College of Science and Technology

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African Center of Excellence in Internet of Thing

Research Thesis Title:

IoT Based Flood and Landslide Disasters Monitoring and SMS Alert System in Northern Province, Rwanda

A dissertation Submitted in Partial fulfilment of the requirements for the award of

MASTERS OF SCIENCE DEGREE IN INTERNET OF THINGS –WIRELESS INTELLIGENT SENSOR NETWORK

Submitted by:

HABUFITE James, Ref.No: 220014318

February, 2022

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Supervised by:

Dr. NGENZI Alexander

Dr. NZANYWAYINGOMA Frederic

February, 2022

Declaration

I hereby declare that this research project report entitled "**IoT Based Flood and Landslide Disaster Monitoring and SMS alert System"** is presented for the award of Master's degree in Internet of Things – Wireless Intelligent Sensor Network at the African Centre of Excellence in Internet of Things, University of Rwanda is my own work. It has never been presented or submitted in any other University or higher learning institution for similar award.

James HABUFITE Ref.No: 220014318

Date: 12 / 12 / 2021

Bonafide Certificate

This is to certify that this submitted Research Thesis work report is a record of the original work done by **Mr. James HABUFITE (REF.NO: 220014318),** MSc. Internet of Things –Wireless Intelligent Sensor Network (IoT-WiSeNet) Students at the University of Rwanda / College of Science and Technology / African Center of Excellence in Internet of Things. Certified further, that according to the best of my knowledge; the work reported here doesn't form a part of any other research work.

Signature: ……………………. Date: ………………………

Supervisor: **Dr. NGENZI Alexander**

Signature: ……………………. Date: ………………………

Co-Supervisor: **Dr. NZANYWAYINGOMA Frederic**

The head of Masters studies and trainings

Signature: ……………………. Date: ………………………

Dr. James RWIGEMA

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Abstract

Floods and Landslides are amongst the major disasters in Rwanda and have had a great impact on human lives, human development, properties, infrastructures as well as environment due to geographical aspect, heavy rain and mining activities. The design and implementation of IoT based floods and landslide disaster monitoring and SMS alert system detect and monitor parameters of flood and landslide disasters at specific high-risk zone of Norther province in Rwanda by using wireless sensor network such as flow sensor, water level sensor, soil moisture sensor, accelerometer sensor and ultrasonic sensor deployed at those specific areas for collecting parameters of flooding and landslide. All sensor nodes are connected to microcontroller board which aggregate sensed data and process, analyses them then send parameters to the cloud platform for being analyzed and monitored on time. The system automatically compares the measured parameters with the threshold value that are settled for the probability of flood and landslide disaster. If the measured values exceed the threshold values that are settled, an alert message generate and data sent to the ThingSpeak cloud platform and through the use of a Global System for Mobile (GSM) as warning notification to the affected citizens for those do not subscribe mobile data or do not have any internet connection then to nearest relevant authorities to take action accordingly and provide a required support to the vulnerable people and properties before predicted time for saving live and environment. The system also calculates and provide the time it would take for flood or landslide to reach them so that they can evacuate accordingly. To implement this solutions researcher, use a recursive algorithm developed using Arduino C programming language which is understood by microcontroller Arduino broad and written in Arduino Integrated Development Environment (IDE) editor.

Keywords: Flood, Landslide, Disaster, Sensor, Arduino

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List of Acronyms

ACEIoT: African Centre of Excellence in Internet of Things

Dr.: Doctor

ESP: Espressif

GPRS: General Packet Radio Service

GPS: Global Positioning System

GSM: Global System for Mobile Communications

IDE: Integrated Development Environment

IoT: Internet of Things

MCU : Micro Controller Unit

NDVI: Normalized Difference Vegetation Index

NDSI: Normalized Difference Soil Index

MINEMA: Ministry in charge of Emergency Management

Ref no: Reference number

SMS: Short Message Services

TWI: Topographic Wetness Index

Wi-Fi: Wireless Fidelity

WISeNet: Wireless Intelligent Sensor Networking

WSN: Wireless Sensor Network

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CHAPTER ONE: GENERAL INTRODUCTION

1.1 General Introduction

Flood and Landslide are one of the natural disasters that cannot be avoided. They happen too fast and affected so many lives and properties. After that, majority of the public cannot monitor and have no idea when the flood going to be happened since they do not have any information and data about the weather condition[1]. Flood and Landslide disasters have frequently occurred on natural slopes during periods of intense rainfall. With a rapidly increasing population on or near steep terrain[2] other are caused by natural conditions and phenomena (topography, rainfall), regional geographical conditions, and human activities that result in changes in land use in an area[3].

Rwanda is currently vulnerable to climate change as it is strongly reliant on rain-fed agriculture both for rural and cities livelihoods where we experience emergency situation from flooding and landslides disasters where people have been killed and hundreds of houses were destroyed in the North-western Rwanda[4]. The main landslide types are debris flows which occur on concave slopes where water concentrates and with the layer of clay downward water pushes the land to slides laterally. These landslides occur on steep slopes that are concave and between slope angles of 140 to 550[5].

The citizens leave in high-risk zone in different areas of the country have experienced floods following on-going above normal heavy rains which resulted into landslides in localized areas of the country where steep slopes and mountain valley are mostly affected by flood and landslide disasters especially in Districts which are adjacent to Virunga National Pack[6] and most of them have not internet connection to receive warning or alert about flood and landslide disasters event but their mobile phone allow them to receive an alert message of flood and landslide disasters.

Before this, majority of the public cannot monitor and have no idea or awareness when the flood or landslide disasters are going to be happened which lead to the failure of those disasters risk prevention. Some measures have been putted in place by citizen through the guidance of local leaders such as collecting rain water and community activities but ware not enough to reduce the risks and impact related to flood and landslide where technological solutions have been started.

Additionally, S. Binti Zahir1 et al[1], had conducted a research by developing the system which detect and monitor flood and landslide disaster by using wireless sensor network and web application approach. Provided solution seems to be inefficacies to the citizens by sending alert message to them using simple web application for monitoring and getting information to evacuate people which require internet connection and additional skills to interact with interfaces.

Other has detect and monitor flood and landslide without notifying the people who should risk their live and some separate research of flood and landslide conducted while due to heavy rainfall and other causes of flooding and landslide disasters in high-risk zone frequently occur at the same time. It is in that way researcher have thank to design and implement IoT based floods and landslide disaster monitoring and SMS alerting system in which will contribute more to society especially the citizen who live in high-risk zone as described.

The proposed solution use methodology of combine a series of sensor node deployed in critical areas where flood and landslide affect to collect parameters corresponding to prescript disasters and aggregated by microcontroller with local processing and analysis. It use wireless network to transfer data to the cloud platform where are being monitored and analyzed through gateway. Some sensors are deployed for operating on flood parameters such as ultrasonic sensor, water level sensor and water flow sensor others deployed for landslide parameters detection like accelerometer sensor and soil moisture sensor.

Collected parameter are pushed to ThingSpeak cloud platform for real time monitoring in order to visualize them before any disaster happen for evacuation and securing people and assets at the same time when threshold data values from deployed sensors is detected with GSM module a notification alert message is sent to the surrounding people and authorities such as police and local government to take decision for helping those citizens and their belongings.

ThingSpeak cloud platform was used as an IoT analytics platform service that allows to aggregate, visualize and analyze live data from sensor to the cloud with communication of wi-fi connection to be linked with the data from sensor controlled by Arduino board and Arduino C programming language written in Arduino Integrated Development Environment (IDE).

1.2 Problem Statement

In Rwanda specifically in Northern province during raining season where heavy rain falls many people whose leave in high-risk zone lose their live, properties such as house destroyed and a lot of hectares of farmland damages[6] due to the lack of information about the prediction of flood and landslide data or parameters for being evacuated. Relevant authorities such as local government leaders and police are not able to monitor and access predictable data about flood and landslide disasters which are mostly affected by it like in sector adjacent to Virunga National Pack[7] in order to protect surrounding people, properties and environments.

The citizens leave in high-risk zone of Northern province in Rwanda most of them have not internet connection to receive warning or alert about flood and landslide disasters but their mobile phone[8] allow them to receive an alert message of flood and landslide disasters.

Before this, majority of the public cannot monitor and have no idea or awareness when the flood or landslide disasters are going to be happened which lead to the failure of those disasters risk prevention.

By designing and implementing IoT based floods and landslide disaster monitoring and SMS alerting system, this will solve all predefined problems for the citizens of Norther province, Rwanda and furthermore, if the public has an internet access, they can monitor what is happening and predict if there is any upcoming flood or landslide from cloud platform by using android application and will issue an alert SMS to the citizens on mobile phone for evacuation so that fast necessary actions can be taken.

1.3 Objectives

1.3.1 General objective

The main objective of this research is to design and implement IoT based floods and landslide disaster monitoring and SMS alert system prototype which sense and detect flood and landslide parameters and push them to cloud platform for monitoring and analyzed and if threshold value detected send an alert message to mobile phone.

