HYBRID COMMUNICATION ARCHITECTURE FOR SUBAQUATIC DATA TRANSMISSION

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Abstract: *Underwater communication and monitoring have become more important for marine research, aquaculture, water quality monitoring, and environmental observation. Conventional underwater communication techniques frequently encounter issues including restricted transmission range, elevated costs, signal degradation, and challenges in real-time monitoring. An Internet of Things (IoT) based underwater communication system is suggested to get around these problems. The ESP8266 NodeMCU is the main processing unit in the proposed system. It collects and sends data about the environment under the water. A LoRa SX1278 module is used to send data wirelessly over long distances between the monitoring station and the underwater sensor nodes. A DS18B20 measures the temperature of the water, and a turbidity sensor keeps an eye on the water's clarity or quality. An OLED display shows the data that was collected, and it can also be sent to a remote monitoring system for more analysis. The system is made to work with cable connections in water to make sure that sensors can talk to each other reliably. LoRa technology, on the other hand, lets sensors send data wirelessly over long distances with little power use. IoT technology makes real-time monitoring, data access, and system efficiency better. The proposed system has a lot of benefits, such as real-time monitoring, less need for people to be involved, lower costs, and less energy use. It can be used in a number of areas, including marine research, aquaculture, environmental protection, and monitoring water quality.Overall, this project shows that IoT technology can be used to communicate underwater in a quick and reliable way. It also shows how traditional monitoring systems can be improved and how smart environmental monitoring can be improved.*

Keywords—*IoT, underwater communication, ESP8266 NodeMCU, LoRa SX1278, water quality monitoring, turbidity sensor, and DS18B20 temperature sensor.*

I. INTRODUCTION

Underwater communication is an important part of marine research, keeping an eye on the environment, and managing water resources.[10] It is hard to keep an eye on the underwater environment because radio waves and optical signals, which are common ways to communicate, don't work well in water. [2]This makes it hard to get real-time data from underwater places.

The Internet of Things (IoT) has made it possible to design underwater monitoring systems that can quickly and accurately collect and send environmental data.[8] IoT technology lets sensors and devices talk to each other over networks, which makes it possible to monitor and control underwater environments from afar.

This project creates an underwater communication system that uses the ESP8266 NodeMCU as the main controller. Using sensors, the system gathers information about the environment, like the temperature and turbidity of the water. It then sends this information using the LoRa SX1278 communication module.

Oceans, lakes, rivers, and reservoirs are all important parts of the ecosystem and human life. There are many reasons why it is important to keep an eye on conditions underwater, such as protecting the environment, controlling pollution, doing marine research, and growing fish.

Traditional ways of keeping an eye on things require people to collect data by hand, which takes a lot of time, costs a lot of money, and can even be dangerous.[3] IoT-based monitoring systems make it possible to collect data automatically and constantly, which saves people time and makes the data more accurate.

The system can give you real-time information about the water environment by using sensors like the DS18B20 to measure water temperature and turbidity sensors to find out how clear the water is.

The Internet of Things (IoT) is a group of connected devices that use the internet or wireless communication technologies to send and receive data. IoT technology has changed a lot of areas, such as smart homes, healthcare, farming, and keeping an eye on the environment.

When used underwater, IoT devices can be used with sensors to keep an eye on environmental conditions and send the data they collect to monitoring stations.[7] This helps researchers and officials look at the state of the water and do what needs to be done when it needs to be done.

An OLED display shows the data that the sensors have gathered. This makes it easy to see real-time information in a clear and compact way. This display lets users see the current weather conditions right from the monitoring device.

II. RELATED WORK

In recent years, there has been a lot of interest in the development of underwater communication systems. This is because there is a growing need for marine research and environmental monitoring. In the past, systems mostly used wired communication and manual data collection, which took a lot of time, money, and didn't work in real time.[1] These old methods didn't work for keeping an eye on things all the time in changing underwater environments.

Automated systems for monitoring water quality have been made possible by the growth of Internet of Things (IoT) technologies.[9] These systems use sensors to measure things like temperature, turbidity, and pH levels. They then send the data they collect over wireless communication technologies. But traditional wireless communication methods have problems like signal loss and a limited range of transmission when used underwater.

