Monitoring of water quality in tilapia farms with IoT technology

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***Abstract*—Water quality monitoring for tilapia farming is essential to increase the productivity and competitiveness of fish farmers, requiring the introduction of technologies that help reduce vulnerability factors and support the processes of tilapia farming, fattening and harvesting. Based on this approach, an electronic prototype was designed and implemented to monitor water quality parameters, such as temperature, pH and dissolved oxygen, in order to identify the optimal values that would guarantee the reduction of mortality rates in tilapia cultures.**

The tests were conducted in a controlled environment. The prototype hardware consists of an electronic conditioning section and a microcontroller, in which the process of sampling, conditioning, data acquisition and processing is performed for sending and storage in the cloud. The information is sent by Wifi connection to our cloud storage provider, which allows our software to show the user the variations of the water parameter measurements in graphical form and the user can take corrective actions according to each situation. This prototype is expected to contribute to the improvement of productive activities in aquaculture, increasing the competitiveness of producers and reducing mortality rates in tilapia.

***Index Terms*—IoT, Aquaculture, Tilapia, Water quality, cloud storage, Embedded system.**

I. Introduction

Globally, aquaculture has become one of the main productive activities, as it provides a great source of food and work for society in general. According to data from the Food and Agriculture Organization of the United Nations (FAO), in 2009 aquaculture provided 81% of the seafood, 76% of the freshwater fish, 69% of the salmon and 42% of the shrimp consumed in the world, generating employment for 9 million people, thus making aquaculture the fastest growing food sector in the world: 7% per year [1].

In this sense, aquaculture brings benefits to the development of a country; therefore, it is important to be in constant surveillance of those physio-chemical elements that help both the health, growth and quality of aquatic species crops. The development of aquaculture does not only imply allocating financial capital; it is also necessary to transform the aquaculture structures and aqua-industrial systems that are indispensable to produce in a harmonious, financial and commercial way. Transformations in this sector must be sustainable and under the advice of specialists in technological innovation, marine biologists and environmental researchers. [2].

IoT (Internet Of Things) technology is a dynamic global information collective network consisting of Internet-connected objects, such as radio frequency identifications, sensors and actuators, as well as other intelligent instruments and devices that make up an integral component of the Internet [3], [4]. IoT solutions are presented as a viable mechanism for efficient data collection and processing in aquaculture systems.

IoT infrastructures [5], have been successfully introduced in aquaculture environments, providing automation in post-harvest operations, with the use of integrated microcontrollers [6] that are incorporated into aquaculture process monitoring systems to identify growth behaviors and the parameters of environmental variables that directly affect aquaculture production. These systems use continuous and non-invasive automated methods such as the vision of information in different devices [7], allowing to minimize delays or possible errors in data analysis, generating immediate responses and decision making, allowing to respond with actions that help to maintain the water quality of the ponds where the tilapia cultures are located.

For these reasons, this article describes the implementation of a water quality monitoring system using IoT technology, to solve the problem of collecting measurements of physico-chemical parameters of water quality used in ponds where aquaculture crops are located. Today this measurement is done manually, which leads to a high risk of death and / or disease of the species. This IoT Prototype solves this problem through the technification and remote monitoring of water quality, in order to obtain accurate data about the following 3 physio-chemical parameters that are present in the water, which are involved in the proper development of aquatic species in the ponds: Hydrogen potential (pH), dissolved oxygen (DO) and temperature (TA).

This prototype water quality monitoring system will be implemented using microcontrollers and low-cost sensors, which connected to a wireless network will send the measurements of the data collected to the Internet, to be later displayed on a visualization platform, which will allow the analysis of the data received to generate answers and decision-making in the treatment of water for tilapia crops [8].

II. Water quality monitoring system

The water quality monitoring system seeks to contribute to the improvement of production processes, reducing costs and time, optimizing response capacity and demand, through processes where information travels through the network, in the form of digitized data from the sensors to the cloud, where it will be processed and stored. See Fig. 1.

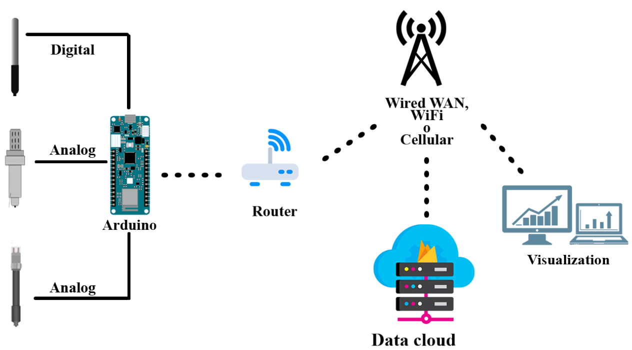

Fig. 1. IoT architecture of water monitoring system.