1.3.2 Specific objectives

To achieve general objective of this research, the flowing specific objectives will be considered:

- To design a wireless sensor network prototype based on different sensors, transceiver and processing devices and improve system of warning and emergency communication for flood and landslide disasters
- To measure the flooding and landslide parameters such as water level, water flowrate, soil moisture, and soil motion in the field test at Musanze district
- To implement a prototype that respond to flooding and landslide parameter detection and send alert message.
- To monitor the density of soil water, water flowrate, water level and moisture parameters send alert message to the residence and concerned authorities to resecure the victims

1.4 Scope and limitation of the study

The research study is to design and implement IoT based floods and landslide disaster monitoring and SMS alert prototype to the nearest people of Musanze and Gakenke Districts of Northern province by using wireless sensor network that can collect and analyze soil parameters such as soil water volumetric and soil motion to predict landslide disaster and collect water level and water speed parameters to predict flooding then sent them to cloud flatform for being monitored and use GSM communication technology to send an alert message through mobile telephone.

1.5 Research questions

- What is the purpose of this research?
- How the system detects, monitor flooding and landslide parameters?
- How to develop a system prototype that detect, monitor flood and landslide parameter and notify with SMS alert?

1.6 Significance of the study

The fruit of this research will help Citizens that are living around in high-risk zone especially in norther province to save their live, to resecure their properties; it will help MINEMA (Ministry in Charge of Emergency Management) to save expenses used to help the victims of flood and landslide. Also, the outcome will be helpful tool for disaster risk management in case the system predicts and provide the notice of flooding and landslide through monitoring feature where will be used by planners and authorities to take decision based on prediction provided and take adequate decision accordingly.

1.7. Organization of the study

The dissertation is organized in six chapters as following, the first one is the general introduction, it gives the study background, statement of the problems objectives and study delimitation. Chapter two is the literature review; it provides the review of the literature and similar studies. It also defines the gaps ignored by other authors and key terms used in this research work. The third chapter is the research methodology; it deals with data collection techniques, data analysis and interpretation of data. The fourth chapter is System Analysis and Design that explain system models, proposed simulation models, simulation parameters, simulation scenarios. The Fifth chapter is result and discuss of the result that describes the graphs result and hypothesis verification of the study. Finally, the last chapter is conclusion and recommendations to other researchers who will be interested to work on the similar work.

CHAPTER TWO: LITERATURE REVIEW

4.1 Introduction

This section gives a brief analysis of other researches that are similar or related to our current research. This includes the problem investigated by the previous researchers, proposed technical solution, methodology approach used, and results found. Eventually, the gaps in the previous similar and related research were identified through this research study and these provide the justification and motivation for undertaking this research.

4.2 Review of related works

The related works have been done where some made research on areas and cause of flooding and landslides in Rwanda and other for reding data from the sensor by using various methodologies and find different outcomes. Those literature have been used to understand my research and to identify the key area of improvement. Most of them are discussed in the following paragraph by determining their proposed technical solution, methodology approach and corresponding gap.

Rwanda Ministry of Disaster Management and Refugee Affairs Unit of Research and Public Awareness Disaster High Risk Zones had identified all areas in Rwanda, prone to floods and landslides in their report [4] of "Disaster high risk zones on floods and landslides" in all over the country intends to show the critical zones, prone to landslide and floods for effective disaster prevention, preparedness and planning. In this research monitoring and alert mechanism or tools have been not elaborated in which is considered as gap.

S. Binti Zahir *et al*, developed a project of Smart IoT Flood Monitoring System which update the water level at the web server as an alert signal for flood disaster with simple interface to the citizens for evacuation so that fast necessary actions can be taken[1] which lead to the system gaps to be inefficiency to citizens for not providing information on time while internet connection is not accessed to everyone where SMS alert is required and landslides parameters.

P. Bahirat,[2015] describes the evolution of a wireless sensor network system for landslide detection in the Idukki district of the southern state of Kerala, India, a region known for its heavy rainfall, steep slopes, and frequent landslides. The deployment and data retrieval or collection from geophysical `1sensors, the design, development and deployment of WSN, the development of data collection and data aggregation algorithms needed for the network, and the network requirements of the deployed landslide detection system, data analysis system [9]

Monitoring and full sensor deployment have been not putted into consideration and citizens are not warned about flood disaster.

M. V. Ramesh, discusses the design and deployment of a landslide detection system using a WSN system at Anthoniar Colony, Munnar, Idukki (Dist), Kerala (State), India by detecting rainfall estimation induced landslides which occur commonly in India [10] using geophysical sensors without providing alert or warning mechanism.

N. V. S. S. Varma, [2009] developed the design of flood prediction with the ultrasonic sensors used to level the flood water and alert the surrounding system. Other hardware used ware level sensor, temperature sensor MEMS sensor to get flood water information. From the database, the data is checked in the webpages and alert the surrounding villages and living areas[11]. Unfortunately, web application which require internet connection to receive alert message and no landslide data generate.

D. Kumari, [2020] Implemented the system that involves the deployment of sensor nodes at specific flood vulnerable locations for real-time flood monitoring and detection. Flood events relating to flash flooding and run-off water or overflow are successfully monitored in real time which saves individuals plenty of time to prepare against predicted flood occurrence[12], but the system can be more enhanced by sending SMS as warning signal to citizens for those did not subscribe mobile data or did not have any internet connection and monitoring platform.

H. Kim., [2008] by using wireless sensor network (WSN) that is composed of sensor nodes, gateway, and server system developed a system that detect Landslide. Sensor nodes comprising sensing and communication part are implemented to detect ground movement. A sensing part is designed to measure inclination angle and acceleration accurately, and a communication part is deployed with Bluetooth (IEEE 802.15.1) module to transmit the data to the gateway[2], ended it does not provide reliability, alert or warning message and it is necessary to predefine the appropriate thresholds to determine the slope stability.

M. V. Ramesh, [2012] in his research paper 50 geological sensors and 20 wireless sensor nodes was deployed in Idukki, a district in the southwestern region of Kerala State, India, a highly landslide prone area. The wireless sensor network system has gathered vast amounts of data such as correlated sensor data values on rainfall, moisture, pore pressure and movement, along with other geological, hydrological and soil properties, helping to provide a better understanding of the landslide scenario[13].

R. Mind'je *et al, [2019]* had applied logistic regression model using flood inventory and ten predicting factors to study and map flood susceptibility in Rwanda. A flood inventory was generated using 153 historical flood locations and a total of 10 predicting factors (elevation, slope, aspect, profile curvature, distance from rivers, distance from roads, the Normalized Difference Vegetation Index (NDVI), the Normalized Difference Soil Index (NDSI), the Topographic Wetness Index (TWI) and rainfall) were utilized. Flood points were randomly subdivided into training (75%) for model building and testing (25%) points for validation through the Area Under Curve (AUC) approach[7].

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Introduction

The chapter discusses different approaches the researchers have used during conducting the research activities. It gives brief explanations about research methodology approaches used by the researcher for currying out this study. The methodological approaches identified are made of both physical design which reflects hardware components selection and logical design which also reflects the software components selection

3.2 Research approach, design of the system and activities sequence plan

This part provides the overview of the research approaches and all steps to follow in system development from gathering different ideas to final prototype and research results.

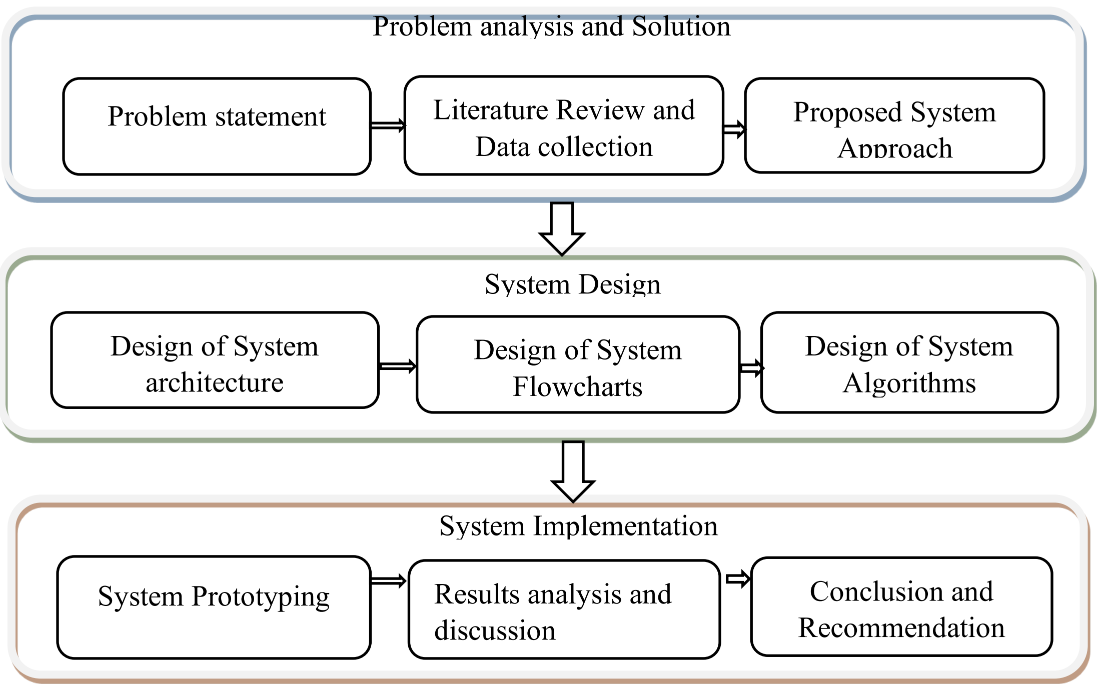


Figure 1: Research Approach

The development approach of this research thesis involves two stages of algorithm and flowcharts design approach and Prototyping approach. To conduct this research, the existing systems are analyzed with intensive literature review and problem identification by study visit and documentation.