Underwater wireless sensor networks (UWSNs) have been suggested as a way to get around these problems. These networks use sensor nodes that are spread out to gather and send environmental data.[4] Research studies show that underwater conditions can make things like energy use, limited bandwidth, and unreliable communication harder. To make the system work better, new routing protocols and low-power devices have been added.

Recent progress has been made in hybrid communication systems that use more than one technology, like acoustic, optical, and radio frequency (RF) communication.[5] LoRa-based communication has also become a reliable way to send data over long distances and with little power in IoT applications. These changes have made underwater monitoring systems more reliable, efficient, and able to grow.

In general, research shows that there is a shift from old-fashioned manual monitoring to new, more advanced

IoT-based automated systems.[6] But there is still a need for underwater communication systems that are cheap, use little energy, and are reliable enough for real-time monitoring. This is what drives the development of the proposed system.

III. METHODOLOGY

The suggested IoT-based underwater communication system uses a structured method to make sure that data is collected, processed, and sent quickly. The methodology comprises the subsequent stages.

A. Analyzing the Requirements:

- Found problems with underwater monitoring, like signals getting weaker and not having real-time data.
- Looked at the problems with old-fashioned wired and manual monitoring systems.
- Set goals: monitoring in real time, communication over long distances, and less human involvement.

B. Designing the System:

- Made a modular system with units for sensing, processing, communicating, and displaying.
- Picked parts like the ESP8266 NodeMCU, LoRa SX1278, DS18B20, and turbidity sensor.
- Made sure that communication was reliable by using wired connections underwater and wireless transmission above water.

C. Collecting Data:

- Sensors (DS18B20 and turbidity sensor) gather information about the environment.
- Getting real-time data from underwater conditions all the time.
- Data sent to the microcontroller through stable wired connections.

D. Processing Data:

- The ESP8266 NodeMCU processes data from sensors.
- Turns raw sensor signals into numbers that can be read by a computer.
- Gets data ready to be sent and shown.

E. Putting Communication into Action:

- Long-range wireless transmission is done with LoRa SX1278.
- Makes sure that data is sent reliably and with little power.
- Data sent to a remote monitoring station.

F. Showing and Watching:

- The OLED display shows sensor values in real time.
- Makes it easy to see the temperature and turbidity.
- The continuous monitoring loop makes sure that the data is always up to date.

G. Testing and Evaluation:

- Tried out the system in a variety of weather conditions.
- Checked for accuracy, dependability, and good communication.
- Made sure that operations were always running smoothly and without mistakes.

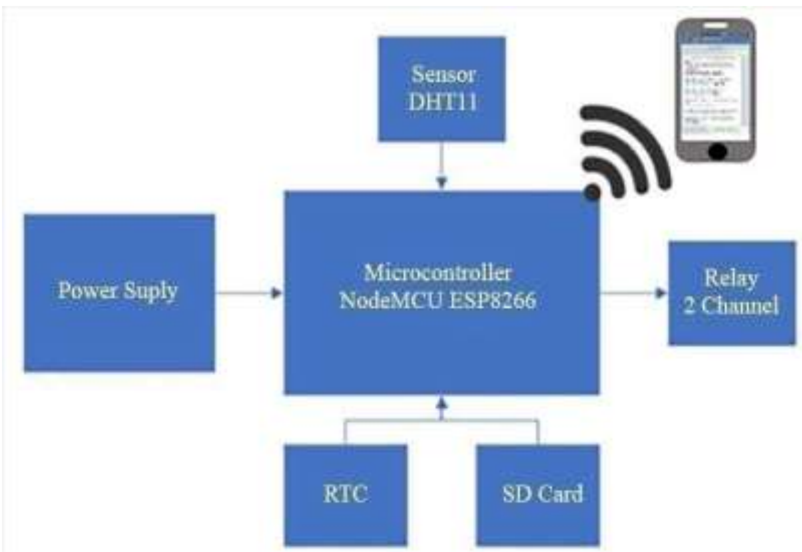
IV. SYSTEM ARCHITECTURE

The IoT-based underwater communication system has a layered design with sensing, processing, communication, and output units. The DS18B20 and turbidity sensor are examples of sensors that are put under water to gather data about the environment. The ESP8266 NodeMCU gets the data that has been collected, processes it, and gets it ready for sending. The LoRa SX1278 module lets the underwater device and the remote monitoring station talk to each other wirelessly over long distances. You can see the processed data on an OLED display near you, and you can also keep an eye on it from far away. The architecture makes sure that underwater environmental monitoring is done in real time, is reliable, and uses less energy.

