Flood Monitoring and Detection System using Wireless Sensor Network

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ABSTRACT— ***Nigeria as a whole and Uyo, a southern province in Nigeria, in particular is facing a serious challenge with an increasing frequency of flood in recent years. It is therefore crucial to utilize the state-of-the-art sensing and communication technologies to monitor and detect flood occurrences The role of the designed Flood Monitoring and Detection System (FMDS) based on WSN is to continuously monitor, detect and report the environment's status to a control unit using relative humidity, temperature, water level and amount of rainfall as flood indicators, whose values are gathered by sensors in the sensor field. The flood monitoring and detection system monitors and know the development of floods and then send flood notification SMS to the inhabitant of such zones for necessary action. The developed Flood Monitoring and Detection System (FMDS) covers 15 flood prone regions in Uyo metropolis in Akwa Ibom State, Nigeria. The GIS map of the flood prone zones is incorporated into the FMDS. The system is composed of three major modules which are the sensor field module, surveillance module and the phone module. The system was developed using Java Programming Language built into surveillance module of the system. The developed system is robust and gives timely alert of flood occurrences.***

Keywords — Wireless Sensor Network, Flood Monitoring and Detection.

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1. INTRODUCTION

Flood is one of the major problems in some countries of the world including Nigeria. It occurs mostly in some populated areas. This may be attributed to climate change which causes high rate of rainfall, placing many cities at increased risk of flooding. In Nigeria, flood occurs when high rate of rainfall takes place for a longer period of time in a given small region and the drainage system could not cope with increased water volumes. In Akwa Ibom State, such flood –prone areas includes the Abak-Ikot Ekpene road by Uduak Abasi clinic, Afaha Esang, Ikot Akpakpan, Ediam Edem-awa villages all in Abak Local Government Area and St. Patrick primary school Abak road by Ukana Offot in Uyo.

Again, Nigeria climate review bulletin 2010 [11] reveals that severe floods, windstorms, heat waves and several other extreme weather and climate events have impacted negatively on Nigeria's socio-economy and many people have been affected. The bulletin also point out that the rainfall amount of 300-1000mm were recorded in the Northeast, 2000-3000mm recorded in Southwest and Southeast, 3000-4500mm recorded for the rest of the country with the highest cumulative rainfall amount of 4224.0mm recorded at Eket in Akwa Ibom State. Uyo also recorded the highest daily rainfall of 199.5mm in June 2010; with a daily rainfall amount of 132.3mm in Eket. Still in 2010, flood related diseases such as Cholera infected nearly 40,000 people and killed more than 1,500 in some parts of Nigeria.

Although the government is aware of the economic losses flood has caused to the country and is embarking on construction of good drainage system in some areas, this construction may not cover the entire flood areas in the country in the nearest future. Wireless Sensor network can be deployed to monitor and detect flood in those areas. In Nigeria, agency like Nigerian Meteorological Agency (NIMET) is able to forecast rainfall or track storm path from satellite images. Input data from satellites for flood forecasting, especially in developing countries, come after a long interval and may be quite insufficient. Therefore the need to have Wireless Sensor Networks (WSNs) monitored data such as water level, temperature, intensity, humidity or rainfall is essential in order to make a reasonable decision on the action necessary to detect flood.

To effectively monitor and detect occurrence of flood in flood prone areas, monitoring and detection systems should be deployed to such areas to measure and record the required parameters. What makes a good monitoring system lies in the equipment used in the detection[1]. Tools used for measurement during natural disasters monitoring are costly, therefore Wireless Sensor Network is needful because it requires less energy, does not need hard wiring and can transmit data over a long distance.

Wireless Sensor Network (WSN) consist of autonomous sensors to monitor physical or environmental conditions, such as temperature, humidity, sound, pressure, etc and to cooperatively pass their data through the network to a main location. In other words, WSN is a network made up of numerous number of sensor nodes with sensing, wireless communications, and computational capabilities. WSNs are capable of sensing the physical world, process the data and transmit the measured data to the base station for further analysis and decision making [10]. WSNs, as defined by [9] is a low power, low cost, multi-hopping systems that are independent of external service providers, can form an extendable network without line of sight coverage; but have self-healing data paths. It is therefore evident that the characteristics of WSNs include small size, integrated sensing, computational capabilities, low power communication etc [8].