3.3 Data collection instruments

This study used primary and secondary information. The information provided the basis for the development of the various components of the application. The techniques included are:

3.3.1 Documentation

From many sources such as thesis, government report, conference papers, and journals covered a large portion of the published information. The main sources of information on the flooding monitoring, landslide detection and the disaster in general have been discussed. In summary, they provided legitimate information about flooding and landslide disaster. This approach helped a researcher to identify the cause of flooding and landslide and the past measures or solutions other research have implemented with their corresponding gaps in which have been considered to develop effective solution of IoT Based Flood and Landslide disaster monitoring and SMS system.

3.3.2 Qualitative interview

This is a type of interview where the interviewer has no specific pre-set question that was to be asked in a particular order. The respondent does most of the talking. These interviews were used during site visits and were used to gather in-depth insights into how Incident rate of Flooding and Landslide in Musanze district. This approach helped research to identify the behaviors and parameter characteristics presented for flooding and landslide.

3.3.1.1 Incident rate of Flooding and Landslide in Musanze district

MIDIMAR profile[6] have describe and evaluate the impacts of floods and landslides on social-economic development in Northern-Western province where specific number of death people, homeless and infrastructure destroyed have been identified for different sectors respectively The sectors adjacent to the Virunga National park are mostly affected by flooding and landslides sourced from heavy rain striking the Volcano National Park and rain water from there created big water channels that impacted on community agricultural soil and crop yields[6]. Figure 2 illustrate Analysis of Flooding and Landslide impacts by sector assessed in Musanze District in 2015-2018

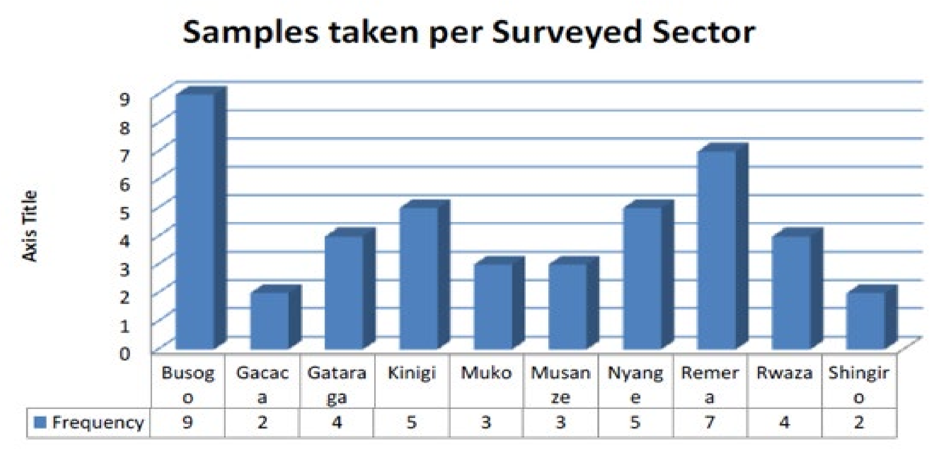


Figure 2: Analysis of Flooding and Landslide impacts by sector assessed in Musanze District in 2015-2018[10]

3.3.1.2 Data collected in Musanze district

The sectors which are adjacent to Virunga National Parks are mostly affected to the flooding and landslide due to heavy rain from volcanoes. Where some crops, houses and infrastructure such as schools, electrical panels were damaged and destroyed form one sector to another as it was indicated and presented in data report collected from Social security and Emergency office at Musanze district.

The collected data from that office are summarized in the chart below where numbers represent the rate of incidence of flooding for corresponding sector from 2019 to 2020.

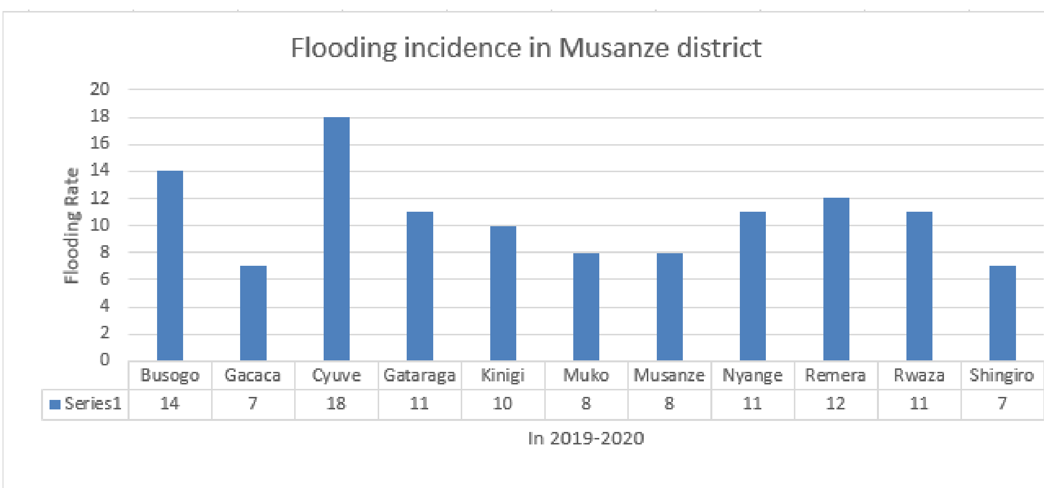


Figure 3: Analysis of Flooding incidence in Musanze District in 2019-2020

3.4 System Architecture Description

IoT based floods and landslide disasters monitoring consists of two main parts. The part for hardware components of different sensor nodes used to collect parameters and process them then send to Cloud platform form monitoring and stored in one place. Another part consists of programming to make system hardware components operational. The software part is for data processing and analytics which will be using Arduino C programming, ThingSpeak cloud platform for graph visualization and monitoring and Arduino Integrated Development Environment (IDE) as an editor.

3.4.1 System Block Diagram

System block diagram describe interconnectivity of different system components to achieve main objective of this research as it is illustrated by figure 4 system block diagram and explained in system block diagram description.

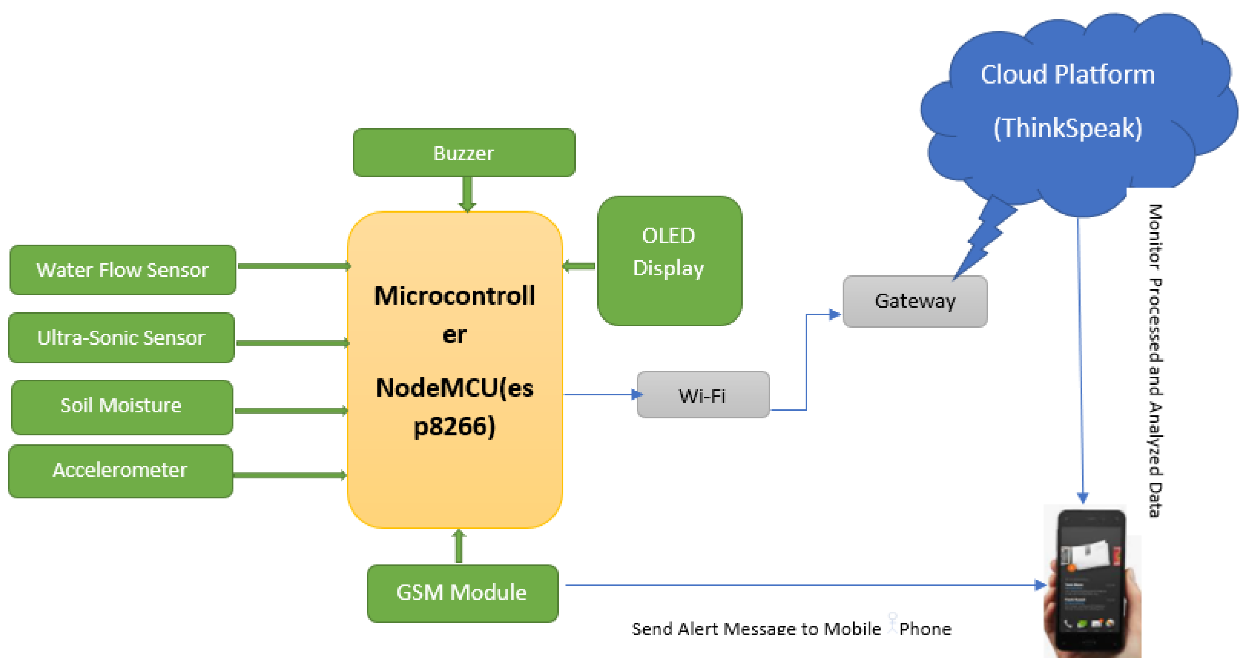


Figure 4: System Block diagram

3.4.2 System Block Diagram Description

System design combines a set of sensor nodes to collect the data as flood and landslide parameters from deployed environments. A microcontroller as NodeMCU(esp8266) for edge processing and analysis connected to Wi-Fi for transmitting data to cloud platform through gateway for monitoring and further analysis. Then GSM module is considered for generating message alert to the citizens and relevant authorities.

