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Short Communication

IoT-based Coastal Fisheries Monitoring System

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Abstract: Coastal fisheries activities play an important role in contributing to economic development, especially for countries that have a wide coastline. Among the coastal fisheries activities that are commonly practiced by the locals is the farming of fish, shrimp, and various other marine life in cages. However, this activity is exposed to natural risks such as marine heat wave, high pH and red tide. In addition, water pollution caused by daily human activities such as tourism and industry also affect coastal fisheries activities. To ensure sustainable and quality seafood, innovation in the field of information technology can be utilised. This technical paper explains the development of a coastal seawater monitoring and data logging system for use by fishers. The data observed by this system are temperature, pressure, air humidity, wind speed, water pH and environmental images using several sensors controlled by NodeMCU ESP8266 and Arduino. The system is deployed on a few buoys located within a range of 10 to 50 meters from the cage breeding area in the coastal region. Its purpose is to identify the occurrence of maritime hazards, such as heat waves and red tides, at an earlier stage. The control system on the buoy that uses battery and solar energy sends the data observed by the sensor using the 4G telecommunication network signal to be stored in cloud storage. Farmers can access water quality information around their cage breeding areas in real-time by using mobile phones and personal computers that are installed with an interface application developed using the Arduino IDE software and Blynk platform. This technology that uses IoT can help coastal farmers to take early action that can reduce the risk of losses due to some natural phenomenon.

Keywords: Arduino; buoy; fisheries; internet of things (IoT); monitoring; photovoltaic

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1. Introduction

The fishing industry is important to countries with coastlines, as well as to their coastal communities, as it can provide employment opportunities and sources of income. In addition to being sold raw, seafood can also be added value in the form of various downstream products. In addition, this industry is also very important because fish is a source of protein, fatty acids and micronutrients that are very necessary for the human body (McClanahan *et al*., 2015; Hall *et al*., 2013). Globally, the fishing industry contributes approximately 80 million tons of marine products for direct human consumption each year (Da Silva, 2016). This industry also contributes to the economy of the country involved with an estimated annual gross income of US$ 80-85 billion (Sumaila *et al*., 2017), in addition to providing various employment opportunities in related fields for an estimated 260 million people, with most fishermen participating in small-scale fishing (Teh & Sumaila, 2013). In Malaysia, coastal fisheries contribute to the national Gross Domestic Product (GDP) and 60–70% of fishes supply the protein intake for national animal with per head consumption of 47.8 kg per year (Mazuki *et al*., 2020). It is also believed that fisheries are one of the main sources of the government's strategy to maintain and increase the domestic food production and as the primer element of food security and nutrition strategy livelihoods.

However, marine fisheries are vulnerable to various anthropogenic threats that affect the economic performance of fisheries, such as overfishing, pollution and climate change (Noone *et al*., 2013). Climate change has posed a major threat to marine fisheries because of changes in the chemical and physical conditions of the ocean (Portner *et al*., 2014) and has directly contributed to the observed increase in the frequency, intensity, and duration of marine heat waves over recent decades (Wernberg *et al*., 2021). Therefore, continuous monitoring techniques need to be carried out especially for coastal fishers who carry out livestock activities in cages. Early detection may speed up follow-up actions to reduce the risk of losses. Therefore, through this research, a prototype of remote data logger with independent power source has been developed to monitor the condition of costal sea water condition.

1.1 Project Objectives

There are three main objectives of this project. The first objective is to design and develop a prototype of remote data logger with sustainable independent power supply system. The next objective is to design and develop a monitoring system to monitor the coastal sea water condition to alert the user earlier for any potentials of natural disaster. The third objective is to study the data acquisition techniques that are suitable for very limited energy resources.