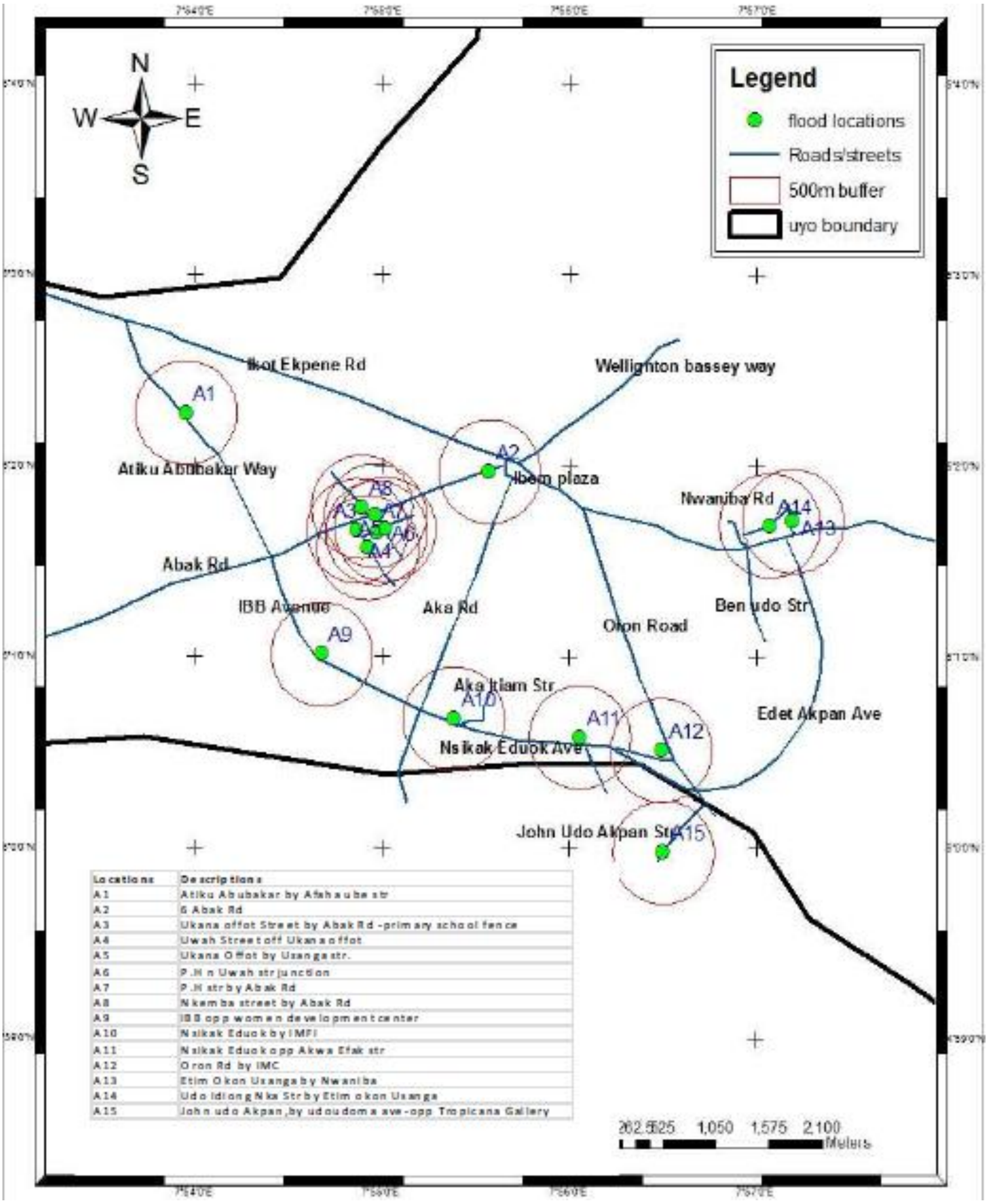


Figure 1.1 - GIS map of the flood prone zones.

Now that the world has become a global village whereby most people and every home have access to mobile phones, computer systems, and other telecommunication devices combined with numerous news media available, flood and other natural disasters should not invade people's farmland, houses, factories etc. without adequate information dissemination channels. Our proposed flood monitoring and detection system will use sensor nodes installed in the sensor field for data collection, the parameters are transmitted via a multi-hop sensor network to the surveillance center. At the surveillance center, the data is received, processed and information concerning the flood status is then disseminated to the people in the affected geographical region via Short Message Service (SMS).