Sensor nodes were used for flooding detecting and monitoring such as Ultra-Sonic sensor and Water flow sensor to determine the flow rate of the water in river. Other sensors for landslide monitoring such as Accelerometer used for vibration sensing based on its operation will provide analogue values at the output corresponding to direction and slope displacement measurement of the soil, Soil moisture sensor to measure the volumetric water content of soil.

The collected data from the sensors are sent to microcontroller for being processed if any specific parameter for flooding or landslide reach threshold value a alert message send to the mobile phone of citizens and concerned authorities based on location where disaster occurred as well as to the ThingSpeak cloud platform for being processed, monitored and analyzed via NodeMCU and gateway.

3.4.3 System Algorithm

The system has the aims to detect and monitor Flood and Landslide parameters and send SMS alert that helps the citizens or people who leave in high-risk zone that are mostly affected by those disasters especially for district that are adjacent to National Volcanic Pack to receive a warning notification message on flooding and landslide through their mobile phone. Also help authorities to monitor timely the data of landslide and flooding parameters for predicting disaster and planning to resecure the victims.

This analysis is done using Arduino C programming and ThingSpeak cloud platform as software and sensor nodes for hardware.

To achieve the system performance, system needs to perform more tasks like detecting flooding and landslide parameters and display them to OLED and cloud platform, process and analyze the data then send a notification alert message to mobile phone.

To implement the objectives of the system, the various main components are connected to the Arduino microcontroller NodeMCU 8266 and sensor that collect different parameters such soilmoisture, soil motion, waterflow rate and water level distance to detect flooding and landslide disaster respectively. GSM module to sent message to mobile phone as warning message then

ThingSpeak cloude plaftform server that contains a storage sytem and analytics algoritm and visualyze the data for monitoring.

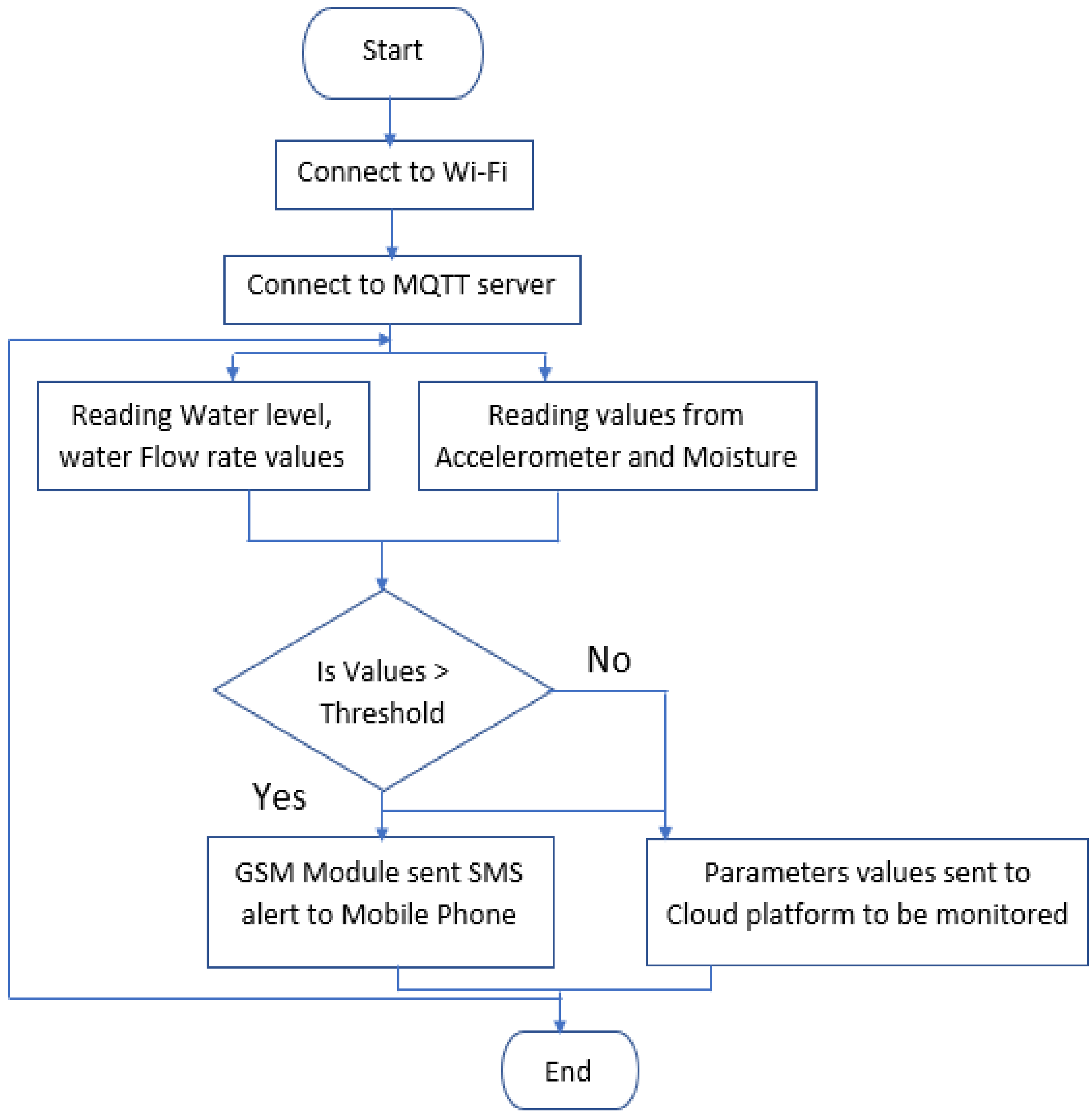


Figure 5: System flow chart

A flowchart is a pictorial representation of an algorithm in which steps are drawn in the form of different shapes of boxes and the logical flow indicated by interconnecting arrows. The flow chart diagram illustrated above demonstrates general working of the system.

3.4.4 System use case diagram

The different entities and their functions are represented in the following use case diagram to interact with system. The proposed solution uses microcontroller ESP8266 as entity that reads the parameters related to flooding and landslide from environment and connect the data to the cloud via wireless communication node and gateway.

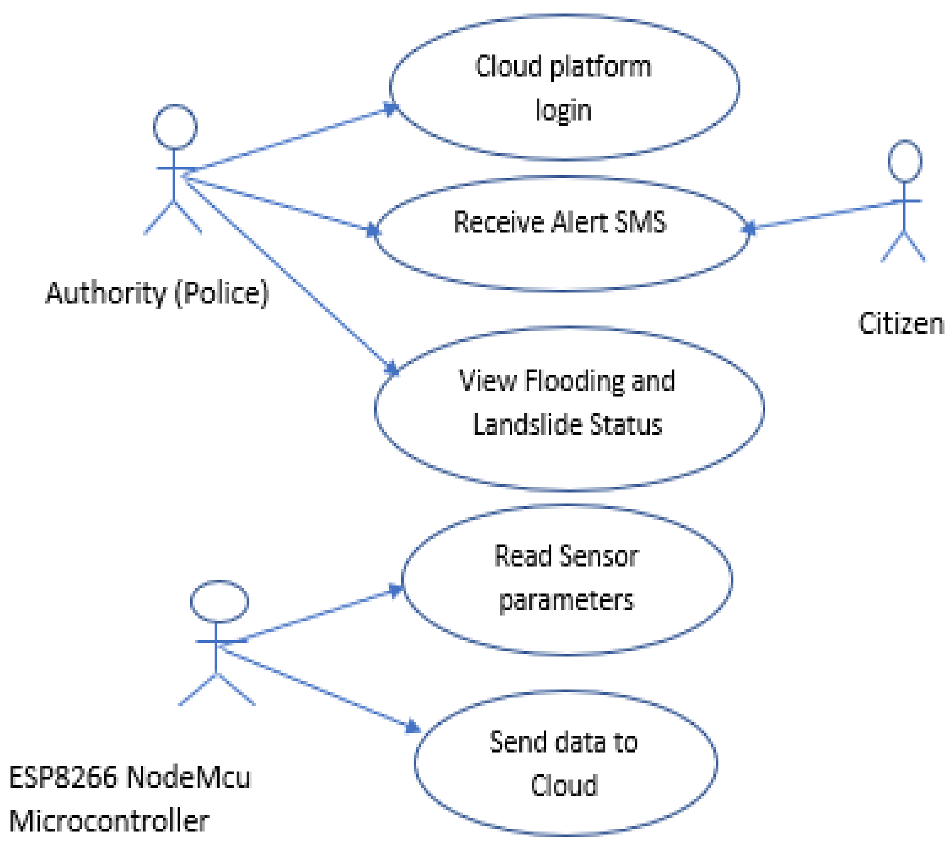


Figure 6: System use case diagram

CHAPTER FOUR: SYSTEM DESIGN AND ARCHITECTURE

4.1 Introduction

This chapter mentions all techniques and approach used to design and implement IoT based floods and landslide disaster monitoring and SMS alert system. The chapter illustrate both hardware and software requirement implementation and provides a description on the architecture of the system prototyped throughout this research.

