Integrated Earthquake and Landslide Monitoring Over Wireless Sensor Network

Th.Nanao, RomeshLaishram

Abstract*:*Natural disasters have mercilessly devastated our lives in so many different terms. The impact of Earthquake and landslides are very severe because of their unpredictability. To alleviate the problem early warning system plays an important role. In this paper, we proposed an integrated earthquake and landslide monitoring system overthewireless sensor network. The Wireless Sensor Network is programmed to acquire the data, which is monitored and controlled centrally or independently and can be distributed widely in a random or planned deployment. By detecting suspicious indications such as tremor or landslides through sensor nodes, the system provides information to the monitoring and warning station. The processing unit is composed of arduino and Sensors such as 4.5 Flex Sensor, Capacitive Soil Moisture Sensor and a3-Dimensional Accelerometer are used in the proposed system to monitor landmass displacement/movement, the moisture level of the soil and the vibrations for earthquakes respectively. An RF module, XBee S2C is used which provides wireless communication with a range of about a 1 km line of sight and 60 meters indoor. The real-time data can be accessed via the internet. It will be powered from a 12V 20W solar panel with rechargeable Li-Ion Battery and fitted with necessary protection and charging circuit boards. The proposed system can be used in earthquake and landslide prone area to avoid damages to life and property in the area of operation by providing crucial information and further warning for any disastrous development. The proposed system is implemented through experiments and proved to be effective.

Keywords:Arduino, Earthquake Monitoring,IoT, Landslide Monitoring, Wireless Sensor Network.

I. INTRODUCTION

Earthquakes and landslides are natural disasters that can cause massive devastation to life and property in the affected area. Certain regions are prone to such events and northeast India including Manipur is located in Zone-V (very severe intensity earthquake zone). As Manipur lies at the junction of two tectonic plates- Indian and Eurasia plate, earthquakes will be more frequent than other lower seismic active zones. In Manipur, Landslides occur frequently during monsoon in hilly areas in the state. Studies have concluded that landslides in Manipur are mostly man-made disasterdue to the road widening and urbanization also increase the potential for landslides.

Monitoring and warning system is one of the solutions that can prevent and minimize losses caused by earthquakes and landslides. The most suitable technology for acquiring information widely in nature or areas for a purpose such as monitoring and maintenance is via Wireless Sensor Network (WSN) technology. WSN can be effectively applied to large geographical areas and find its application indifferent domains like pollution or air contamination monitoring systems,habitat monitoring areas, fire detection systems, nuclear reactor controllers, object tracking, etc. It requires an integrated wireless system such as WSN that is an early warning and able to detect early indications of natural disasters such as landslides and earthquakes and also monitor the large scale environmental conditions. Wireless Sensor Network (WSN) collects the information from the environment to measure the incidence ofbiological,thermal,mechanical, chemical, optical or magnetic and transmit information collected from sensor node to a sink node or network coordinator the information may be sent to a monitoring station for further processing.

In this paper, we proposed an integrated earthquake and landslide monitoring system using a wireless sensor network as a backbone. The advantage of an integrated system is that instead of multiple monitoring stations only one monitoring station can be used for gathering information about both types of disasters. The proposed system is tested in Imphal, Manipur, India.

II. LITERATURE REVIEW

Many researchers are actively doing various research work on Wireless Sensor Network to use it in small scale or large scale such as home security, agriculture, livestock, etc. in terms of small scale and in large scales such as military, wildlife monitoring, forest fire monitoring, post-natural disaster management, traffic management, earthquake detection, flood detection, landslide detection, etc. All these systems are implemented to suit their requirements of their respective areas of habitat.

Many systems based on WSN have been used as warning systems in natural calamities or disasters. A model proposed for landslide detection uses three sensors viz. soil moisture sensor, humidity sensor and accelerometer sensor with warning system at the remote place and ZigBee for communication. The drawback(s) of this mentioned system is their limited power supply and it's off-grid meaning the information won't be transmitted over the internet or mobile devices[1].

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Another similar system used smaller microcontroller is used and lesser sensors[2]. An author discussed existing different types of monitoring systems using WSN[3].

For landslide detection, sensors such as extensometers, clinometers, soil hygrometers, and bar extensometers are also employed[4].

