Landslide-Based Early Warning using Wi-Fi and LoRa Technology

Norbaya Sidek[1], Mohamed Ahmed Hafez[2], Azlina Idris [*3] Mohd Fadzil Arshad[1] and Mohd Hafizi Pauzi[3]

[1]School of Civil Engineering, College of Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[2]Faculty of Engineering and Quantity Surveying INTI -IU, University
[3] School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[*]Corresponding author: azlina831@uitm.edu.my

Article Info
Page Number: 7209-7225
Publication Issue:
Vol. 71 No. 4 (2022)

Article History
Article Received: 25 March 2022
Revised: 30 April 2022
Accepted: 15 June 2022
Publication: 19 August 2022

Abstract

Disaster can be defined into two types: natural and human-made. Landslide disaster is one of the disasters that frequently occur in Malaysia due to the country being in a tropical climate with enormous rainfall intensity. Many reasons can make the landslide happen, such as soil movement and heavy rain. The landslide monitoring system is essential for reducing and preventing the damage of landslides. With the help of a wireless sensor network (WSN), it is possible to create a landslide monitoring system to provide early warning. However, the existing system has a limited range, and the current system does not notify people immediately. This paper proposes a low-cost landslide early warning besides creating a system that can monitor the soil's movement, vibration, and moisture in real-time using the LoRa (Long Range) technology. Three sensors, a vibration sensor, soil moisture sensor, and accelerometer sensor (MPU6050), are connected to the Arduino UNO. The data collected by Arduino is then sent through the LoRa module. The data that has been collected will be received by another Arduino UNO that was equipped with another LoRa module and Wi-Fi shield. The Arduino will analyse the data, and the result will then be sent to the Blynk application via IoT for real-time monitoring. From the result, the maximum range that LoRa can tolerate in the countryside area is 300 meters. With the distance between devices, the maximum RSSI level is -130 dBm, and the average delay between the LoRa transmitter to the LoRa receiver at 100 meters is 0.0514 seconds.

Keywords: Landslide, Internet of Things, LoRa, Arduino UNO, MPU6050

Introduction

A natural disaster like landslides can be proved to be significant harm to humanity. Landslides can affect socio-economic threats to areas whose geography favors them. According to the Cambridge dictionary, the definition of landslide is a mass of rock and earth suddenly and quickly down a steep slope. Although Malaysia is not a steep country (mountains and hills are less than 25% of the terrain), slope failures/landslides frequently happen [1]. Landslides affect public safety, economics, scientific exploration, and urban planning. The landslide also can cause property damage, death and even affect our resources. If the property is damaged, the economy will be affected as it is expensive to repair the public property. Recent years shows that landslide can affect every aspect of human life [2][3].

Disaster can be categorized into two types: natural and human-made. However, these both can be contributing factors in causing a landslide. Many factors can cause landslides. Biological causes include destabilizing the slope erosion at the bottom of a slope by rivers and ocean. Landslides can also trigger by human-made such as deforestation, rapid urbanization, and economic development of the country. A recent study stated that design error is the main cause of landslide events in Malaysia, followed by natural causes [4].

In Malaysia, a few agencies supervise the landslide disaster: Jabatan Kerja Raya, the Department of Mineral and Geoscience (JMG), and the National Disaster Management (NADMA) Agency. However, these agencies have their ways of managing landslide management [5]. Besides that, the information regarding landslides in landslide-prone areas is not accessible via the internet. To reduce the damage that was caused by the landslide, a landslide-based early warning needs to be created.

The internet of things (IoT) enables advanced communication between physical and virtual things. IoT can be embedded well with sensors resulting in networks and new innovative models and processes. Implementing IoT into the technologies offers many benefits that save time, be easily accessible, and have a low operating cost. Many wireless technologies are used in systems, such as Zigbee, Wi-Fi, and Bluetooth Low Energy (BLE) [6]. However, there are limitations in terms of range and power consumption. LoRa, also known as Long Range, is a new wireless technology offering long-range and secure data transmission for M2M and IoT applications [7]. There are a few reasons that make LoRa suitable for IoT applications. LoRa offers low power consumption and has an extensive coverage range. LoRa uses license-free megahertz radio frequency bands to transmit data over which the radio frequency for each region is different. Combining the existing system with LoRa allows data collection for landslides to be monitored continuously without wasting time. This research proposes a low-cost landslide early warning, creating a system that can monitor the soil's movement, vibration, and moisture using LoRa and Wi-Fi.

A study has been carried out on previous research regarding landslide monitoring systems. Based on previous research, many methods have been used to create landslide monitoring. Table 1 shows the comparison component used in previous research. The main parameters of this research are to monitor the movement, vibration, and moisture level of the soil. The parameter for this research has been adapted from the previous research [8] and [9]. There is a difference between this proposed project and previous research. The communication network that has been used for transmitting data from sensor node to receiver node as in previous research [10], [11], and [12] uses Zigbee. However, for the proposed research, the LoRa module has been used as the medium for transmitting data from the sensor node to the receiver node, with the receiver node acting as IoT Gateway. IoT Gateway works by transmitting data to cloud Blynk using Wi-Fi. The advantage that LoRa offers compared to other wireless technology is the range that can be operated long-range.