4.2 System Architecture

A system's architecture is a high-level description of the entire system that specifies the essential architecture components and services, as well as the principles that the elements must follow when interacting and cooperating.

Embedded systems, as well as other technologies such as pervasive systems and sensor networks, are deeply anchored in the Internet of Things. The Internet of Things (IoT) is a system in which "things" are connected to one another via a network (over Internet protocol) to collaborate and perform tasks while engaging with the digital and physical environment.

The IoT architecture paradigm was used to create the flood and landslide disaster monitoring and SMS alert system.

4.2.1 Hardware Architecture

There are various components to develop a complete IoT system and service. Data sampling, which might be aperiodic sampling based on event and therefore useful to relax resource such as power and bandwidth limitations, is a key feature of the IoT Architecture. The capture of data from the environment that reflect a given state that is relevant for the system (input), such as waterflow rate, soil motion, and so on, is referred to as sampling.

Because it reacts when a change of any value parameter is detected, the flood and landslide disaster monitoring and SMS alert can be classified as aperiodic sampling.

4.2.2 Software architecture

At the end of the day, software is employed at the business layer for management, control, and security, at the application layer to meet the need by executing the use case, and at the processing layer for data filtering, aggregation, and other functions.

As a result, software architecture must be considered, particularly when describing the system's structure at the top tiers.

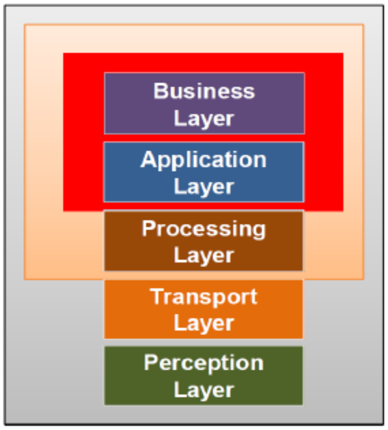


Figure 7: Upper layers responsible for Software Architecture[14]

Software architecture mainly are based modules varies amongst programming languages:

- Module can refer to encapsulation of data and functions;
- In some cases, it can also refer to a collection of numerous functions/classes, which is referred to as a package.

4.2.3 System design requirement

4.2.3.1 Functional Requirements

In order to monitor flood and landslide parameters the following functional requirements should be in place

- Sense water parameters through the sensors
- Send sensed data to cloud for storage
- Analyze and visualize data using ThingSpeak cloud platform
- Send SMS to mobile phone

4.2.3.2 Non-Functional Requirements

Performance: Based on its hardware, network, software, stability, startup, and storage

Availability: This system will be activated every time.

Reliability: This product will meet desired performance standards and gives output for accurate in certain environmental conditions.

Scalability: Many sensor nodes will be enrolled in the deployment

Usability: Anyone with ICT knowledge can use this system

Recoverability: When something is wrong in the system, it is easily recoverable

4.2.3.3 Hardware and Software requirements

Requirements for sensors and application Specifications

A sensor is a device that creates a proportionate output signal (electrical, mechanical, magnetic, etc.) when it is exposed to a physical phenomenon (soil moisture, displacement, force, etc.), whereas an actuator is a machine component that moves or controls a mechanism or system. Every closed loop control system relies on sensors and actuators to function properly. The controller receives data from the sensing unit, uses the control algorithm to make judgments, and then sends commands to the actuation unit[15] replaced by cloud application.

The following are specifications of sensors and actuators used in this research:

- water flow sensor with Op range -4o C-85oC, accuracy of ±1oC ,7mA,3.5V-20V
- ultrasonic sensor 3.3V / 5V compatible Wide voltage level: 3.2V – 5.2V Measurement Range 3cm – 350cm 2cm – 400cm
- The specifications of the FC-28 soil moisture sensor are as follows: Input Voltage: 3.3–5V, Output Voltage: 0–4.2V, Input Current: 35mA

4.3 Prototype Circuit Design

IoT Based Flooding and Landslide disaster monitoring and alert SMS system was made up by the following circuit which consist of sensors connected on microcontroller ESP8622 NodeMCU with Wi-Fi module as show in figure below

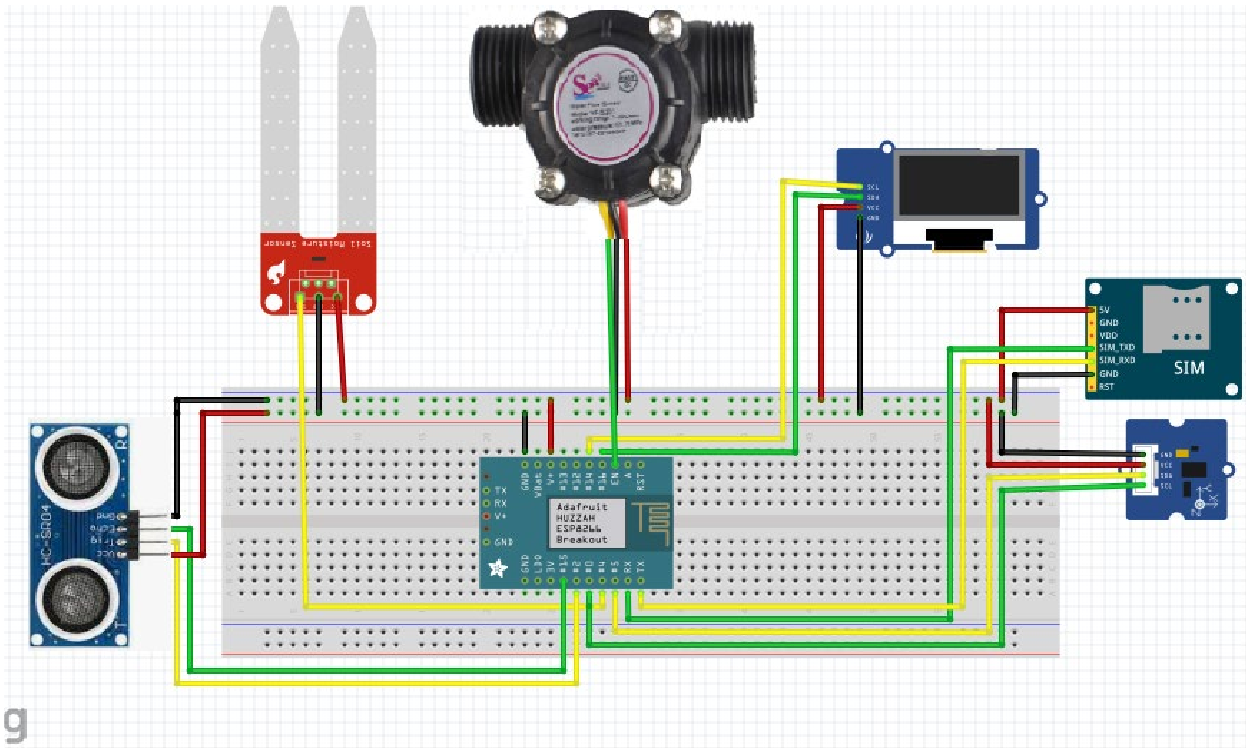


Figure 8: Prototype Circuit design

This circuit combines a set of sensor nodes to collect the data for flood and for landslide parameters from deployed environments. A microcontroller NodeMCU(esp8266) is used for edge processing and analysis with Wi-Fi communication data are pushed to the ThingSpeak cloud platform through gateway for being monitored and further analysis. Then GSM module is considered for sending message alert to mobile phone of the citizens and relevant authorities.

Ultra-Sonic sensor capture the distance between initial level of water from enviroment to high level considered as 2m in this reaserch where is prosseced by NodeMCU to detect flooding event. Water flow sensor connected to microcontroller when water pass through it determines the flow rate of the water in river in L/min; the capacity of device used in this experiment is from 1 to 30L/min so when 2L/min detected SMS notification sent as flooding warning.

Other sensors like accelerometer read positioning of Y axis at different angles based on its operation will provide analogue values at the output corresponding to direction and slope displacement measurement of the soil, Soil moisture sensor to measure the volumetric water content of soil both sent them to microcontroller for being processed and analyzed.

