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Telegram-Based Earthquake Early Warning

Arfanda Anugrah Siregar[1*], Erwinsyah Simanungkalit[1], Nasrudin[1]

[1] Lecturer of Telecommunication Engineering, Politeknik Negeri Medan, Indonesia

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Corresponding Author:
Arfanda Anugrah Siregar
arfandasiregar@polmed.ac.id

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Abstract: Earthquakes are one of the natural disasters whose arrival cannot be ascertained and have a very detrimental impact, both in terms of property losses and lives. Indonesia, with its very active tectonic plate conditions, often experiences earthquakes, so it needs an effective early warning system. BMKG has developed an early warning system that informs of earthquake events through various media. However, this system still has weaknesses in the speed of delivering information to the public. This research aims to design and make a prototype of an earthquake early warning tool that can send information in the form of notifications and warning alarms using the Telegram application. The use of Telegram as a medium for conveying information was chosen because of its high-speed, security, and accessibility. This research was carried out at the Telecommunications Laboratory, Politeknik Negeri Medan starting from the system design process, system implementation, MPU6050 sensor testing, LoRa SX1278 testing, microcontroller ESP32 testing, and Telegram BOT testing to detect earthquake vibrations and send earthquake scale notifications via the Telegram. It produced a prototype of an earthquake early warning tool that uses Telegram for the dissemination of warning information in real-time, so that people can more quickly take self-rescue actions.

Keywords: Early warning system; Earthquake; Internet of Things (IoT); MPU 6050 sensor

Introduction

Earthquake Early Warning (EEW) systems are pivotal tools in mitigating the devastating impacts of seismic events by providing critical seconds to minutes of advance notice before significant ground shaking occurs (Allen & Melgar, 2019; Cremen & Galasso, 2020). As seismic risks intensify in tectonically active regions such as Indonesia (Muthahhari & Firdaus, 2024), the urgency to enhance and democratize EEW dissemination mechanisms has never been greater. Traditional warning systems often rely on costly infrastructure and centralized communication protocols, which may not be accessible to all communities, particularly in remote or under-resourced areas (Minson et al., 2018; Wu & Mittal, 2021).

The Meteorology, Climatology and Geophysics Agency (BMKG) reported that 7,358 earthquakes rocked Indonesia throughout 2024. Small earthquakes with a magnitude of less than Magnitude (M) 5.0 occurred 7,172 times, while earthquakes with a magnitude above M5.0 occurred 186 times. BMKG's Director of Earthquakes and Tsunamis, from the total number of earthquakes, earthquakes were felt 743 times, and earthquakes caused damage 20 times (Mufarida, 2024). This further emphasizes the urgency of developing an earthquake early warning system as offered in this study to minimize the risks and impacts of disasters on the community.

Earthquakes can cause significant impacts, both physically, socially, and economically (Hiden et al., 2022). The resulting vibrations can cause damage to buildings, infrastructure, and public facilities, endangering the safety of life and property (Kanata et al., 2024). In the case of strong earthquakes, fatalities and injuries are often unavoidable due to collapsed buildings

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or being hit by falling materials (Khan et al., 2020). In addition, earthquakes can also trigger secondary disasters such as landslides and tsunamis, which worsen emergency situations (Li, 2021; Rudyanto et al., 2024). On the social side, earthquakes can cause mass panic, psychological trauma, and disrupt educational, economic, and government activities (Zambrano et al., 2017). Overall, the impact of earthquakes is not only felt when the incident occurs, but also in the long-term recovery process.

Recent advances in the Internet of Things (IoT), artificial intelligence, and cloud computing have significantly improved the accuracy, timeliness, and scalability of EEW systems (Esposito et al., 2022; Pwavodi et al., 2024; Topan Indra et al., 2023). These technologies enable real-time seismic monitoring, predictive analytics, and decentralized data sharing, forming the backbone of next-generation disaster management frameworks (Rosca & Stancu, 2024; Sharma et al., 2021). However, the challenge of ensuring that warnings reach individuals promptly and reliably remains a major concern (Chan & Tsai, 2023).

