Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

IoT Based Earthquake Detection System

Norfatihah Bahari[1,*], Nor Irfan Multazam Nor Azmi[1], Mohd Wafi Nasrudin[1], Rashidah Che Yob[1], Nur Hidayah Ramli[1], Herwansyah Lago[2]

[1] Faculty of Electronic Engineering & Technology, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia
[2] Faculty of Engineering, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia

ARTICLE INFO

Article history:
Received 10 February 2024
Received in revised form 4 July 2024
Accepted 15 August 2024
Available online 2 September 2024

Keywords:

Earthquake detection system; Internet of Things (IoT); Transmitter and receiver antenna

ABSTRACT

This paper proposes an IoT based Earthquake Detection System for the early warning and quick detection of the earthquake. Earthquakes are one of the rare natural disasters in Malaysia but when the earthquake happened, it could damage infrastructure and cause deaths. This system is aimed to monitor the earthquake levels and warn people about earthquake dangers. To detect the vibration on the ground surface, an accelerometer has been connected to the microcontroller Arduino Uno R3. Then NRF24L01 transceiver module has been used to connect between the transmitter and receiver part. In order to receive the notifications about the earthquake, the ESP8266 Wi-Fi module is linked to the Blynk App. This proposed system is very user-friendly and economical, making it favourable to be used in the earthquake zones.

1. Introduction

Earthquakes are one of the biggest catastrophes that afflict many people each year in various places across the world. The greatest occurrence ever recorded in Malaysia occurred in 1976, and the most catastrophic occurred in 2015, with 18 fatalities reported [1]. Both occurrences occurred in Sabah, and the list clearly indicates that Sabah is the state that has experienced the most earthquakes in Malaysia. The impact of earthquakes has been increased due to the demographic location of Sabah nearby to the Pacific Ring of Fires countries such as Indonesia and the Philippines. Therefore, to avoid more losses of life, Malaysia should have a technology that linked into the system to warn the public and authorities about the earthquakes. According to [2], seismic risk assessment in Malaysia has seen significant improvements. However, despite these advancements, the seismic risk assessments still encounter numerous challenges and issues such as the absence of sufficient scientific data [3], an inadequate state-level framework for hazard assessment [4], the absence of national standards for seismic vulnerability assessment guidelines and methodologies [5], and a shortage of essential data required to evaluate the vulnerability of exposure elements [5,6].

* *Corresponding author.*
E-mail address: norfatihah@unimap.edu.my

https://doi.org/10.37934/araset.51.1.160170

Normally, the earthquake detection system uses seismometer to detect ground movement. It is capable of detecting and converting vibration signals into electrical signals and is widely used in oil and gas resource exploration, and building and bridge detection [7]. However, the utilization of seismometers is very costly, and they are improbable to provide extensive coverage with sub-kilometre interstation spacing [8]. Besides that, the sensing ranges of traditional seismometers are inherently restricted and most of the seismic networks are situated on the continents rather than the seafloors. As technology and data processing capabilities have progressed, risk reduction mechanisms like earthquake early warning (EEW) systems have arisen as vital safeguards, potentially saving lives. These systems typically rely on a combination of sensors [9,10], data analysis [11-13], and communication technologies [16] to detect seismic activity and provide early warnings to help mitigate the potential impact of earthquakes.

The fundamental principle behind such systems is to detect the initial, less destructive P-waves (primary waves) generated by an earthquake, which travel faster than the more damaging S-waves (secondary waves) and surface waves. In Taiwan, MEMS-based P-Alert sensors have demonstrated their value by facilitating proximity sensor placement and meticulous monitoring of seismic activities. These sensors are characterized by their cost-effectiveness, low power consumption, and ease of installation [14]. The performance of EEW based on MEMS technology has also been applied in Italy, which capable of detecting events with a magnitude exceeding 4.1 within a 30 km radius [15]. Furthermore, the system will typically use an antenna to transmit information between the sender and receiver. However, the smooth transmission of information for the distance of an area depends on the specifications of the antenna. In [16], the implementation of LoRa communication technology has been proposed for high-rise buildings. However, 10% of packet loss has been detected and may impact the accuracy and effectiveness of earthquake warnings.

Nowadays, the earthquake warning is based on the integrated Internet of Things (IoT) system [17-24]. In Canada, ShakeAlarm uses the technology detection by P-waves and S-waves for the earthquake early warning system [19]. Besides that, ShakeAlert has been used in America to recognize and describe an earthquake within a few seconds of its occurrence, assess the expected severity of ground shaking that will occur, and make notifications available for distribution to individuals and infrastructure at danger [20]. Meanwhile in Indonesia, the Geographic Information System (GIS) Application has been proposed for the landslide susceptibility assessment [21]. On the other hand, the Earthquake Early Warning (EEW) is used in Japan [22], and the Earthquake Network [23] and Android Earthquake Alerts System [24] have been used globally.

