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WSN and IoT Based Landslide Monitoring System

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Abstract: Landslide is one of the most severe natural disaster has caused huge socioeconomic losses. Statistics from the Centre for Research on Epidemiology of Disasters (CRED) estimates that 17% of fatalities caused from all natural disaster are due to landslides. This paper demonstrate a proposed monitoring and early warning system for landslide utilising Wireless Sensor Networks WSN and Internet of Things IoT technology. The system will include soil moisture sensor as it has been demonstrated by various researcher that rainfall is one of the leading cause of landslide. DHT22 sensor is used to record the air temperature and humidity of the soil surface. MPU6050 gyro-accelerometer which consisted of 3-axis gyroscope and 3-axis accelerometer will be utilized to detect soil movement and vibration with relatively high accuracy and resolution. Arduino Mega 2560 will record the temperature, humidity, vibration and moisture of the soil surface. These real-time data will be transmitted using via ZigBee to a receiver unit which is equipped with ESP8266 Wi-fi module so that the data can be uploaded to the cloud. The data and status of the terrain is assessable to other researchers and public via smart phone application developed using Blynk Internet of Things IoT platform. The landslide alert will be broadcast through smartphone application unlike other proposed system in the literature. Communities can receive the alert in real-time thereby potentially reduce the fatality risk.

Keywords: *Wireless Sensor Network, ZigBee, IoT, Landslide*

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I. INTRODUCTION

Landslides is a geological phenomenon that has caused numerous death toll and loss of properties every year. In regions susceptible to slope failures, land slide risk assessment must consider the available economic resources, environmental impact and safety of [1-3]. Once a landslide is triggered, material is transported bydifferent components including sliding, streaming and falling. The sorts of landslides vary with respect to the type of material, rate of movement and nature of movement. Constant monitoring of environmental disasters such as landslide can reduce the number of fatalities especially in developing countries.

Wireless Sensors Networks WSN is one of the innovations that can rapidly react to fast changes of information and send the information to the collector sectionin territories where wired or cabling is not accessible or expensive. WSN

innovation has the ability to process and transferring transmission of required data continuously. There are several limitation of WSN such as low memory, limited processing capability, low power transmission and low data transfer capacity. However its ability to be deployed in hostile condition, energy efficient and require minimal support made it one of the most appropriate technology for continuous monitoring of steep sided hills that are prone to landslide.

In this paper, a development of an early warning system for landslide utilising Wireless Sensor Networks WSN technology namely Zigbee protocol and Internet of Things IOT is presented. WSN enables the developed system to be distributed and deployed over a relatively vast area at relatively low cost. Unlike other landslide monitoring system proposed in [4-8], the alerting system and data collected by the proposed system is assessable through smartphone application. A study conducted by [9] estimates that global smartphones adoption stood at 59 percent in 2017 and projected to increase by 79 percent in 2025. Therefore, the proposed system can provide an early warning to communities residing in regions susceptible to landslide. Moreover, the ground movement data can be analysed by governmental agencies formulate effective national policy, strategy and action plan to reduce public risk and minimizing the loss of economic activities.

II. LITERATURE REVIEW

According to [2-3], it is found that most of the landslides in tropical countries such as Malaysia can be categorized as shallow landslides. Majority of these shallow landslides are triggered by substantial rainfall during the monsoon season. The rain water is absorbed by the soil resulting in loss of negative pore water pressure. Landslide warning system can be produced by utilizing a rainfall monitoring system. Nonetheless, it is relatively expensive and difficult to accurately gauge the ground water level.

In [4], the research was conducted with the intention of providing an alert on the presence of a landslide. The system includes three types of sensors; angle sensor which gives the readings of incline edge if there is any regression in landslide, fluid level sensor to gauge the depth of water at the mountain cliff and temperature sensor acts as a detector to any adjustments in the temperature. As the coding is set in Arduino sketch for the sensors, every one of the hubs of sensors are associated with the Raspberry Pi for gathering of data. After every one of the data gathering step is finished, the readings are given to ZigBee for transmission.

Meanwhile in [5], three sensors were utilized which are: water level sensor gathers the profundity of water at the mountains while the angle sensor gives the readings of slant edge if there is any movement in landslide. Temperature sensor traces the adjustments in the temperature. These all hubs of sensors are associated with the LPC 2148 ARM processor for data collection process. The LPC2148 microcontroller depends on a 32bit ARM7TDMI-S CPU with ongoing imitating and installed trace bolster, that consolidates the microcontroller with implanted high-speed flash memory up to 512kb. A 128-bit wide memory interface and a sophisticated accelerator. As the information is gathered, the GPS gives scope and longitude and every one of the readings are given to ZigBee for transmission. As the data reached the recipient side by LCD display at receiver station, alerting the people to save lives and property. This design combines of GSM wireless communication technology and Wireless Sensor Network.

