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Sustainable IOT Architecture for Real-Time Water Quality Assessment Using ESP-NOW Communication

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Abstract

This paper introduces an IoT-based, real-time water quality monitoring solution with low power demands, specifically based upon ESP32 microcontrollers with the ESP-NOW protocol. This system allows for effective, remote measurement of important water quality variables - including Total Dissolved Solids (TDS) and turbidity - without requiring conventional Wi-Fi infrastructure. The system is designed with an emphasis on being scalable, having low power requirements, and with the ability to function in remote or rural areas, making it a low-cost solution that measures can be easily utilized for long-term environmental monitoring.

Keywords: IoT, Water Quality Monitoring, ESP32, ESP-NOW, TDS, Turbidity, Real-Time Monitoring, Blynk, Wireless Sensor Network, Environmental Sensing

1. Introduction

Water pollution is a growing global problem affecting public health, environmental health, and industry. Current water quality monitoring systems are typically based on either resource heavy systems and infrastructure, or depend on labor-based manual sampling, which can be cumbersome and costly in remote or under-resourced markets. When deployed, these systems usually require constant power and dependable networking capabilities, further limiting their ability to be deployed, in particular rural and under-resourced locations. The present invention hopes to address these issues by utilizing ESP32 microcontrollers with TDS and turbidity sensors. The system, when designed, utilizes the ESP-NOW protocol which allows for peer-to-peer, low latency communications between ESP32 devices without needing to rely on a conventional Wi-Fi network.By integrating this into the Blynk IoT platform, it can provide users with real-time remote data access, allowing quicker response times to changes in water quality.A brief overview of the inventionThe invention is a scalable IoT-based water quality monitoring system, which uses ESP32 microcontrollers to collect, process, and communicate real-time data on TDS and turbidity levels. The ESP32 microcontrollers are programmed to utilize the ESP-NOW protocol, to establish a peer-to-peer network, allowing the microcontrollers to directly communicate with each other. This also allows the monitoring at areas where an internet connection may not be available or at least limited, as the microcontrollers will exchange the data.The system has a sending unit with TDS and turbidity sensors that measure the water quality parameters. The data from the sensors is read by an ESP32 microcontroller, sent to a receiving ESP32 via ESP-NOW, then sent to the Blynk IoT platform via Wi-Fi to allow the user to see the water quality remotely on a mobile app or web page. The transmitter ESP32 module has TDS and turbidity sensors connected to its analog pins.

The TDS detector identifies the concentration of total dissolved solids, while the turbidity sensor determines the cloudiness of the water. The ESP32 picks up the analog signals from the sensors, performs data processing details, and wirelessly sends it to the receiving ESP32 using the ESP-NOW protocol, which is energy-efficient and battery-life friendly for extended periods of use for the system.When the receiving ESP32 obtains data, it sends the water quality parameters to the Blynk IoT platform over Wi-Fi. The user can then view the data on the Blynk IoT platform in real time and receive notifications if the sensor values surpass threshold limits. This allows the user to act on the water's quality in the event of increased pollution levels. The system is also equipped with LEDs to signify whether the transmission was successful for the sending and receiving ESP32.

This system allows users - from regulatory agencies to local communities - to monitor and immediately identify anomalies in order to make informed decisions and prompt corrective actions. On its part, the architecture of the system is geared towards global sustainability, with specific reference towards the United Nations Sustainable Development Goals by enabling access to clean water (SDG 6), innovating the new technologies (SDG 9), and protecting terrestrial and aquatic ecosystems (SDG 15).

2. Literature review

Growing concerns about water pollution have ignited the deployment of smart sensing technologies for the real-time monitoring of water quality. Traditional systems often involve manual sampling and laboratory analysis that can be accurate, but are labor-intensive, slow, and do not deliver timely results [1]. To address these challenges, many researchers have developed IoT-based monitoring systems to automate data collection and transmission.

K. Sasinath et al. [1] presented a water quality monitoring system that used an STM32 offering real-time monitoring of pH, turbidity, and total dissolved solids (TDS). The work demonstrated the technical feasibility of using inexpensive sensors and embedded systems. However, the use of standard Wi-Fi network modules limited the approach to scenarios where network features were available and reliable.