Table 1 Comparison component of research

Research	Soil Moisture Sensor	Accelerator Sensor	Vibration Sensor	Arduino	Wi-Fi	Smart Phone	LoRa Module	GSM	Zigbee
Landslide Early Warning System Based on Arduino with Soil Movement and Humidity Sensor	✓	✓	X	✓	X	X	X	X	X
Slope, Humidity and Vibration Sensors Performance for Landslide Monitoring System	✓	✓	✓	✓	X	X	X	X	X
Wireless Sensor Network Design for Landslide Warning System in IoT Architecture	✓	✓	X	✓	X	X	X	✓	X
WSN And IoT Based Landslide Monitoring System	✓	✓	X	✓	✓	✓	X	✓	✓
Landslide Based Early Warning Using IoT and LoRa Technology	✓	✓	✓	✓	✓	✓	✓	X	X

Methodology

This section can be separated into two main parts: the hardware and software parts of the system

Hardware Part

Figure 1 shows the block diagram of the system. Those devices are used for creating the system. The system started by powering up the Arduino Uno using battery 9V and USB cable. The input needed for measuring important parameters is the vibration sensor, accelerometer sensor, and capacitive soil moisture sensor. The data received by Arduino will be proceeded and sent to another Arduino using the LoRa SX1278 module. Another Arduino will check the value whether it exceeds the threshold value. If the value exceeds the threshold, the Buzzer will be triggered. Lastly, the measured data will be sent to the Blynk cloud, and the data can be viewed in the Blynk application for live monitoring.

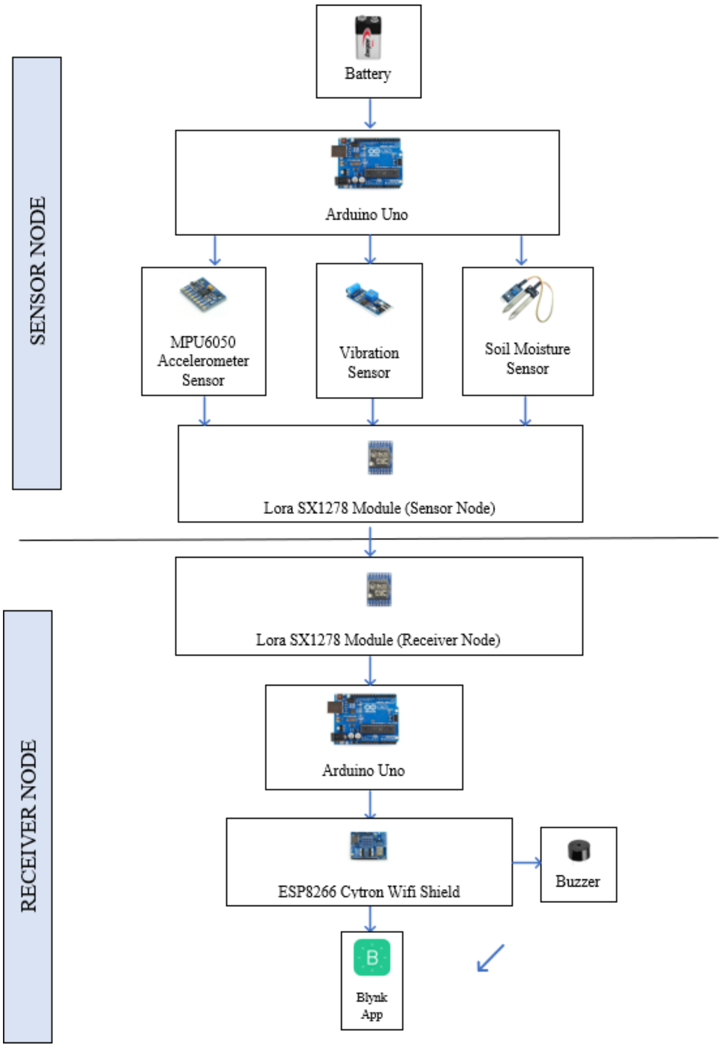

Figure 1 Block diagram of the system

Figure 2 shows the prototype of the research. There are two prototypes which are the Sensor node and the Receiver node. The sensor node is placed in the model created by using acrylic material. The soil moisture sensor will be placed in the soil to get the moisture value. Meanwhile, the vibration and accelerometer sensors will be placed in the prototype box in a static position.

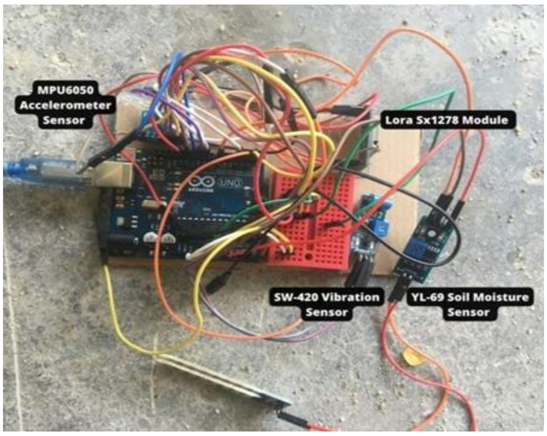

Figure 2 Sensor node

Figure 3 shows the receiver node. The receiver node consists of the LoRa SX1278 module, Cytron Wi-Fi Shield, and Buzzer. At the receiver node, LoRa SX1278 will act as the receiver to receive the data from the sensor node. Cytron's Wi-Fi shield will act as an IoT gateway to transmit all the data to the Blynk Cloud. The Buzzer is functional as an alert when one of the thresholds is triggered.