Although various researchers such as [4][6] and in [7] have proposed the use of WSN technology to detect occurrence of landslide, the public still faces difficulty in receiving the alert or warning message.[8] and [9] have integrated their land

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slide monitoring system with the ThingSpeak IoT platform. The data collection and landslide alert system developed by [8] can therefore only be accessible to the developer and authorized personnel only.

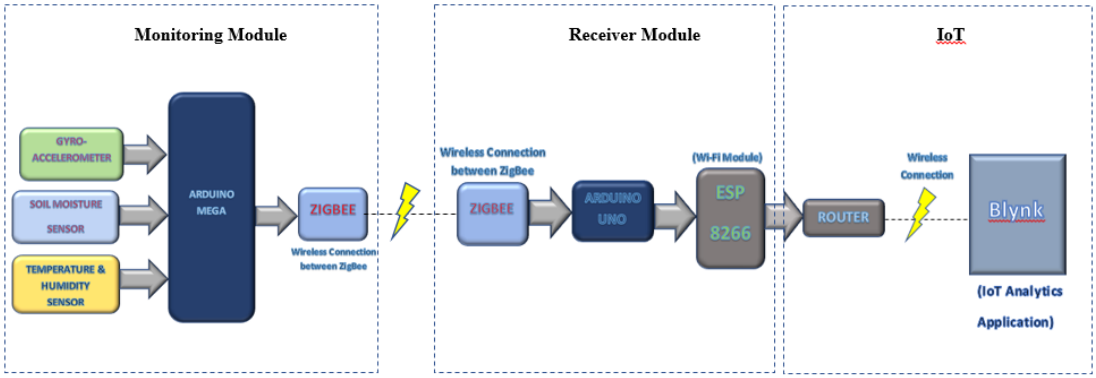

Figure 1.0: Block diagram of WSN and IoT based landslide monitoring system

III. WSN AND IOT BASED LANDSLIDE MONITORING SYSTEM

The modules and components utilized as a part of the proposed system are Arduino Mega 2560, Arduino Uno R3, ESP8266 Wi-Fi and Wireless Sensor Network ZigBee modules. The sensors include DHT22 temperature and humidity sensor, MPU6050 gyro-accelerometer and soil moisture sensor. The DHT22 is an ultra-low-cost digital temperature and humidity sensors. It utilizes a capacitive humidity sensor and a thermistor to quantify the encompassing air, and spits out a digital signal on the data pin (no analog input pins needed). When using the DHT22 library in the Arduino sketch, sensor readings can be up to 2 seconds old. The MPU 6050 is a six-axis IMU (Inertia Management Unit). Three values from the gyroscope and another three-collected data is from the accelerometer. In fact, the gyroscope and accelerometer are both installed inside a single chip. The chip utilizes I2C (Inter-Integrated Circuit) protocol for connection. MPU 6050 sensor and will be used to measure the 3-dimensional ground (x,y,z axis) surface movement.

Another sensor utilized is the soil moisture sensor which records the soil moisture data in percentage value. Arduino records the temperature, humidity, vibration and moisture of the soil surface while the transmitter ZigBee transmits the information gained from transmitter side processor. At the point recipient side ZigBee gains the signal and automatically obtains data transmitted from transmitter.ESP8266 acts as a web-server that transmits this information to the internet. Blynk is an open source application and programming interface to store and retrieve data from things using HTTP over the Internet or via a Local Area Network. This application likewise permits the user can make sensor logging applications and area tracking applications with notifications. In this project, Blynk used to collect and monitor the sensors collected information from Arduino. The block diagram of the proposed system is presented in Figure 1.0. The prototype of landslide monitoring and receiver modules are given Figure 2.0 and Figure 3.0, respectively.

