

Earthquake Detection and Early Warning Tools Using Internet of Things Technology

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Abstract— Indonesia is highly susceptible to earthquake disasters due to its location at the convergence of three major active tectonic plates: the Pacific Plate, the Eurasian Plate, and the Indo-Australian Plate. When an earthquake occurs, it generates primary (P) waves and secondary (S) waves. Primary waves travel longitudinally towards the epicenter and move faster but have lower energy. In contrast, secondary waves travel transversely and carry stronger energy. Due to their higher speed, primary waves arrive approximately 1.5 times faster than secondary waves. The aim of this design is to create a system that detects earthquake vibrations at the primary wave stage when the energy is still low, thus providing early warning before the earthquake's energy escalates and causes significant damage. The system utilizes a 3-axis ADXL335 accelerometer sensor, with its data processed by an Arduino UNO. When the system detects earthquake vibrations, a warning is sent to the user's Telegram application via the Node MCU ESP8266 after serial communication between the Arduino UNO and Node MCU ESP8266. Testing has demonstrated that this device can detect minor vibrations and send early earthquake warning notifications to the Telegram app. Notifications are triggered when the predefined threshold values set in the system are reached.

Keywords— Earthquake, ADXL335, Telegram, Internet of Things

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I. INTRODUCTION

Indonesia, comprising thousands of islands from Sabang to Merauke, lies at the junction of three active tectonic plates: the Pacific Plate, the Eurasian Plate, and the Indo-Australian Plate. This geographical position makes Indonesia highly susceptible to earthquakes. Common types of earthquakes include volcanic, tectonic, artificial, and collapse earthquakes, all of which produce vibrations felt by humans. Unfortunately, earthquakes cannot be predicted and often occur suddenly, resulting in significant casualties due to the lack of early warning systems.

Current earthquake detection technology in Indonesia only provides information about the magnitude after the earthquake occurs, not early warnings when the tremors are still weak. Therefore, the speed of information delivery from earthquake detection systems is crucial. This project aims to develop an

earthquake detection system using the ADXL335 sensor and Arduino UNO, which can send early warnings through the Telegram application via Node MCU ESP8266 [7]. The goal is to provide early notification to residents, allowing them time to take cover before the earthquake's intensity increases. Telegram was chosen for its compatibility with IoT integration through its Bot API and API Key features, as well as its widespread use among users.

II. THE MATERIAL AND METHOD

A. Earthquakes

An earthquake is the shaking of the earth caused by the sudden release of energy within the earth, marked by the fracturing of rock layers in the earth's crust. The energy causing earthquakes is generated by the movement of tectonic or volcanic plates. This energy radiates in all directions as seismic

3. TCP/IP Protocol

TCP/IP (Transmission Control Protocol/Internet Protocol) is a standard data communication protocol used for exchanging data over the internet. It is popular and easily applicable to all types of computers and network interfaces. TCP/IP consists of several protocols, each responsible for different parts of data communication.

TCP/IP model	Protocols and services	OSI model
Application	HTTP, FTP, Telnet, NTP, DHCP, PING	Application
		Presentation
		Session
Transport	TCP, UDP	Transport
Network	IP, ARP, ICMP, IGMP	Network
Network Interface	Ethernet	Data Link
		Physical

Fig 6. TCP/IP Protocol Model and OSI Layer [5]

3.1 Internet Layer

The Internet Layer is responsible for delivering data packets to the correct address and choosing the best route within a network. Protocols in this layer include IP (Internet Protocol), ICMP (Internet Control Message Protocol), and ARP (Address Resolution Protocol) [10].

3.2 Transport Layer

The Transport Layer is responsible for breaking down data and reassembling it from the Application Layer. It includes protocols like TCP (Transmission Control Protocol) and UDP (User Datagram Protocol) [10].

3.3 Network Interface Layer

The Network Interface Layer manages the sending and receiving of data through physical media such as cables, fiber optics, or radio waves. Protocols in this layer include Ethernet, SLIP, and X25 [10].

3.4 Application Layer

The Application Layer contains all applications using the TCP/IP protocol, such as FTP (File Transfer Protocol), HTTP (Hypertext Transfer Protocol), SMTP (Simple Mail Transfer Protocol), Telnet, and POP (Post Office Protocol) [10].