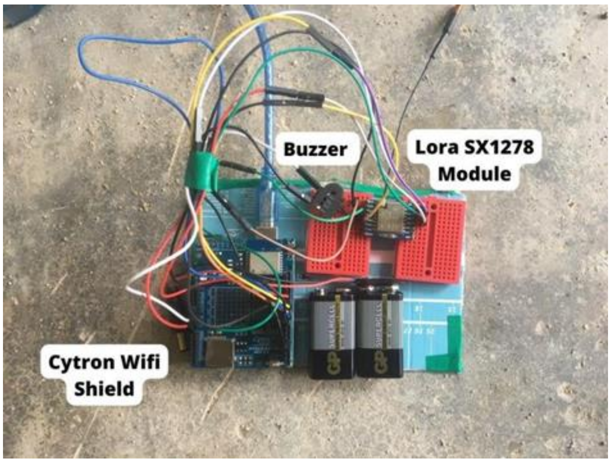

Figure 1 Receiver node

Component Description

There are a few components and modules that are important for this research. LoRa SX1278 module is a module that provides ultra-long range while also providing a benefit that can maintain their low current consumption. To make this module work properly, this module needs to be supplied with 3.3V. LoRa SX1278 module uses FSK/ GFSK and spread spectrum technology to operate. The device uses a free license frequency to transmit data. For this proposed project, a 433 MHz frequency band has been used as the proposed project in Asia. This module has also been equipped with a 433 MHz antenna with a gain of 3dB and an IPEX connector extension cable.

The soil moisture sensor is the sensor that can measure the moisture of the soil. For this research, the Yl-69 Soil moisture sensor has been used as it is cheaper than the capacitive type of sensor. However, the resistive type of sensor has a weakness that will lead to an electrolytic breakdown [13]. The power will be supplied to the soil moisture sensor only during the measurement session to avoid the problem.

The SW-420 vibration sensor is the sensor that can sense vibration. It is embedded with an LM393 comparator and 10k potentiometer to adjust the sensor's sensitivity. With the help of LM393, it can sense the vibration and give a logic high if vibrations are detected. However, this sensor cannot provide the value that determines the strength of the vibration as it is non-directional. When the module detects the vibration, the output will be low and vice versa.

MPU6050 sensor is a sensor that has both a 3-Axis accelerometer and 3-Axis gyroscope integrated on one single chip. MPU6050 measures the acceleration with MEMS (Micro Electro Mechanical Systems) with four programmable full-scale ranges of ± 2g, ±4g, ±8g, and ±16g.

MPU6050 needs 3 to 5V to operate, using the I2C protocol to communicate with the Arduino. Digital Motion Processor (DMP) that was built-in in this module enables the module to perform complex calculations. For this research, the movement of the soil will be recorded by comparing the value of the X and Y axis when the sensor is in an idle state and the position when the soil is moving. The differences obtained from the sensor can indicate the ground movement is taking space [9].

Cytron Wi-Fi Shield is a Wi-Fi Shield developed by Cytron Technology based on ESP8266 SoC. This Wi-Fi Shield needs to be stacked on another Arduino UNO to use it. This shield also provides a microSD card slot for data storage. On top of the shield, there is TX, and RX LED indicator for the ESP8266 Wi-Fi module. It uses 802.11 b/g/n technology for connecting Wi-Fi and supports Wi-Fi Direct (P2P).

Software Part

Blynk

The system makes use of Blynk as the IoT platform. Blynk is a platform with IOS and Android applications to control Arduino and another microcontroller with internet connections [14]. Blynk has been chosen as this research's IoT platform because it is suitable for data collection and monitoring. It provides a digital dashboard where it can add a powerful widget for monitoring by only drag and drop. Besides that, data that has been collected can be exported to Microsoft Excel. Figure 4 shows the widget that has been set up for this system. The moisture of the soil, the accelerometer value of the x and y axis and vibration will be displayed in real time monitoring. The widget called as Superchart will be used for plotting the graph of moisture, accelerometer value of x and y- axis.

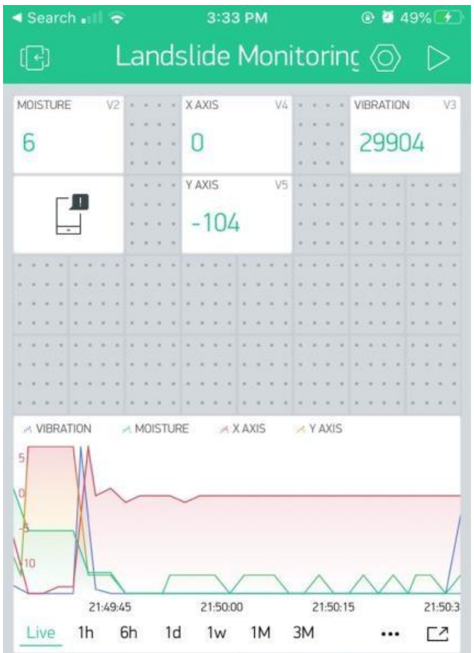

Figure 2 Blynk application in smartphone

Flowchart of the system

Figure 5 shows the flowchart of the sensor node. At the start of the sensor node, Arduino will initialize all the programs and libraries needed for this system. Then, the accelerometer, vibration, and soil moisture sensors will start to measure the value needed using the MPU6050 accelerometer sensor, SW420 vibration sensor and YL-69 vibration sensor. After Arduino finishes analyzing the data, the data will be sent via the LoRa module, which acts as a transmitter, to the LoRa module, which acts as the receiver.

