An IoT-Based Cloud Solution for Intelligent Integrated Rice-Fish Farming Using Wireless Sensor Networks and Sensing Meteorological Parameters

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***Abstract*—Internet of Things (IoT) based automated farming processes and integrated rice-fish farming field monitoring can reduce wastage by allowing more efficient water management, water quality maintenance, and growth rate monitoring for higher production. Our research was inspired by developing countries, where agriculture, aquaculture and climate conditions play a significant role in the economy. Our main goal is to build an IoT-based automated integrated rice-fish farming system that leverages portable wireless sensor networks (WSN) to monitor environmental factors remotely. Our suggested system uses sensors such as temperature, humidity, dissolved oxygen (DO), water level, pH, and turbidity sensors to monitor and operate the integrated rice and fish farming system. Because of user notification and the IoT cloud server employing wireless sensor networks, the collected data from the sensors is transferred to the created Developed Website for Integrated Farming System (DWIFS). All sensors will be continuously monitored by our multi-sensor system. The data will be stored on cloud systems based on DWIFS and IoT to provide an increased scalability and access to cloud data from anywhere on the planet. The user is notified by turning on and off LEDs, receiving SMS, and phone call messages on a regular basis.**

***Index Terms*—Internet of Things, Cloud Solution, Wireless Sensor Networks, Integrated Rice-Fish Farming, and Sensors**

I. Introduction

Analysts have recognized the fish and seafood sector as a key component of Bangladesh's economic development because the country is predominantly rural. The agriculture and aquaculture industries are vital to Bangladesh's economy which generate millions of jobs as well as consistent international export profits. Bangladesh was the world's fifth-largest aquaculture producer in 2018 and this industry is likely to expand in the next few years. Bangladesh is expected to go from low-income to lower-middle-income status within the next seven years, according to economists; aquaculture exports will play a key part in this transformation. Aquaculture production has increased threefold since 2000, owing in part to technological developments and producer-friendly legislation [1]. Furthermore, agriculture is an important industry in increasing Gross Domestic Product (GDP), which is critical in defining a country's economic performance whether developed or developing. Because of important raw materials are derived from the farm, it is the backbone of agro-based industrial products. As a result of our country's unequal rainfall distribution, several difficulties to farming situations is appeared. Crop development and efficient fish growth are limited by a lack of rainfall and inconsistent feeding applications during specific months of the year, resulting in a drop in the contribution of foreign exchange to the economy. Severe unseasonal rainfall, fast temperature swings, insufficient water quality control, and growing an unstable atmosphere for the development of numerous insects can be sabotage for rice and fish farms. To address these problems, various old technologies have been adopted, but they require a lot of people, so the investment is negligible every time. For this reason, the most cost-effective and efficient solution to the problems will be an automated method. Due to the uneven distribution of rainfall, it is physically hard for a farmer to maintain effective water quality and an optimum temperature level for efficient rice and fish production. As a result, a sophisticated integrated rice and fish production infrastructure is necessary to deliver water efficiently across the entire farm land for increased output [2]. IoT is a notion that first originated roughly 20 years ago and is currently generating headlines all over the world. We are able to continue with IoT because everyone talks about connectivity, smart gadgets, and real-time data extraction. About 35 billion IoT devices is installed globally by 2021. In 2021, 46 billion gadgets is already linked with

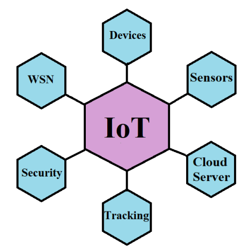

Fig. 1. Different internet-connected devices that support IoT

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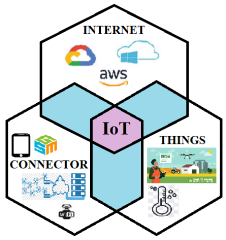

Fig. 2. IoT skeleton which connects people, places, and things to the internet

IoT [3]. Fig. 1 depicts the different internet-connected devices that support IoT.

