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A Decentralized Data Logger System for Water Related Disaster with Wireless Mesh Topology

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Abstract: Climate change refers to the increase of earth's temperature. It results to catastrophic disasters such as floods, heavy rains, tsunamis, storm surge, and extreme heat. The events produces property destruction, loss of crops, landslides, melting of ice and many more. Most of the disasters stated are water-related, that parameters such as water level and water flow are the primary factors of such phenomena, so this study developed a smart environment network that monitors the rise of water level and water flow. The system utilized a Zigbee protocol (802.15.4) for the transmission of the signal from the Base Station to other nodes. Bluetooth technology was used for the access of the users to the network. A localized water level sensor was utilized with the help of an operational amplifier and together with the water flow sensor. The system underwent evaluation tests such as functionality test and reliability test for three days. Analysis of the results showed that the system functions as expected. It indicates that the study was reliable for detecting water level and water flow reading especially on the transmission of data even if there were no electric power, no internet connection and no cellphone signal.

Keywords: Disaster risk management, flood, wireless network, automated system, android

1. Introduction

There are climate change impacts such as environmental, social and economic. These impacts will be adverse and out of its severity, it can cause the rise of earth's average temperature. Climate change brings extreme weather conditions and there will be a worldwide experience on it. Most of the impacts are water-related, that is why this is now the focus of this study. According to the study [1], "the categorization of water-related disasters include floods, storms, waves, slides, droughts, epidemics, contamination and climate change".

Floods can happen to a place if the drainage system is not totally good or the place is a flood prone area. Sometimes, even if there is no typhoon, there are flooding in some areas because of rains. But, when it comes to river flooding, then there must be a greater force or event that could lead to overflow the river. Most cases, such event occurs at an instant especially when the rain is heavy. According to [2], climate change can result to floods particularly on rivers that can result to frequent occurrence in some places and have a light impact in others. As the temperature arises, evaporation of water from land and oceans can change the size and frequency of precipitation, thus it can affect river flooding.

There is a flood forecasting and warning system project of National Irrigation Administration (NIA), National Power Corporation, and Philippine Atmospheric, Geophysical and Astronomical Services Administration [3]. This project is

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Flood Forecasting and Warning System for Dam Operation (FFWSDO), wherein it mitigates flood damages by giving warning to the nearby communities because of dam operations. The said project was installed in five dam sites (Ambuklao and Binga dams in Agno River Basin, Magat Dam in the Cagayan River Basin, Angat and Pantabangan dams in the Pampanga River basin). Another project of DOST-PAGASA is Koica Project, wherein it is installed on rivers to monitor flood and it has an operation center as well as it has warning facilities (siren and voice) backed by Korean technology [4].

The main drawbacks of the said systems were some of the equipment was not functioning, the system had misconfiguration, there was a slow process of information distribution and a centralized system. Moreover, a problem can occur if there is an upcoming flood then there is a failure to transmit the data going to the equipment in giving warnings. Through this failure of transmitting the data, the data will not be received to give warning. On the other hand, system misconfiguration draws a lot of attention since it can result in miscommunication of the whole system. Large power consumption loss is inevitable because the system transmits data but no one receives it.

From the occurrence of the drawbacks of the equipment mentioned, the researcher developed a localized flood warning system and has features of smart environmental network and wireless mesh topology with real-time monitoring for fast data access. With this system, the transmission of data is consistent even if one node in the network malfunctions. With the utilization of a smart environment, it offers a stand-alone system for data acquisition and it scans the network first if there are nodes that are not good then there will be no data going to those malfunctioned nodes. It results in less power consumption. The said system can be accessed via the mobile application of the users to monitor flood even without Operation Center (Control Office). Therefore, the system is decentralized meaning the user can directly access the network for fast data information. This device can still operate even if there is no power from electric companies and no internet connection. And, the water level was anchored to [5], as Low is <0.5m, Moderate is 0.5m to 1.4m & High is >=1.5m.