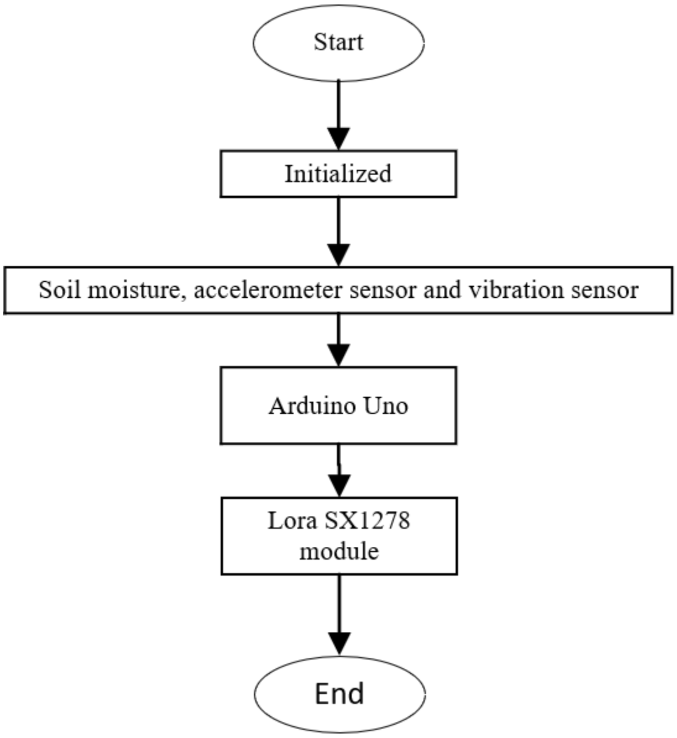

Figure 5 Flowchart of the sensor node

Figure 6 shows the flowchart of the receiver node. At the receiver node, the LoRa module that acts as the receiver will receive the data and forward it to Arduino Uno to be analyzed. The data will be analyzed by the Arduino Uno to decide whether the data meet the requirement that has been set in the system. If the value exceeds any of the threshold values, the Buzzer will be triggered, and the data will be sent into the Blynk cloud. The data will be displayed, and notification also will be popup when one of the three values is triggered. On the other hand, if the value received does not exceed the threshold, the Buzzer will not be triggered, but still, the data will be sent to the cloud. The data can be displayed through the Blynk application.

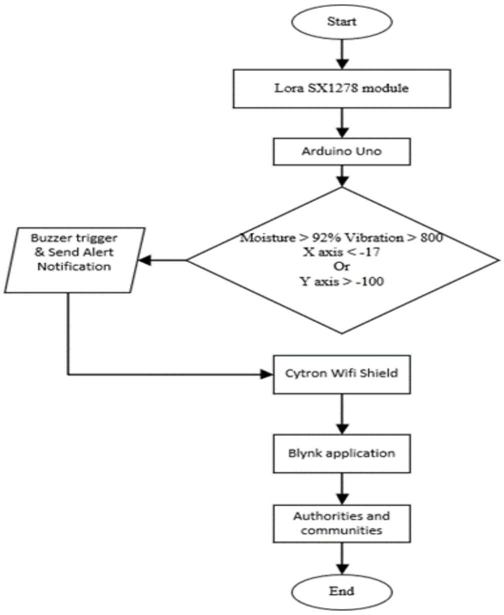

Figure 6 Flowchart of the receiver node

Result and Discussion

LoRa Testing

This research has conducted distance testing, RSSR, and delay to know how far LoRa can perform. For distance testing, the sensor node is placed outdoors, and another node is carried out by testing at a different distance. This testing is carried out in suburban areas where the environment has many obstacles, such as buildings and trees. The testing has been executed by repeatedly collecting the data repeatedly 30 times for 30 meters until the LoRa cannot communicate with each other anymore. LoRa has equipped with a 3dBi antenna, and the frequency has been set at 433Mhz because 433MHz ISM is free to use in Asia countries. Figure 7 shows the distance between the Sensor node and Receiver node recorded in Google Map during the experiment.

Figure 7 The distance between the Sensor node and Receiver node

Based on the test result in Table 5, the result is divided into three conditions: connected, unstable connection, and lost connection. During the first 210 meters, the receiver still can get the data that has been sent by the sensor. However, when the receiver node is placed at 270 meters, the data sometimes does not receive as it is indicated that the connection between the sensor node and receiver node is unstable. Lastly, at 301 meters, the receiver node does not receive anything from the sensor node. It can be concluded that, at this distance, the receiver node cannot communicate with the sensor node anymore due to the increasing noise. According to previous research that used Zigbee [10], the maximum distance of Zigbee is 107.21m. By using LoRa, the distance can be improved by 67.5%.

Table 2 Result of distance testing in the suburb

Distance (m)	**Remarks**
30	Connect
60	Connect
90	Connect
120	Connect
150	Connect
180	Connect
210	Connect
240	Connect
270	Unstable
300	Unstable
>300	Lost Connection

Comparison of RSSI between LoRa and Zigbee

The Table 3 below shows the comparison of RSSI between LoRa and Zigbee.