Here we designed a Flood Monitoring and Detection Syetem (FMDS) for Uyo metropolis of Akwa Ibom State, Nigeria. The system covers 15 flood prone areas and provides event monitored interface for flood detection. Figure 1.1 shows the GIS map of the flood prone zones.

The rest of the paper is structured as follows: Section 2 gives a brief summary of related work in the area of WSN. Section 3 presents the design of the FMDS showing its hardware and architectural design, including the decision rules for the flood status as well as a brief approach to designing the system. Section 4 shows the result of the designed system with some screen shots. Finally, the work is concluded in section 5.

2. RELATED WORK

The deployment of WSN on numerous applications areas such as transportation, logistics, environmental and habitat monitoring, security and surveillance, industrial automation, military, precision agriculture and healthcare, has been reported. [2] used a WSN to monitor volcanic activities. [3] developed early warning flood detection system which was installed along a river in Hunduras. [8] designed a WSN for environmental monitoring as a platform as well as the implementation of a prototype system which could be beneficial to developing countries. [1] designed a disaster and alert system using WSN to send weather information and disaster alerts by a Zigbee module. This weather information was analyzed using decision tree techniques to announce the alerts. [6] implemented a wireless data acquisition network to collect climate data and soil moisture for a smart irrigation system in Portugal to enhance efficiency of irrigation. [7] proposed flood early warning system using SMS and web to record rainfall and water level data and SMS on flood status to attendants and stakeholders. The website can be accessed from anywhere.

In this paper, we design flood monitoring and detection system using water level, amount of rainfall, relative humidity and temperature as monitored variables for flood detection. The relative humidity and temperature values are used to monitor the rate of rainfall. The amount of rainfall values are used to predict the water level. The water level will determine the extent of the flood as low, medium or high. This will enhance early flood detection. The flood status is sent directly to the occupants of the flood prone region directly from the surveillance centre.

3. SYSTEM DESIGN

The Flood Monitoring and Detection System (FMDS) uses a ZigBee radio which uses ZigBee/IEEE 802.15.4 standard which is the only standard-based technology designed to address the unique needs of low-cost, low-power wireless and control networks [4] and [5] The hardware design block diagram is shown in figure 3.1. The black lines represent data buses, while the red ones are power lines. The sensors - Temperature, Rainfall, Humidity and Water Level sensors capture signals (data) and send them to the microcontroller (PIC24). The data sent is analog in nature, which is digitalized by Analog-Digital converter the microcontroller integrates. The Zigbee module sends the information it receives from its radio to the microcontroller for processing. The microcontroller can also send packets received from the sensors to the Zigbee module so that it can be radiated and received by other nodes. The microcontroller can also send commands to the Zigbee module to configure the network.

The architecture of the FMDS has three modules and a wireless gateway as seen in figure 3.2. The three modules are sensor field, surveillance centre and mobile phone modules. The WSN Ethernet gateway module coordinates communication between distributed measurement nodes in the sensor field and the host computer in the surveillance center. The sensor field module comprises sensors sensing and communicating parameters values to the gateway. Surveillance centre module consists of a database in the host computer which holds the phone numbers and the monitored parameters, printer (in case a hard copy of the status is needed), a broadband modem to enable the sending of SMS. The host computer is a manned node for monitoring the GUI and to raise / send alert SMS to the occupants of the flood area. Mobile phone module represents the occupants of the flood prone region who will receive the alert via the SMS.