In another system, they presented a monitoring and prediction system for deeply sloped Landslides which uses 3 axis accelerometer and capacitive soil moisture sensor [5]. A proposed work used geophone, pore pressure transducer, strain gauge, tiltmeter, and dielectric moisture sensor[6]. The methods in one model used sensors for collecting data like vibrations, moving speed, and GPS trajectories to infer the slope movement[7]. The inclinometer, soil moisture sensor, piezometer, and rain gaugeare employed in the proposed model and the work in used geophone for incoming vibration, accelerometer, and microphone[8], [9]. Another model proposed a self-powered, soil water content measurement sensor is used to trigger the event[10]. A mechanism is implemented to solve the problem of energy supply, which wakes up the sensor and communication circuits when the water content in soil increases more than a certain threshold level. The authors in two modelsused soil moisture sensors, accelerometer sensors, and temperature sensors and one of the, used an inclinometer sensor with GSM module attached to it[11],[12]. Another model used accelerometer only for detecting landslide but the system is self-powered (solar-powered)[13].

For earthquake detection, few authors used an accelerometer to predict earthquake which is also used in this proposed system[14]. Since it is very sensitive and supports 3-axis, its application is widely used. One model used 3 accelerometers to detect an earthquake and uses PIC168F77 to process the data and similarly uses ZigBee to transfer the data over to another ZigBee which is connected to a computer and further transfers them to the internet [15].

In this paper, we proposed an integrated earthquake and landslide monitoring system which is an upgrade system to its predecessors in terms of accuracy, processing speed, durability, power independent, access and future upgradeable. And also the combination of monitoring these two phenomena will be cost-effective and more suitable in a region that is susceptible to such natural disasters. In this work, we used an upgraded Processor-Arduino Mega2560 which has more analog and digital i/o ports, upgraded RF module- XBee S2C with more area coverage and better sensors.

III. SYSTEM MODEL

A wireless sensor network (WSN) is a wireless network that utilizes sensors that are internetwork to monitor the state of physical or environmental conditions. WSN is formed by a number of sensor nodes scattered in an area called the sensor field in different modes of deployment. Each sensor node is capable of collecting data and communicate with other sensor nodes and coordinators.

The block diagram of the proposed model is as shown in Figure 1.

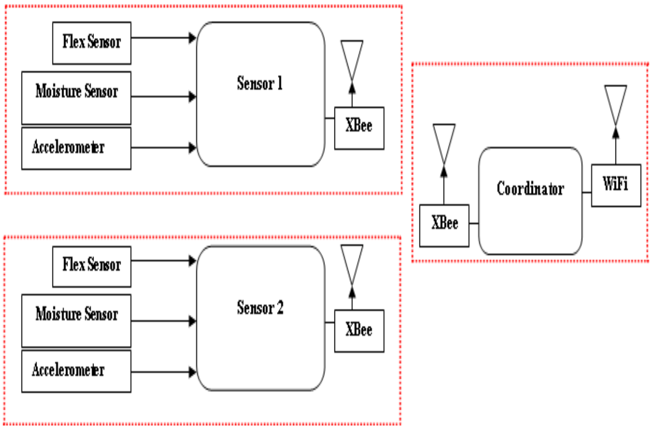


Fig. 1. Proposed Model.

Here, an integrated system for monitoring earthquake and landslide in real-time is designed by employing different sensors. In this study, we have used three sensors on each sensor node. The flex sensor is intended to detect any forced movement of the soil, soil moisture sensor for detecting the moisture level of the soil and accelerometer sensor for detecting vibrations or tremors. The sensor nodes in the system are linked in a wireless sensor network (WSN), and the WSN is connected to the internet via the coordinator by the NodeMCU. The WSN is configured in a star topology and for wireless data transmission, ZigBee technology is used. The information is all accessible through the monitoring station and the internet on a web-based interface. Solar-Powered rechargeable Li-ion batteries are used as the power supply system throughout the year.

The working of the proposed model is summarized in the flowchart shown in Figure 2.

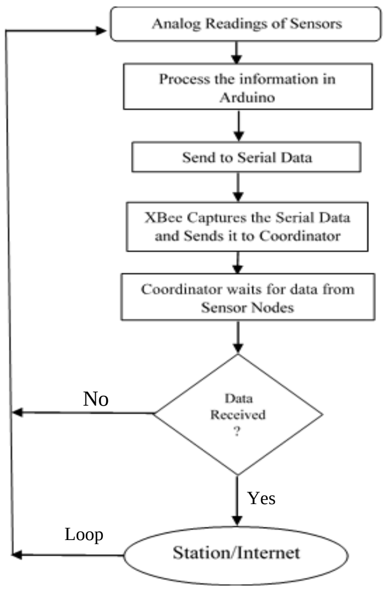


Fig. 2. Flowchart of the proposed system

The subsystem of the model in Figure 1 are described as below:

A. *Sensor Node*

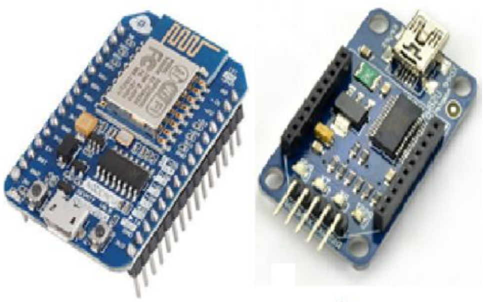
The Arduino Mega 2560(Fig.3.a) is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. The operating voltage is 5V with input voltage from 7V to 12V and the operating current for each I/O pin is 40mA. It has a flash memory of 256KB of which 8KB is used by the bootloader and an SRAM of 8KB and EEPROM of 4KB. In this research, we used Arduino Mega 2560 for the sensor nodes with transceiver ZigBee based XBee S2C (Figure 3.b) RF module for communication and 3 sensors for sensing such as flex sensor, soil moisture sensor and accelerometer sensor on both the nodes.

(a) (b)

Fig. 3. (a).Arduino Mega2560 (b)XBee S2C

B. *Coordinator*

For a coordinator, NodeMCU (Figure 4.a) is used which is also known as ESP8266 microcontroller IoT device. It consists of a 32-bit ARM microprocessor with support of Wi-Fi network and built-in flash memory so that it can be programmed independently. It has 17 GPIOs (General Purpose Input Output). This module will be the main processor unit of the coordinator attached with XBee S2C for communication between the nodes and the coordinator. The Wi-Fi is for connecting to the internet for real-time monitoring through Google's free real-time database website "Firebase" and for graphical representation of the sensors data an HTML file is designed with the help of javascript fetching the data from the Firebase.



(a) (b)

Fig. 4. NodeMCU, (b) XBee USB Adapter

In this study, we used XBee S2C as the main communication module between the nodes and the coordinator which is attached to each sensor and the coordinator. XBee is a module produced by the Digi International company, mainly used as a radio communication transmitter and receiver. It is a mesh communication protocol that sits on top of IEEE 802.15.4 ZigBee standard. XBee supports peer-to-peer as well as point to multi-point network communications wirelessly with the speed of 250 Kbits/s with serial of up to 1 MBPS. Most of the XBee modules in the market are utilized in 2.4 GHz bandwidth with various types of antennas. They are whip antenna, U. Fl. RF connector and an in-build chip antenna. The operating voltage is from 2.1V to 3.6 V with an operating current of 28mA to 33mA. The working range is 60m indoor and up to 1.2Km in line of sight. Here XBee USB adapter (Figure 4.b) is used for convenience as it is easier to configure the XBee module directly through USB to a computer.

C. *Sensors*

The sensors used in the proposed model are shown in Figure 4. Three sensors i.e. flex Sensor, soil moisture sensor and accelerometer. are used for each sensor node.

Flex sensors are used to measure the amount of deflection or bending. Flex is made up of plastic and carbon. The resistance of the sensor increases when the body is bent. When bent, the conductive layer is stretched and thus extends, resulting in reduced cross-section. This reduced cross-section and increased length results in increased resistance.

Capacitive Soil Moisture Sensor consists of three plates. A positive plate, a negative plate, and the dielectric plate. The changes in the dielectric are how we measure the changes. It does not measure the moisture directly, instead, it measures the ions that are dissolved in the moisture.

Accelerometer(ADXL335) measures acceleration in the form of analog inputs, in three dimensions such as X, Y, and Z. Accelerometer employs MEMS (Micro Electro Mechanical System) which consists of a micro-machined structure built on top of a silicon wafer. This structure is suspended by polysilicon springs. It allows the structure to deflect at the same time when the acceleration is applied on a particular axis. Due to this deflection, the capacitance between the fixed plates attached to the suspended structure is changed. This change in capacitance is proportional to the acceleration on that axis. The sensor processes this change in capacitance and converts it into an analog output voltage.

(a) (b) (c)

Fig. 5. Sensors (a) Capacitive soil moisture sensor (b) Flex sensor (c) Accelerometer sensor

IV. EXPERIMENTS AND RESULTS

In this section, we present the experiment done using the proposed model. Before the actual deployment of the system for real event scenarios, we create an environment for testing the system.