Table 3 The comparison of RSSI between LoRa and Zigbee [15]

Distance (m)	**RSSI (dBm)**	
	LoRa	**Zigbee**
20	-53	-31
30	-62	-35
40	-68	-40
60	-76	-56
80	-79	-79
90	-83	-83
100	-87	-85
120	-88	-
150	-93	-
170	-102	-
210	-109	-

240	-112	-
270	-120	-
300	-130	-

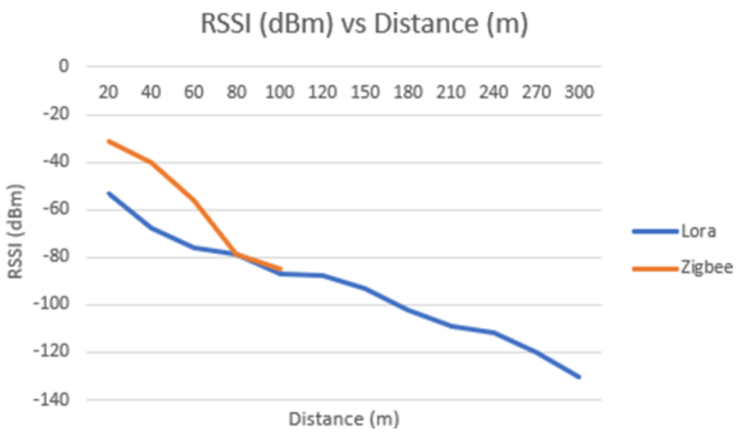

Figure 8 RSSI vs distance for LoRa and Zigbee

The test measured RSSI (Figure 8) over the distance between LoRa and Zigbee. Received Signal Strength Indicator (RSSI) measures how well the wireless technology communicates with each other. The RSSI has been recorded using an Arduino serial monitor. The collected data later has been streamed from Arduino to Excel to create the graph. From the graph, at 20 meters, the RSSI for LoRa and Zigbee are -53 dBm and -31 dBm, which is considered good for receiving and transmitting the data. At 40 meters, the result of LoRa and Zigbee in terms of RSSI is -68 dBm and -40dBm. At 60 meters, the RSSI of LoRa and Zigbee are -76dBm and -56dBm. In the 80-meter scenario, the RSSI of LoRa and Zigbee are the same, which is -79 dBm. At 100 meters, the RSSI of LoRa and Zigbee are -87dBm and -85dBm. Although the RSSI of LoRa is higher than Zigbee during the first 100 meters, the LoRa can communicate with each other.

Without having problems in transmitting and receiving the data. Above 100 meters, the RSSI of the Zigbee cannot be recorded because the Zigbee cannot communicate with each other anymore. However, LoRa can transmit and receive the data without a problem. When above 300 meters, the RSSI is -130 dBm, indicating that the signal is very weak, and the LoRa will not receive the data. From this graph, we can conclude that the RSSI is inversely proportional to distance.

Comparison of Delay between LoRa and Zigbee

The system response has been carried out to know the average delay of the transmission from the sensor node to the receiver node using the LoRa module. Table 4 shows the comparison of delays between LoRa and Zigbee. The testing has been carried out for a 100-meter distance to compare the performance with Zigbee. The formula to calculate the delay is adapted from a paper [15]. The sensor node was placed every 20 meters in between the receiver node.

Table 4 Comparison of delay between LoRa and Zigbee [15]

Distance (m)	**RSSI (dBm)**	
	LoRa	**Zigbee**
20	0.046	0.045
40	0.053	0.049
60	0.049	0.048
80	0.051	0.051
100	0.058	0.052
Average	0.0514	0.049

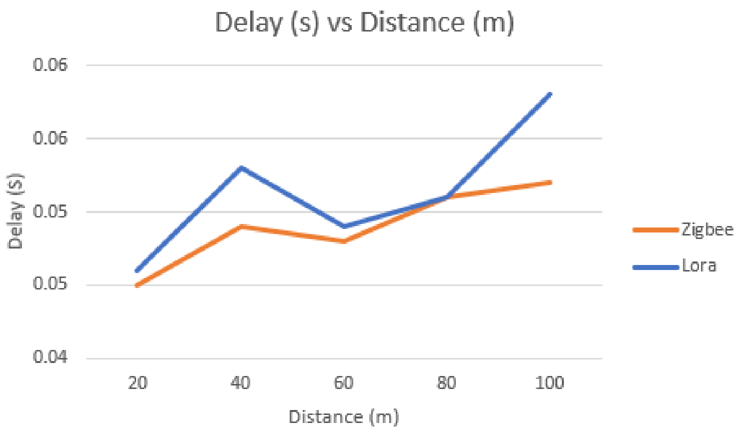

Figure 3 Average delay for LoRa from sensor node to receiver node

Figure 9 below shows the result of the testing. The graph shows that the average delay for the first 100 meters between Zigbee and LoRa is 0.049 seconds and 0.0514 seconds. The delay of Zigbee is slightly lower than LoRa's. However, the maximum distance of Zigbee is about 100 meters; meanwhile, the LoRa can be used up to 300 meters. If the distance increases between the LoRa transmitter and the LoRa receiver, the delay between the transmitter and LoRa receiver also increases. This is because there are obstacles that can interfere with the LoRa signal between the LoRa transmitter and the LoRa receiver. So, the landslide early warning system using LoRa is acceptable and reliable for the system because of the difference in delay between Zigbee and LoRa is 0.023 seconds, which is suitable for real-time monitoring.