All collected data from the sensors are aggregated by microcontroller NodeMCU 82666 for being processed and through gateway push them to the ThingSpeak cloud. If any specific value detected as threshold an alert message send to the mobile where in this experiment 2m for ultrasonic, 5L/min for water flow rate, 510 acceleration and 50% for soil moisture parameters.

Updated data to the cloud platform at time are displayed to LCD display.

4.4 System three layered architecture

This architecture organizes the services needed to meet the requirement into three levels:

- Perception layer – Data input
- Network /Processing layer – Processing and connectivity
- Application layer – Information output as specific service

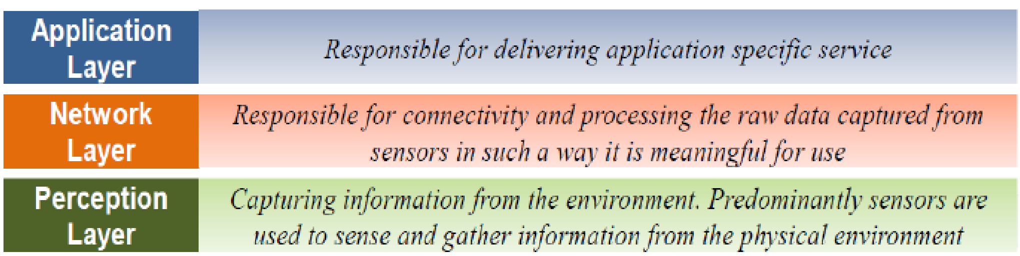


Figure 9: Prototype Circuit Diagram[14]

4.5 System components design

IoT based floods and landslides disaster monitoring with SMS alert system prototype architecture design contains four subsystems. These include sensing subsystem part, wireless communication subsystem, and application subsystem.

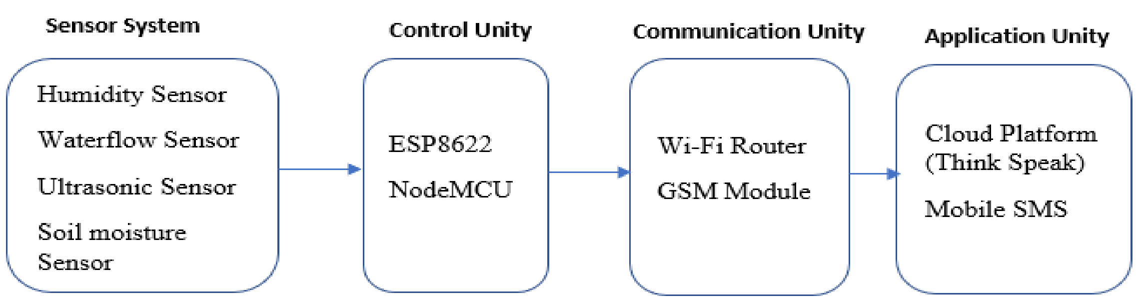


Figure 10: System components design diagram

4.5.1 Sensing subsystem

The subsystem describes the sensing part of the system. A sensor generally refers to a device that converts a physical measure into a signal that is read by an observer or by an instrument[16]. A sensor converts any type of energy into electrical energy.

1. **Accelerometer**

It contains accelerometer used for vibration and motion sensing of the soil. The basic structure of accelerometer has a fixed plate and moving plate[17] where moving plate deflects due to the acceleration that return unbalances differential capacitance and give the output voltage proportional to the acceleration.

Angle	**-90**	**-80**	**-70**	**-60**	**-50**	**-40**	**-30**	**-20**	**-10**	**0**
Acceleration	662	660	654	642	628	610	589	563	537	510
Angle	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
Acceleration	510	485	455	433	408	390	374	363	357	355

Table 1: Accelerometer readings

Above table, are some accelerometer readings collected by positioning the y-axis of an ADXL322 2g accelerometer at various angles from ground. Values should be the same for the other axes, but will vary based on the sensitivity of the device. With the axis horizontal (i.e. parallel to ground or 0°), the accelerometer reading should be around 512, but values at other angles will be different for a different accelerometer because reading values change from one device to another and change according to the change of angle on ground.

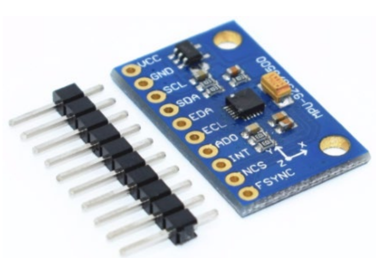


Figure 11: Accelerometer Sensor

2. Soil moisture sensor

The soil moisture sensor is one kind of sensor used to gauge the volumetric content of water within the soil. As the straight gravimetric dimension of soil moisture needs eliminating, drying, as well as sample weighting.

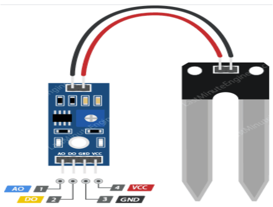


Figure 12: Soil moisture sensor

2. **Water Flow Sensor**

Water flow rate sensor that collects physical data from the environment such as water velocity in the pipe and input to the microcontroller ESP8266 for further processing.

During the working of the system, the magnetic flow water sensor will measure water quantity in water pipe. The flow rate sensor is sort of pinwheel whose speed is proportional to the liquid flow rate passing through it. During prototyping the researchers use water flow sensor YF-S201[18][19]. In which the sensor installed to generate output frequency of 7.5Q where Q is flow rate in liters per minute (L/min)

Figure 13: Arduino flow sensor

The experiment conducted by D. Guimar in research [20] demonstrated the Esp8266 to be IoT module with ultraLow Power and low cost module which makes it to be the best to connect to wireless infrastructure and share data with internet security techniques . The study through the experiment concluded the module to be suitable to implement gateways in IoT application without external WiFi shield which results in low power computation power compared to other popular embedded frameworks mainly Raspberry pi, BeagleBone and many more.

5. Ultrasonic Sensor

Ultrasonic sensor used to measure the level of water and define its distance from initial level. The ultrasonic works on the bases of sound waves generated in the trigger and echo system[11]. When the obstacle is observed in the trigger path, immediately the reflection path is observed at echo.

Figure 14: Ultrasonic sensor

4.5.2 Wireless Communication Subsystem

The subsystem describes the wireless communication part of the system. The collected data from the sensors are sent to microcontroller for being processed if any specific parameter for flooding or landslide reach threshold value a alert message send to the mobile phone of citizens and concerned authorities based on location where disaster occurred as well as to the ThingSpeak cloud platform for being processed, monitored and analyzed via NodeMCU and gateway.

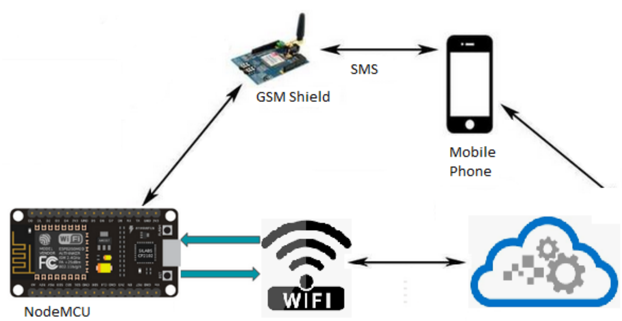


Figure 15: Wireless communication block diagram

For communicating flooding and landslide parameters to the cloud and users below components were considered

1. ESP32

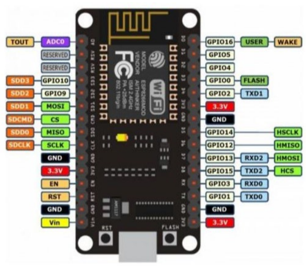
For detecting flooding and landslide parameters, the sensors are connected to arduino microcontroller ESP8266 NodeMcu. ESP8266 is WiFi built in capability board that allows connecting to the Wi-Fi using TCT/IP protocol[21]. Consequently the board operates in three mode mainly access point mode (AP), Wi-Fi station or both at the same time[22]. The Esp8266 arduino board is programmed in C++ programming language using arduino development Environment (IDE) software platform  .

Figure 16: ESP8266 NodeMCU microcontroller

2. GSM

Global System for Mobile communication (GSM) module is designed for wireless radiation monitoring through Short Messaging Service (SMS). This module is able to receive serial data from radiation monitoring devices such as survey meter or area monitor and transmit the data as text SMS to a host server. It provides two-way communication for data transmission, status query, and configuration setup[23].

Figure 17: GSM Module

3. Wi-Fi

Wi-Fi is the popular name for the wireless Ethernet 802.11b standard for WLANs and it refers to the technology surrounding the radio transmission of the Internet protocol data from an Internet connection wirelessly to a host computer[24]. Wi-Fi enables computers to send and receive data indoors and outdoors; anywhere within the range of a base station[24]. It is in that way was used in this research to send flooding and landslide information to the cloud platform

Figure 18: Wi-fi router

4.5.3 Application and Cloud Subsystem

1. **Cloud platform**

Cloud computing is Internet-based computing where virtual shared servers provide software, infrastructure, platform, devices, and other resources and hosting to customers on a pay-as-you-use basis[25]. Cloud computing is accessing on demand computing resources via the internet, such as software, storage and even infrastructure[26]. In this research ThingSpeak cloud platform was considered as an IoT analytics platform service that allows to aggregate, visualize and analyze live data.