In this context, integrating EEW alerts with widely used instant messaging platforms such as Telegram presents a promising solution. Telegram offers features such as real-time broadcasting, automation via bots, and cross-platform accessibility, making it a suitable channel for rapid disaster communication (Chan & Tsai, 2023). By leveraging Telegram's extensive user base and API capabilities, a Telegram-based EEW system can act as an accessible, low-cost complement to conventional alerting methods.

This article explores the potential of using Telegram as a dissemination medium for earthquake early warnings. It examines the technical feasibility, infrastructure requirements, and integration potential with existing IoT-based seismic networks. Grounded in current literature and technological trends (Abdalzaher et al., 2024; Cheng et al., 2023; Damaševičius et al., 2023), the study highlights how such a system could enhance public preparedness, especially in high-risk regions like Indonesia (Kurniawan et al., 2023; Rudyanto et al., 2024), where community-centered, cost-effective solutions are essential for effective disaster response.

The novelty of this research lies in the integration of MPU 6050, NodeMCU ESP8266, and Telegram sensors in one IoT-based earthquake early warning system. The integration forms the core sensing-to-alert pipeline. The MPU6050, is responsible for continuously capturing ground motion data. This raw sensor data is processed locally by the NodeMCU ESP8266, a low-cost microcontroller with built-in Wi-Fi capabilities. The ESP8266 periodically analyzes accelerometric readings to detect anomalies that may correspond to seismic P-wave activity. When a predefined threshold is exceeded—indicating potential early seismic movement—the ESP8266 initiates an HTTP or MQTT request to a cloud-based server (or optionally processes directly using onboard logic). This server then validates the signal by aggregating data from multiple nodes to minimize false alarms. Upon confirmation, a Telegram bot, connected via the Telegram Bot API, is triggered to broadcast an early warning message to users or groups. The message contains critical information such as the time of detection, location, and estimated intensity. This seamless integration enables low-latency, internet-based earthquake alerts, combining real-time edge sensing with instant communication technology accessible to the public (Abdalzaher et al., 2023).

This research was conducted at the Telecommunications Laboratory, Politeknik Negeri Medan, beginning with the system design process, system implementation, MPU6050 sensor testing, LoRa SX1278 testing, microcontroller ESP32 testing, and Telegram BOT testing to detect earthquake vibrations and send earthquake scale notifications via the Telegram. Through the use of Telegram, this tool is expected to provide warnings quickly and effectively, which can minimize the risk of earthquakes.

Method

The research methodology for the Earthquake Early Warning System includes determining the Equipment Specifications, creating diagram blocks, hardware design, software design, and tool profile testing.

System Specifications

The system specifications need to be determined in advance as a reference for the design of the tool, so that the tool can be developed according to the expected purpose. The specified appliance specifications include: sensor type MPU6050, acceleration Range ±16g, gyroscope range ±2000 degrees/sec, sampling frequency at least 100 Hz for accurate readings, communication module LoRa SX1278, operating voltage 3.3V to 5V for ESP32 and sensor, rechargeable lithium battery with a minimum capacity of 2000 mAh, Internet Connection: Wi-Fi module (integrated in ESP32) for real-time data uploading to a cloud server, and Database Connectivity.

The MPU6050 integrates a 3-axis accelerometer and 3-axis gyroscope, making it a cost-effective and compact option for detecting both linear acceleration and angular velocity — two important parameters in earthquake analysis. An acceleration range of ±16g allows the sensor to detect very strong ground movements without saturating the signal. While most earthquakes cause peak ground accelerations (PGA) below 1g, the high range ensures the sensor remains operational during extreme shaking, such as near-field events or in areas with soft soil amplification. It also avoids clipping in high-intensity events, ensuring data integrity and signal fidelity across magnitudes. Gyroscope plays a role in identifying rotational ground motion or equipment/structure responses. The ±2000°/s range ensures the sensor can capture rapid angular displacements, which are useful in understanding dynamic structural responses or detecting abrupt movements in rugged terrain during an earthquake.