1.2 Scopes of Project

This project was developed modularly by combining several sensor modules and processing systems that are readily available on the shelf. The data detection and processing part uses the Arduino platform, which was NodeMCU ESP8266. This component has a built-in wireless network module. In addition, the implementation of the project must be surrounded with 3G or 4G network coverage area so that continuous data could be obtained as shown in Figure 1. For the user interface, Arduino IDE and Blynk software had been used to develop the interface application. Users can access the observed data and images of the coastal environment using personal computers and smartphones. Finally, an independent power supply had been designed and developed using a photovoltaic (PV) system. The excess energy generated during the day was stored using lead-acid batteries for use as power back-ups when there is no sunlight condition. Due to limited energy storage, power consumption analysis is required so that the monitoring system can optimally function.

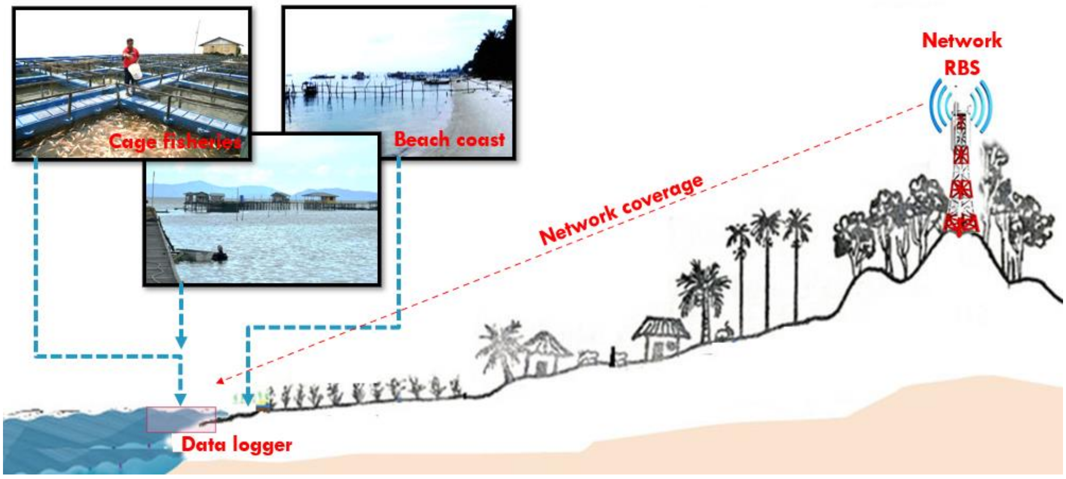

Figure 1. The overview of project implementation

2. Methodology

The project required the observation of many parameters, including pH level, temperature, relative humidity, wind speed, air pressure, and surrounding imagery. The pH electrode probe sensor (Mybotic E-201-C) is used to detect the levels of acidity and alkalinity in the water. Simultaneously, the temperature sensor (Cytron DS-18B20) is used to ascertain the temperature of the sea, while the wind speed anemometer (Zigbee BGT-FS1) is utilised to compute the velocity of the wind encompassing the coastline region. Humidity sensor (Mybotic DHT11) and barometric pressure sensors (Mybotic BMP180) are used to gauge the surrounding moisture and air pressure in the nearby coastal region. A set of images depicting the coastal region was acquired utilising an ESP32 OV2640 image sensors module.

All sensors were interfaced with the microcontroller NodeMCU ESP8266 that acts as an open-source IoT platform as shown in Figure 2. The MCU sent the observed data to the registered cloud storage, while the user interface application that had been developed on personal computers and mobile phones accesses the data. Continuous data received by cloud storage was continuously displayed on the user interface terminal such as real-time data.

The implementation routine of this system had been developed using the Arduino IDE, which is an open-source programming language provided by Arduino. In addition to the Arduino IDE, graphic programming called Blynk had also been used to build interface applications on smartphones, whether IOS or Android platforms. In addition to the real-time data, users can also download data in bulk using the "data import" function available on the Blynk platform. The downloaded data is in comma-separated values (CSV) format and sent via the email registered during Blynk account setup.

