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**RESEARCH ARTICLE**

# Development of a Microcontroller-Based Wireless Sensor Network for Monitoring and Detection of Flood

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**ABSTRACT**

*System design deployed a wireless sensor network (WSN) in the monitoring and detection of flood. The WSN architecture comprised the sensor nodes, routing nodes, and a base station that connects with each other. Manometer and optical water level sensors, microcontroller, and the SIM900 GSM module form the sensor nodes. The sensor nodes were interfaced, configured, programmed, and powered by a 5vdc integrated power supply. Three water flow rate threshold values of <100m3/h, 100m3/h, and 330m3/h were selected as "Normal", "Warning" and "Flooding" respectively for SMS alerts. Empirical measurements were carried out and readings were collected every 5sec for 3hrs. Results showed that the microcontroller-based WSN system predicted flooding status with a 0.04% error in accuracy based on the water flow rate parameter and an average delay of 0.048sec in response time*

**Keywords:** *Flood; Microcontroller-Based; Water Flow Rate; Wireless Sensor Network (WSN)*

## Introduction

Flood is caused by frequent and extremely heavy rains or sudden melting snow combined with significantly reduced ability and the inability of an area to retain rainwater (WHO, 2022). Occupants of flood-prone localities need to safeguard their lives, and properties and most importantly, evacuate to safe locations if there are systems that can pre-warn them of the likelihood of flooding at a specific time. Though flooding positively impacts the environment, the negative aspect far supersedes the positive. Take for instance, in Africa, western Nigeria, Lekki precisely, millions worth of properties that were damaged and lives that were lost would have been averted if, there are on-ground detection and monitoring systems that can forecast the possibilities of flooding at the time.

There are existing flood detection and monitoring systems but, they are not intelligent, complex in design, delays in response time also, and implementation and maintenance costs are quite high. Here, the computational capabilities of the microcontroller (Arduino Uno) are used with the GSM module and data acquisition sensors, to deploy a wireless sensor network (WSN) for real-time data transcribing via a base station in the monitoring and detection of floods.

## Literature Review

The impact of flood on the ecosystem of a locality is usually high and detrimental, it is vital to analyze the flooding situation and develop a means of pre-warning the stakeholders for appropriate action to be taken. Pre-warning will eliminate emergency situations and ensure that timely precautions are taken. Effects of flood can be categorized under economic, environment, and people (Eschooltoday.com, 2022). During flooding, roads, bridges, farms, houses, and automobiles are destroyed, and people become homeless. Government deploys firemen, police, and other emergency apparatuses to help those affected, palliatives are rolled out, and governmental and non-governmental organizations are deployed. However, all these come at a heavy cost to people and the government. It usually takes years for affected communities to be rebuilt and businesses to come back to normalcy.

Many models of flood monitoring and detection have been proposed and implemented, with many lapses in either cost of implementation, maintenance, or ability to detect floods early enough for appropriate and timely action to be taken. In Ramesh (2022), Internet of Things (IoT) based early flood detection using machine learning was implemented using Artificial Neural Network (ANN) Convolution Neural Network (CNN). The work used water level and rainfall sensors as input to the Arduino microcontroller. Communication between the sensors and the microcontroller was achieved using the ESP8266 Wi-Fi device. It was shown that their predicted result came out to be 97.7722% accurate. The result did not specify the actual parameter on which the achieved accuracy was based.

In Anthone et al. (2014), Short Message Services (SMS) of length up to 7 bits over Wireless Mesh Sensor Network (WMSN) was used for early detection of flood. It is relatively simple and inexpensive to implement but, the system showed delays in the response time.

Also, in Degrossi et al. (2013) a model which is based on Open Geospatial Consortium’s (OGC) Sensor Web Enablement (SWE) standards, which collects data to be shared in an interoperable and flexible manner was deployed. Spatial Data Infrastructure (SDI) geospatial software platforms were used to manage environmental risks; however, the system was complex and expensive.

In Victor (2012), a real-time model based on an alarm system was implemented. In the design, the alarm start is activated when a plain area is flooded however, the technique cannot be used for real-time flood detection. In (Basha, 2008) Sacramento Soil Moisture Accounting (SAC-SMA) was deployed for easy detection of flood, and it is very efficient but, quite expensive to implement and maintain.

In Hughes et al. (2006), an inexpensive model of flood detection that could be implemented in developing and poor countries was implemented but, the maintenance cost is very high. Review shows that several commercial models of flood warning systems are currently available but, many of them are either expensive to implement, and maintain or unable to sense water levels early enough to alert the residents. It may be established that the shortcomings of the existing flood detection and monitoring systems bother on the response time, complexity in the design, and high cost of implementation and maintenance.