A sampling frequency of ≥100 Hz is critical for accurately capturing the fast onset of P-waves, which can have frequencies ranging from 0.5 Hz to 20 Hz or more. According to the Nyquist theorem, to capture a signal accurately, the sampling rate must be at least twice the maximum signal frequency. A 100 Hz rate ensures fidelity in capturing rapid ground acceleration changes and reduces latency in event detection and alert triggering. Communication Module LoRa SX1278 offers low-power, long-distance communication, cost-effective, cost effective, high scalability. In early warning applications, LoRa ensures that even when internet access is unavailable, the system can still relay critical alerts to a central node or gateway for processing

Choosing components that operate between 3.3V and 5V simplifies power system design and compatibility. Both the ESP32 and MPU6050 function reliably within this range, reducing the need for level shifters or voltage regulators. This allows for efficient power management and reduces system complexity, which is vital for remote, autonomous deployments.

Rechargeable lithium battery with a minimum capacity of 2000 mAh ensures at least 8 hours of continuous operation, which is essential during power outages often caused by earthquakes. It allows the system to operate autonomously in the critical immediate post-event window, where power infrastructure might be compromised. Lithium batteries are also lightweight, rechargeable, and have a good energy-to-weight ratio, ideal for portable or field-deployed sensing units.

The system must be able to connect with Firebase Realtime. The Firebase Realtime Database serves as the centralized cloud-based storage and communication hub for managing sensor data, alert logs, and user notifications (El Anshori et al., 2025). Upon detecting seismic activity through the MPU6050 sensor, the ESP32 microcontroller processes the raw data and generates a structured event report. This report typically includes timestamp of the event, device ID or location coordinates of the sensor, Peak ground acceleration (PGA) value, angular velocity readings from the gyroscope (if used), detection status (e.g., P-wave detected, threshold breached), event severity level or classification, Battery level or device health status.

Block Diagram

The design begins with the creation of system diagram blocks. Each block is simply designed and interconnected with each other. This block diagram for design can be seen in the image 1.

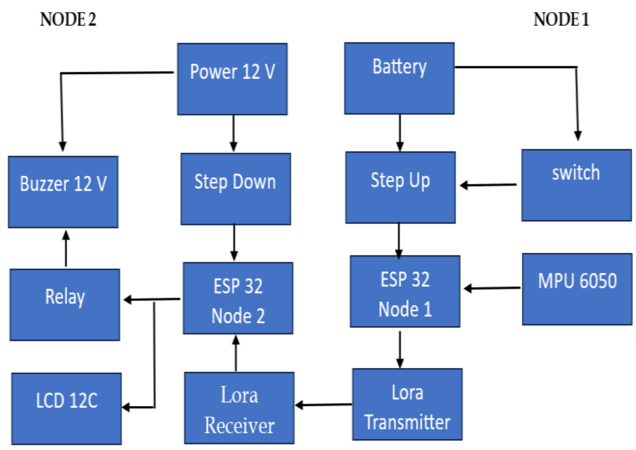

Figure 1. System Diagram Block

In the diagram block above, it is known that there is node 1 connected to the gateway, the way the system works starts from ESP32. The ESP32 as a data processor to process the work of the system starts when power is provided from the battery at node 1 and 12-Volt power at the gateway. In the step-down module to lower the voltage to 5 Volts, and in the step-up module to increase the battery voltage from 3.7 Volts to 5 Volts. Then the output voltage of the two step down or step up modules is applied to the two nodes of ESP32, so that it gets a power supply. Furthermore, all components connected to the ESP32 will be able to work according to the program that has been designed. When these two nodes are connected to each other using LoRa then this tool will run as it should, but if it is not connected between LoRa node 1 and LoRa gateway or vice versa then this tool will not run.

Hardware Design

The overall picture of the earthquake early warning series with telegram can be seen in Figure 2 and Figure 3.