The technology used for devices to send or receive data from their Arduino platform to the cloud is Wifi, which uses the 802.11 protocol, which reduces the form of latency between communications and improves the response time of sensors and display devices.

For data storage, cloud technology is used, which allows remote data storage and management of IoT devices, allowing this data to be accessible on multiple devices on the network.

A. Sensors and microcontroller

The sensors are the devices that will be in charge of constantly collecting the physio-chemical data of the water, pH, Dissolved Oxygen and Temperature. These sensors send the information through the Arduino.

The fundamental hardware base of the prototype is the Arduino MKR Wifi 1010 microprocessor, which has specific libraries that support the design of IoT applications. This allowed the establishment of a wireless connection that, with the help of sensors, makes links between the natural variables of the environment that are converted into electrical variables, making transitions that allow these electrical values to be converted into data that can be understood by any user.

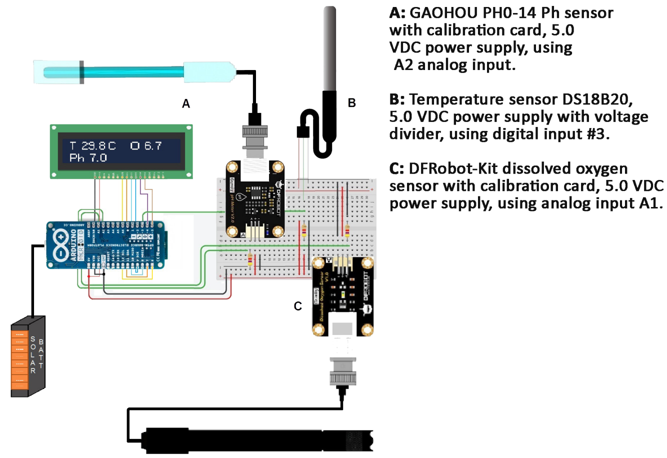

Fig. 2. Hardware architecture for water measurement prototype.

The source of electrical self-supply of the sensors and microcontroller is through a solar panel that generates photovoltaic energy [9]. This option was chosen because the sensors need to be able to work 7/24 and there is no electrical distribution close to the crop ponds.

B. Data acquisition system

The water quality monitoring system has a collective network of microcontrollers with IoT technology that facilitates communication between the sensors and the cloud, as well as between the sensors themselves in a reliable and scalable way, the realization of communication between the microcontrollers and the database is centralized, all data are sent to be stored in the cloud, see Fig. 3.

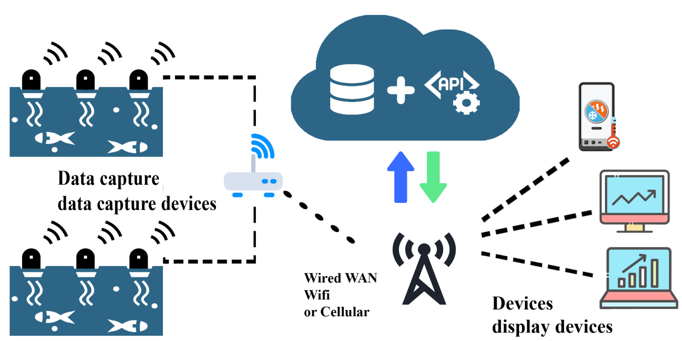

Fig. 3. Data storage system.

The water quality monitoring system has a centralized server that is in charge of receiving the messages from all the transmitting devices and distributing them to the receivers. Generically we will call this server Broker. This device has a fixed address on the Internet, so that it is accessible to all microcontrollers, solving the problem of having to find another microcontroller.

Our cloud service provider, allows us to store large volumes of information and provides a barrier of security, cost-effectiveness and cost reduction in data storage.

C. Display system

In this paper, a system was developed for the visualization of the data stored in the cloud, corresponding to the physio-chemical parameters captured by the IoT microcontrollers in the monitoring system. The displayed information acquired can come from different locations and, in turn, be displayed in the same visualization system because all the data is processed and hosted in the same server in the cloud. This information,

Fig. 4. Data display system screen.

stored remotely, is presented to the person who manages the ponds and this person can identify when the values vary from the ideal levels of the configured parameters through the graphs presented on the screen, see Fig. 4; helping the responsible persons to make decisions to solve the detected problems and take pertinent actions in the pond corresponding to the measurement.

III. Methodology

In this research we have used the experimental methodology which allows us to test our prototype at the time of capturing the values of physio-chemical parameters of the water where tilapia are raised, based on the measurements of ideal water conditions presented by other authors who have conducted similar research. [10] and [11].