In this paper, an IoT based earthquake detection system has been proposed to alert people about the earthquake so that the number of losses can be reduced. Several earthquake warning systems have been reviewed, followed by the methodology of the proposed system. Next the results and discussion are presented, and a brief conclusion is given.

2. Methodology

2.1 Operational Flow

This project uses an accelerometer sensor to identify the magnitude of an earthquake and transmits data to a rescue squad as a warning. The rescue team can use the results of the point prediction model to trigger timely warnings and provide information to users who are vulnerable to earthquakes. For the detection system, an accelerometer sensor is utilized as a marker or detector earthquake level, and this system will send a message warning via the Blynk App via data transfer between the NRF24L01 transceiver module on both the transmitter and receiver parts of the system. The NRF24L01 serves as a medium for information transmission to the rescuer via Blynk App so that they can know information about the earthquake condition that happens in the affected area. If the Wi-Fi module in the receiver part cannot trace or connect with the Internet and will prevent the message from being received by the Blynk App, the message still can be obtained by the user and rescuer since it is stored in the system and signalled by the buzzer, LED, and LCD. Figure 1 shows the operational flow of this project.

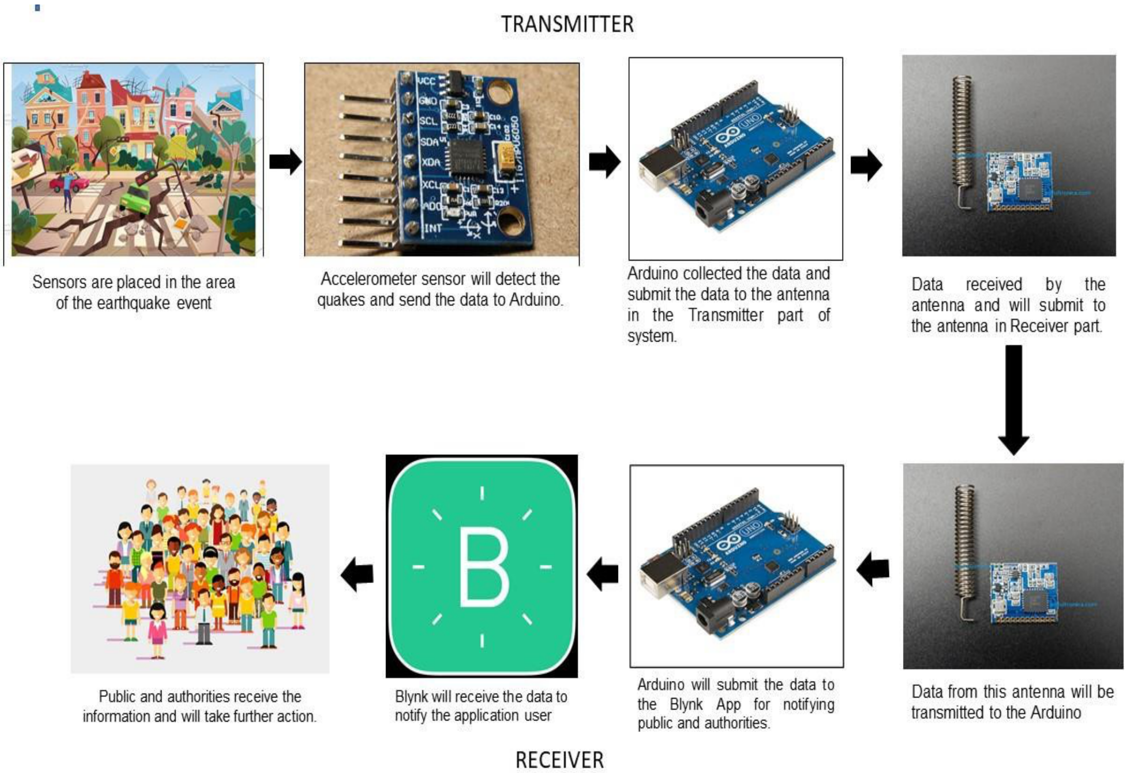
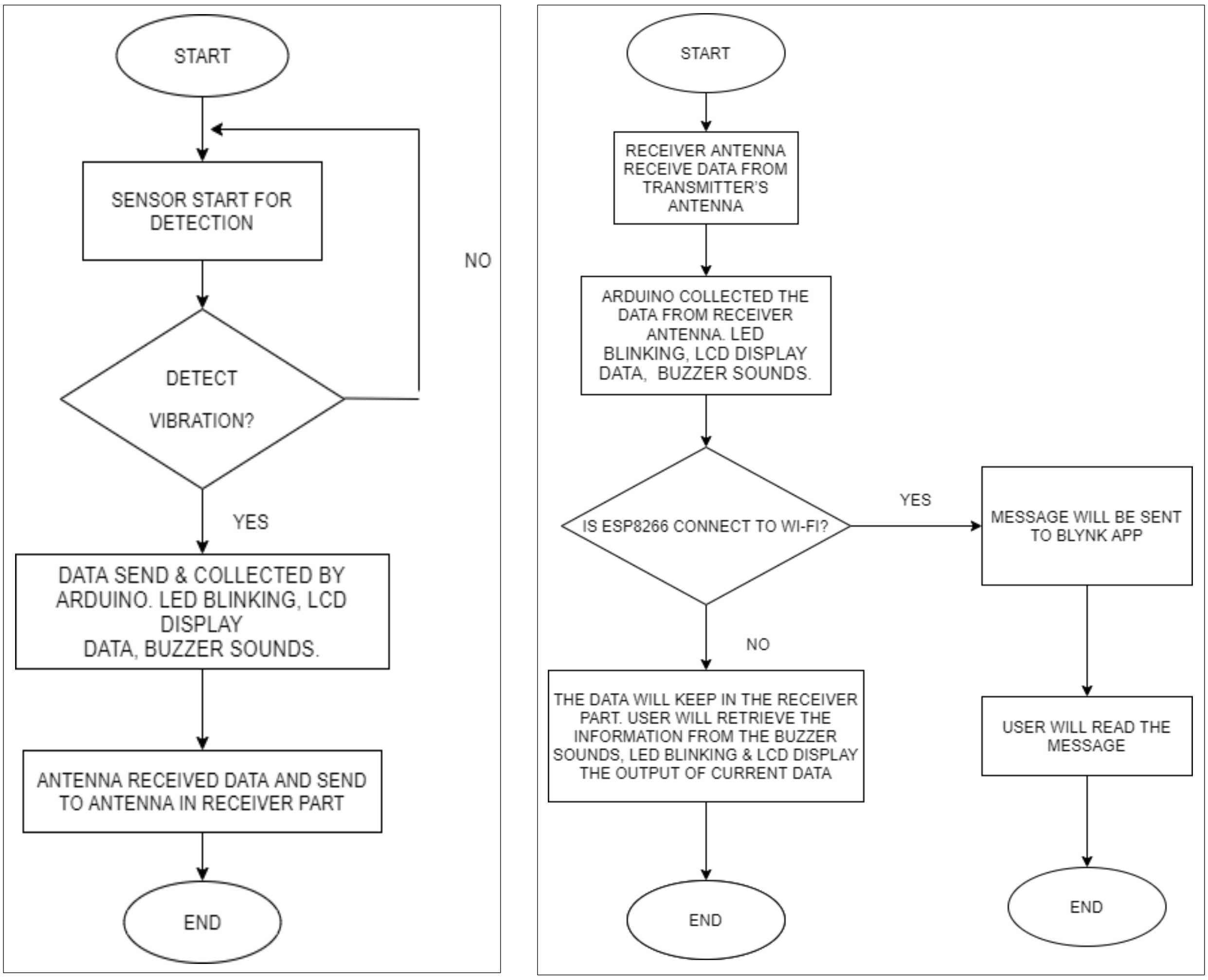


Fig. 1. The operational flow of the proposed Earthquake Detection System