Landslide Monitoring System

Table 5, Table 7, and Table 9 show the threshold for soil moisture level, vibration sensor, and accelerometer sensor that have been applied in this monitoring system. The threshold value for Table 5 has been adapted from previous research [16].

Soil Moisture Sensor Testing

Table 5 Threshold value and remark for soil moisture sensor [16]

Sensor Reading Result	**Remark**
Soil Moisture	
Less than 80%	Normal
Between 80-92%	Warning
92% and above	Danger

For sensor reading results, there are three levels: normal, warning, and danger. Each level has its range of soil moisture sensors, as stated above. The soil moisture sensor range indicates the soil's water percentage. When the soil moisture sensor reaches a value above the warning, the Buzzer will trigger, and an alert notification will be sent to the smartphone via the Blynk application.

Table 6 shows the performance of the Soil moisture sensor between Zigbee and LoRa. In this test, the range has been changed to know how the sensor will perform. The soil will be added with water to ensure the sensor works properly. The result of the Zigbee has been taken from [11].

Table 6 The performance of the Soil moisture sensor between Zigbee and LoRa [11]

Range (meter)	**Soil Moisture (%)**	**Remark (Zigbee)**	**Remark (LoRa)**
30	0	Notify	Notify
60	10	Notify	Notify
90	17	Notify	Notify
120	25	No Notify	Notify
150	40	No Notify	Notify
180	58	No Notify	Notify
210	60	No Notify	Notify
240	63	No Notify	Notify
270	80	No Notify	Notify
300	94	No Notify	No Notify

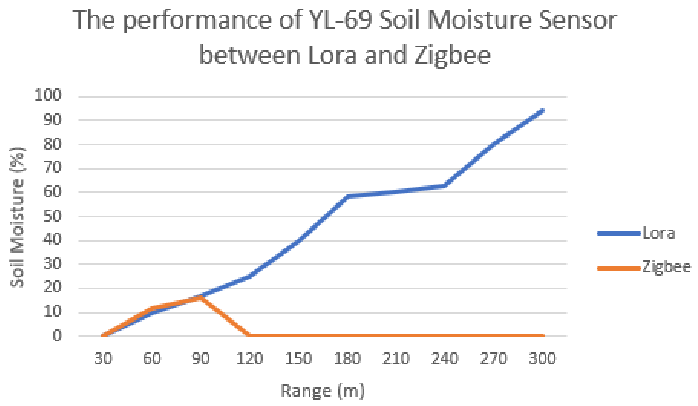

Figure 4 The performance of YL-69 Soil Moisture Sensor between LoRa and Zigbee

Figure 10 shows the YL-69 soil moisture sensor performance between LoRa and Zigbee. During the first 100 meters, the readings can be read for both LoRa and Zigbee, and both have been notified about the soil condition. However, the reading after 100 meters for Zigbee is unreadable. This is because the Zigbee cannot receive the data anymore from the sensor. For the LoRa, the sensor readings can still be read until the range is 300 meters.

Vibration Sensor Testing

Table 7 shows the threshold value for the vibration sensor. The vibration sensor has two remarks, vibration detected and no vibration. The output for the SW420 vibration sensor is 0 and 1. When vibration is detected, the Buzzer will trigger, and the data will be sent to the cloud, which will notify the smartphone.

Table 7 Threshold value for vibration sensor [17]

Sensor Reading Result	**Remark**
1	Vibration detected
0	No vibration

The sensor was proposed to be used as input to this research hardware was the SW420 vibration sensor. The vibration sensor has been tested by simulating the vibration at the sensor box at a different range. The result of the simulation between LoRa and Zigbee is shown in Table 8 below.

Table 8 Vibration Sensor testing between LoRa and Zigbee [18]

Range (m)	**Vibration Sensor**	**Remark (Zigbee)**	**Remark (LoRa)**
30	1	Notify	Notify
60	1	Notify	Notify
90	1	Notify	Notify
120	1	No Notify	Notify
150	1	No Notify	No Notify
180	1	No Notify	Notify
210	1	No Notify	Notify

240	1	No Notify	Notify
270	1	No Notify	Notify
300	1	No Notify	Notify

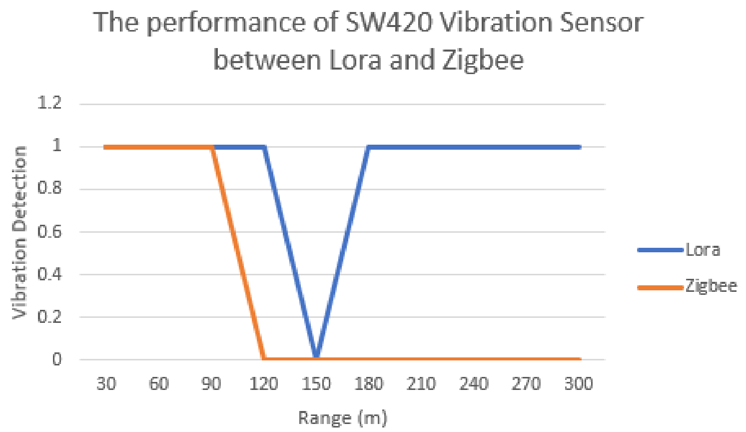

Figure 11 Graph of the performance of SW420 Vibration Sensor between LoRa and Zigbee

Figure 11 shows the performance of the SW420 vibration sensor between LoRa and Zigbee. The vibration of the soil has been mimicked to ensure that the SW420 can work properly even at long distances. From the graph, both wireless technologies can communicate well with vibration sensors during the first 100 meters. However, the readings of the vibration sensor cannot be read anymore when using Zigbee due to range limitations. At a range of 150 meters, the LoRa also cannot sense the vibration, although the soil vibration was mimicked at that time. However, the result can be read again on the serial monitor after restarting the program. The testing has been done until 300 meters; the LoRa that acts as the receiver does not receive the data anymore from the transmitter.