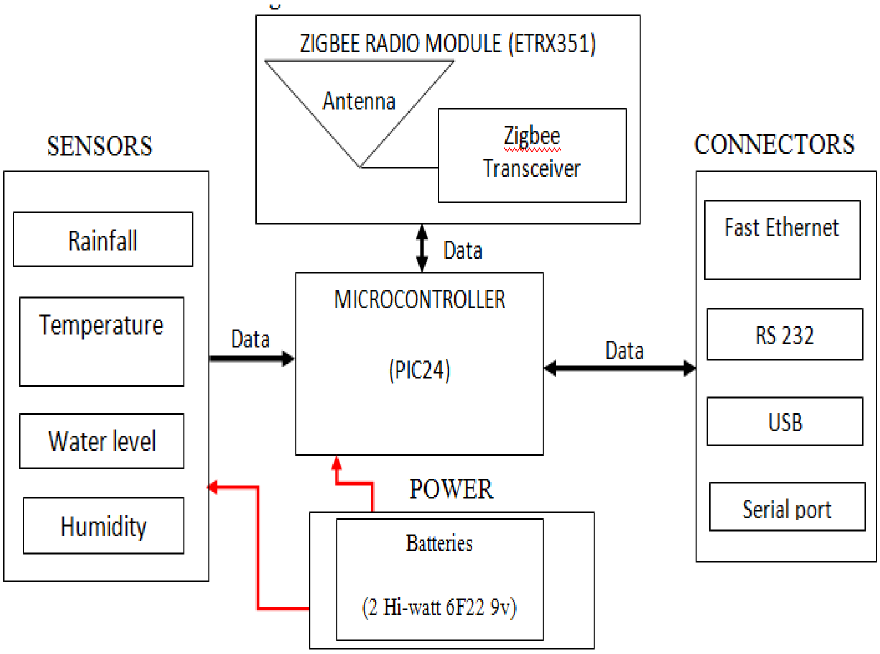


Figure 3.1 – Hardware design block diagram

The entire FMDS procedure and operations can be depicted in a high level model block diagram as shown in figure 3.3. The collection sensors get values of the monitored parameters and sent to the communication medium through the gateway to the surveillance centre, where the data are collected, processed and stored in the database. The software running at the surveillance centre is developed using Java programming language. The values set for the monitored parameters within the inference engine in the program are shown in table 3.1 and the rules governing the flood status to be sent are:

RULES

1) If Rel. Humidity = very high AND
Min.Temp = warm AND
Max.Temp = hot AND
Rainfall = small rain AND
Water level = low THEN
FLOOD STATUS = No Flood

2) If Rel. Humidity = high AND
Min.Temp = moderate AND
Max.Temp = hot AND
Rainfall = small rain AND
Water level = low THEN
FLOOD STATUS = No Flood

3) If Rel. Humidity = high AND
Min.Temp = moderate AND
Max.Temp = warm AND
Rainfall =not heavy rain AND
Water level = high THEN
FLOOD STATUS = Moderate Flood

4) If Rel. Humidity = low AND
Min.Temp = low AND
Max.Temp = warm AND
Rainfall =heavy rain AND
Water level = very high THEN
FLOOD STATUS = Extremely Serious Flood