### Wireless Sensor Network (WSN)

Wireless Sensor Network (WSN) is a non-infrastructure wireless network deployed in many wireless sensors basically in an ad-hoc manner that is used to monitor a system, physical or environmental conditions. Sensor nodes are used in WSN with the onboard processor that manages and monitors the environment in a particular area. They are connected to the Base station which acts as a processing unit in the WSN System. Base Station in a WSN System is connected through the internet for data sharing.

### Theory of Work

This work considered Ugwuaji river as a case study model. The case study location is Enugu state, eastern Nigeria. The model of the river is designed as conceptualized in Figure 1.

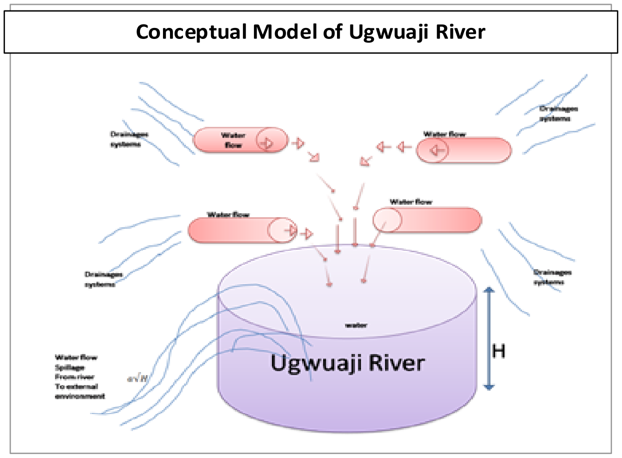


**Fig 1**: Model of the Ugwuaji River

The model architecture shows the river dynamics and water from various drainage systems that flows into the river to be proportional to pressure *P*. The river when overflowed spilled through the environment at a rate that is proportional to the square root of the water height, *H*, of the river. The square root in the water flow rate makes the river nonlinear. This is represented differentially by:

$$\frac{d}{dt}\,Vol = A\,\frac{dH}{dt} = bP - a\sqrt{H} \quad (1)$$

Where *H* is the river height, *V* is the volume of the water, *P* is the applied pressure, *A* is the cross-sectional area of the river, *b* is the flow rate constant into the river, and *a* is the flow rate constant out of the river. The sensing element considered pressure as a key factor that will differentiate flood from erosion and water. The linear relationship between the sensor output and the height of the river is achieved through the programming of the microcontroller. The output function of the microcontroller is then determined through the variations in pressure and water level. Therefore, pressure and water level parameters form the input to the system. The linear relationship is presented using volume at varying heights *X* and sensor differential output *Y* (Mumu and Yadav, 2012).

$$\Delta v_s = \frac{\Delta Y}{x} * H \qquad (3)$$

Where $\Delta v_s$ is the sensor's differential output and *H* is the height. The linear relationship is deployed to determine the sensor's differential output ΔV at the new height. The sensor is then calibrated using the linear relationship which considers the pressure and water level.

The relationship between pressure and water flow rate is established using the Bernoulli equation, expressed as:

$$p + \frac{1}{2}\rho v^2 + \rho g h = C \qquad (4)$$

Where; p is the pressure of a certain point in the fluid; v is the flow velocity of the fluid at that point; ρ is fluid density; g is the acceleration of gravity; h is the height of the point; C is a constant. It can also be expressed as:

$$p_1 + \frac{1}{2}v_1{}^2 + \rho g h_1 = p_2 + \frac{1}{2}v_2{}^2 + \rho g h_2 \; (6)$$

## Materials and Method

Threshold values of the sensor's parameters were determined and used in programming the microcontroller (Arduino Uno) for processing and updating, such that when the threshold value is surpassed, an SMS is activated. The WSN architecture comprised the sensor nodes, routing nodes, and a base station that connects with each other. The sensor nodes are the pressure (manometer), optical water level sensors, the microcontroller, and the SIM900 GSM module. The manometer and optical water level sensors are programmed, configured with the microcontroller and the SIM900 GSM module then, powered by a 5vdc integrated power supply. The system architecture is presented in Figure 2. The sensors at intervals measure the corresponding parameter's values. The microcontroller processes these values by comparing the updated values with the thresholds to determine deviation. SMS is activated by the microcontroller through the transmitting GSM module if, the updated parameter value is greater than the threshold value. The receiver SIM900 GSM module which is interfaced with an LCD receives real-time updates (SMS) from the microcontroller via the base station.