Stability of Result for Accelerometer Sensor Testing

Table 9 shows the accelerometer sensor set up at the static angle to detect any soil movement at the x-axis and y-axis values. When X-axis is less than -10 or Y-axis is more than -100, it will indicate the movement of the soil, and the Buzzer will be set off. Also, the data will be sent to the cloud, and a notification alert will be sent to the smartphone via the Blynk application.

Table 9 Threshold value for MPU6050 accelerometer sensor [9]

Sensor Reading Result	**Remark**
X-axis < -10 or Y Axis > -100	Soil moving

The test result was conducted in a slope model that was designed beforehand. The box with Arduino Uno, LoRa Module, and the proposed sensor was positioned at the middle of the model, filled with soil. PVC pipe has been used as the support for the sensor box. First, a simulation for soil movement has been done to ensure the sensor is working properly. This collection of values x and y has been recorded at a distance of 300 meters, and the result has been compared with [19] for ZigBee and LoRa, as shown in Table 10.

Table 10 Accelerometer value for Zigbee and LoRa [19]

Range (m)	Accelerometer Sensor			
	Zigbee		LoRa	
	X	Y	X	Y
30	6 6	-65	-2	-105
60	6 4	-66	-2	-105
90	6 3	-67	-2	-105
120	-	-	-2	-105
150	-	-	-5	-97
180	-	-	-6	-97
210	-	-	-5	-97
240	-	-	-2	-105
270	-	-	-2	-105
300	-	-	-2	-105

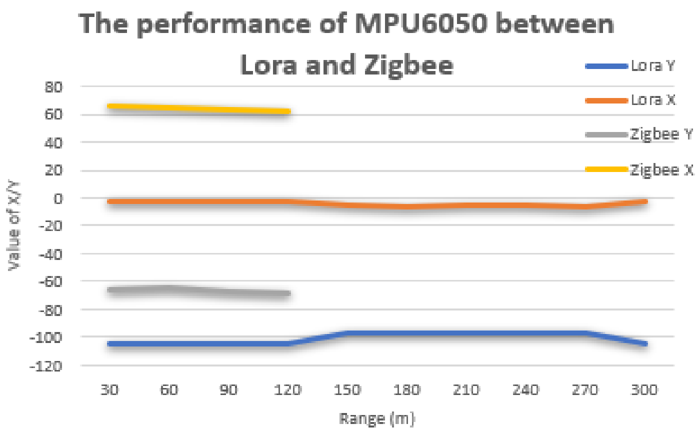

Figure 12 Graph of the performance of MPU6050 between LoRa and Zigbee

Figure 12 shows the result of the performance of MPU6050 between LoRa and Zigbee. As in the figure, the value of X and Y is different between Zigbee and LoRa. This is because the value of x and y depends on where the accelerometer sensor is placed. The Zigbee has an inconsistent result which is about 4.6875%. However, the LoRa performs better as the inconsistent at about 0.952.% At 100 meters, the ZigBee cannot record the X and Y value as it reaches the maximum range. At 150 meters, the simulation of soil movement was done by moving the box of the sensor at 45° [9]. This is to ensure that the sensor and the system are working correctly. At 301 meters, the LoRa cannot receive more reading from the sensor due to distance limitations.

Conclusion

This research has proposed to design landslide-based early warning using IoT and LoRa. Based on the result obtained, it developed a monitoring system that can monitor the soil's movement, vibration, and moisture in real-time using Wi-Fi and LoRa technology. It also has overcome the problem that the past system lacked range and did not notify the communities. Moreover, this research has concluded that in a countryside area, the maximum range that LoRa can function adequately is 300 meters, improving by 67.5% compared to Zigbee. With the distance between devices, the maximum RSSI level is -130 dBm, and the average delay between the LoRa transmitter and LoRa receiver when placed at 100 meters is 0.0514 seconds.

Future Work

The system can be improved using a personal cloud database such as Firebase. This is because the Blynk cloud has limited functionality in terms of widgets and accessibility. By having a private cloud database, the data can be controlled easily. Besides that, the system can use solar as the main supply instead of a battery to ensure the system can work for a long time.

Acknowledgment

The authors would like to extend the gratitude to the College of Engineering, Universiti Teknologi MARA, for providing the necessary facilities for this research.

References

[1] A. Akter, M. J. M. M. Noor, M. Goto, S. Khanam, A. Parvez, and M. Rasheduzzaman, “Landslide Disaster in Malaysia: An Overview,” *Int. J. Innov. Res. Dev.*, vol. 8, no. 6, 2019, doi: 10.24940/ijird/2019/v8/i6/jun19058.