Table 1 presents a summary of the ideal values for the physico-chemical parameters of water quality for tilapia culture. These data are taken into account because the development of fish depends largely on water quality; therefore, in order to achieve good production, it is important that the physical, chemical and biological properties of the water are maintained within the optimal parameters for the species to be cultured.

Finally, we use the deductive method to draw conclusions from the results obtained with the implementation of the monitoring system for water quality in a controlled environment.

Results and discussion

A water quality monitoring system was implemented with an IoT platform designed with a waterproof casing containing a microcontroller, sensors, solar panel, and even a micro USB cable for device configuration. This prototype was specially

TABLE I
Table Physico-chemical parameters for tilapia culture water

Parameter	**Ideal Conditions**	
	Range	***Effect***
Dissolved Oxygen	5 a 7 mg/l	Tilapia require an adequate level of dissolved oxygen in the water to breathe properly.
Temperature	25 ºC a 30ºC	Water temperature plays a crucial role in tilapia metabolism
Hydrogen Potential	6.5 a 8	Values outside this range may affect the health of tilapia and their ability to obtain nutrients.

designed to measure the physio-chemical elements of water: temperature, oxygen and pH. The microcontroller receives the data captured by the sensors. Subsequently, the microcontroller uses Wifi technology to send the data of these measurements to our cloud storage system.

The IoT platform test was performed in a controlled environment, where the ambient temperature was 29.4ºC and 57% humidity in the environment. In this same environment, the pH and dissolved oxygen sensors were calibrated with the substances defined for this purpose.

To compare the functionality of our sensors, we took parallel measurements of the parameters (pH, oxygen and temperature) for water quality monitoring, using commercial sensors and the sensors of our IoT platform. Table II, III and IV show the measurements obtained from the pairs of sensors, at 15-minute intervals and with the margin of error generated in each measurement.

TABLE II
Parameter measurements Hydrogen Potential water

Times Average	**PH values**		
	Sensor Platform	***Commercial Sensor***	***% Error***
10:10 a.m.	7.2	7.53	-4.38
10:25 a.m.	7.15	7.48	-4.41
10:40 a.m.	7.18	7.46	-3.75
10:55 a.m.	7.14	7.46	-4.29
11:10 a.m.	7.12	7.5	-5.06

TABLE III
Parameter measurements Dissolved oxygen water

Times Average	**OD values**		
	Prototype Sensor (mg/l)	***Commercial Sensor (mg/l)***	***% Error***
10:10 a.m.	8.0	7.4	+8.1
10:25 a.m.	7.67	7.4	+2.7
10:40 a.m.	7.67	7.4	+2.7
10:55 a.m.	7.08	7.4	-4.32
11:10 a.m.	7.32	7.4	-1.08

The storage of the data received via WiFi from our IoT platform is done through Firebase BaaS (Backend as a Service)

TABLE IV
PARAMETER MEASUREMENTS WATER TEMPERATURE

Times Average	Values Temperature		
	Prototype Sensor(ºC)	***Commercial Sensor(ºC)***	***% Error***
10:10 a.m.	28	28	0
10:25 a.m.	28	28	0
10:40 a.m.	28	27	+3.7
10:55 a.m.	28	27	+3.7
11:10 a.m.	28	27	+3.7

which allows us to increase the scalability of our system and gives us the opportunity to statistically analyze the data series and know precisely the status of the fish in real time. In Fig 5. We see the data of water quality parameter measurements stored in Firebase.

Fig. 5. Visualization of the data stored in our cloud storage provider.

The presentation of the data for monitoring water quality parameters in our system is shown in Fig. 4, confirming that the connection was successful and we were able to send and receive data from the sensors in real time.

CONCLUSIONS

Our IoT-based water quality monitoring system allows staff to measure pH levels, dissolved oxygen and water temperature from remote locations and closely monitor the well-being of the tilapia culture.

The implementation of the water quality monitoring system is a clear example of the benefit that technology brings to the Tilapia farming ecosystem, with the collection of data using IoT, providing information that is analyzed and displayed in real time, which is useful for fish farmers to respond immediately with accurate actions that help maintain the quality of water used in the tilapia farming ponds.

Our IoT-based water quality monitoring system could be enhanced by implementing machine learning methods to generate water regulation strategies focused on predicting, classifying and evaluating water quality indicators such as dissolved oxygen, pH and temperature.

ACKNOWLEDGMENTS

Ministerio de Agricultura y ganadería (MAG), through the Centro de Desarrollo de Pesca y Acuicultura (CENDEPESCA) for lending its facilities for testing.

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