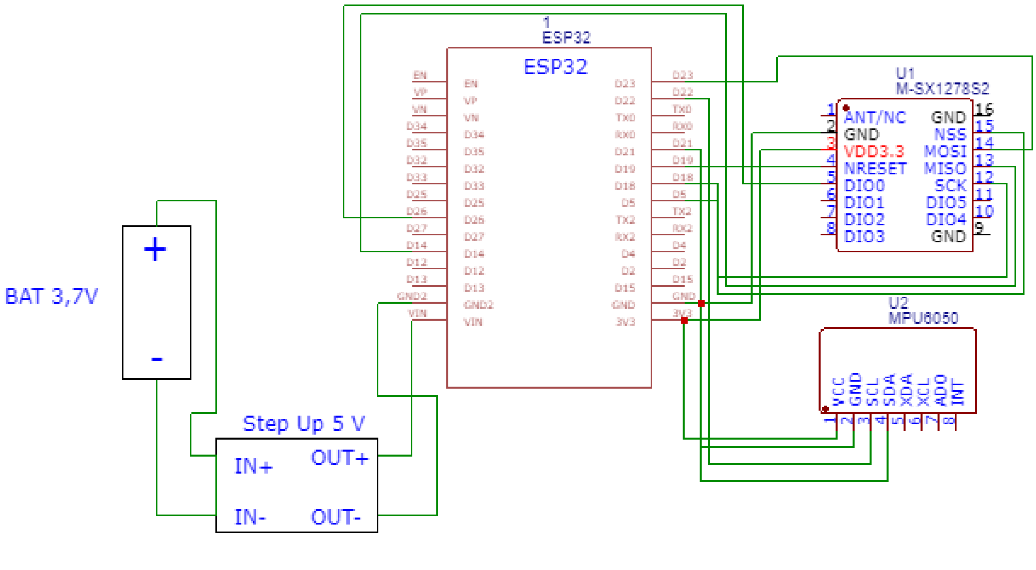

Figure 2. Schematic of Node 1

This overall range consists of ESP32 components, MPU6050 Sensor, Step down Module, Step up Module, LoRa SX1278 Module, I2C LCD, Lithium 18650 Battery, Buzzer, Relay, and Power 12 Volt. All circuit pin connections are in accordance with the program created in the Arduino IDE software so that all circuits can function as planned. The entire network can be seen in Figure 2 for node 1 and in Figure 3 for node 2.

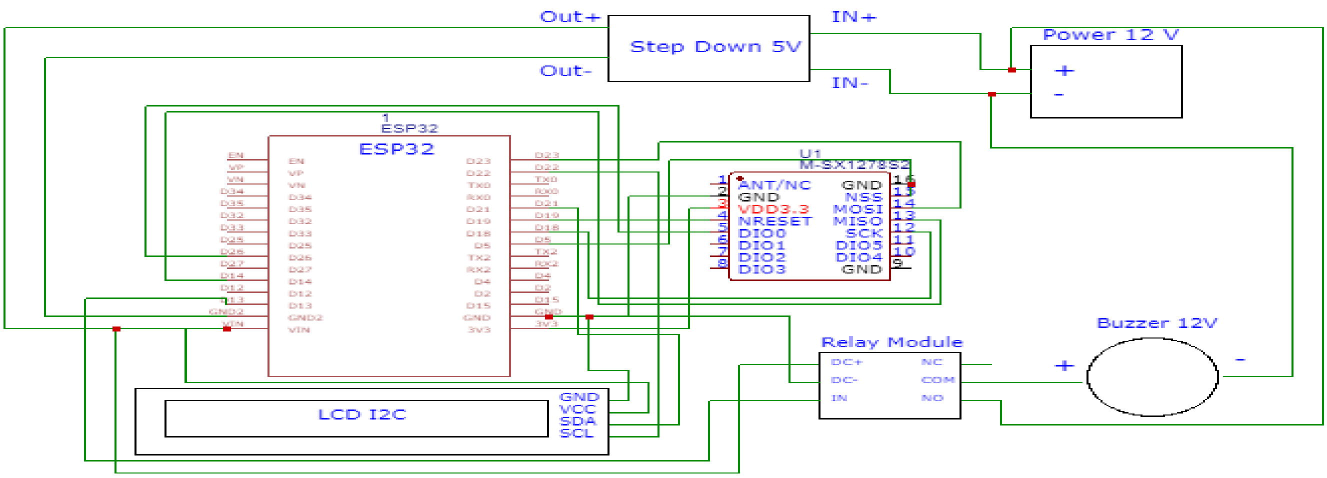

Figure 3. Schematic of Node 2

Software Design

The flowchart of the Earthquake Early Warning System begins with initialization and initial values to determine the input and output parameters of each variable. Then it is continued by connecting the node 1 device to the gateway using the LoRa SX1278. Meanwhile, the sensor MPU6050 used as a component to read the earthquake vibration value, then continued with the reading of the MMI scale value whose value is sent to the gateway as a monitor. Furthermore, the ESP32 gateway displays the MMI scale on the LCD. After knowing the magnitude of the MMI scale detected by the MPU6050 sensor, then ESP32 as an access sends the MMI scale value to BMKG Telegram Bot API connected via Wi-Fi. When the sensor MPU6050 detect it, the buzzer will sound as a warning alarm warning sign of an earthquake. The flowchart image can be seen in Figure 3.