[2] M. I. N. Diana, N. Muhamad, M. R. Taha, A. Osman, and M. M. Alam, "Social Vulnerability Assessment For Landslide Hazards In Malaysia: A Systematic Review Study," *Land*, vol. 10, no. 3, pp. 1–19, 2021, doi: 10.3390/land10030315.

[3] N. A. Majid, “Historical Landslide Events in Malaysia 1993-2019,” *Indian J. Sci. Technol.*, vol. 13, no. 33, pp. 3387–3399, 2020, doi: 10.17485/ijst/v13i33.884.

[4] A.A. Ab Rahman, N. Abd Majid, and S.N. Selamat, "A Comprehensive Deriving the Factors of Landslide Happened in Malaysia," *Int. J. Emerg. Technol.*, vol. 11, no. 5, pp. 310–314, 2020, [Online]. Available: https://www.researchtrend.net/ijet/pdf/46 A Comprehensive Deriving the Factors of Landslide Happened in Malaysia-3209-A.A.pdf.

[5] N. Omar Chong and K. H. Kamarudin, "Disaster Risk Management in Malaysia: Issue and Challenges from The Perspective of Agencies," *Plan. MALAYSIA*, vol. 16, Jul. 2018, doi: 10.21837/PM. V16I5.415.

[6] C. Del-Valle-Soto, L. J. Valdivia, R. Velázquez, L. Rizo-Dominguez, and J. C. López-Pimentel, "Smart Campus: An Experimental Performance Comparison of Collaborative and Cooperative Schemes for Wireless Sensor Network," *Energies*, vol. 12, no. 16, 2019, doi: 10.3390/en12163135.

[7] U. Noreen, A. Bounceur, and L. Clavier, "A Study of LoRa Low Power and Wide Area Network Technology," *Proc. - 3rd Int. Conf. Adv. Technol. Signal Image Process. ATSIP 2017*, no. May, 2017, doi: 10.1109/ATSIP.2017.8075570.

[8] F. Aji Purnomo, N. Maulana Yoeseph, and G. Wijang Abisatya, "Landslide Early Warning System Based on Arduino with Soil Movement and Humidity Sensors," *J. Phys. Conf. Ser.*, vol. 1153, no. 1, 2019, doi: 10.1088/1742-6596/1153/1/012034.

[9] F. Nursuwars and N. Kurniati, "Accelerometer as Land Movement Early Detection with the Internet of Thing (IoT) Concept," no. January, 2020, doi: 10.4108/eai.11-7-2019.2297558.

[10] M. R. Sruthy, R. Anjana, R. Archana, V. Dhanya, and H. Hridya, "WSN and IoT Based Landslide Monitoring System," no. 4, pp. 596–599, 2020.

[11] N. Galley, T. Yangzom, U. Tshering, and K. K. Chapagai, "Wireless Sensor Network Based Land Slide Detection and Early Warning System., "vol. 3, no. 1, 2016.

[12] S. Kapoor, H. Pahuja, and B. Singh, "Real time monitoring & alert system for landslide," *Proc. 2016 2nd Int. Conf. Contemp. Comput. Informatics, IC3I 2016*, pp. 584–589, 2016, doi: 10.1109/IC3I.2016.7918030.

[13] M. Saleh, I. H. Elhajj, D. Asmar, I. Bashour, and S. Kidess, "Experimental evaluation of low-cost resistive soil moisture sensors," *2016 IEEE Int. Multidiscip. Conf. Eng. Technol. IMCET 2016*, no. November, pp. 179–184, 2016, doi: 10.1109/IMCET.2016.7777448.

[14] M. Markovic, M. Maljkovic, and R. N. Hashanah, "Smart Home Heating Control using Raspberry Pi and Blynk IoT Platform," *EECCIS 2020 - 2020 10th Electr. Power, Electron. Commun. Control. Informatics Semin.*, pp. 188–192, 2020, doi: 10.1109/EECCIS49483.2020.9263441.

[15] A. M. Latupapua Haziel, Wahab Abdi, "Wireless Sensor Network Design for Earthquake s and Landslide s Early Warnings," vol. 11, pp. 437–445.

[16] M. M. Sejera, A. H. Ballado, B. N. H. Fernando, M. F. I. A. Montemayor, and A. V. D. Niebres, "Mobile App-Based Early Warning System for Landslides Using Land Monitoring through GSM," *2020 IEEE Reg. 10 Symp. TENSYMP 2020*, no. June, pp. 90–93, 2020, doi: 10.1109/TENSYMP50017.2020.9230936.

[17] E. D. Chikhliwala and C. G. Gelinas, "Monitoring System for Landslide Early Detection Based on Internet of Things," no. 110, pp. 255–267.

[18] K. H. Woo and L. B. Gyo, "Landslide Detection Using Wireless Sensor Network," *Pros. Konf. Musim Semi Korea Geotech. Soc.*, vol. 1, no. 1, pp. 369–372, 2009.

[19] D. F. Supriyadi, "Sistem Monitoring Pergerakan Tanah Terhadap Potensi Longsor Secara Wireless Berbasis Mikrokontroller," *ADLN - Perpust. Univ. Airlangga*, no. Bagian Ii, 2016, [Online]. Available: http://repository.unair.ac.id/55177/13/FV.OSI 24-16 Sup s TUGAS AKHIR D3-min.pdf.