IoT is a network that support devices for computing, digital as well as mechanical gear these are used by humans or animals and objects that can be perceived, collected, and transmitted data over the internet without human interaction. It has changed the society in which we now live. Smart cities, automobiles, and houses might all are connected to the IoT. Agriculture, business, healthcare, transportation, and logistics are all possible applications. The use of cloud computing in the IoT platform allows data collection from devices to be preserved on dependable storage servers. Fig. 2 depicts the IoT skeleton which connects people, places, and things to the internet.

On a daily basis, the global temperature and population are rising. As the world's population is expanded, the more amount of food is needed. Weather, climatic change, and various environmental factors, such as temperature, water level, water quality, efficient water quality maintenance, fertilizer applied quantity, and so on, are all affected to farming techniques. Agriculture and aquaculture are the backbone of most developing countries' economies. Farmers in several parts of the world are facing substantial farming issues as a result of seasonal climate change. Excessive water due to extraordinary rainfall or a scarcity of water and incerased temperatures due to extreme sunlight has a significant impact on integrated rice and fish production. Furthermore, due to an excess or lack of efficient water level and quantity, farming has experienced unusual growth. Smart water management, the administration of the appropriate amount of fertilizer, and integrated rice-fish farming field shedding, temperature, and water level variations are all that is required to remedy the above mentioned issue.

To address the issues, it is critical to improve an intelligent integrated rice-fish farming process that can effectively notify the user or farmer of water management events, such as water supply or drainage, water quality maintenance in different seasons, water level in the farming fields, appropriate fish food supply, and fertilizer quantity applied in terms of pH level, water quality, and farming field shedding based on weather conditions. To overcome these issues, we employed wireless sensor networks and environmental data to develop an intelligent system. Wireless sensor networks also known as a wireless sensor and actuator networks where different sensors are distributed to monitor environmental and physical factors including sound, pressure, and temperature. This system consists of a gateway that connects throughout the world and scattered nodes that can send data via the network to a central location. The sensor activity is enabled by current networks, which are bidirectional in nature.

Our research provides a significant contribution by developing an intelligent integrated rice-fish farming framework based on IoT and cloud computing technology that sends automated signals concerning effective water management, proper water quality maintenance, and shedding of farming fields. Mobile SMS, email, website notification, and LED status will be used to notify the user. We also developed a website named DWIFS that can provide sensor data to users. Users can access those sensor's data from anywhere and take proper decisions to maintain integrated rice-fish farms. We also monitor 5 rice-fish farm at the same time by using our website. To our knowledge, no research has looked into an intelligent integrated rice-fish farming system that is proposed based on efficient water management, appropriate water quality maintenance, and farming field shedding with sufficient time, where an IoT-based cloud solution is combined with dynamic website notification.

The following association is how the rest of the paper is organized: Similar work in a variety of related disciplines is discussed in Section II Section III depicts an IoT cloud-based rice-fish farming with integrated techniques. The skeleton of our developed rice-fish farming with integrated techniques is discussed in Section IV. The schematic circuit diagram for the environmental parameter monitoring device that we built, as well as the seven-day notification result, are both included in Section V. The paper comes to a close with Section VI.

II. Related Work

The water controller's major responsibility is to detect and depict the amount of water in the field. Water is distributed through a network system using pumps, pipes, sprinklers, and valves. Sprinklers are used in a range of environments, including industrial, commercial, residential, and agricultural [4]. Chen and his colleagues advocated that IoT deployment be done in the fish farming industry as well as in the city.Water temperature, pH, dissolved oxygen, and water level were used to construct an IoT intelligent system for fish farming in this paper [5]. Channe et al. suggested an IoT-based transdisciplinary precision agricultural model. As examples of potential applications for their approaches, they listed online agriculture data analysis, agricultural cloud, agribusiness, soil and weather analysis and forecasting, as well as a mobile app for farmers, merchants, and government officials [6]. The study presents a real-time monitoring and controlling system for aquaculture based on the concept of cloud integration. The system may create the IFTTT (if this, then that) rules for the optimal water state for the pond in [7] using the web and Android applications.

Kiani et al. demonstrated an IoT-based small farm monitoring system that measures temperature and humidity in order to plan farming and horticulture more efficiently [8]. For efficient water distribution and management, Karpagam et al. presented an IoT-enabled intelligent irrigation system.