2. System Design Setup

2.1 System Architecture

In Fig. 1, it illustrates the components used such as the input sensors (localized water level sensor by the use of an operational amplifier, water flow sensor), base station and nodes (Zigbee transceiver modules, microcontroller and Bluetooth module) and the mobile application. The first thing to do is to gather the data from the sensors, then transmit it to the Base Station, so that it can transmit to the nodes. Then the nodes processed the data by utilizing microcontrollers and send it to the Bluetooth modules so that the users can access the data. There is a mobile application that is dedicated to access the data in the network.

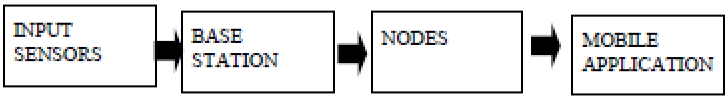

Fig. 1 - Block diagram of the system

2.2 Project Setup

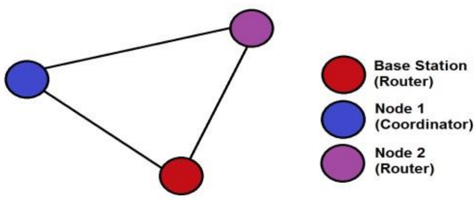

Fig. 2 - Design Setup of the Whole System

Referring to Fig. 2, it starts when the device gathered the data about the water level and flow rate on the Base Station. After which, the device transmitted the data to the nodes (Node 1 and Node 2) so that the mobile phones with the mobile application can access the data. This platform has become public or an open access so that all users can monitor the data about the events happening. Moreover, normal users such as citizens can access also the data. They could be prepared if there would be an upcoming disaster since there would be a warning on the data stored in the network. There are cases that there are no internet connection, no power, and no cellphone signal and from that, the system can cope with it, so the users can still access the data.

In a network, there must be only one Coordinator and the rest can be Routers and End-Devices. In this case, if there are children (nodes) that would be added to the network then obviously the family will grow. Therefore, the more children the greater distance for the data transmission. Lastly, the Routers must connect first to the Coordinator.

2.3. Smart Environment and Wireless Mesh Topology

The researcher used a smart environment and mesh topology for the system. According to [6], “a smart monitoring system when the environment itself becomes a self-monitoring and self-protecting environment that is aware of its current status with the possibility of an automatic alarm rising if some event occurred.”

With the help of this environment, the analysis of transmitting data would be more power efficient if there are nodes that are malfunctioning. If there is a non-operative node, then the system will sense it and it will not transmit the data going to that malfunctioned node. So from that, there would be less power consumption on the transmission of data. Therefore, it tells that the network is smart because of its self-monitoring of network function that is also a built-in algorithm of the Zigbee modules. In addition, the system was also automated on the data acquisition of water level and flow rate as inputs.

The system used wireless mesh topology to transmit the data to the nodes since it cannot be stopped because it is a non-hierarchical type of transmission. The network can widen the area of scope by adding additional nodes. This study used 2 nodes since it is only for laboratory testing purposes.

Wireless mesh topology and a smart environment gave the system the features that made the reason for deploying it for water level monitoring and water flow reading on remote areas. The system consists of radio nodes organized in a mesh network.

2.4 System Components

2.4.1 Water Level Sensor

Fig. 3 shows a localized sensor that was made out of an operational amplifier that served as the water level sensor. It was connected to a microcontroller (Atmega328P-PU) for data analysis. It has a digital output that is suitable as input for the said microcontroller.

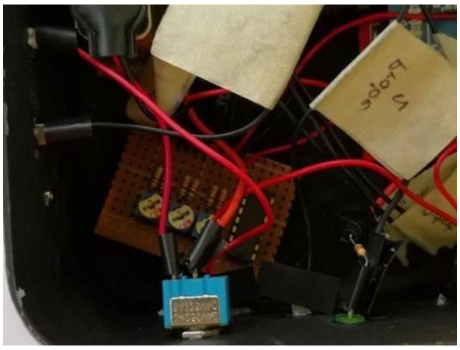

Fig. 3 - Localized Water Level Sensor

2.4.2 Control Unit

The microcontroller (Atmega328P-PU) was used in this study. It served as the control unit of the system, that it handles the data processing. It follows the original STK500 protocol for communication.