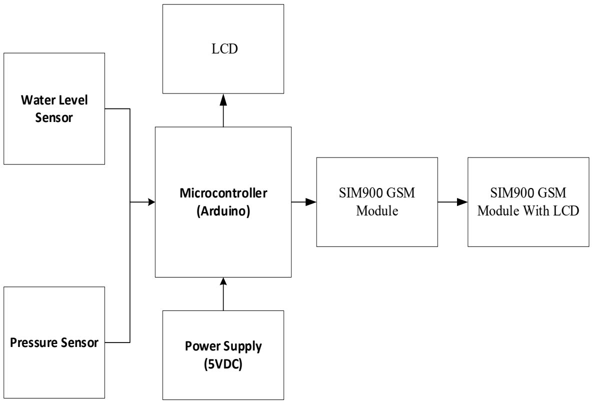
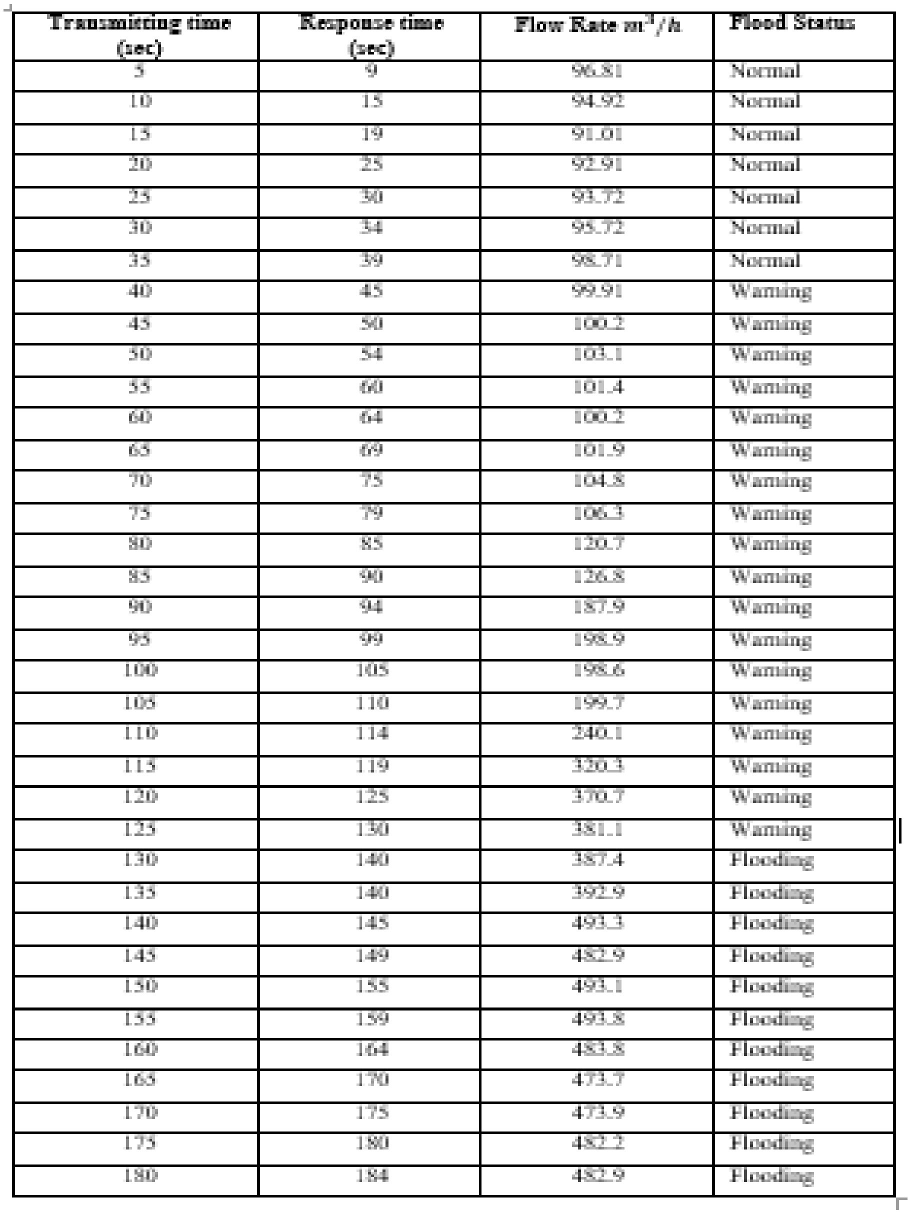


**Fig 2**: ***System Architecture***

The sensor nodes that acquire real-time data from the river basin and transmit it to the receiver SIM900 GSM module were deployed in the case study location for physical measurement. Three water flow rate threshold values of <100m$^3$/h, 100m$^3$/h, and 330m$^3$/h were selected as "Normal", "Warning" and "Flooding" respectively for SMS alerts (Amy, 2016). The microcontroller was programmed to activate the three specific levels of action. The first level is activated if the system threshold is less than 100m$^3$/h, then an SMS indicating "Normal" is sent. The second level of action is activated if the threshold of 100m$^3$/h, is reached then, an SMS indication "Warning" is sent. On the other hand, if the threshold is 330m$^3$/h and above, then an SMS indicating "Flooding" is sent.