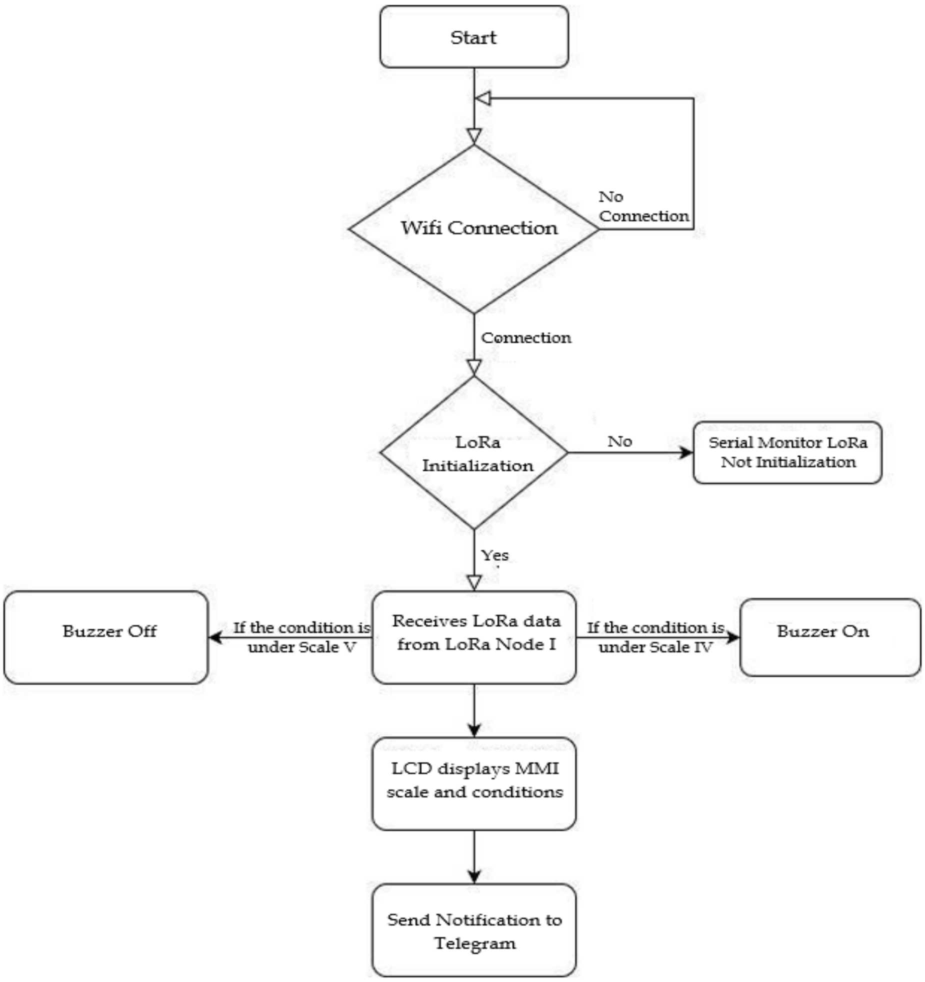

Figure 3. Flow of research

Result and Discussion

Sensor testing MPU6050 used to measure acceleration in three axes (ax, ay, az). These acceleration values are then used to calculate the magnitude of the vibration using the Formula 1.