The site chosen for conducting the experiment is the hillside of Langol Hills situated in Imphal, Manipur, India. In this experiment, we have deployed two sensor nodes and a coordinator as indicated in Figure 5.

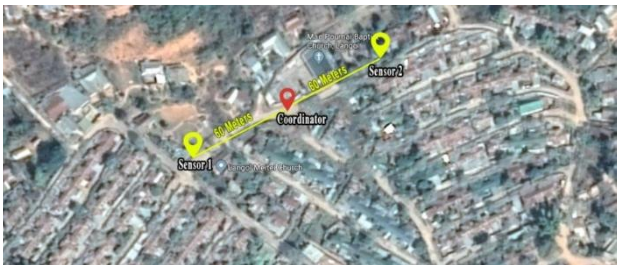


Fig. 6. Wireless Sensor Network System

Fig. 7.

Experiments are conducted in real-time with the sensor nodes placed at a maximum distance of 60 meters from the coordinator using non-line of sight(LOS) communication. The data from the coordinator can be directly monitored from the Arduino IDE serial monitor by plugging in the coordinator to any computer via a serial monitor application. An example is shown in Figure 7 which displays the sensor values from a sensor node.

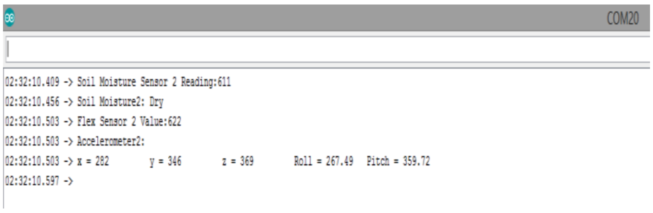


Fig. 8. Arduino IDE serial monitor

To avail real time monitoring in a monitoring station, a web based interface is developed as shown in Figure 8, that access the data through the internet on firebase, a free real-time database website from Google[www.firebase.google.com]. The coordinator uploads all the received sensors data to the Firebase. Firebase allows real-time synchronization of data and stores it on its cloud with limited space but enough for fresh application developers. The real-time data from the firebase is as shown in Figure 9. In order to show all the sensor values in a systematical order and graphically, we made one HTML file to grab the sensors data from firebase and display the sensors data graphically as shown in Figure 10, 11 and 12 respectively.

Fig. 9. Main Web Page UI

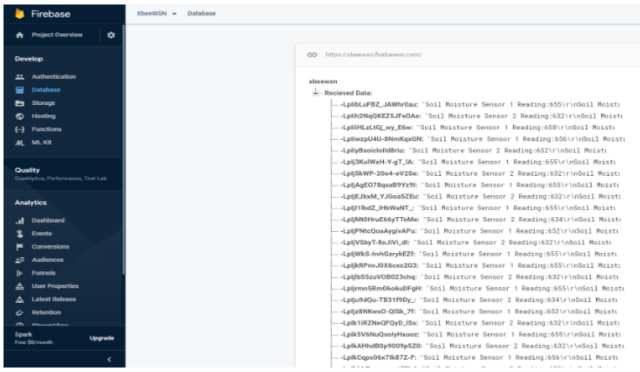


Fig. 10. Firebase Real-Time Data

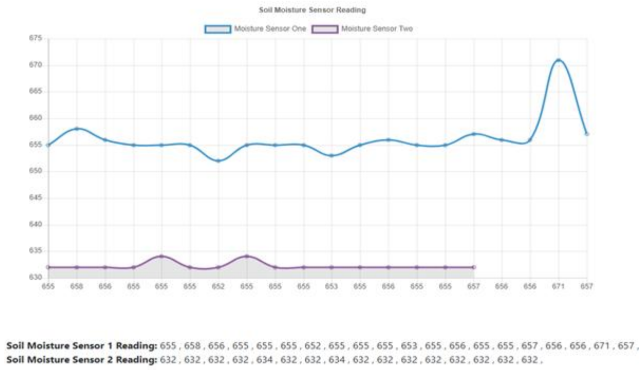


Fig. 11. Graphical representation of a soil moisture sensor (Web-Based)