The flowchart of the transmitter and receiver part are illustrated in Figure 2 (a) and Figure 2 (b), respectively.



(a) (b)

Fig. 2. Flowchart of the (a) Transmitter part, (b) Receiver part

In this project, an accelerometer MPU6050 sensor will be used to detect the earthquake levels. This type of sensor is compact, small-sized, and cost-effective compared to other sensors with similar functionalities. Besides that, MPU6050 offers a wide range of sensitivity settings, allowing flexibility in choosing the sensitivity that suits the specific applications, with the minimum sensitivity of ±2g. In real-life scenarios, this sensor has been put in a potentially hazardous region where it is prone to earthquakes and seismic activity, such as a location near to an island or a hilly area. On the other hand, the accelerometer sensors are installed in the system's Transmitter to detect the ground vibration and motion. This accelerometer has been connected to Arduino Uno, as illustrated in Figure 3. The accelerometer sensor will send data collection to the Arduino. Arduino will process the data to send the information message to the NRF24L01 transceiver module for data transmission to the antenna of the Receiver part. The public will receive the information through Blynk App via the Internet connection by ESP8266 Wi-Fi module. For people who are unable to connect to the Internet, data still can be obtained from the signalling through the system's buzzer, LED, and LCD. Typically, the ESP8266 Wi-Fi module operates on the 2.4 GHz frequency band, but it can vary based on factors like interferences and environmental conditions.