The features such as Analog and Digital pins were utilized, since the sensors should be connected to these types of pins to have communication.

2.4.3 Transmitting Module

This study used XBee modules as shown in Fig. 4 that operates in Zigbee protocol (802.15.4). These modules handled the long range communication between the Base Station and the nodes for the transmission of data. It operates an Outdoor/RF Line-of-Sight range of 1200 meters [7].

Fig. 4 - XBee module

2.4.5 Communication Module

This study utilized Bluetooth technology to serve as the gateway of the users to access the data in the network. They can connect their mobile phones with the mobile application installed that is exclusively dedicated to the device.

The target of this project is to have the said mobile application as a pre-installed app.

2.4.6 Water Flow Sensor

The study used water flow sensor (YF-S201) for the reading on the flow rate as it follows the principle of "Hall effect". The unit for the water flow is in L/Hr and it is powered by 5-24 Vdc.

3. Evaluation Background of the System

3.1 Testing of the Components

The researcher calibrated the materials by conducting tests. For the water level sensor, it was tested on a container that has water if it can detect water variations. Water flow sensor was also tested by making the motor rotate and watch over the readings. For the RF modules, they were configured in order to communicate with the same network by using a software (XCTU). Bluetooth module was also configured together with the microcontroller if it can be detectable by mobile phones and can be connected as well. Furthermore, the whole system was developed as shown in Fig. 5

(a) Node 1 (b) Node 2 (c) Base station

Fig. 5 - The Decentralized System

3.2 Data Gathering Procedure

As for the data gathering, the researcher conducted the testing on the functions of the device such as to detect water level and water flow reading. At first, the researcher set the measurement for each level (Low, Medium and High) according to the Project NOAH's website on the flood tab [5]. The probes of the water level sensor were placed on a blue pipe with designated level of measurement.

The flow sensor was positioned at the bottom of the river. The researcher made a casing that was submersible since the said sensor was not designed for underwater purposes. Flow rate was recorded to the device as well as the water level reading and it reflects it to the mobile application developed by the author. Moreover, if the Retrieve button is pressed, the system will show the very first start of data logging as illustrated in Fig. 6 If the Delete button is pressed, automatically the data will be deleted. The time of the mobile application depends on the time of the mobile phone and it gives the exact data reading every second. The screen shows the water flow reading and water level, however they appear one at a time because of data transmission.

Fig. 6 - Mobile application of the System

3.3 Test Installation of the System

Fig. 7 shows the test setup of the whole system in the River. The product was placed at the Antiao River, Samar, Philippines to gather data without human intervention. The Base Station was installed beside the riprap in order to compound its foundation. It was limited to that part of the river.

The setup was conducted for three (3) days for the evaluation of the functions. Moreover, the actual installation was conducted during the first day of the evaluation.

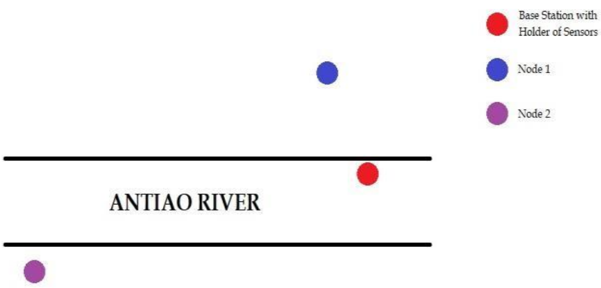

Fig. 7 - Test Setup in Antiao River

4. Experimental Results

4.1 Functionality Test

The product was tested for three (3) consecutive days to test its functionality for pilot testing. Table 1 shows the data for the testing of the product. The results revealed that the data is consistent on giving information to the user via mobile application.