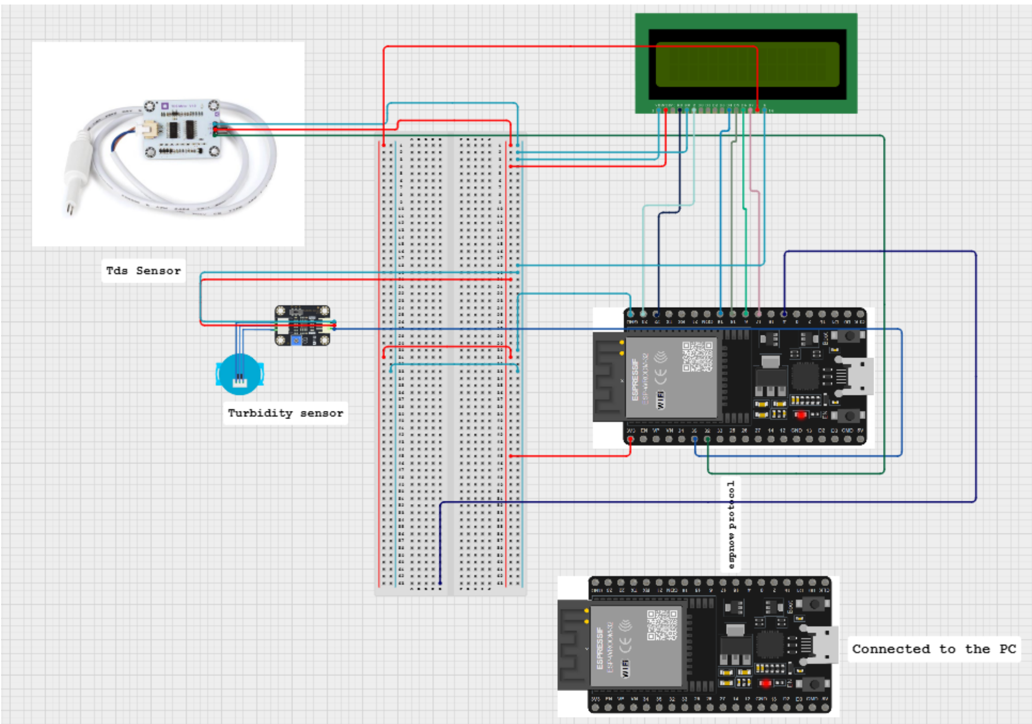
In the same manner, J. Zeng et al. [2] studied a water quality monitoring and classification framework based on the Internet of Things. Their proposed system included a combination of sensor arrays and cloud-based data classification models to enhance the detection of outlier water conditions. However, their overall architecture relied heavily on cloud connectivity and incurred latency and delays during poor network availability.

Other studies, like Alfiqri et al. [3], have explored microcontroller-based monitoring methods targeting real-time performance characteristics, with many relying on centralized networks or the public internet to reconvene the sharing of environmental data. Khaire and Wahul [4] produced an IoT-based water quality data analysis platform that utilized cloud services for storage and predictive analysis, valuing data visualization but forgoing a certain robustness when remote or offline.

Although these contributions demonstrate the utility of sensor-based monitoring and the promise of pooling IoT applications for assessing water quality, few solutions have attempted to solve for data trust and power consumption in the absence of consistent Wi-Fi or cellular connectivity. ESP-NOW, a low-power, peer-to-peer wireless protocol designed for ESP32 microcontrollers, is a sophisticated protocol that elicits these concerns. ESP-NOW removes the need for a conventional network infrastructure to enable the scalability and sustainability collection in isolated and unserved regions. This paper expands on these existing studies by leveraging ESP-NOW in a water quality monitoring system which is based on IoT. The design seeks to prioritize characteristics of real-time data transmission, energy consumption, and cost — which are important considerations for deployment in environmental conservation programs and public health monitoring.

3. Methodology

Monitoring the quality of water is necessary for the normalization of water resources. This report considers the methodical foundation for the development of a water quality monitoring system that can provide information that can mitigate the challenges with traditional monitoring systems.



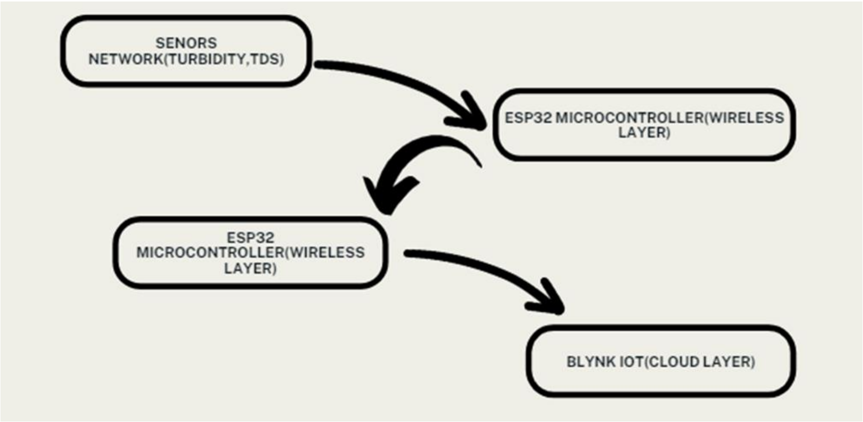
1. Sensor Selection: The first step in developing a water quality monitoring system is to determine what parameters you would like to measure. Some common parameters, such as pH, turbidity, and conductivity are normally measured with common sensors. With respect to measurements, make sure to determine the best sensors based on sensitivity, accuracy, and microcontroller compatibility. Because cost was a consideration, we chose to use a turbidity sensor and a TDS sensor.

