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An Intelligent IoT Framework for Real-time Water Quality Monitoring in Biofloc Aquaculture

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Abstract- Biofloc aquaculture is a water-efficient production method that depends on maintaining suitable environmental conditions for fish, shrimp, and beneficial microbial communities. Parameters such as pH, temperature, and total dissolved solids (TDS) can change over time and require regular monitoring. This paper presents an Internet of Things (IoT)-based water-quality monitoring framework developed using an ESP32 microcontroller, a pH sensor, a TDS sensor, and a DS18B20 temperature sensor. The system collects measurements at predefined intervals and transmits them through Wi-Fi to a cloud-based platform. A web dashboard supports tank monitoring, 24-hour trends, historical readings, and species-specific acceptable ranges. The prototype was operated on a live 1000-litre tilapia biofloc tank for several days, with readings recorded approximately every ten minutes. A second inactive shrimp tank profile was used to evaluate the multi-tank dashboard. The trial demonstrated the feasibility of using a low-cost IoT framework to improve access to water-quality information. Wi-Fi interruptions caused gaps in the history log, indicating the need for improved connectivity and data buffering. Future work may include additional water-quality sensors, SMS alerts, machine-learning-based risk prediction, and automatic equipment control.

Key Word: Internet of Things; Biofloc Technology; Water Quality Monitoring; ESP32; Smart Aquaculture; Real-Time Dashboard

I. INTRODUCTION

1. Biofloc Fish Farming

Biofloc technology is an aquaculture approach that uses microbial communities to improve water quality and reduce the need for frequent water exchange. Heterotrophic bacteria assimilate organic waste and nitrogenous compounds, forming microbial aggregates known as bioflocs. These aggregates can serve as an additional nutritional source for cultured organisms. The method can reduce water consumption and waste discharge when properly managed [1, 2].

2. Rationale for Selecting Biofloc Aquaculture

Biofloc aquaculture was selected because its performance depends strongly on stable water-quality conditions. High stocking density, continuous aeration, feed input, and microbial activity can cause water conditions to change rapidly. Maintaining suitable environmental parameters is therefore important for supporting fish health, microbial stability, and production performance.

3 Limitations of Manual Monitoring

Manual water-quality testing is generally performed at selected times during the day. Although this approach provides useful information, it may not identify changes occurring between measurement periods. Manual monitoring may also be affected by inconsistent sampling, differences in test interpretation, improper storage of test materials, and limited personnel availability.

4., Need for IoT-Based Monitoring

IoT technology can address these limitations by enabling automated data collection and remote access to water-quality information. A microcontroller with wireless connectivity can receive sensor readings, transmit them to a cloud platform, and present the data through a web dashboard. This approach can improve monitoring consistency and support historical analysis and threshold-based alerts.

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II . LITERATURE REVIEW

1. Existing IoT-Based Aquaculture Monitoring Systems

Previous research has investigated wireless sensor networks and IoT architectures for aquaculture monitoring. These systems generally consist of sensors, a processing unit, a communication network, a cloud or server platform, and a user interface. Common parameters include pH, temperature, dissolved oxygen, turbidity, and total dissolved solids. Wireless monitoring has demonstrated potential for remote observation and control in aquaculture environments [3, 4].

2. ESP32-Based Monitoring

The ESP32 microcontroller is suitable for low-cost monitoring applications because it integrates Wi-Fi connectivity, provides digital and analog interfacing options, and is supported by development environments such as the Arduino IDE. Its integrated communication capability reduces the need for an additional network module. The present work follows this established hardware approach while emphasizing a multi-tank dashboard and species-specific monitoring ranges.

3. Research Contribution

Many monitoring systems are designed for general aquaculture applications. The framework described in this paper focuses on biofloc aquaculture and combines pH, TDS, and temperature monitoring with a web dashboard supporting multiple tank profiles, historical data, trend visualization, and species-specific threshold configuration.

3. METHODOLOGY AND SYSTEM ARCHITECTURE

1. System Architecture

The proposed system consists of three layers: the sensing layer, the microcontroller layer, and the cloud-and-dashboard layer. The sensing layer collects water-quality measurements. The ESP32 processes the readings and transmits them through Wi-Fi. The cloud layer stores timestamped readings and supplies data to the web dashboard.

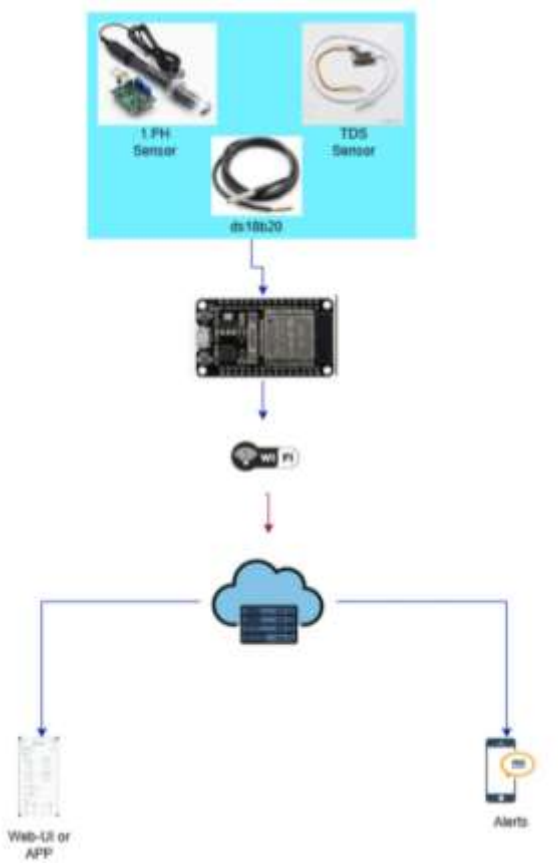

Figure 1. Proposed IoT-Based Water Quality Monitoring System Architecture

2. Hardware Components

The prototype uses a pH probe, a TDS sensor, and a DS18B20 digital temperature sensor. The pH probe measures acidity or alkalinity. The TDS sensor estimates dissolved substances in parts per million and is used as an additional indicator of changes in water conditions. The DS18B20 provides a waterproof digital temperature measurement. All sensors are connected to an ESP32 development board.