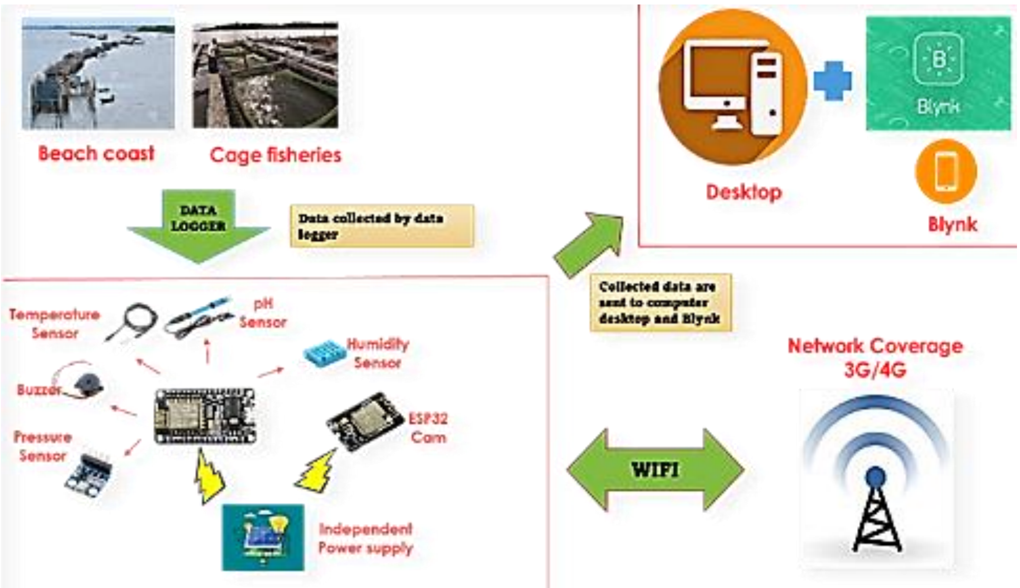

Figure 2. System overview

3. Results and Discussions

IoT-based system can furnish exhaustive and real-time data pertaining to a multitude of environmental factors that are vital for the well-being and efficiency of marine ecosystems, as applied to the monitoring of coastal fisheries. The system utilises an assortment of sensors, with each one fulfilling a distinct function. The pH of the water is a crucial parameter for marine life. Substantial deviations from the ideal pH range have the potential to detrimentally impact the survival of marine species. The sea temperature is crucial for the growth of phytoplankton and other marine plants and influences the metabolism and behaviour of marine species. However, wave conditions, coastal erosion, and the distribution of nutrients and pollutants are all influenced by wind speed. The rate of evaporation and precipitation, which in turn has an impact on humidity, affects the salinity levels in the water. The variations in atmospheric pressure have the potential to impact various meteorological phenomena, such as precipitation and cyclone patterns. The image sensor concludes by capturing images of the coastal region. The visual data contained in these images can be utilised to track physical changes along the littoral or detect the presence of particular species.

Figure 3 shows part of the module that functions to control the monitoring and data acquisition system. The same diagram also shows the output obtained from the activity of this control system has been displayed on the user interface. All sensors were connected to the open-source IoT platform NodeMCU ESP8266. The MCU sends observed data to cloud storage, where the PC and mobile phone user interface applications would access it. Cloud storage data was shown on the user interface terminal in real time. The Arduino IDE, an open-source programming language from Arduino, was used to construct this system. Blynk was used to develop smartphone interface apps for iOS and Android platforms in addition to the Arduino IDE.