Resultant Acceleration = ax2 + ay2 + az2 (1)

Where ax, ay, and az are accelerations in units of g-force. After that, the acceleration value is converted to a Modified Mercalli Intensity (MMI) scale using the ToMMI (float vibration) convert function. The ToMMI (float acceleration) function is designed to convert the maximum ground acceleration value into an earthquake intensity value in the MMI Scale, which is easier for users to understand. In sensor-based earthquake early warning systems such as the MPU6050, vibration values are measured as acceleration (usually in units of g or m/s²). The following table shows the results of sensor testing MPU6050.

Table 1. MPU 6050 sensor test

Vibration Conditions	MMI	Ax (g)	Ay(g)	Az (g)	Gx (°/s)	Gy (°/s)	Gz (°/s)
Undetected	I	0.01	0.01	0.99	0.5	0.5	0.5
Weak	II-III	0.02	0.02	0.98	1.0	1.0	1.0
Light	IV	0.03	0.03	0.97	1.5	1.5	1.5
Moderate	V	0.05	0.05	0.95	2.0	2.0	2.0
Strong	VI	0.07	0.07	0.93	3.0	3.0	3.0
Very Strong	VII	0.10	0.10	0.90	4.0	4.0	4.0
Severe	VIII	0.15	0.15	0.85	5.0	5.0	5.0
Terrific	IX	0.20	0.20	0.80	6.0	6.0	6.0
Extreme	X+	0.30	0.30	0.70	7.0	7.0	7.0

In this section, the data read by the MPU6050 sensor present in node 1 will be sent through the LoRa SX1278 and will be forwarded to the LoRa SX1278 present in the gateway. The following table shows the LoRa test of the distance between successfully connected nodes.

Table 2. LoRa test table

Distance (m)	Message sent	Message received	Information
10	POLMED	POLMED	-67 dBm
50	POLMED	POLMED	-70 dBm
100	POLMED	POLMED	-81 dBm
200	POLMED	POLMED	-87 dBm
500	POLMED	POLMED	-91 dBm
1000	POLMED	POLMED	-100 dBm
2000	POLMED	POLMED	Lost Connection

This experiment was carried out without any obstacles between the 2 LoRa nodes. Inside the product, it is claimed to be able to reach 10 km, but due to the limitation of the test distance, the author has not been able to try up to a distance of 10 kilometers.

LoRa SX1278 Testing Sending and Receiving Sensor Data MPU6050

LoRA SX1278 permissioning sends and receives data is done through the ability to send and receive sensor data from the MPU6050 from node 1 to the LoRa gateway. The test results prove that LoRa can transmit data responsively without too long a delay. To find out the data sent and received, you can see it on the Arduino software monitor series.

To see if the LCD (Liquid Crystal Display) I2C successfully reads the data sent from node 1 to be visualized through the LCD located on the gateway. LCD functions to monitor hardware. In figure 4 and 5, you will see an LCD screen showing the MMI Scale V condition, meaning the vibration scale is in the moderate category and MMI scale VIII, meaning the vibration is in the severe category.

Figure 4. LCD display shows moderate MMI scale V condition

Figure 5. LCD display shows severe MMI VIII scale conditions

It was found that the LCD successfully visualized the MMI Scale and the conditions read by the MPU6050 sensor located at node 1 according to the existing scale and conditions.

Testing the Telegram BOT was carried out to see if the data read by the MPU6050 sensor in node 1 could be connected to the Telegram BOT and send notifications according to the existing scale and conditions. The test procedure is to activate the internet either on the Wi-Fi router at home or turn on the hotspot on the smartphone according to the name that has been programmed. In this case, the SSID (Service Set Identifier) and the password set is called TelkomJaya with a specific password. Wait for the connectivity to succeed, then a notification will appear on Telegram showing the conditions that node 1 is feeling.

Figure 6. Telegram display

This experiment was carried out to find out whether Telegram can display the latest earthquake data information from BMKG by running a program made with the Node.js programming language as an in figure 7. Once successful, navigate to the saved program file and then run the program.