2. **Integrated Development Environment Requirements (Arduino IDE)**

The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards[27], but also, with the help of third-party cores, other vendor development boards. In this research Arduino 1.8 version was used.

3. **Arduino C programming**

Arduino C programming language fed and compile instructions into machine code that the microprocessor or microcontroller can execute. This is an extra step, but it results in a more efficient program than an interpreter. An interpreter turns your code into machine language while it's running, essentially a line at a time[14].

CHAPTER FIVE: RESULT AND ANALYSIS

5.1 Introduction

In this chaper, the core parameters or data for flooding and landslide from sensors was tested, where data captured by sensor nodes are localy procesed by microcontroller ESP8266 NodeNCU and sent to the cloud to be analysed, proceded and monitored on the dashboard in different forms. Different data such as humidity, soilmoisture, soil acceleration, waterflow rate and water level distance to detect flooding and landslide disaster are well analysed.

5.2 Waterflow rate data for flooding Evaluation

To evaluate waterflow rate for flooding, the water flow sensor use its venturi meter and orifice plate restric the flow and use the presure difference to determine the flow rate. When the water flows through it ganerate the signal to the microcontroller which corresponding to the water flowrate in litre per min (L/min). The flowing figure represent waterflow rate sensed then update the data to the ThingSpeak cloud within each five minites

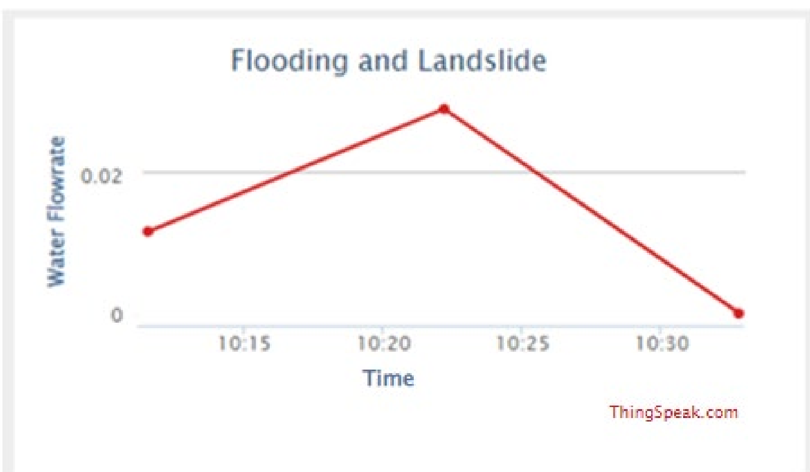


Figure 19: Waterflow sensor data to the cloud

This result from the above figure 19 was generated to the ThingSpeak cloud platform when water flows through the water flow sensor by using hall-effect principal generate an electrical pulse with every revolution. That signal applied to digital pin of microcontroller is processed and transmitted to the cloud within five minutes as indicated in X-axis graph. This curve increased up during water flow in sensor then decrease down at zero when there is no water flow during explement testing.

5.3 Water level data for flooding Evaluation

To evaluate water level parameter for flooding, ultrasonic sensor use to send out a sound wave (pulse) at frequence above the range of human hearing. The sensor determines the distance to a target by measuring time lapses between the sending and receiving of the ultrasonic pulse. The flowing figure represent distance sensed from initial level of water to high levet with updating the data to the ThingSpeak cloud within each five minites. When sensed water level excude 2m system should notify flooding event for evacuation.

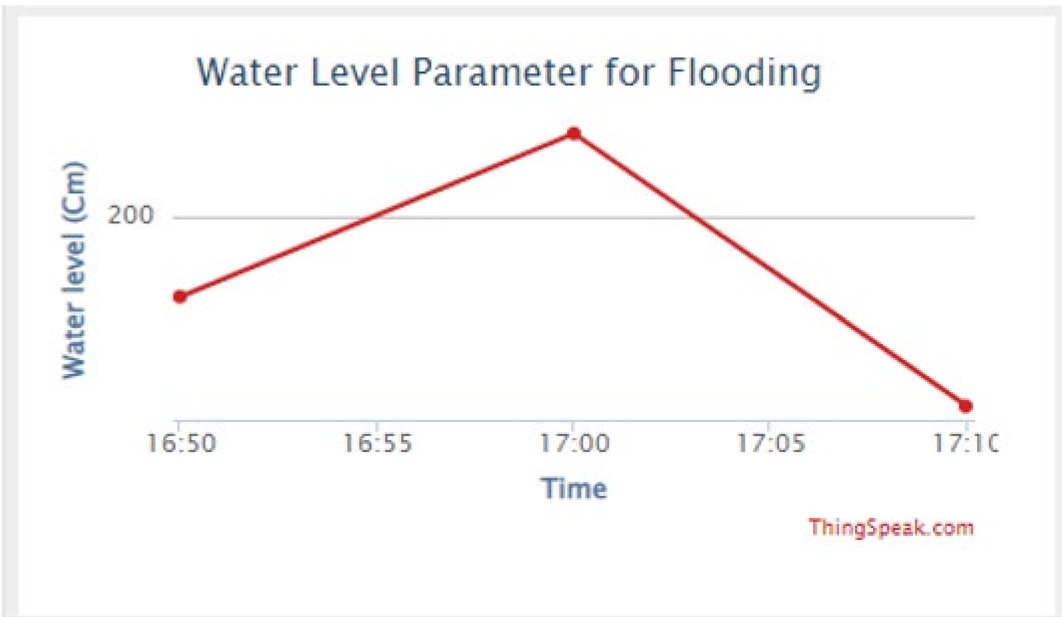


Figure 20: Water level data to the cloud

This result from the above figure 20 was captured from ThingSpeak cloud platform when ultrasonic sensor send out a sound wave (pulse) at frequence above the range of human hearing. At return distance from current level of water and bord of liver where sensor diployed is measured with the signal applied to digital pin of microcontroller process and transmit it to the cloud within five minutes as indicated in X-axis graph. Based on given result from 16:50 time level of water increased until 17:00 time then reduced where in period of five minutes from 16:55 level reach 2m to prompt GSM module to send flooding alert SMS notification.

5.4 Soil moisture data for Landslide Evaluation

To evaluate water volume in the soil for predicting landslide soil moisture sensor is used .When the water volume is increased in the soil the humidity increased and soil go in motion for resulting landlisde. The flowing figure 21, water volume sensed from soil then update the data to the ThingSpeak cloud within each one minite.

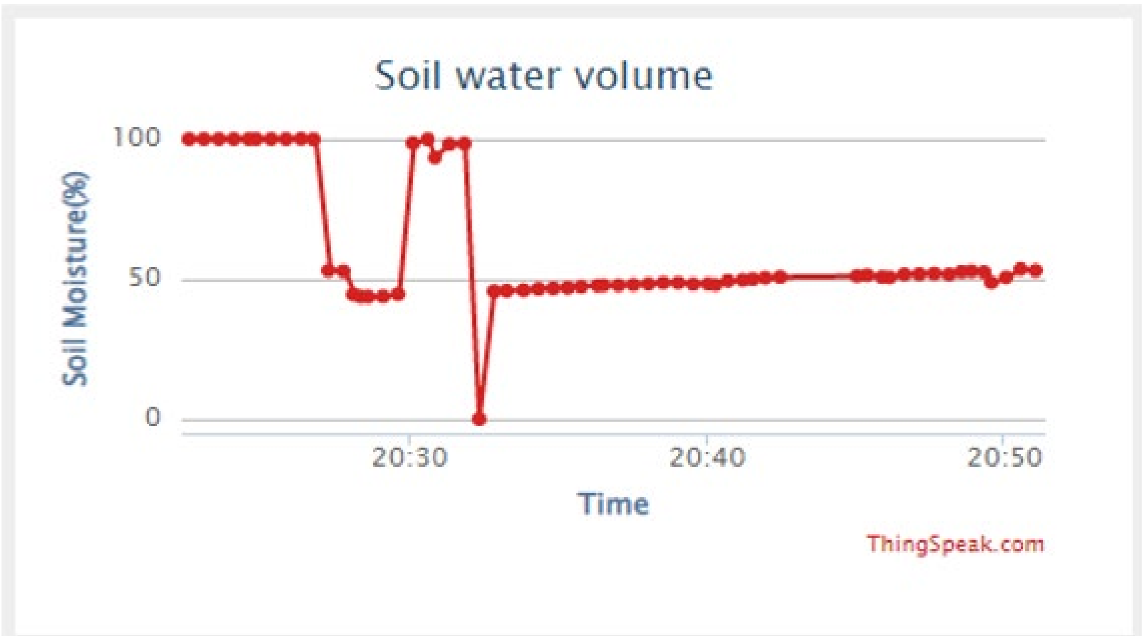


Figure 21: Water volume from the soil to the cloud

Figure 21 captured from ThingSpeak dashboard produced by data sensed by soil moisture as water quantity from the soil. Based on working principal when the soil was dry reading value is around 10% and when was completely wet is around 100%. In research during experiment value have converted in percentage by considering 50 percent as threshold value to consider wait soil in which should be in movement for resulting landslide disaster and absolutely landslide notification message sent to warn people for landslide event.