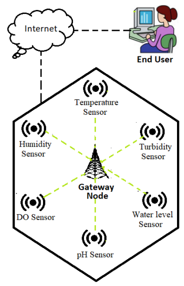

Fig. 3. The basic skeleton of wireless sensor network

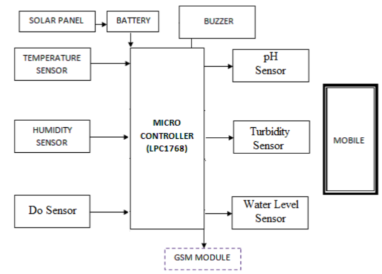

Fig. 4. IoT connected sensors are represented through block diagrams [15]

With minimal human intervention, their method checks the water level in the field and supplies water as needed [9]. Meethongjan and colleagues proposed a project to develop a mobile application for controlling the aquarium's water system using IoT technologies and an Android browser. As a result, their aquarium fish and fish farmer group profited, which helps their community financially. In addition, their smartphone application can be used by other agricultural farms as a model [10]. Lee et al. proposed the IoT and cloud computing can be leveraged. To demonstrate agriculture and environmental monitoring as a service on the cloud using augmented reality. According to this article, the Cloud Computing paradigm is a perfect fit for IoT applications [11]. Finally, Maswood et al. represents an intelligent IoT based weather monitoring system using smart umbrella [12].

III. IoT Cloud-Based Intelligent Integrated rice-fish Farming System

A. *Wireless sensor networks for environmental data collection*

The greatest issue in the twenty-first century is feeding the world, especially for clever farm enterprises. The farm used an agriculture automation system instead of traditional agriculture. Our research's major goal is to come up with a long-term, sustainable solution for integrated rice-fish farming and agricultural automation. As a result, we created a website controlled portable measurement device for effective water management, water quality management, temperature, water level, and pH level sensors for gathering environmental data and managing integrated rice-fish farming systems. The purpose of this experiment is to find better ways to use an autonomous system to govern an intelligent agricultural system. In order to regulate a farming system, we also developed a wireless sensor network communication technology for collecting environmental data and delivering control signals to turn on or off devices [13]. By persuading agriculture monitoring is a new WSN's application feature, it can be utilized for monitoring, sensing, and controlling the amount of pesticides used in large agricultural fields, monitoring crop, soil, and climate factors [14].

B. *Data monitoring with wireless sensor*

With the use of wireless sensor networks and sensed data, the IoT can accurately control the humidity and temperature of plants. Because of the variable air circumstances, atmospheric conditions may differ from one location to the next, making consistency difficult to maintain throughout the fish farm. A suggested IoT and cloud-based integrated rice-fish farming system could be allowed for regular environmental conditions to be maintained. Our research's main purpose is to develop an intelligent monitoring system for the agricultural environment that includes temperature, humidity, pH, water level, and other potentially essential characteristics. The goal of this study is to investigate a remote monitoring system for effective water management and water quality control. This node wirelessly transmits data to a central server, which collects, stores, and analyzes the information before presenting it and delivering it to the client mobile [12]. Fig. 3 depicts the structure of wireless sensor networks. Temperature, humidity, and other sensor readings are automatically monitored by the environmental monitoring sensors. The monitored data from the sensors can be accessed remotely by the user. A block diagram of our intelligent integrated farm surveillance system that connects with different sensors is shown in Fig. 4 [15].

1) Humidity sensor: A humidity sensor detects, measures, and reports both moisture and air temperature (or hygrometer). The purpose of a humidity sensor is to detect changes in electrical currents and air temperature. Humidity sensors are used to determine the moisture content;

2) Temperature sensor: Electrical impulses from a temperature sensor are used to calculate temperature values. When they detect a temperature change, the sensor is made up of two metals that produce electrical voltage or resistance;

3) Water level sensor: The amount of chemicals that can flow is detected using water level sensors. Liquids, slurries, granular materials, and powders are examples of such items. Water levels can be measured in containers or at the surface of a river or lake;

4) Turbidity sensor: As the amount of total suspended solids (TSS) in the water grows, a turbidity sensor is used to measure the turbidity level (and cloudiness or haziness) of the water. Turbidity sensors measure how much light is scattered by suspended objects in water;