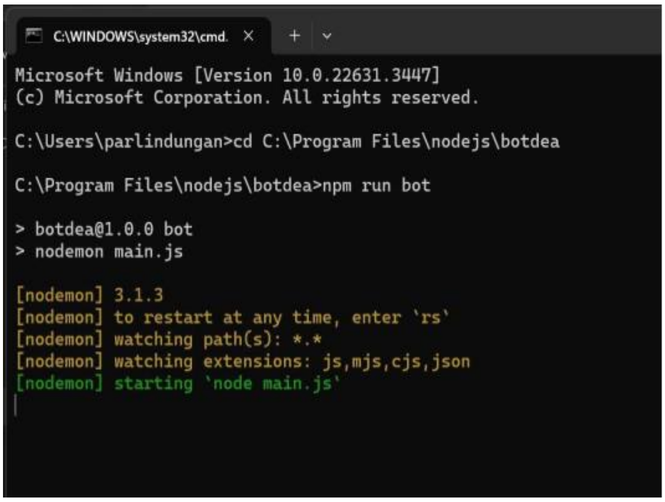

Figure 7. Program successfully executed

Then, reopen the Telegram message group and start the message by typing /earthquake, then the BMKG earthquake information will appear. The information provided by BMKG in the form of time, magnitude, area, potential, depth, image of the area, and the MMI scale felt will be visible as in Figure 8.

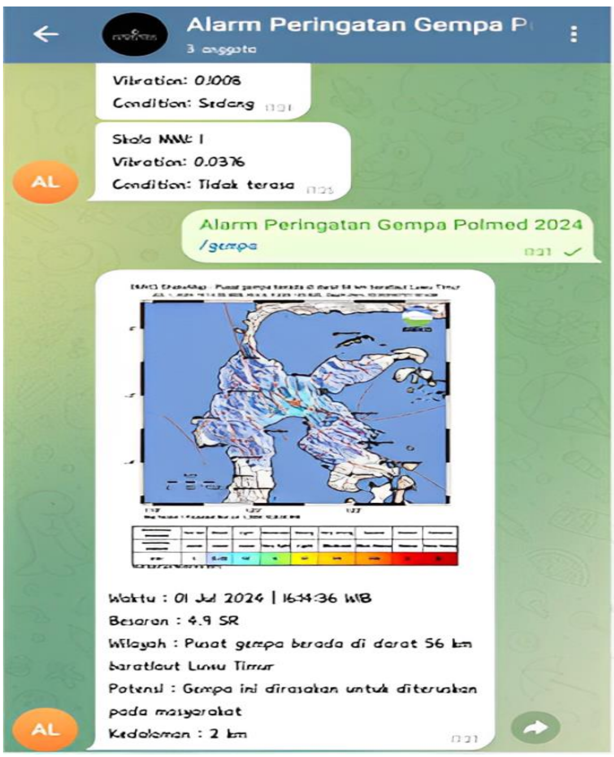

Figure 8. Display information from BMKG

The buzzer is a component that functions as an additional indicator to find out the signal sent by the microcontroller. When the circuit gets a high signal, the buzzer will sound and will turn off when it gets a low signal. This tool uses a relay because the buzzer used has a voltage of 12 V, so it needs to be connected to the relay and power 12 from the adapter to turn it on. When the early warning device detects an earthquake, the buzzer also makes a sound warning people around to immediately save themselves. Buzzer testing can be seen in table 3.

Table 3. MMI scale

MMI scale conditions	Logic	Buzzer condition
I	0 / Low	OFF
II – III	0 / Low	OFF
IV	0 / Low	OFF
V	1 / High	ON
VI	1 / High	ON
VII	1 / High	ON
VIII	1 / High	ON
IX	1 / High	ON
X+	1 / High	ON

WiFi connectivity testing is carried out to find out the signal strength that ESP32 can provide so that data transmission to the Telegram application is stable. Table 4 is the WiFi connectivity test table obtained.

Table 4. WiFi testing

Distance of sensor node to internet source	RSSI
1 M	-10 dBm
5 M	-55 dBm
10 M	-67 dBm
15 M	-72 dBm
20 M	-89 dBm

Overall, the tool went well, and it lived up to the expectations of the initial plan. The test can be seen in the table 5. Based on voltage testing for ESP32, MPU6050 sensor testing, inter-node testing using LoRa SX1278, LCD testing, Telegram testing as a notification, BMKG information testing in Telegram BOT, and buzzer testing, this tool works according to what has been programmed in the Arduino IDE.