5.5 Soil motion data for Landslide Evaluation

To evaluate motion for predicting landslide accelerometer sensor is used . Some accelerometer readings collected by positioning the y-axis of an ADXL322 2g accelerometer at various angles from ground has 510 values as acceleration. Based on monitored data from it desion should be taken and if execed 510 the message notification is sent as lindslide event.

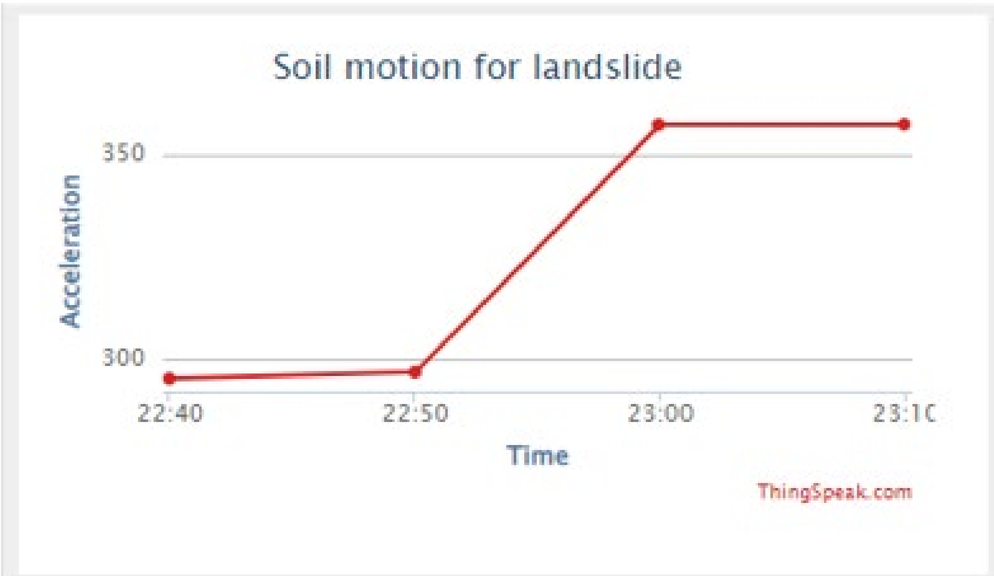


Figure 22: Soil motion data to the cloud

This result from figure 22 is due to soil wait condition and goes in motion as lasndslide measured by accelerometer sensor. As it have been explained in design section this sensor use threes axis to form diffeerents angles so initialy sensor readings is when positioning or angle of the y-axis of an ADXL322 2g accelerometer to the ground was increased means soil is in motion. Then angle reduce to bring acceleration high as is indicated by graph where it lead to landslide because in experment of this research 80 degre of 357 value considered as threshold value to notify as alert message of landslide event.

5.6 Alert SMS for Flooding and landslide Evaluation

The flowing figures are notification messages that ware receive through telephone device in various time when one of described above threshold values are reached. Below figure 23 show screenshoots notifying flooding another for landslide reported to mobile of citizen or nearest authority for evacuation or providing prevention support.

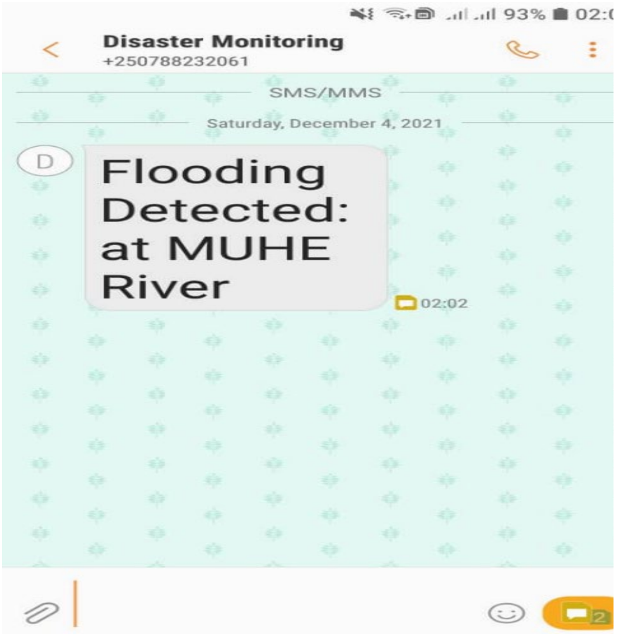


Figure 23: (a) Alert Message Notification for Flooding to Mobile phone

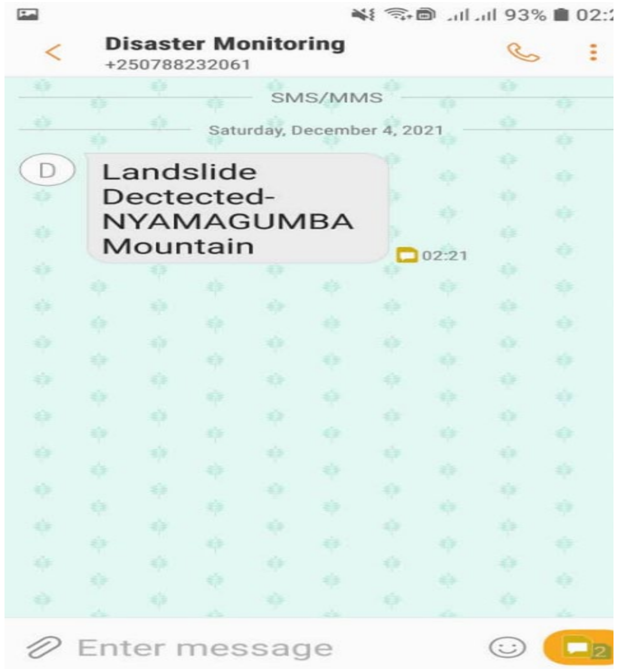


Figure 24 (b) Alert Message Notification Landslide to Mobile phone

This notification results describe type of disaster and probable location based on the ID of device deployed in corresponding location.

5.7 Prototype Efficiency

As a prototype, the flood and landslide disaster monitoring and SMS alert system has been successfully implemented. All of the sensors and other equipment function as expected.

The sensors successfully sense and provide readings based on the surrounding conditions. Flooding and landslides are effectively predicted based on readings. The system continuously senses and transmits data.

When NodeMCU tries to connect to Wi-Fi, it consumes 1.6 Watt owing to 320mA current drawn at 5V supply voltage, and 0.49 Watt due to 98mA current drawn at 5V supply voltage when NodeMCU connects to Wi-Fi and delivers data. The NodeMCU can be run in duty-cycled mode to reduce power consumption and boost battery backup. The system takes 10 milliseconds to respond. The system collects data from the sensor and sends it to NodeMCU in 10 milliseconds.

In addition, uploading data from NodeMCU to ThingSpeak cloud at the sametime a message to mobile phone takes an extra 20 milliseconds where are all proving great effectiveness of solution mapped to the research objectives.

CHAPTER SIX: CONCLUSION AND RECOMMANDATION

6.1 Conclusion

An IoT Based Flood and Landslide disaster Monitoring and SMS alert system collects data with sensors that contain water level, waterflow rate, soil water volume and soil acceleration and send them to the cloud through Wi-Fi and Network protocal then stored in cloud. Those data are monitored in real time through mobile phone and ThingSpeak cloud platform application. This system solution respond to the research questions of detecting and monitoring described data and paramenters which were the main purpose of this study by controlling sensed data with Arduino C programming and process, analyse them by Arduino microcontroller NodeMCU ESP8266 and ThingSpeak cloud to visualize and monitor data timely. Additionally researcher use GSM technology to send message notification to help people for evacuation, ended help disaster managers for planning to secure the victims and by saving money they should used for impacted people in term of socio-economic, injuries and dameged assets.

The complete scope of this study was covered, and the results of many tests show that the flood and landslide monitoring system can have a favorable impact on society. Also the data generated by the system would contribute in further studies or / and further researches.

6.2 Recommandations

The following are recommandations after conducting this research thesis on IoT Based Flood and Landslide disaster monitorng and SMS alert system:

- The local authorities and the comminity itself are reqested to be familier with the use of ICT skills in order to manipulate the system and monitor the flood and landslide parameters on time from cloud platform.
- Intermitted power outages constitute a big challenge too, the use of renewable energy resources such as solor energy especially in rural areas or high risk zone where deployment of electical infrastrure is not easy can help mitigate this problem.
- Ministry in charge of Emergency Management (MINEMA) is suggested to use this system as tool prevention for risk of flooding and landslide disaster.
- Future researchers are recommanded to enhanced the capability of designed solution by using Satallite and GPS techonologies .

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