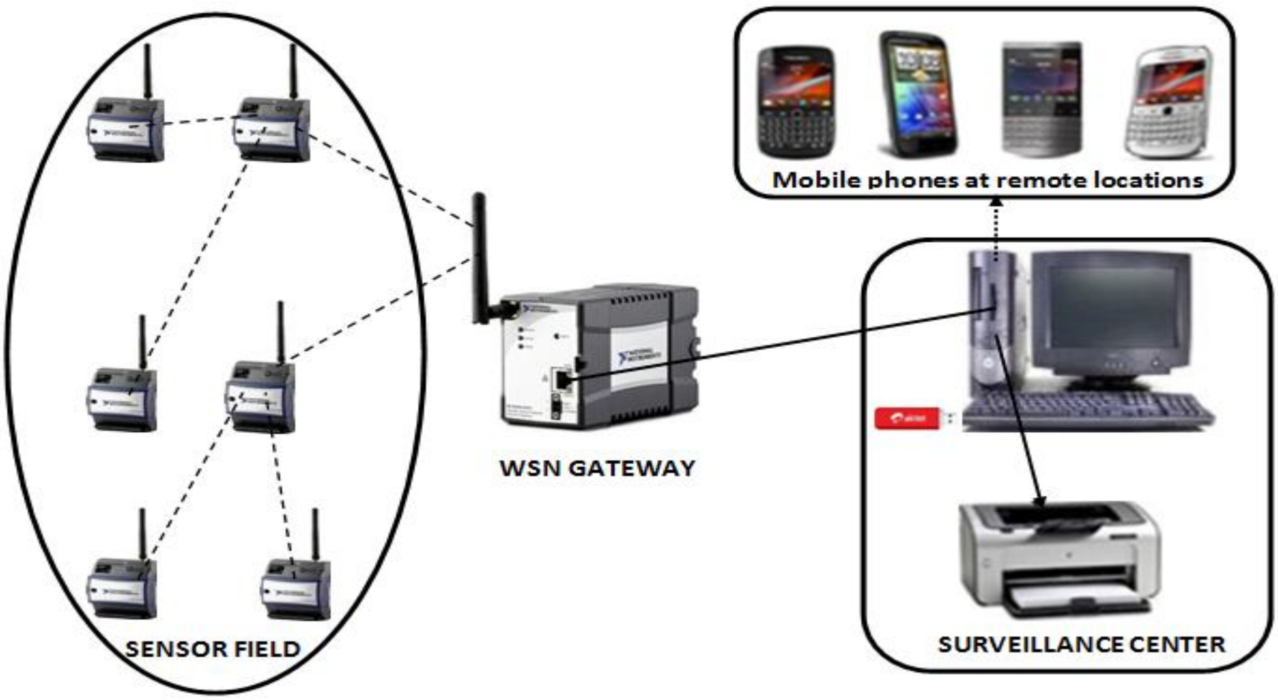


Figure 3.2 – Architecture of the FMDS

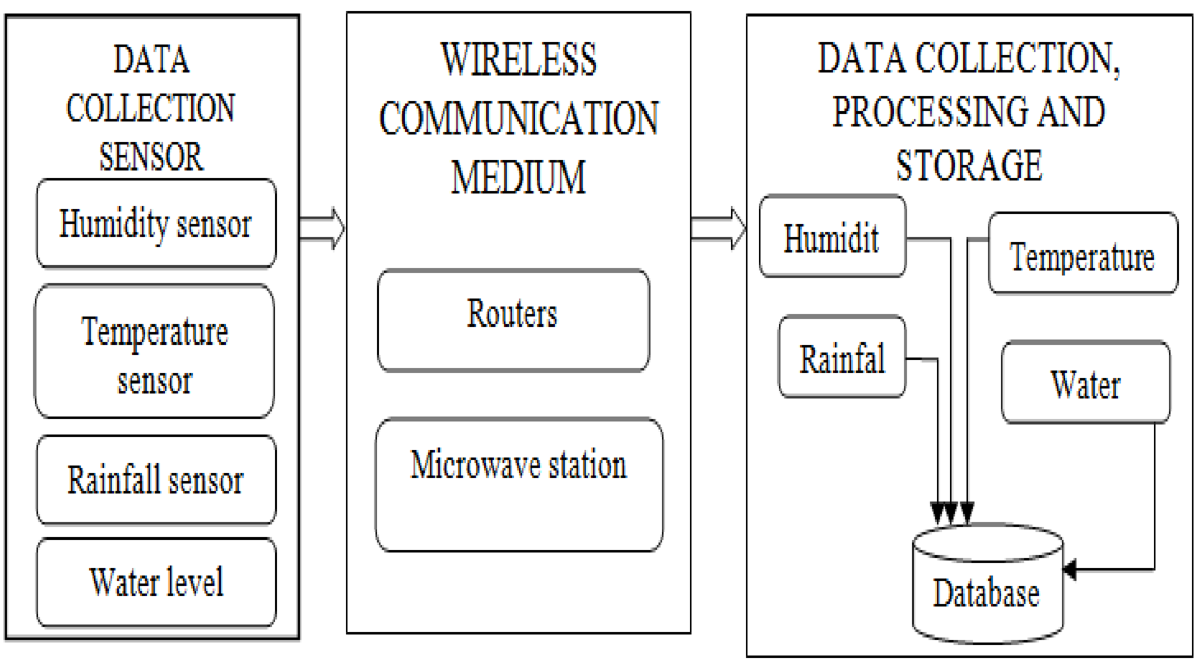


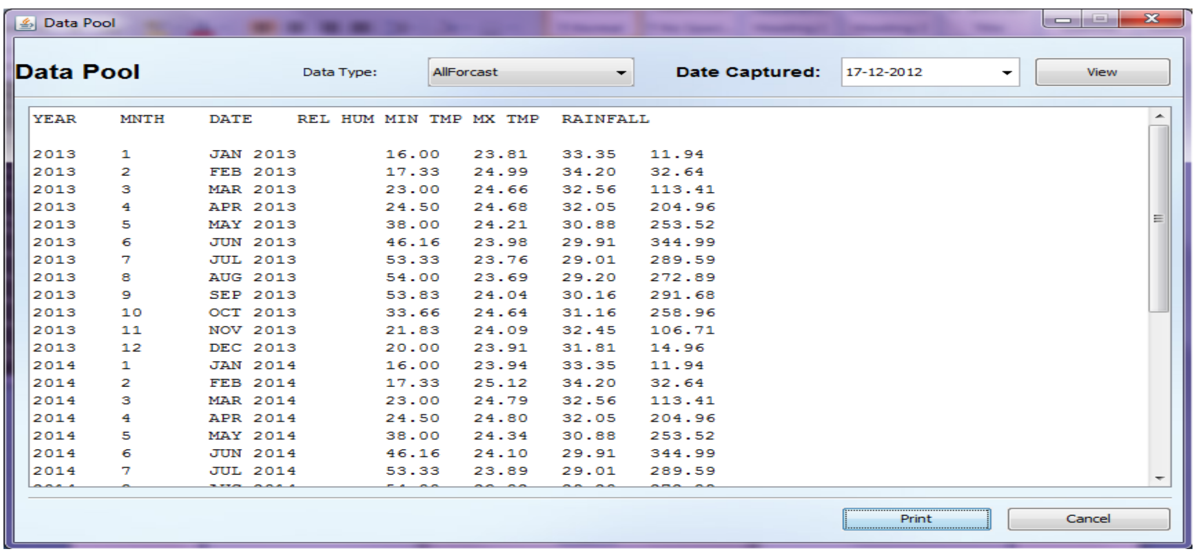
Figure 3.3 – Block diagram of the proposed FMDS

Table 3.1 – Inference engine values

PARAMETER	RANGE OF VALUES	STATUS
Relative Humidity (%)	>= 48.00 31.00 - 47.99 16.00 – 30.99	Very High High Low
Minimum Temperature (^{o}c)	25.00 – 28.99 24.00 – 24.99 <= 23.99	Warm Moderate Low
Maximum Temperature (^{o}c)	>= 33.00 32.00 – 32.99 29.00 – 31.99	Very hot Hot Warm
Rainfall (Mm)	>= 300.00 101.00 – 299.99 <= 100.99	Heavy rainfall Moderate rainfall Low rainfall
Water Level(M)	>1.2 >0.81 AND <1.2 <0.8	Very High High Low

4. FDMS OUTPUT

Several testing has been performed to ensure that the program is executed and produce the intended result. Figure 4.1 shows the readings captured by the sensors in the sensor field while Figure 4.2 shows the main menu of the software running at the surveillance centre.