The sensor is programmed with ten different levels to show the intensity of the shake. Level 1 to 4 indicates the small scale, level 5 to 6 will be set as moderate, level 7 to 9 is set as great level and level 10 indicates the dangerous level. Every level will be represented by the specific value of scale to indicate the level of the shaking, as tabulated in Table 1. Creating an effective earthquake detection system requires a critical ability to distinguish vibrations originating from actual earthquakes or from those caused by other sources. Consequently, the utilization of intensity thresholds, as outlined in Table 1, becomes imperative. Earthquakes typically generate more robust vibrations, characterized by very severe and extreme movements, as opposed to vibrations resulting from routine human activities or environmental factors. Therefore, instances of minor movement prompt the accelerometer to classify them as lower levels of shaking, suggesting the likelihood of vibrations originating from other non-seismic issues.

Table 1
The measurement of the earthquake level

Parameter	Description	Occurrence	Movement	Sensor Scale
1	Small	Daily	Small	-5
2	Small	Daily	Small	-4
3	Small	Daily	Small	-3
4	Small	Daily	Small/ Moderate Sudden	-2
5	Moderate	Monthly	Strong Sudden	-1
6	Moderate	Monthly	Strong Sudden	0
7	Great	Monthly	Very Severe	1
8	Great	Yearly	Very Severe	2
9	Great	Yearly	Very Severe	3
10	Dangerous	Rarely	Extreme	4

This system starts its operation in the Transmitter part, as shown in Figure 3. When there is a ground movement, the accelerometer detects that movement and sends the information to the Arduino. The information signal from the Arduino will be shown on the LCD Display, with a buzzer and LED to indicate the current state. Then the NRF24L01 acts as the communication medium for data transmission between the transmitter and receiver. The signal from the transmitter will be received by the antenna in the receiver part, and the signal will be sent to the Arduino. The Blynk App will distribute all information obtained by the Arduino to people. This system needs to be linked with the Internet through ESP8266 Wi-Fi module in order to retrieve information from the Blynk App. The buzzer, LED, and LCD monitor from the Receiver part will perform the same functions as in the Transmitter. However, if there is no Internet connectivity, user can still receive the information because the system will store the data and indicate the current situation of the earthquake event through the buzzer that will sound, blinking LED, and LCD that will display the message.