4. Addressing

Addressing is necessary in a network to identify the sender and receiver of data packets. There are two types of addresses used: IP Address and MAC Address.

4.1 IP Address

An IP Address is a unique address assigned to a computer or device connected to a network. IP addresses are divided into two versions: IPv4 and IPv6. IPv4 addresses consist of 32 bits divided into four 8-bit segments, while IPv6 addresses consist of 128 bits with a hexadecimal system. IPv4 addresses are categorized into classes A, B, C, D, and E based on the number of bits used for the network ID [17].

4.2 MAC Address

A Media Access Control (MAC) Address is a unique physical address of a network device, consisting of 48 bits divided into six segments, each containing two hexadecimal digits. The last six digits represent the device code [17].

5. Arduino Uno

Arduino Uno is a microcontroller based on the ATmega328, open-source and open hardware, meaning anyone can develop it without needing permission from the related company [1]. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. Arduino Uno supports programming in C and C++ using the Arduino Integrated Development Environment (IDE).



Fig 7. Arduino Uno [1]

6. ADXL 335 Accelerometer Sensor

An accelerometer measures acceleration, vibration, and gravity-induced acceleration. The ADXL335 accelerometer is a small, low-power device with three axes (X, Y, Z) that measures acceleration with a range of $\pm 3g$. It is used in this project to detect earthquake vibrations due to its high sensitivity [2].

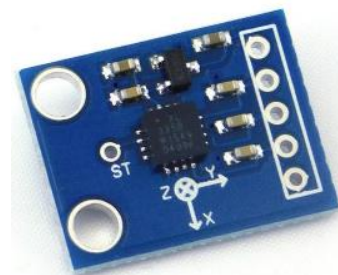


Fig 8. ADXL335 Accelerometer Sensor [2]

7. NodeMCU ESP8266

NodeMCU ESP8266 is a microcontroller board with built-in WiFi capability, allowing it to connect to wireless networks. It uses the Lua programming language and can also be programmed using C with the Arduino IDE [13].

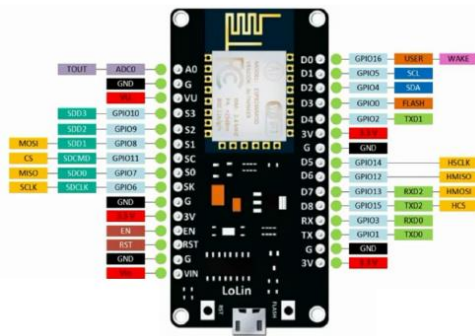


Fig 9. Pins on NodeMCU ESP8266 [13]

8. LCD I2C 16x2

An LCD (Liquid Crystal Display) 16x2 displays characters, letters, and numbers. It consists of 16 columns and 2 rows. The I2C (Inter-Integrated Circuit) module allows the 16-pin LCD to be condensed into 4 pins, saving input pin usage on the Arduino board [11].



Fig 10. Physical form of LCD 16x2 [11]

9. Buzzer

A buzzer converts electrical signals into sound and is commonly used in alarms or notifications. There are two types: active buzzers, which produce sound independently, and passive buzzers, which produce sound when given an oscillating signal [3].



Fig 11. The physical form of the buzzer [3]

10. Arduino IDE

The Arduino Integrated Development Environment (Arduino IDE) is software used to create and edit microcontroller programs. It uses the C programming language and can program various Arduino boards with the appropriate configurations [19].

11. Telegram Application

Telegram is a multi-platform cloud-based instant messaging application available for Android and Apple devices.

Developed by Telegram Messenger LLP, it uses the MTProto protocol for end-to-end encryption, providing high security. Telegram also offers an API for developers to support IoT applications [21].



Fig 12. Telegram application logo [21]

III. RESULTS AND DISCUSSION

This chapter discusses the testing of the Earthquake Detection and Early Warning Device using Internet of Things (IoT) technology that was previously designed and built. The objective of the testing is to ensure that each component of the device operates as expected and that the results obtained are accurate and applicable.

A. Testing Preparation

1. USB Cable: Connects the microcontroller to the laptop to read sensor values and for serial communication.
2. Laptop: Monitors the results and sensor test values and data transmission.
3. Weights: Tests sensor sensitivity to small vibrations using weights of 1kg, 2kg, and 3kg.
4. Distance Meter: Determines the drop point of the weights from the sensor device at distances of 5cm, 10cm, and 15cm to test sensor sensitivity.