During the 24-hour period per day of testing, the researcher chose to limit the time to the interval of six (6) hours. The data were recorded in the memory storage of the mobile phone, by pressing a button on the mobile application the user can retrieve the logged data. The data were logged at the exact time as the time interval. A validated testing instrument was provided for the evaluation of the system.

Table 1 Summary of the 3-Day Functionality Test

(a) First day of Evaluation

FUNCTIONS	6:00 AM	12:00 NN	6:00 PM	12:00 MN
Water level variations	Low	Moderate	Low	Low
Flow rate (L/Hr)	8	24	24	20

(b) Second day of Evaluation

FUNCTIONS	6:00 AM	12:00 NN	6:00 PM	12:00 MN
Water level Low variations	Low	Moderate		Low
Flow rate (L/Hr)	9	20	23	27

(c) Third day of Evaluation

FUNCTIONS	6:00 AM	12:00 NN	6:00 PM	12:00 MN
Water level Low variations	Low	Moderate		Low
Flow rate (L/Hr)	12	18	23	35

This graph in Fig. 8 presents the water level reading on the 3-day testing of the device. In this scenario, the water level variation depends on low tide and high tide. During the evaluation, the weather was fine. The medium level were reached during the 12 noon throughout the evaluation days. As referring to the calendar for the record of low tide and high tide, it tells that during those time the water level in the river starts to rise until it reached its maximum level. Moreover, after the High tide, the water level decreases and it started to Low tide.

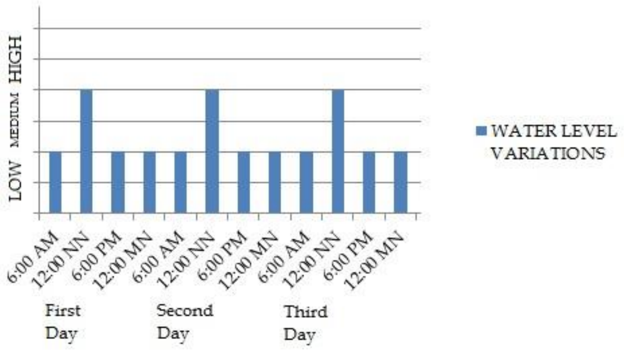

Fig. 8 - Logged Data for Water Level

Fig. 9 displays the different readings of the flow rate since Day 1 to Day 3. During the reading process, the value got zero in terms of its water flow because the river became still.

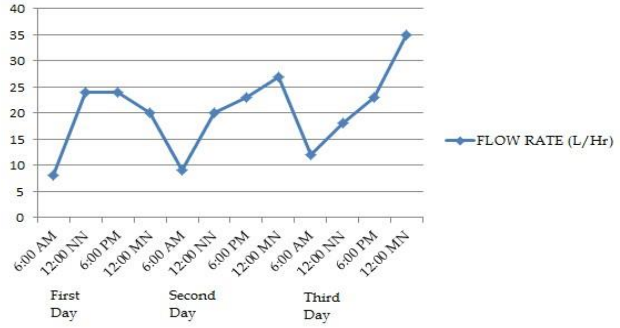

Fig. 9 - Logged Data for Flow Rate

5. Conclusions

This study has shown that the product identified the water related parameters in terms of its Normal Depth (Low Level, < 0.5 meters), Critical Depth (Medium Level, 0.5 to 1.4 meters) and Greater than Critical Depth (High Level, > 1.5 meters). In addition, the study developed a data logger that gave warning of the water level if it is equals or exceeds the critical value. It can log data also on water level variations and flow rate on the developed mobile application. Lastly, the results of the evaluation revealed that the system was reliable on the data transmission and logging of data on water level and flow rate.

Future research should therefore focus on installing a renewable power supply so that there can be a longlasting operation of the product. Moreover, changing the mode of communication from the product to the user, since the present study used Bluetooth technology. Obviously, this module is limited only to one user. Also, to add more nodes for multiple data gathering and present the data gathered in tabular form on the mobile application.

Acknowledgement

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