## Result and Discussions

Enugu State's monthly rainfall data shows that rainfall is heavy during the months of July and September (Igwenagu, 2016). Therefore, Empirical measurements were carried out in the month of July and readings were collected every 5sec for 3hrs. Table 1 presents the results showing the transmitting time, system response time, water flow rate, and flood status of the case study river.



| Transmitting time (sec) | Response time (sec) | Flow Rate $m^3/h$ | Flood Status |
|---|---|---|---|
| 5 | 9 | 96.81 | Normal |
| 10 | 15 | 94.92 | Normal |
| 15 | 19 | 91.01 | Normal |
| 20 | 25 | 92.91 | Normal |
| 25 | 30 | 93.72 | Normal |
| 30 | 34 | 95.72 | Normal |
| 35 | 39 | 98.71 | Normal |
| 40 | 45 | 99.91 | Warning |
| 45 | 50 | 100.2 | Warning |
| 50 | 54 | 103.1 | Warning |
| 55 | 60 | 101.4 | Warning |
| 60 | 64 | 100.2 | Warning |
| 65 | 69 | 101.9 | Warning |
| 70 | 75 | 104.8 | Warning |
| 75 | 79 | 106.3 | Warning |
| 80 | 85 | 120.7 | Warning |
| 85 | 90 | 126.8 | Warning |
| 90 | 94 | 187.9 | Warning |
| 95 | 99 | 198.9 | Warning |
| 100 | 105 | 198.6 | Warning |
| 105 | 110 | 199.7 | Warning |
| 110 | 114 | 240.1 | Warning |
| 115 | 119 | 320.3 | Warning |
| 120 | 125 | 370.7 | Warning |
| 125 | 130 | 381.1 | Warning |
| 130 | 140 | 387.4 | Flooding |
| 135 | 140 | 392.9 | Flooding |
| 140 | 145 | 493.3 | Flooding |
| 145 | 149 | 482.9 | Flooding |
| 150 | 155 | 493.1 | Flooding |
| 155 | 159 | 493.8 | Flooding |
| 160 | 164 | 483.8 | Flooding |
| 165 | 170 | 473.7 | Flooding |
| 170 | 175 | 473.9 | Flooding |
| 175 | 180 | 482.2 | Flooding |
| 180 | 184 | 482.9 | Flooding |

From the table, the microcontroller-based system predicted the flooding status of the river with a 0.04% error in accuracy based on the water flow rate parameter. On the other hand, the system response time is lagging by an average of 0.048sec as shown in Figure 3. The operational performance analysis implies that with the WSN, the stakeholders of the Ugwuaji river will have the updated flood status, timely enough to initiate appropriate actions where necessary.

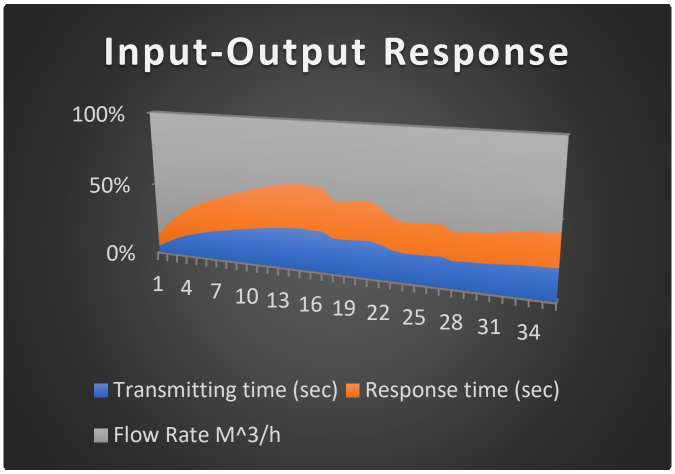


**Fig 3**: ***System Input-Output Time Response***

## Conclusion

Flood can impact negatively on the economy, environment, and people within any flood-prone area. Flood can be caused by so many factors such as rainfall, change in water level, water flow from drainage systems, etc. Timely pre-warning of the stakeholders is one of the appropriate actions deemed necessary because it will eliminate emergencies. A wireless sensor network is one of the effective means to timely monitor and detects flood. Pressure, water level, and water flow rate could be used as sensing element parameters in the monitoring and detecting system. The empirical result showed that the microcontroller-based WSN system predicted flooding status with a 0.04% error in accuracy based on the water flow rate parameter and an average delay of 0.048sec in response time. The operational performance analysis implies that with the WSN, stakeholders will have timely access to the updated flood status such that appropriate actions can be initiated.

## Acknowledgment

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