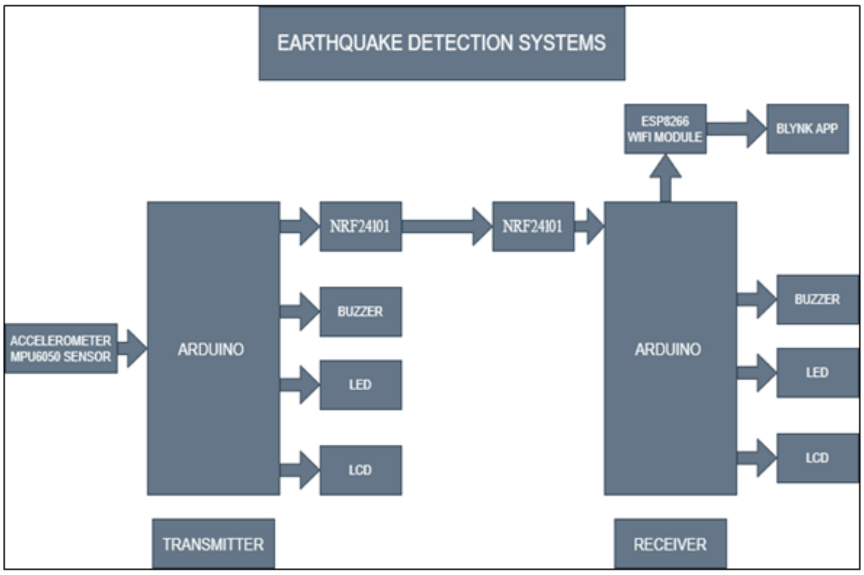
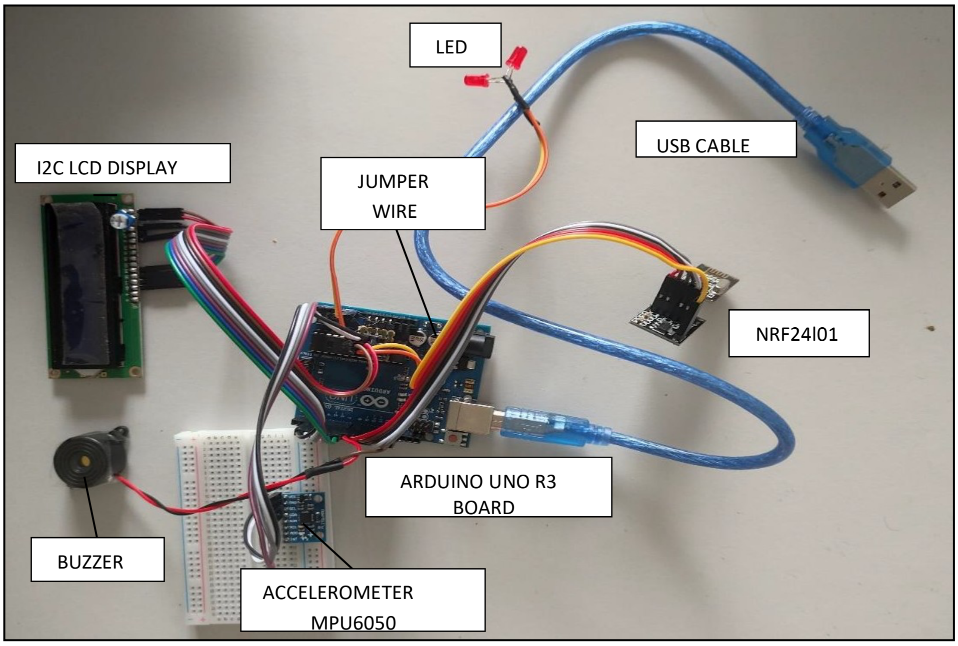


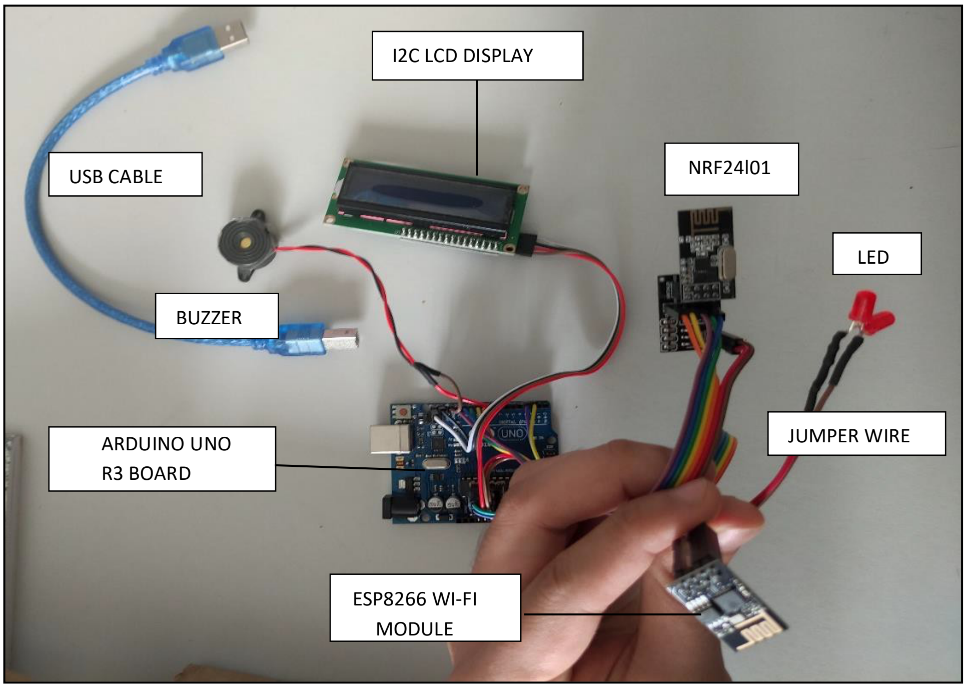
Fig. 3. The block diagram of the system

2.2 The Circuit Installation

Figure 4 (a) and Figure 4 (b) illustrate the circuit installation of this project. To secure the connection between the component and the Arduino board, a jumper is used. Connection verification is conducted to ensure that all system components perform well their respective functions.