YEAR	MNTH	DATE	REL HUM	MIN TMP	MX TMP	RAINFALL
2013	1	JAN 2013	16.00	23.81	33.35	11.94
2013	2	FEB 2013	17.33	24.99	34.20	32.64
2013	3	MAR 2013	23.00	24.66	32.56	113.41
2013	4	APR 2013	24.50	24.68	32.05	204.96
2013	5	MAY 2013	38.00	24.21	30.88	253.52
2013	6	JUN 2013	46.16	23.98	29.91	344.99
2013	7	JUL 2013	53.33	23.76	29.01	289.59
2013	8	AUG 2013	54.00	23.69	29.20	272.89
2013	9	SEP 2013	53.83	24.04	30.16	291.68
2013	10	OCT 2013	33.66	24.64	31.16	258.96
2013	11	NOV 2013	21.83	24.09	32.45	106.71
2013	12	DEC 2013	20.00	23.91	31.81	14.96
2014	1	JAN 2014	16.00	23.94	33.35	11.94
2014	2	FEB 2014	17.33	25.12	34.20	32.64
2014	3	MAR 2014	23.00	24.79	32.56	113.41
2014	4	APR 2014	24.50	24.80	32.05	204.96
2014	5	MAY 2014	38.00	24.34	30.88	253.52
2014	6	JUN 2014	46.16	24.10	29.91	344.99
2014	7	JUL 2014	53.33	23.89	29.01	289.59