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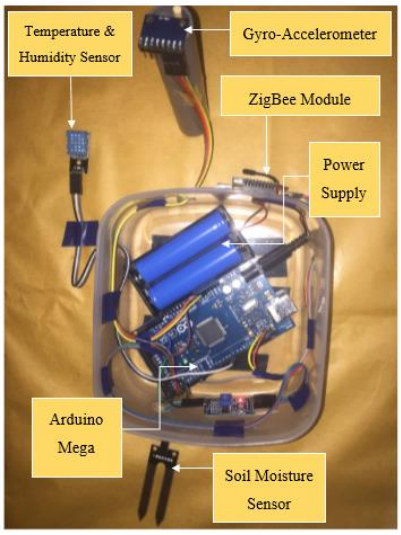

Figure 2.0: Monitoring Module

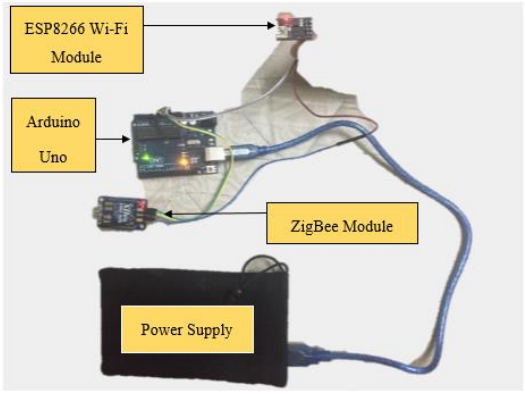

Figure 3.0: Receiver Module

The operation flow for the modules is given in Figure 4. The aforementioned sensors along with the microcontroller will measure soil environmental condition. Specifically MPU6050 gyro-accelerometer will measure the 3 dimensional ground surface movement (x,y,z axis). Other sensors will measure the environmental condition such as air temperature, humidity and soil moisture. In order to reduce the power consumption and prolonging the battery lifetime of the system, the data is sampled everyone hour. However, if soil movement is detected via the MPU6050 gyro-accelerometer, the system will sample and record the data for at every soil movement detected. The data will then we wirelessly relayed to a receiver via ZigBee. The receiver which is equipped with ESP8266 Wi-Fi module will transfer the data to the cloud. All the sampled sensors data is displayed through Blynk mobile phone application. The application will provide alert should signification ground movement is detected.

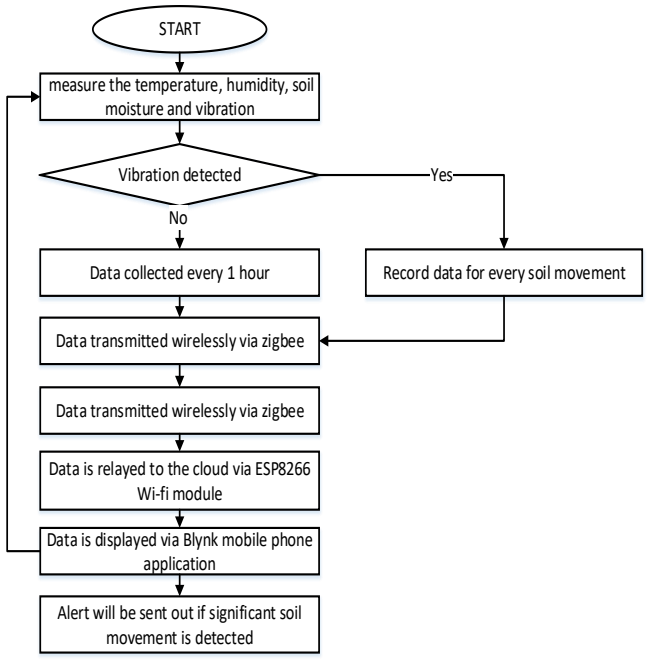

Figure 4.0: Operation flow of WSN and IoT based landslide monitoring system

IV. RESULTS AND DISCUSSION

The landslide monitoring module was placed on a steep sided hills with the MPU6050 gyro-accelerometer placed on the surface of the soil to measure 3 dimensional soil surface movement. The receiver was placed in an area with Wi-Fi connectivity to enable uploading the data onto the cloud.

1. Zigbee communication range

Figure 5 shows the maximum separation distance between in which the receiver can reliably receive data packets which loss from the landslide monitoring module using the WSN Zigbee protocol. The measured maximum distance is 351.75 ft. or 107.21m is in line with the urban

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transmission range specification of ZigBee XBee Pro S2B.

Figure 5.0: Zigbee range for the landslide monitoring system

2. Data collection on the landslide monitoring and receiver modules

As mentioned in section III, the landslide monitoring module consists DHT 22 temperature and humidity sensor, MPU 6050 gyro-accelerometer, LM 393 soil moisture sensor and ZigBee XBee Pro S2B. Sensors will sampled the data at for each movement or vibration detected by 6050 gyro-accelerometer or every one hour. The readings of the sensors before the data is transmitted to the receiver module via ZigBee XBee Pro S2B module is shown in Figure 6. The result shows the data collection from each sensors as displayed through the serial monitor of Arduino. There are 4 main elements collected as displayed in the figure for the landslide monitoring system; vibration, temperature, humidity and soil moisture.