(a)



(b)

Fig. 4. The circuit installation of the proposed earthquake detection system (a) Transmitter part, (b) Receiver part

3. Results and Discussion

When there is a movement in the system, the vibration will be detected through the sensor in the transmitter part. The ground motion observed is not real, and this is attributed to considerations of safety and cost. In order to ensure the well-being of individuals and manage expenses effectively, simulated testing is employed instead of exposing the environment to actual ground motion events. All data by that vibration will be transferred to the Arduino board and then to the transmitter antenna, which is NRF24L01 module. Simultaneously, the LED is then will light up, the buzzer will make a sound and the LCD will display the message "Earthquake Detected". Earthquake data can be viewed through the Serial Monitor and Serial Plotter of the Arduino IDE software. The Serial Monitor displays the tremor's outcome based on the coordinates of the X, Y, and Z axes, which represent the earth's instability at the moment of the earthquake.

Next, in the Receiver part, data from Transmitter part will be transferred to the Arduino board through the NRF24L01 receiver antenna module. This will also activate the LED, the buzzer and the LCD, as happened in the Transmitter part. After that, the earthquake data is retrieved analysed through the Serial Monitor, as shown in Figure 5.

Fig. 5. Serial Monitor display shows the tremor's outcome based on the coordinates of the X, Y, and Z axes to show the earth's instability

Besides that, the data from the earthquake's impact is then presented through the graph variation in Serial Plotter, as illustrated in Figure 6.

Fig. 6. Serial Plotter that displays the variation of the impact of earthquake

In Receiver part, the ESP8266 Wi-Fi module is connected to the Blynk App. Once the ESP8266 is successfully responding, the data of earthquake will be received, and user will be notified through Blynk App. As a result, the Blynk notification is displayed on the user's smartphone and through e-mail, as shown Figure 7. This will help user to take immediate precautions after they received the notifications.