5) pH sensor: A pH sensor is one of the most important tools for water analysis. This sort of sensor can detect alkalinity and acidity levels in water and other liquids. pH sensors, when utilized correctly, can ensure a product's safety and quality;

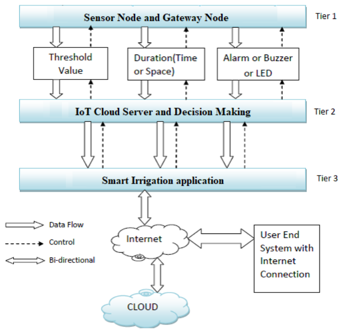

Fig. 5. A proposed model for intelligent integrated farming systems [16]

6) DO sensor: This dissolved oxygen meter is used to determine the amount of dissolved oxygen in water and thus the water quality. It is commonly used to determine water quality in a variety of situations.

IV. The Skeleton of Our Developed Intelligent Integrated Rice-Fish Farming System

A. Proposed model for integrated intelligent farming system

Figure 5 depicts an intelligent, integrated rice-fish farm monitoring system based on the IoT concept. The parameters for efficient water management and water quality control in the form of supply and drainage water are shown in Tier 1 of Fig. 5. Tier 1 also applies to sensor equipment, with each sensing and sensitivity range is being regulated and operated separately. Tier 2 stores data on an IoT cloud server and makes decisions based on a threshold value. Between Tier 1 and Tier 2, the necessary threshold value and duration for taking suitable action is analyzed based on sensing data. Tier 2 is in charge of data processing, acquisition, and decision-making from sensor devices. The third tier is the application level. The sensed data is analyzed and saved on the DWIFS and IoT cloud servers. The data can be viewed on mobile phones, laptops, and other devices [16].

DWIFS is the designed website's appearance. For designing a readable website, it requires efficient coding. Our website provides sensors data such as humidity, temperature, water level, pH level, dissolved oxygen level, and water quality. These websites can also send weather notifications to users via the IoT. It has a storage section where you may keep photos, paragraphs, and the table of contents. Initially, a website called DWIFS [13] was constructed using Javascript and CSS. The pages, themes, and posts are then edited using the Dashboard. After that, various sensors sensed weather-related data are placed automatically into the form of Table I by utilizing Table Press. Fig. 6 displays the home page of our developed website for monitoring an integrated farming system.

Figure 7 depicts the proposed IoT-based cloud solution for the intelligent integrated rice-fish farming system design. We used a range of sensors to capture meteorological data from the aquaculture and agricultural fields, including temperature, humidity, water level, pH level, dissolved oxygen level, and turbidity. A WSN was built, and the data sensed by the sensors is collected by a WSN gateway node. The sensed data is sent from the WSN access point to the DWIFS server and the IoT cloud server. End users of our intelligent farming system will be able to make intelligent farming decisions using data from the DWIFS server and the IoT cloud server from anywhere on the earth.

Fig. 6. The home page of our developed website for monitoring an integrated farming system

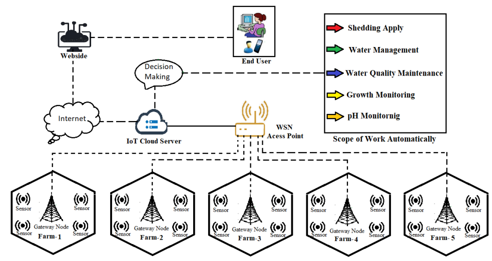

Fig. 7. The architecture of the proposed IoT and cloud solution-based intelligent integrated farming system

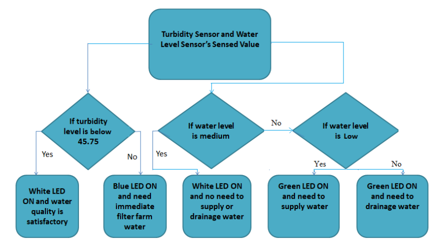

Fig. 8. Proposed water quality and water level management flowchart

B. Proposed algorithm for intelligent integrated process

Figure 8 depicts the flow chart that we use for intelligent water level management by analyzing water level sensor sensed data. If the water level is medium, then the white LED is ON and there is no need to supply or drain water to the fish-farm field. Moreover, if the water level is low, the green LED is ON and immediately needs to supply water to the fish-farm field. Again, if the water level is high, it is necessary to drain water from the fish-farm field. On the other hand, if the turbidity level is below 45.75%, then the white LED is ON. It indicates that water quality is satisfactory and there is no need to filter water or supply new water. Furthermore, if the turbidity level is higher than 45.75%, then the blue LED is ON. It is needed to filter the field water.

