume less power compared to traditional LCD screens since they only illuminate the pixels needed to display content. This energy-efficient operation extends battery life in portable devices and reduces power consumption in other applications [26].

Figure 7: OLED Display

V. CONCLUSION

As the number of autonomous vehicles in space and underwater increases, an upgrade to the underwater communication system is required. Acoustic signals are the foundation of traditional underwater communication, and although significant progress has been made in this area, acoustic communication still struggles to provide enough bandwidth at a low latency. Because of the substantial absorption of electromagnetic signals at radio frequencies, RF transmissions for UOWC can only be employed at ELF. Underwater activities are limited in range and agility by the usage of coaxial cables or optical fibers. Because optical underwater communication has higher data speeds, lower latency, less power consumption, and smaller packaging than conventional acoustic communication, it has a lot of opportunity to improve upon it. Furthermore, this technique stands to gain significantly from advancements in terrestrial optical wireless communication. However, the kind of water, abortion, scattering, and other propagation losses all limit the optical beam's range and extent underwater. Because it offers a low attenuation window and high bandwidth transmission (in the order of MHz) across modest distances (10 - 100 m), UOWC uses the blue-green wavelength of the visible spectrum. Furthermore, stringent pointing and tracking mechanisms are necessary for a conventional UOWC with a point-to-point connection, particularly for mobile platforms. The stringent point and tracking requirements for narrow optical beams may be loosened by using electronic beam steering, segmented FOV, or smart transmitters and receivers. This study also covers several link configurations, such as retro-reflective, diffused, and NLOS connections, to make the link functional for a variety of underwater circumstances and avoid loss due to LOS. A thorough understanding of the channel model, system architecture, materials and components of the system, modulation methods, operating wavelength, and its impact on the underwater environment are necessary for a dependable and efficient underwater optical connection.

We conclude that although acoustic waves are now the most reliable and practical carrier, they will become more promising in the near future with fast technical advancement and intensive continuing research at UOWC.

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