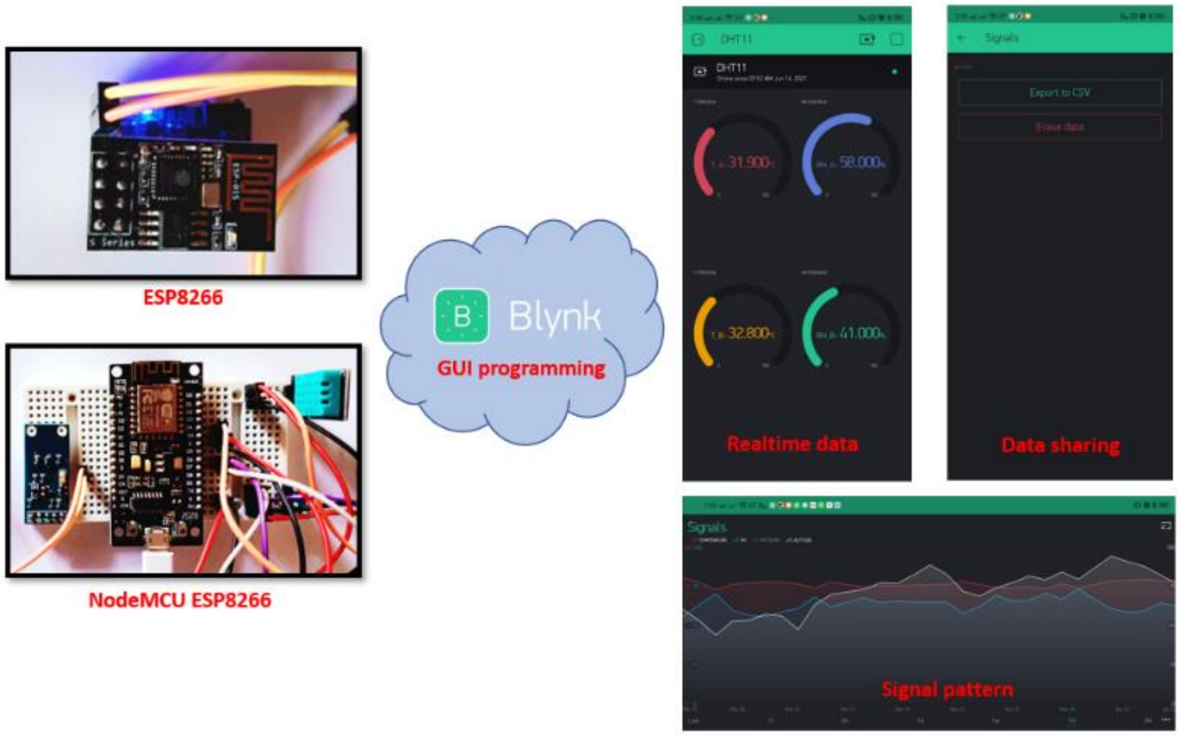

Figure 3. NodeMCU ESP8266 hardware setup and Blynk user interface

The monitoring system was tested in a lake area located about 30 meters from the weather station of the National Defense University of Malaysia (UPNM). The weather station is under the supervision and maintenance of the Civil Engineering Department. The accuracy and reliability of the data observed by the monitoring system are confirmed by the data obtained from the UPNM weather station, as shown in Table 1. In addition, the pH data of the lake water is compared with the data observed using the Oakton AO-35613-22 digital pH sensors. On average, the difference between the data observed by the monitoring system and the weather station is less than 5%.

Table 1. Comparison between data observed using monitoring systems and weather stations

	pH			***Temp (°C)***			***Wind speed (ms^{-1})***			***Humidity (%)***			***Pressure (mb)***		
	Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
IoT-based system	7.0	7.7	7.3	23	32	27	12.8	20.2	15.4	74	86	80	1010	1017	1012
Weather station	7.2	7.6	7.4	23	34	28	10.5	22.5	16.3	72	89	78	1006	1019	1011

Figure 4 shows an example of bulk data imported from cloud storage. The NodeMCU ESP8266 controller module has a maximum data transmission rate of 72.2 Mbps, making it suitable for real-time applications such as data and video streaming. Nevertheless, the effective rate of data transmission is significantly contingent upon the rate of the data communication network inside a certain region. This raw data file uses CSV format and can be opened and manipulated using Microsoft excel software. This data can also be imported repeatedly without limit.