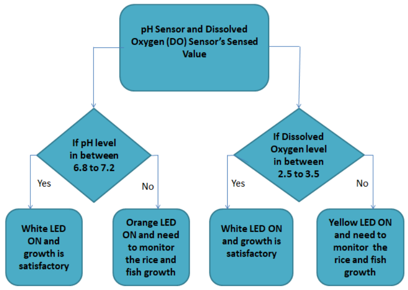

Fig. 9. Flowchart for monitoring rice-fish growth in an integrated farming

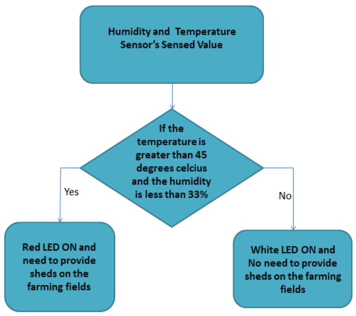

Fig. 10. Proposed flow chart for shedding application

Figure 9 represents the flow chart that we use for intelligent rice and fish growth monitoring by analyzing dissolved oxygen level and pH level. From the pH sensor and dissolved oxygen sensor's data, we determine that if the pH level is between 6.8 to 7.2, the white LED will illuminate, indicating that fish growth is satisfactory and no additional food or fertilizer is required. Again, if the pH level is lower than the above mentioned value then orange LED is ON and fish growth level is not satisfactory as well as we need to apply the necessary food or fertilizer. The same manner will be applied to rice-farming. On the other hand, if the dissolved oxygen level is somewhere between 2.5 to 3.5, there is satisfactory growth and there is no need to monitor growth. Again, if the dissolved oxygen level is lower than the above mentioned value then yellow LED is ON. That's why, it is necessary to take steps for growth monitoring.

Figure 10 depicts the flow chart that we apply shadding based on temperature and humidity sensor's data. Based on the sensor's data, users will be notified about the importance of applying shedding in terms of time frame. The red LED will turn ON later if the temperature is higher than 45°C and the humidity is lower than 33%, and the user will be notified to provide shade for fish-farm fields promptly. If the temperature is below 45°C and the humidity is lower than 33%, the white LED will turn ON, and there will be no need to offer shade for fish-farm fields. Fig. 11 depicts the overall work procedure using block diagrams.

V. Results and Discussion

The Schematic circuit diagram of our planned intelligent Integrated rice-fish farm system's hardware connections is

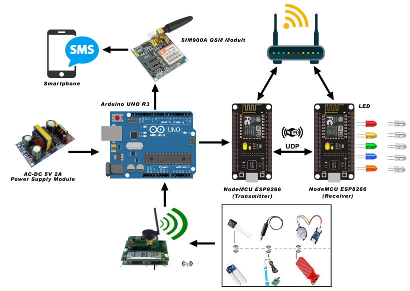

Fig. 11. Overall block diagram for intelligent integrated rice-fish farming

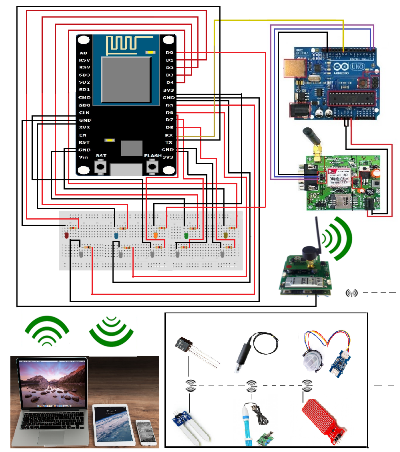

Fig. 12. The schematic circuit diagram shows the hardware connections of our designed intelligent integrated farming system