3. Software and Data Flow

The ESP32 firmware is developed using the Arduino IDE. During operation, the controller reads the sensors, applies basic smoothing to reduce isolated noisy samples, and transmits readings to the cloud platform at regular intervals. Each reading is associated with a tank profile and timestamp. The

dashboard provides a Tank Overview page, a 24-hour Trend page, and a History page.

4 . Configured Monitoring Ranges

For the tilapia prototype, the configured ranges were 25–30 °C for temperature, 500–2000 ppm for TDS, and 6.5–8.5 for pH. The selected optimal reference values were approximately 28 °C, 1200 ppm, and 7.5, respectively. These values were used as prototype settings and should be validated against local aquaculture guidance before commercial deployment.

IV. RESULTS AND DISCUSSION

1. Prototype Testing

The prototype was operated on a live 1000-litre biofloc tank stocked with tilapia. Measurements were recorded approximately every ten minutes over several days. The trial evaluated data collection, dashboard visualization, historical logging, and monitoring against configured ranges.

2. Multi-Tank Dashboard Evaluation

A second inactive tank profile configured for shrimp was used to evaluate multi-tank functionality. The dashboard allowed the user to switch between tank profiles and assign individual species and monitoring ranges without modifying the underlying program code.

3. Connectivity Limitation

During the trial, the dashboard displayed an offline status when the ESP32 lost its Wi-Fi connection. Consequently, the history log contained gaps rather than a perfectly continuous data stream. This result demonstrates that network reliability is important for rural aquaculture applications. Future versions should consider local data buffering and automatic reconnection.

4. Discussion

The prototype demonstrates the feasibility of collecting and visualizing water-quality data through a low-cost IoT architecture. Nevertheless, the trial does not establish sensor accuracy, long-term reliability, disease-prediction capability, or production improvement. These aspects require calibration against reference instruments, longer testing periods, controlled experiments, and larger datasets.

V. FUTURE SCOPE

1. Additional Parameters

Future development may include dissolved oxygen, ammonia, nitrite, alkalinity, and turbidity sensors for a more complete assessment of biofloc water quality.

2. Predictive Analytics

Machine-learning techniques may be applied to historical sensor data to identify patterns associated with water-quality deterioration. Reliable prediction would require a sufficiently large and well-labelled dataset containing sensor measurements and corresponding aquaculture outcomes.

3. Alerts and Automated Control

Future versions may include SMS or mobile notifications when a measurement exceeds a configured threshold. Automatic control of equipment, such as aerators or water-exchange mechanisms, may also be investigated with suitable safety controls and field validation.

4. Expanded Deployment

The prototype can be extended to support multiple tanks and farms, individual alert histories, user accounts, species-specific configurations, and improved connectivity management.

VI. CONCLUSION

This paper presented an IoT-based framework for monitoring water quality in biofloc aquaculture using an ESP32 microcontroller, pH sensor, TDS sensor, and DS18B20 temperature sensor. The system collects readings at regular intervals and transmits them through Wi-Fi to a cloud-based dashboard. The dashboard supports live monitoring, 24-hour trends, historical records, and multiple tank profiles with species-specific ranges. Testing on a live 1000-litre tilapia tank and an additional shrimp tank profile demonstrated the feasibility of the approach.

Wi-Fi interruptions caused gaps in the recorded data, highlighting the need for improved connectivity and local data buffering. The framework provides a foundation for future work involving additional sensors, reliable alerts, predictive analytics, and automated aquaculture control.

Table 1. Hardware and System Components

Component	Role in the System	Typical Specification
ESP32 development board	Reads sensors, processes data, and transmits readings	Dual-core microcontroller with built-in Wi-Fi
pH sensor probe	Measures acidity or alkalinity	Approx. 0–14 pH
TDS sensor probe	Estimates dissolved solids	Approx. 0–2000+ ppm
DS18B20 probe	Measures water temperature	Waterproof digital probe
Wi-Fi connection	Transfers data to cloud platform	2.4 GHz local network
Cloud server	Stores readings and supports dashboard	Timestamped data storage

Table 2. Configured Tilapia Monitoring Ranges

Parameter	Configured Range	Optimal Reference
Temperature	25–30 °C	Approximately 28 °C
TDS	500–2000 ppm	Approximately 1200 ppm
pH	6.5–8.5	Approximately 7.5

Table 3. Sample Readings Recorded During the Prototype Trial

Time	Temperature (°C)	TDS (ppm)	pH
10:01:43 PM	28.55	1383	7.66
10:01:33 PM	26.62	1170	7.27
10:01:23 PM	26.21	1398	6.95
9:01:23 PM	26.35	1387	7.93
8:01:23 PM	28.36	1047	7.23
7:01:23 PM	29.23	1095	7.31

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