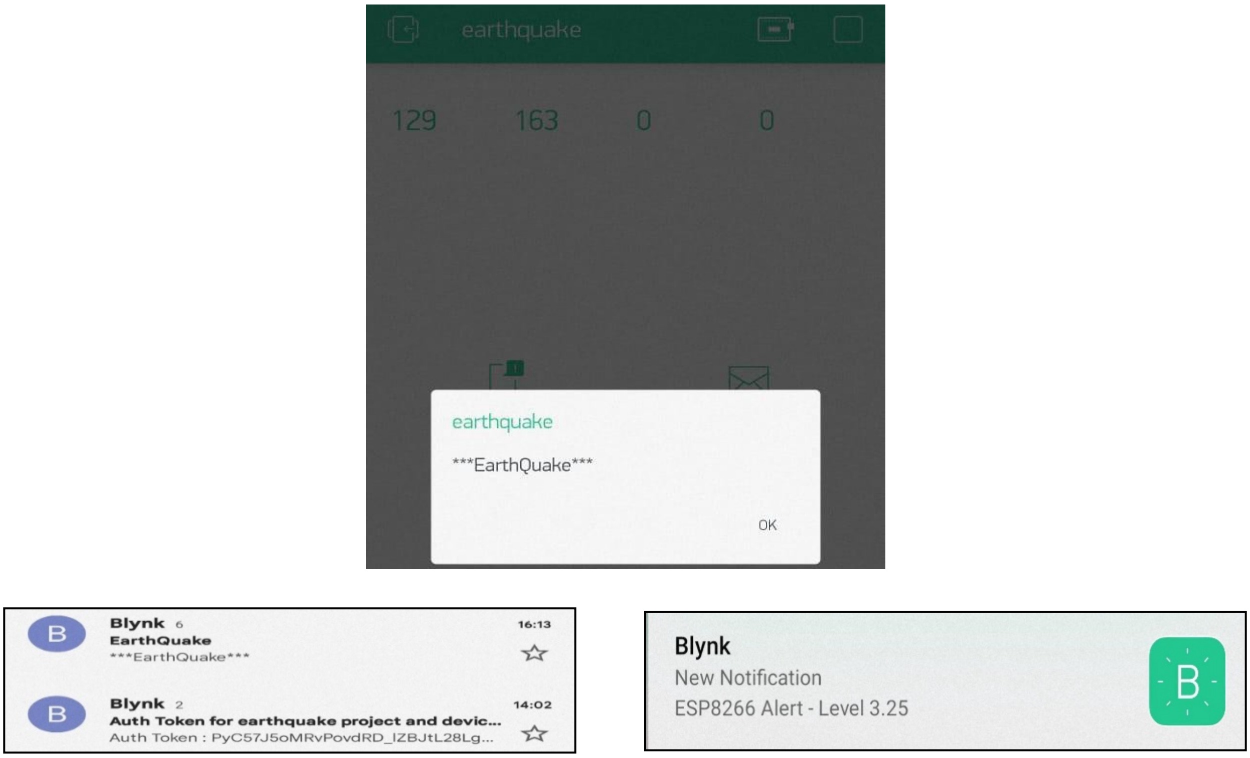


Fig. 7. Blynk App notifications

4. Conclusion

This project proposed the development of disaster control technology in Malaysia, primarily for earthquake disasters, to minimize property and human loss. This project will assist authorities in Malaysia in controlling the earthquake situation by using a robust sensor network system compared to existing systems. The proposed earthquake detection system consists of two parts, which are Transmitter and Receiver. Both parts are connected through the NRF24L01 antenna module, and the data of the earthquake is analysed using the Arduino Uno. The proposed design's prototype has been successfully constructed, and it is planned to be installed in a high- risk earthquake location in Malaysia. Notably, the system's ability to record earthquake magnitudes through the accelerometer, coupled with efficient data transmission to users' homes via NRF24L01 and timely notifications through the Blynk App, signifies a comprehensive approach to disaster preparedness.

Acknowledgement
The authors would like to thank to Universiti Malaysia Perlis (UniMAP) for the sponsorship of the research work through Research Materials Fund (RESMATE), number 9001-00627.

References
[1] Adnan, Azlan, and N. Harith. "Estimation of peak ground acceleration of Ranau based on recent earthquake databases." *Malaysian Journal Geosciences* 1, no. 2 (2017): 6-9. https://doi.org/10.26480/mjg.02.2017.06.09
[2] Noh, Muhammad Ramzanee Mohd, Shuib Rambat, Ida Sharmiza Binti Abd Halim, and Fauzan Ahmad. "Seismic Risk Assessment in Malaysia: A Review." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 25, no. 1 (2021): 69-79. https://doi.org/10.37934/araset.25.1.6979
[3] Loi, Daniel Weijie, Mavinakere Eshwaraiah Raghunandan, and Varghese Swamy. "Revisiting seismic hazard assessment for Peninsular Malaysia using deterministic and probabilistic approaches." *Natural Hazards and Earth System Sciences* 18, no. 9 (2018): 2387-2408. https://doi.org/10.5194/nhess-18-2387-2018
[4] Tongkul, Felix. "An overview of earthquake science in Malaysia." *ASM Science Journal* 14 (2021): 1-12. https://doi.org/10.32802/asmscj.2020.440

[5] Sauti, Noor Suhaiza, Mohd Effendi Daud, Masiri Kaamin, and Suhaila Sahat. "GIS spatial modelling for seismic risk assessment based on exposure, resilience, and capacity indicators to seismic hazard: a case study of Pahang, Malaysia." *Geomatics, Natural Hazards and Risk* 12, no. 1 (2021): 1948-1972. https://doi.org/10.1080/19475705.2021.1947903

[6] Jainih, V., and N. S. H. Harith. "Seismic vulnerability assessment in Kota Kinabalu, Sabah." In *IOP Conference Series: Earth and Environmental Science*, vol. 476, no. 1, p. 012053. IOP Publishing, 2020. https://doi.org/10.1088/1755-1315/476/1/012053

[7] Qi, Wenjie, Chao Xu, Bowen Liu, Xu She, Tian Liang, Deyong Chen, Junbo Wang, and Jian Chen. "MEMS-based electrochemical seismometer with a sensing unit integrating four electrodes." *Micromachines* 12, no. 6 (2021): 699. https://doi.org/10.3390/mi12060699

[8] Li, Zefeng. "Recent advances in earthquake monitoring I: Ongoing revolution of seismic instrumentation." *Earthquake science* 34, no. 2 (2021): 177-188. https://doi.org/10.29382/eqs-2021-0011

[9] Chen, Fu-Hsien, Horng-Lin Shieh, and Jih-Fu Tu. "Development of Earthquake Detection and Warning System Based on Sensors." *Sensors & Materials* 35 (2023). https://doi.org/10.18494/SAM4116

[10] Kwon, Young-Woo, Jae-Kwang Ahn, Jimin Lee, and Chul-Ho Lee. "Earthquake early warning using low-cost MEMS sensors." In *IGARSS 2020-2020 IEEE International Geoscience and Remote Sensing Symposium*, pp. 6635-6637. IEEE, 2020. https://doi.org/10.1109/IGARSS39084.2020.9323438

[11] Junior, Rio, Ary Murti, and Dien Rahmawati. "Implementation of Random Forest Classifier for Real-time Earthquake Detection System." In *2023 IEEE International Conference on Industry 4.0, Artificial Intelligence, and Communications Technology (IAICT)*, pp. 227-231. IEEE, 2023. https://doi.org/10.1109/IAICT59002.2023.10205761