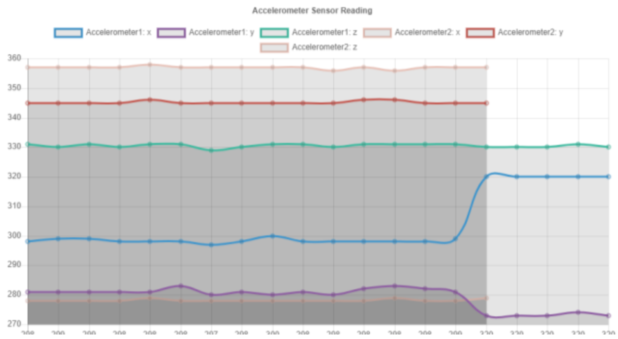


Fig. 12. Graphical representation of Accelerometer Sensor (Web-Based)

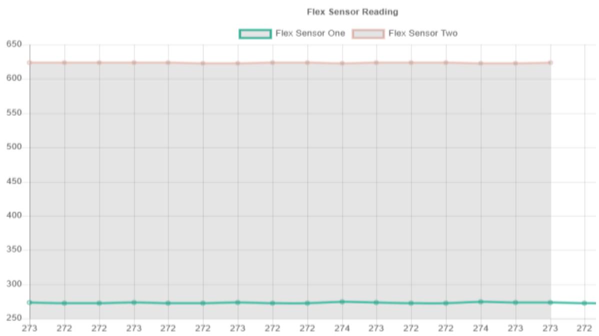


Fig. 13. Graphical representation of a Flex Sensor (Web-Based)

Figure 7 is the data received from the sensor nodes by the coordinator and further sent to the real-time online Database-Firebase. In this database, all the sensor values are stored here sequentially.

This can be accessed by anyone who has a shared link to this database. Now figure 8 is the Java Script HTML main page which gets the data from the firebase, distinguishes each value according to different sensors and converts it to a chart for easier understanding. Figure 10 shows the data received from soil moisture sensors from both the sensor nodes. As shown in the graph, soil moisture from the sensor node 1 has detected moisture (the peak). Figure 11 shows the accelerometer sensor readings and the vibration in sensor node 1 can be seen as there is variation in the X-axis and Y-axis of the accelerometer 1. Figure 12 is the graph of flex sensors from both the sensor nodes, as there is no disturbance to either sensor the graph is stable.

A quantitative analysis of the proposed model is done by measuring the quality of service (QoS) parameters namely Throughput (1), Packet Loss Ratio (2) and Delay (3) which are defined as follows[15], [16]:

$$\text{Throughput (kbps)}=\frac{Number\ of\ packets\ sent}{Time\ Taken} \quad (1)$$

Packet Loss Ratio is a value that states the number of packets that failed to be received at the destination through the transmission medium. It can be calculated in the following equation

$$\text{PacketLoss Ratio(\%)}=\frac{Number\ of\ Packets\ Sent - Number\ of\ Packets\ Received}{Number\ of\ Packets\ Sent} \quad (2)$$

The delay or latency is the time it takes the data to travel from origin to destination. It can be calculated as follows

$$\text{Delay(seconds)}=\frac{Packets\ Receiving\ Time - Packet\ Delivery\ Time}{Packets\ Receiving\ Time} \quad (3)$$

The QoS parameters are measured by varying the distance of the sensor nodes from the coordinatorat the mentioned location in figure6. The measured values are shown in table 1.FromTable.I, it is observed that when the sensor nodes are at a lesser distance from the coordinator the system performs efficiently. However, the delay time through web-based varied largely as it depended on the Wi-Fi speed and coverage.

Table I. Measured QoS

Sensor node to Coordinator distance (in meters)	Throughput Average (in Kbps)	Delay Average (in seconds)	Packet Loss Ratio (%)
10	6.88	0.004	0
20	6.84	0.01	0.024
40	6.73	0.07	0.051
60	6.56	0.08	0.061

The total current consumption of one sensor node is 103mA in idle mode and uses 122mA in the working mode. So the total power consumed is $P = I \times V$, where I is 122mA and V= 7.4 Volts. Therefore, P = 0.9028 W.

V. CONCLUSION

In this paper, we proposed an integrated system for earthquake and landslide monitoring. The proposed model employs wireless sensor networks as the backbone and it monitors and provides information on the landslide possibilities and earthquake detection. Through a web interface, the sensor data can be access in a monitoring station.

The proposed model can be used as an alert or warning system that will help to minimize the loss of lives and property. The proposed system proved to be an efficient upgrade of its predecessors in terms of energy dependency, wireless mode of communication, its sensitivity and most importantly its ability to add more sensors in the future with very little effort.

Though the proposed model is efficient, there is scope and need for improvement. The main concern of this system is the requirement of reliable Wi-Fi connectivity for real-time synchronization. Alerting residents through mobile applications may be considered in the future.

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