A. Overview

The system architecture is an integrated IoT framework for monitoring things underwater. The ESP8266 NodeMCU processes the temperature and turbidity data that the sensors collect. The LoRa SX1278 module sends the processed data over long distances, and an OLED screen shows it in real time so you can keep an eye on it. The system makes sure that data is always being collected, processed quickly, and communicated reliably, which makes it possible to monitor the underwater environment effectively.

B. Architecture Diagram



V. EXPERIMENTAL SETUP

The IoT-based underwater communication system's experimental setup was made to test how well, how reliable, and how efficient real-time environmental monitoring is. The setup includes getting data from sensors, setting up the system, testing communication, and checking how well it works in different underwater conditions. The main goal was to check how accurate the sensor readings were, how reliable the communication was, and how stable the whole system was.

The system's dataset is made up of real-time environmental data that was gathered using sensors like the DS18B20 temperature sensor and the turbidity sensor. The ESP8266 NodeMCU processes the data from these sensors, which keep an eye on things like temperature and clarity of the water. The LoRa SX1278 module sends the data, which is then shown on the OLED display for real-time monitoring.

The ESP8266 NodeMCU microcontroller, LoRa SX1278 communication module, DS18B20 sensor, turbidity sensor, and OLED display are all part of the hardware environment. The Arduino IDE is the software environment, and it uses embedded C/C++ programming. The system is set up to run all the time, which means it can collect, process, and send data in real time.

Because the system is based on hardware, it doesn't need to be trained in the usual way. But sensor calibration and system configuration are done to make sure that readings are correct and communication is reliable. The system runs in a loop where it collects, processes, sends, and shows sensor data.

To see how well the system works, we look at data accuracy, communication reliability, response time, power efficiency, and system stability. These metrics help figure out how well the system works for real-time monitoring underwater. The experimental setup shows that the system can collect data accurately, communicate quickly, and run reliably all the time.

VI. RESULTS :

The system was very accurate at keeping track of underwater environmental parameters, which showed that it could collect and process data in real time. The LoRa SX1278 module was used to send data over long distances with little data loss, and it was found to be reliable for communication. The OLED screen showed sensor readings in a clear and timely way, making it easier to use. The system ran all the time without any problems, which showed that it was stable and worked well. The results show that the proposed system is reliable, cost-effective, and good for real-time underwater monitoring applications.

Result Table

Test Case	Attack Type / Scenario	Detection Result	Response Action	Status
TC1	Normal Web Traffic	No Threat Detected	No Action	Pass
TC2	SQL Injection Attack	Detected by DL Module	Malicious IP Blocked	Pass
TC3	Cross-Site Scripting (XSS)	Detected as Anomaly	Request Blocked	Pass
TC4	Unauthorized Login Attempt	Detected by Auth Module	Access Denied	Pass
TC5	Adversarial Attack Simulation	Detected by ARL Module	Threat Blocked	Pass
TC6	Log Tampering Attempt	Prevented by Blockchain	Tamper-Proof Log	Pass
TC7	High Traffic Attack (DoS)	Detected as Abnormal	Traffic Filtered	Pass
TC8	Malware File Upload	Detected by Detection Module	File Rejected	Pass

VII. CONCLUSION

The use of an IoT-based underwater communication system is a big step forward in technologies for monitoring the environment. The system uses sensors, a microcontroller, and LoRa communication to keep an eye on things like temperature and turbidity in real time. The ESP8266 NodeMCU makes data processing faster, and the LoRa SX1278 lets you talk to people over long distances without using much power.

The system works around the problems with traditional monitoring methods by making it easier to use, more accurate, and able to collect data all the time. The OLED display shows things in real time, which makes the system easy to use and useful for field work. The test results show that the system works reliably with little data loss and steady performance.

The proposed system is also cost-effective, scalable, and works for a wide range of uses, such as monitoring water quality, doing marine research, aquaculture, and protecting the environment. It lays a strong base for future improvements, like connecting to cloud platforms, using AI for analysis, and using more advanced ways to talk to each other.

In conclusion, the IoT-based underwater communication system is a modern, effective, and dependable way to keep an eye on aquatic environments. It helps with sustainable water resource management and protecting the environment.

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