Figure 4.1 – Data pool of sensor values

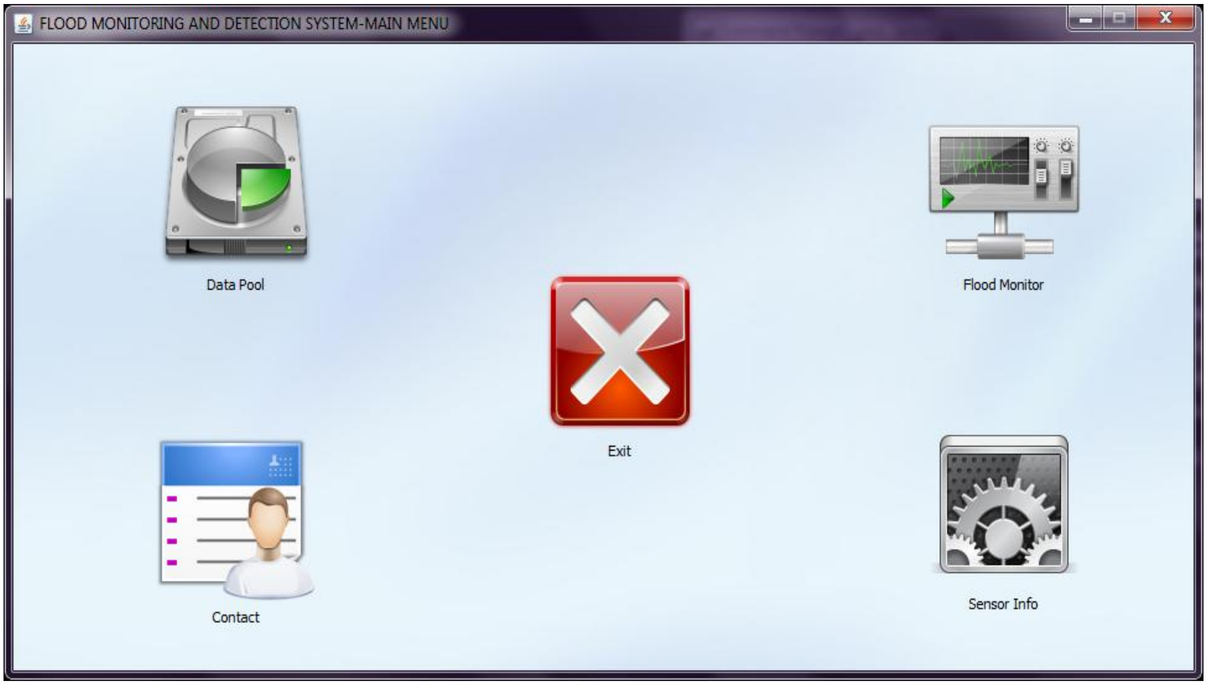


Figure 4.2 – FDMS main menu

Flood monitoring GUI is the engine room of the FMDS application. This is where the flood monitoring is done. In the event of an extreme flood, the system generates alarm and flag the location/zone where flood will occur. The system triggers SMS to people in that region. Figure 4.3 shows a case where the monitoring system sends an alert to a particular flood prone region in a case of extreme flood while figure 4.4 show the FMDS SMS dialog box