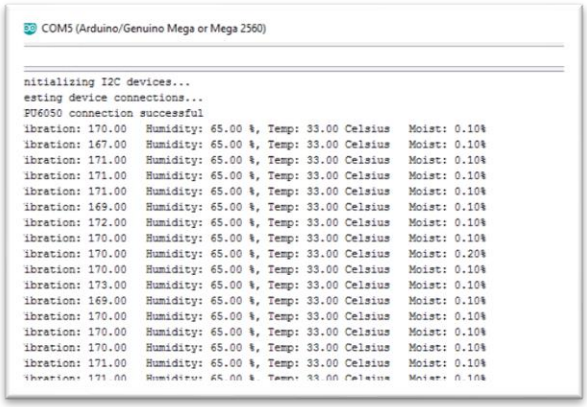

Figure 6.0: Data collection at the monitoring module

The receiver module consists of ESP8266 Wi-Fi module and ZigBee XBee Pro S2B module. The sensors data receive via the Zigbee can be viewed using the Arduino serial monitor as shown in Figure 7. The Figure shows five different values which represent each of the sensor. The first one is the combination of x-axis and y-axis for the gyro/accelerometer sensor while the second one represents the z-axis of the sensor. Third value indicates the temperature reading of DHT 22 and the final reading is the soil humidity in percentage form.

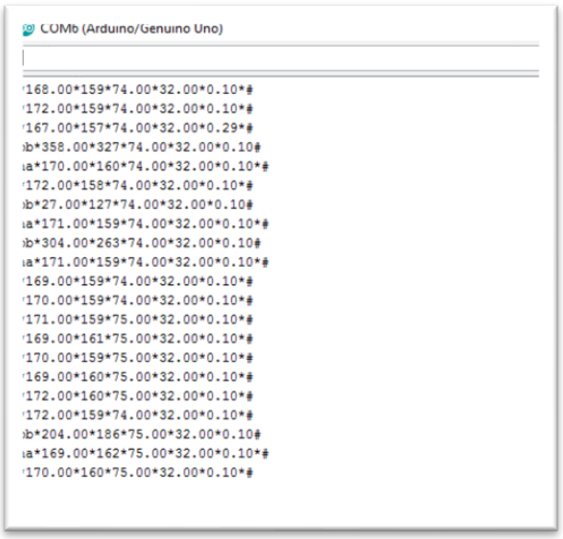

Figure 7.0: Receive data at the receiver module

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3. Alert system through Mobile phone application

Figure 8 illustrates the collected data graph under normal condition (no landslide occurrence) of the slope. The result is as displayed on a mobile phone application developed using Blynk IoT platform. The graph indicates the data collection of vibration, humidity and temperature while the value of the soil moisture remains below zero during the normal condition. The absent of alarm or alert signifies that the condition of the slope is normal.

Figure 8.0: landslide data as displayed through smartphone application

Figure 9 shows the result of a simulated rainfall induced landslide. The large soil movement causes the z-axis reading from MPU6050 gyro-accelerometer sensor to drastically fluctuate. Furthermore, the rainfall induced landslide also results in high humidity reading. The developed mobile application will detect the high activity of gyro-accelerometer reading and will provide alert to the public on the potential landslide occurrence.

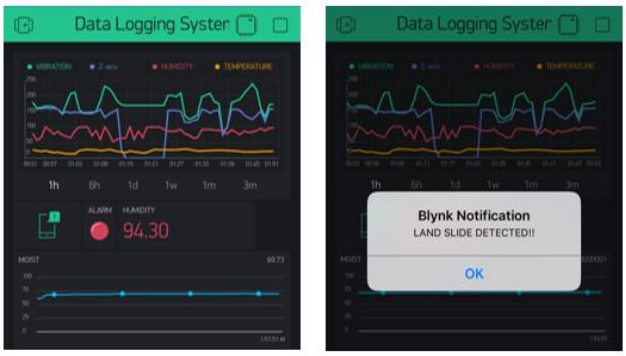

Figure 9.0: landslide data as displayed through smartphone application

V. CONCLUSION

Given the widespread usage of smartphones in emerging countries, the proposed WSN and IoT based landslide can provide an early landslide detection and warning via mobile phone application. This reduces the fatality risk of communities residing in regions susceptible to landslide.

Moreover, the system also utilized Wireless Sensor Network technology and thus reduces the development cost. The system can therefore be mass produced distributed and deployed over a relatively vast area.

The data collected by the proposed system is also easily be accessible to scientists, researcher and government agencies such National Meteorological Department. The historical data can be used to model the probability on the occurrence of a landslide.

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