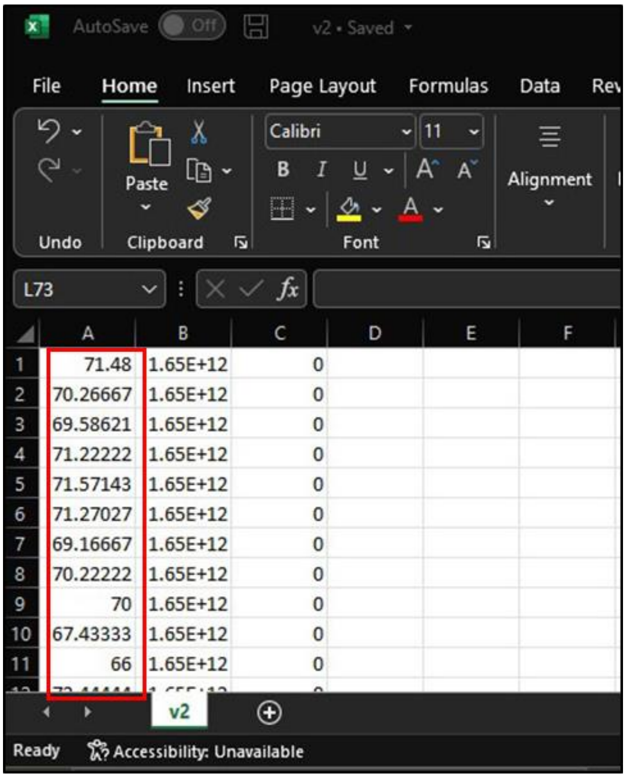

Figure 4. Relative humidity data downloaded from cloud storage in CSV format

Figure 5 shows a real-time image display using the ESP32-CAM module. The ESP32-CAM is a small size, low power consumption camera module based on the ESP32 module. It comes with an OV2640 camera and optionally provides an onboard TF card slot. The ESP32-CAM can be widely used in intelligent IoT applications such as wireless video monitoring, WiFi image upload, QR identification, and so on. By default, video streaming by ESP32-CAM was displayed on the web-server page provided by the manufacturer that can be accessed using any internet browser such as Google Chrome and Microsoft Edge. To be more flexible, developers can develop their own display platform in various ways such as using C programming. For now, this project still using the web-server page provided for video-streaming. This page also allows the adjustment of image quality according to the user's needs such as setting the resolution, display speed and the use of filters.