[12] Pierleoni, Paola, Roberto Concetti, Simone Marzorati, Alberto Belli, and Lorenzo Palma. "Internet of Things for Earthquake Early Warning Systems: a Performance Comparison between Communication Protocols." *IEEE Access* (2023). https://doi.org/10.1109/ACCESS.2023.3271773

[13] Carratù, Marco, Vincenzo Gallo, Vincenzo Paciello, and Antonio Pietrosanto. "A deep learning approach for the development of an Early Earthquake Warning system." In *2022 IEEE International Instrumentation and Measurement Technology Conference (I2MTC)*, pp. 1-6. IEEE, 2022. https://doi.org/10.1109/I2MTC48687.2022.9806627

[14] Wu, Yih-Min, and Himanshu Mittal. "A review on the development of earthquake warning system using low-cost sensors in Taiwan." *Sensors* 21, no. 22 (2021): 7649. https://doi.org/10.3390/s21227649

[15] Pierleoni, Paola, Alberto Belli, Marco Esposito, Roberto Concetti, and Lorenzo Palma. "Earthquake Early Warning Services Based on Very Low-Cost Internet of Things Devices." In *2022 61st FITCE International Congress Future Telecommunications: Infrastructure and Sustainability (FITCE)*, pp. 1-5. IEEE, 2022. https://doi.org/10.23919/FITCE56290.2022.9934792

[16] Wenanda, I. Gede Krisna Pradnya, Pandu Halimie Prahatama, Muhammad Ary Murti, and Dien Rahmawati. "Analysis of LoRa (Long Range) Performance as The Development of Remote Communication for Earthquake Detection Systems in High-rise Buildings." In *2023 International Conference on Computer Science, Information Technology and Engineering (ICCoSITE)*, pp. 313-318. IEEE, 2023. https://doi.org/10.1109/ICCoSITE57641.2023.10127702

[17] Waworundeng, Jacquline Morlav S., Micha Adeleid Tisyana Kalalo, and Daniel Putra Yudha Lokollo. "A Prototype of Indoor Hazard Detection System using Sensors and IoT." In *2020 2nd International Conference on Cybernetics and Intelligent System (ICORIS)*, pp. 1-6. IEEE, 2020. https://doi.org/10.1109/ICORIS50180.2020.9320809

[18] Kumar, Nitin, and Maneesha Vinodini Ramesh. "Accurate iot based slope instability sensing system for landslide detection." *IEEE Sensors Journal* 22, no. 17 (2022): 17151-17161. https://doi.org/10.1109/JSEN.2022.3189903

[19] Matsumura, Shozo. *Development of an Earthquake Early Warning System and Its Benefi ts*. NISTEP Science & Technology Foresight Center, 2011.

[20] McBride, S. K., Ann Bostrom, Jeannette Sutton, Robert Michael de Groot, Annemarie S. Baltay, Brian Terbush, Paul Bodin *et al.,* "Developing post-alert messaging for ShakeAlert, the earthquake early warning system for the West Coast of the United States of America." *International Journal of Disaster Risk Reduction* 50 (2020): 101713. https://doi.org/10.1016/j.ijdrr.2020.101713

[21] Shariffuddin, Saidah Izzati Mohd, and Wani Sofia Udin. "Landslide Susceptibility Assessment Using Geographic Information System (GIS) Application of Putat Area, Gunungkidul, Yogyakarta, Indonesia." In *IOP Conference Series: Earth and Environmental Science*, vol. 596, no. 1, p. 012055. IOP Publishing, 2020. https://doi.org/10.1088/1755-1315/596/1/012055

[22] Kodera, Yuki, Naoki Hayashimoto, Koji Tamaribuchi, Keishi Noguchi, Ken Moriwaki, Ryo Takahashi, Masahiko Morimoto, Kuninori Okamoto, and Mitsuyuki Hoshiba. "Developments of the nationwide earthquake early warning system in Japan after the 2011 M w 9.0 Tohoku-Oki earthquake." *Frontiers in Earth Science* 9 (2021): 726045. https://doi.org/10.3389/feart.2021.726045

[23] Finazzi, Francesco. "The earthquake network project: A platform for earthquake early warning, rapid impact assessment, and search and rescue." *Frontiers in Earth Science* 8 (2020): 243. https://doi.org/10.3389/feart.2020.00243
[24] Android Early Earthquake Warnings. "How Android Earthquake Alerts System Works." https://crisisresponse.google/android-alerts/