Table 5. Overall testing of the tool

LoRa distance (m)	Vibration	MMI scale & conditions	Telegram notification time interval (s)	Buzzer condition	BMKG API response (s)	Internet speed
2 meters	0.0258	MMI I = Not Felt	0.10 s	Off	0.4 s	40 Mbps
10 meters	0.0580	MMI II – III = Light	0.15 s	Off	0.4 s	40 Mbps
50 meters	0.1089	MMI V = Sedang	0.11 s	On	0.4 s	40 Mbps
100 meters	0.0200	MMI I = Not Felt	1 s	Off	0.4 s	40 Mbps
250 meters	0.3819	MMI VI = Kuat	1.3 s	On	0.4 s	40 Mbps
500 meters	0.0147	LoRa not detected	-	Off	0.4 s	40 Mbps

Based on the test results and analysis, several important things were obtained, namely: System Reliability; The system has been proven to be able to send and receive earthquake data reliably via LoRa communication. The received data is processed properly and used to activate the early warning system. Detection Accuracy; The MPU6050 sensor shows good performance in detecting vibrations that indicate an earthquake. The data obtained can be relied on to measure earthquake intensity based on the MMI scale. Integration with Telegram; The Telegram BOT developed can provide earthquake warning notifications to users quickly and efficiently. Users can also receive more information about the detected earthquake through the Telegram application. Warning Effectiveness; The buzzer and LCD successfully provide effective audible and visual warnings to users. This allows users to immediately take the necessary actions after receiving a warning. Power Consumption; The system's power consumption is within acceptable limits, allowing the system to operate for a long period of time using available resources. Overall, the designed earthquake early warning system has succeeded in meeting the research objectives by providing fast, accurate warnings that can be sent to users via the Telegram application.

By harnessing the power of Internet of Things (IoT) technology, emergency response systems can achieve significant improvements in speed, accuracy, and overall effectiveness. IoT devices enable real-time monitoring and communication, allowing authorities to detect hazards quickly, assess risks more accurately, and respond efficiently to mitigate impacts. In the context of this research, the integration of the MPU6050 sensor with NodeMCU ESP8266 and LoRa communication allows for the immediate detection and transmission of seismic activity data. These data are then processed and sent as real-time alerts via Telegram, a widely accessible instant messaging application. This method ensures that critical warnings can reach users instantly, even in remote areas where conventional alert systems may be limited.

This is in line with research which states IoT-based disaster management systems enhance situational awareness through interconnected sensing and data-sharing infrastructures (Finazzi, 2020). Furthermore, IoT technologies improve coordination between agencies and enable faster, data-driven decision-making during emergencies (Pierleoni et al., 2023). The use of Telegram in this system complements these strengths by serving as a low-latency, user-friendly alert platform, making the warning system both effective and inclusive in reaching various user groups during a seismic emergency.

Conclusion

The conclusion of this study is that the implementation of an Earthquake Earthquake Early Warning System Early Warning System using an ESP32 microcontroller, MPU6050 sensor, and LoRa SX1278 module successfully provides earthquake scale notifications through the Telegram application, although there are limitations in sensor sensitivity to detect earthquakes with low magnitudes or those far from the sensor center. In addition, this study also integrates the latest earthquake data from BMKG using Node.js as an earthquake information server. However, the functionality of this tool depends on the availability of the internet, which is a major obstacle in the operation of the earthquake information bot gateway and server. This research aims to produce an effective Earthquake Early Warning System in providing information and notifications to the public. In addition, this study highlights the importance of further development in terms of increasing sensor sensitivity and alternative solutions for operations without relying on the internet, so that this Earthquake Early Warning System can be more reliable and used in various network conditions. The results of this study show great potential in the application of IoT technology for disaster mitigation, with the hope of making a positive contribution to efforts to overcome and prepare for earthquakes in the future.

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Author Contributions
A.A.S. contributed in conceptualization, system design, hardware development, software implementation, data analysis, and manuscript drafting; E.S. contributed in supervision, methodology review, technical validation, and manuscript editing; N. contributed in Laboratory Coordination, Resource Management, Data Collection, and Administrative Support. All authors have read and approved the final version of the manuscript.

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Conflicts of Interest
The authors declare that there are no conflicts of interest related to the publication of this research.

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