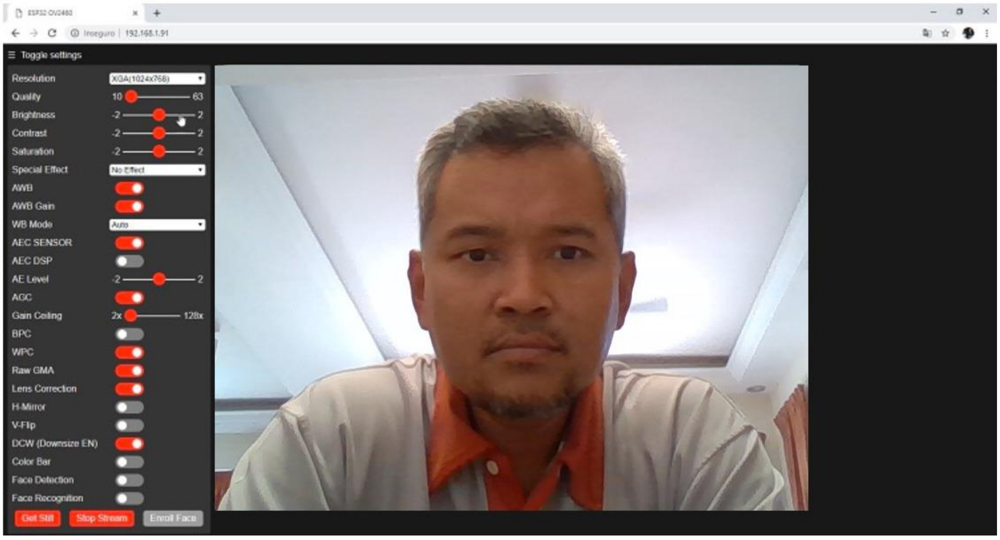

Figure 5. Image captured by ESP32 camera

Finally, Figure 6 shows an independent power generator that works to supply DC current to the system. Because the size and weight of the load that can be accommodated by the buoy is limited, the power supply unit has been designed optimally. The results of the analysis for energy performance showed that all the modules used in this monitoring system required an energy supply of 18.5 watts per hour. Therefore, as many as 3-unit 40W, 12V PV panel, 1-unit 25AH, 12V battery pack and 1-unit 10A, 12V charge controller are required. With the components mentioned, this power generator unit can produce 444W of energy per day to meet the requirements of the monitoring system in order to operate continuously for 24 hours. However, the efficiency of the PV panel will decrease by an estimated 0.5% per year as well as the charge and discharge capacity of the battery pack used. Therefore, regular maintenance is required from time to time to ensure that the energy supply is sufficient.

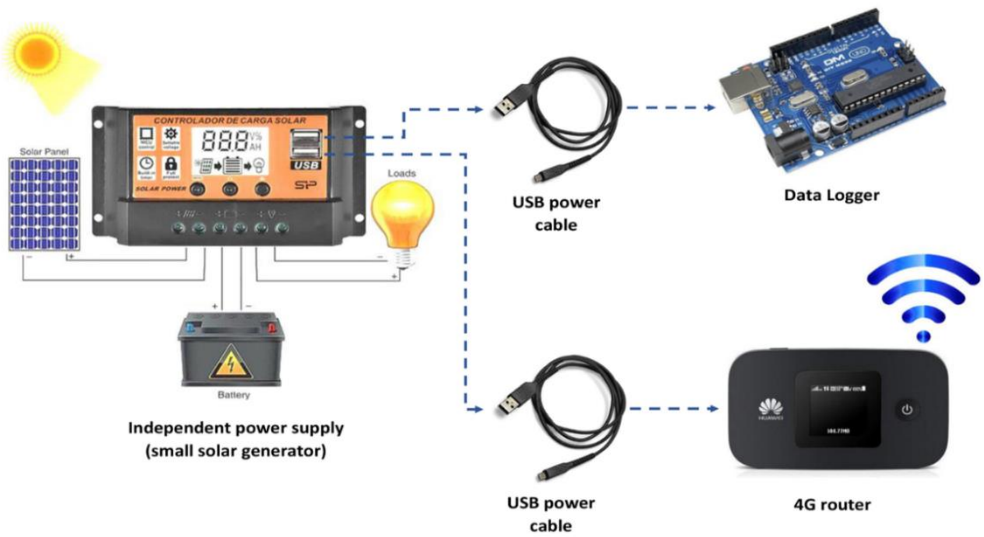

Figure 6. Independent power generator using PV system

4. Conclusion & Recommendations

This project has proven that the IoT module can be used as a component for a data logger and monitoring system. Not only the system development cost is economical, this IoT module is also supported by professional development software by Arduino IDE and Arduino Blynk for free. Arduino's existence as an open source has catalysed creativity and innovation in IoT technology worldwide. For coastal fishermen, this system can help them obtain early information related to the environmental conditions of their livestock. With the available information, the necessary actions can be planned and implemented efficiently to reduce the risk of loss. This system operates continuously and can be reached from any place at any time. The continuation of this project is the construction of a buoy that can accommodate the size and weight of the system safely. In addition, a suitable protection box is also required so that the system hardware and power supply units able to endure extreme situations that often occur in coastal areas. In addition, the efficiency of the power supply unit can also be improved through a hybrid energy generation method, which is a combination of solar energy, wind, and tidal currents.

Author Contributions:

Jaafar Adnan: Conceptualization, Investigation, Methodology, Data collection and analysis. Mohd Taufiq Ishak: Literature review, data analysis, and manuscript writing. Fakroul Ridzuan bin Hashim: Securing funding and project administration. Mohd Rashdan Saad and Mohd Rosdzimin Abdul Rahman: Supervision, validation and visualization. All authors participated in revising the manuscript and approved the final version for submission.

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Conflicts of Interest: The authors declare no conflict of interest.

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