shown in Fig. 12. Our implemented sensor's sensed data from farm-1 which is collected from DWIFS server and IoT cloud server are stored in Table I. From the first row of the table, the temperature, humidity, pH, Dissolve Oxygen, water level, and turbidity read from the website and IoT cloud server for farm-1 are 28°C, 50%, 6.9, 3.1, Mid, and 45.1%. That is depicted in Table I. As there are no values lower than threshold, so the turning condition of red, orange, yellow, green, and blue LEDs is not satisfied and they remain OFF, where all white LEDs associated with red, orange, yellow, green, and blue LEDs satisfy the condition and remain ON. This indicates that it is a good day. On the next day, the temperature, humidity, pH, Dissolve Oxygen, water level, and turbidity were observed. In this case, the temperature, humidity, pH, Dissolve Oxygen, and turbidity are lower than threshold value, so the condition of turning ON red, orange, yellow, and blue LEDs are not satisfied where the water level is higher than the threshold value, so the condition of turning on green LED is satisfied. Therefore, the red, orange, yellow, and blue LEDs are turned OFF while the green LED remains ON. The person would be notified that, it needs to be water drained. Similarly, on the third day, the temperature, humidity, Dissolve Oxygen, and water level are lower than the threshold value, so the turning condition of red, yellow, and green is not satisfied and they remain OFF, where all white LEDs associated with red, yellow,

TABLE I
INTELLIGENT INTEGRATED RICE-FISH FARM SYSTEM MONITORING AND 7 DAYS FEEDBACK ANALYSIS DATA USING OUR PROPOSED IOT BASED SYSTEM

Day	Temp °C	Hum idity	pH Sensor	DO Sensor	Water Level	Turbidity Sensor	Red LED	Orange LED	Yellow LED	Green LED	Blue LED	SMS & Email farm-1(F1)
Sun	28	50%	6.9	3.1	Mid	45.1%	OFF	OFF	OFF	OFF	OFF	F1-Good Day
Sat	25	51%	7.1	3.4	High	45.2%	OFF	OFF	OFF	ON	OFF	F1-Water drain
Fri	30	47%	6.6	3.2	Mid	48.6%	OFF	ON	OFF	OFF	ON	F1-Adjust pH & Water Filter
Thu	47	30%	6.8	2.8	Low	44.3%	ON	OFF	OFF	ON	OFF	F1-Shedding & Water Supply
Wed	41	34%	6.9	2.1	Mid	45.2%	OFF	OFF	ON	OFF	OFF	F1-Adjust Growth
Tue	36	36%	5.4	2.9	Mid	49.6%	OFF	ON	OFF	OFF	ON	F1-Adjust pH & Water Filter
Mon	27	42%	7.0	2.7	Mid	45.5%	OFF	OFF	OFF	OFF	OFF	F1-Good day

and green LEDs satisfy the condition and remain ON. On the same day, the pH is below and turbidity is higher than the predefined value. Therefore, the orange and blue LEDs remain ON and both white LEDs associated with the blue and yellow LEDs remain OFF. This assembled LED status can clearly disclose to the user that it is needed to Adjust pH & Water Filter. Other information for 7 days monitoring of intelligent irrigation processes for farm-1 are tabulated in Table I. Similarly, all sensor's sensed information from other fish-farms are associated in DWIFS and notify the user via LED, SMS, and Email.

VI. CONCLUSION AND FUTURE WORK

For efficient fish-farming, our IoT-based intelligent integrated system measures water turbidity, water level, pH level, dissolved oxygen level, and climatic variables using field-deployed sensors. The wireless sensor network is the first module of our proposed intelligent integrated rice-fish farming solution, and it collects sensors' perceived information through a WSN gateway. The detected data is sent to the DWIFS and IoT cloud servers for efficient decision-making based on specified values. The user can obtain farming field information via DWIFS and the IoT cloud server in the form of SMS and email from anywhere on the globe for intelligent fish farm monitoring. The system's design will benefit users. It brings down the cost of integrated farming while speeding up production. We intend to use a machine learning (ML) approach to analyze vast amounts of farmed field monitoring data in the future. Furthermore, we want to release an Android app that will allow customers to remotely view output data from their mobile phones.

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