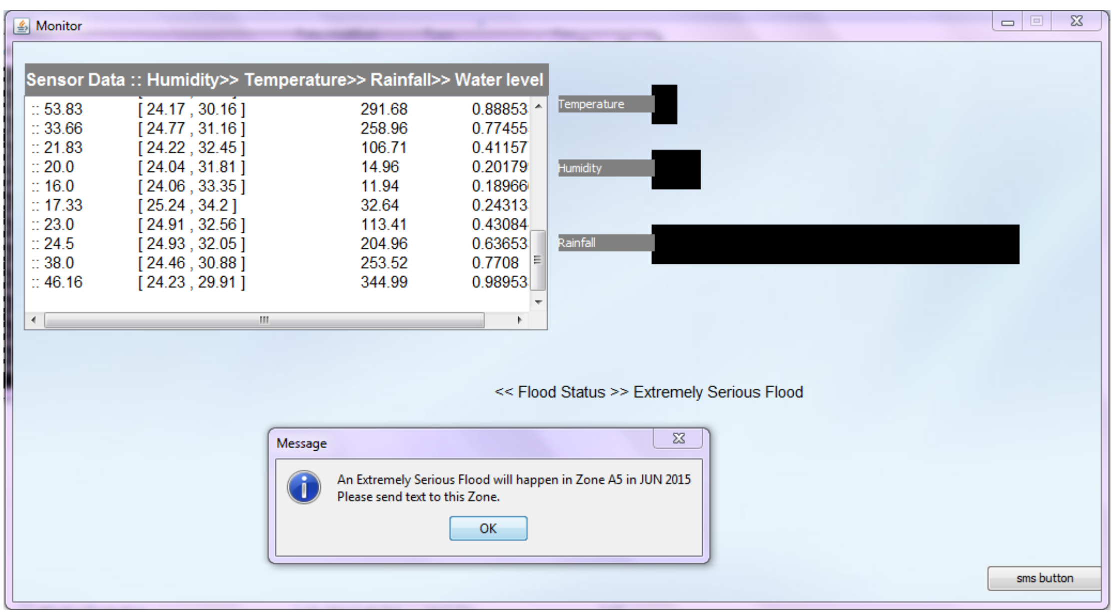


Figure 4.3 – Flood Monitoring GUI

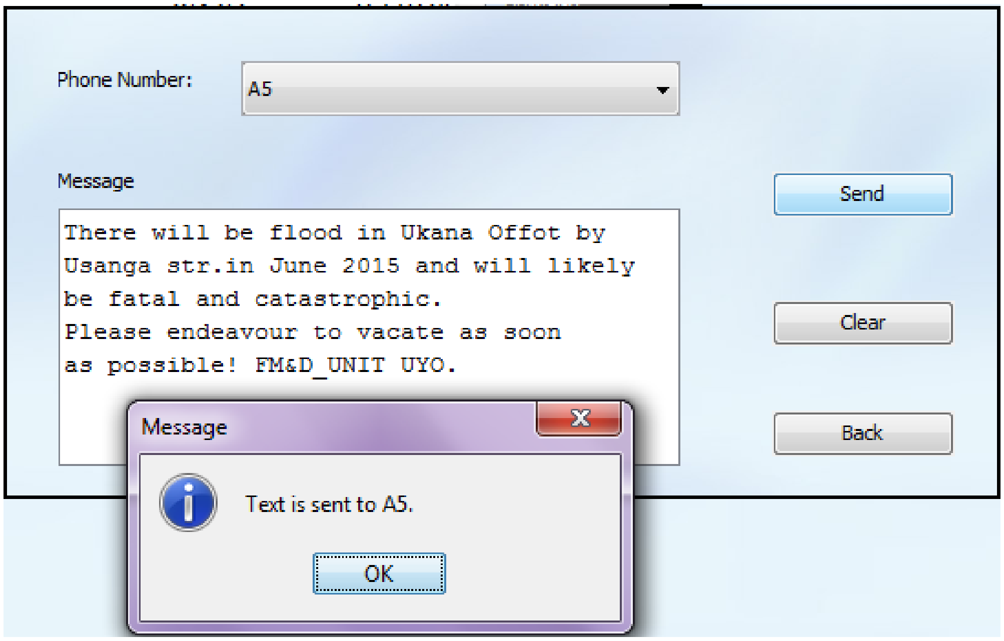


Figure 4.4 – FMDS SMS Dialog Box

5 SUMMARY

It is crucial to utilize the state-of-the-art sensing and communication technologies to monitor and detect flood occurrences in Nigeria. The designed Flood Monitoring and Detection System (FMDS) based on WSN is to continuously monitor, detect and report the environment's status to a control unit using relative humidity, temperature, water level and amount of rainfall as flood indicators. The flood monitoring and detection system monitors and know the development of floods and then send flood notification SMS to the inhabitants of such zones for necessary action. The developed system is robust and gives timely alert of flood occurrences.

6 CONCLUSION

We have presented the design and implementation of WSN-based Flood Monitoring and Detection System (FMDS) using relative humidity, temperature, water level and amount of rainfall as flood indicators, whose values are gathered by sensors in the sensor field. The flood monitoring and detection system monitors and know the development of floods and then send flood notification SMS to the inhabitant of such zones for necessary action. The developed Flood Monitoring and Detection System (FMDS) covers 15 flood prone regions in Uyo metropolis in Akwa Ibom State, Nigeria. In the future, we will develop a prediction and forecasting system for the flood prone region of Uyo using data from the Nigerian Meteorological Agency (NIMET). The developed system is robust and gives timely alert of flood occurrences. The system can be expanded to cover a wider area than the one under study.

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