Turbidity: A turbidity sensor is a meter used to measure the turbidity or cloudiness of a liquid, in most cases, water. Turbidity is an important parameter within water quality monitoring because it identifies the cloudiness of the water which means the presence of higher suspended material. This can include sediment, organic material, microorganisms, and pollutants.

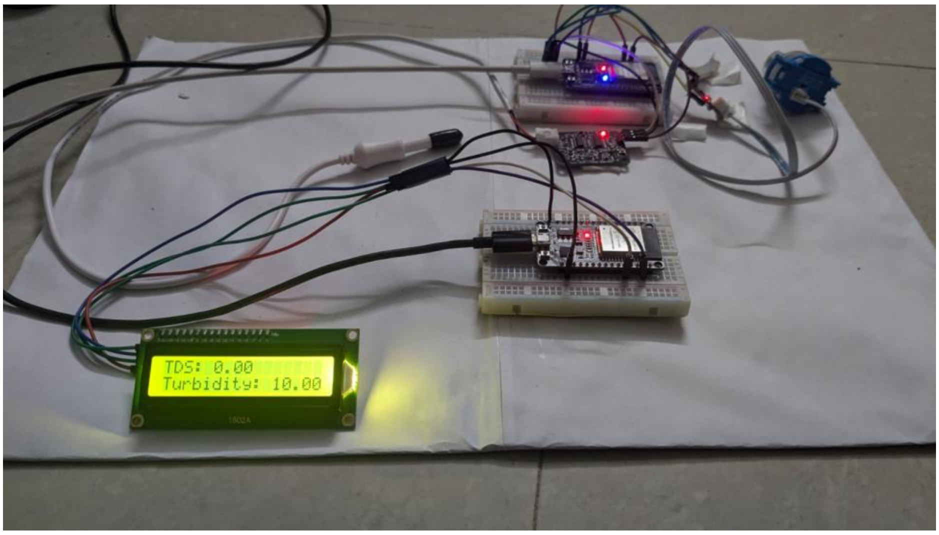
TDS: A Total Dissolved Solids (TDS) sensor is a scr device used to detect the concentration of dissolved substances within a measurement of water. TDS is an important category in water quality monitoring since TDS represents the total concentration of all inorganic & organic substances dissolved within a measurement of water (minerals, salts, metals, cations, and anions).

2. Hardware Design: After selecting the sensors, the next step is to design the hardware for the monitoring system. The Esp32 microcontroller is a preferred choice due to low power consumption, high performance, and numerous peripheral support. The hardware design entails interfacing the specified sensors with the Esp32 microcontroller, supporting appropriate protocols such as EspNow.

3. User Interface Development: To create a secure user experience, a suitable user interface (UI) must be developed. The UI can be developed using a variety of technologies, including graphical LCD displays, touchscreens, or simply smart mobile apps. The UI is developed to provide real-time measurements, visual alerts for parameters beyond normal thresholds, and to review historical data if desired.



4. Results and Discussion



Based on the Values for various water types and their respective turbidity and Total Dissolved Solids (TDS) levels, here are the conclusions:

1. Filtered Water:
    - Turbidity: 10 NTU (Nephelometric Turbidity Units)
    - TDS: 170 ppm (parts per million)
    - Conclusion: The filtered water has low turbidity, indicating that it is relatively clear with minimal suspended particles. The TDS level is moderate, suggesting that while some dissolved solids are present, it is likely safe for consumption.
2. Soap Water:
    - Turbidity: 350 NTU
    - TDS: 700-800 ppm
    - Conclusion: The soap water exhibits high turbidity and elevated TDS levels. This indicates a significant presence of suspended particles and dissolved solids, which are likely due to the soap content. This water is not suitable for drinking or general use without proper treatment.
3. Muddy Water:
    - Turbidity: 200 NTU
    - TDS: 700 ppm
    - Conclusion: Muddy water shows high turbidity, indicating a large amount of suspended particles, likely soil or other sediments. The TDS is also high, which suggests the presence of a significant amount of dissolved solids. This water is highly contaminated and unsafe for consumption or general use.
4. Tap Water:
    - Turbidity: 50 NTU
    - TDS: 340 ppm
    - Conclusion: Tap water has moderate turbidity and TDS levels, indicating that it contains some suspended particles and dissolved solids. While it may be safe for consumption in some areas, it could require further filtration or treatment, depending on local water quality standards.

Overall Conclusion:

- Filtered Water is the safest and cleanest among the samples, with the lowest turbidity and a moderate TDS level.
- Soap Water and Muddy Water are highly contaminated, with high turbidity and TDS levels, making them unsuitable for consumption or general use.
- Tap Water is relatively clean but may still contain impurities that could require additional filtration.

5. Conclusion

This invention provides a practical, scalable solution for real time water quality monitoring; using ESP32 devices and the ESP_NOW protocol, this invention overcomes issues associated with conventional water quality monitoring methods and provides a potentially viable solution for rural and field based environments. The systems integration with the Blynk platform also ensures accessibility making the invention extremely impactful for environmental monitoring and pollution prevention

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