B. Testing the ADXL335 Sensor

1. Output Voltage Reading

Tests the sensor's ability to read acceleration and send results to the Arduino UNO. The purpose of reading the output voltage of the ADXL335 sensor is to determine whether the sensor is functioning in detecting static acceleration, specifically Earth's gravity. The output voltage generated is analog.

TABLE I.

ADXL335 THREE AXIS OUTPUT VOLTAGE

X Axis Voltage (Vout)	Y Axis Voltage (Vout)	Z Axis Voltage (Vout)
1.54 V	1.27 V	1.59 V

2. Sensor Calibration

Obtains accurate axis values due to factors such as soldering heat. Calibration is performed to determine the precise speed change parameters.

The following are the results of the sensor readings before calibration.

TABLE II.
ADXL335 THREE AXIS OUTPUT VALUE

Axis (X)	Axis (Y)	Axis (Z)
328	325	260
329	325	261
329	325	261
328	325	261
328	325	261

Sensor calibration is carried out by getting the maximum value (+1g) and minimum value (-1g) on each axis sensor ADXL335. To get the maximum and minimum values, then the position of the sensor must be made perpendicular to the vertical according to the direction guide on each axis.



Fig 13. Minimum and Maximum Axis X calibration

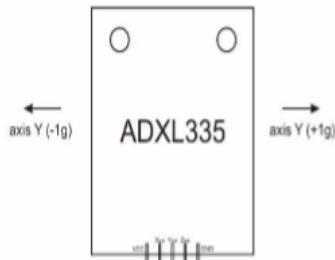


Fig 14. Minimum and Maximum Axis Y calibration

Based on the guide in fig 13 and fig 14, to get the maximum value and the minimum X and Y axes are to position the sensor perpendicularly vertically. Meanwhile, for the Z axis, it is done by flipping the sensor ADXL335 to obtain the maximum and minimum axis values.

TABLE III.
ADXL335 THREE AXIS MIN AND MAX VALUE

Axis	+1g(max)	-1g(min)
X	390	260
Y	390	260
Z	386	260

After the minimum and maximum values are obtained, the sensor can be calibrated in a program using the Arduino IDE.

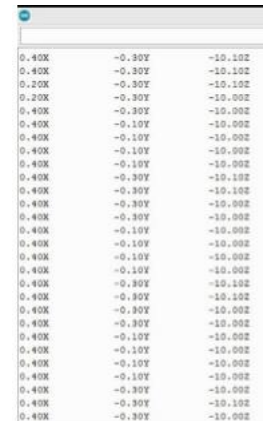


Fig 15. ADXL335 Testing After Calibration

C. Output

The output of this system consists of 2 components, namely LCD and LED. The LCD is used to display system description written characters and the LED as a color indicator of a condition. For IoT systems, this system use a telegram bot system for alert notification.

1. LCD I2C 16x2

Displays real-time data and provides evacuation alerts when small earthquakes are detected.



Fig 16. LCD Testing

2. LED

Device Output: Green LED indicates internet connection status, red LED and buzzer serve as earthquake alerts.

3. Telegram Alert Notification

Telegram is used as a real time danger notification system which is used as an alarm to users

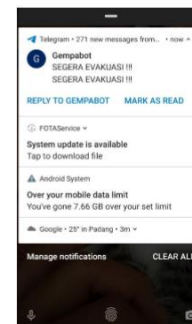


Fig 17. Telegram Alert

In testing the system as a whole, the author designed a trial by providing a trigger using loads with masses of 1kg, 2kg and 3kg to simulate earthquake vibrations. Where each load will be dropped at a distance of 10 cm, 20 cm and 30 cm from the device. This experiment itself is done on a wooden table.

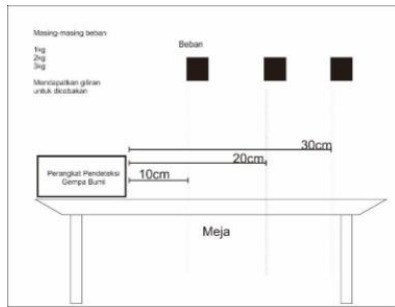


Fig 18. Illustration of Testing a Device by Dropping a Load

Dropping the load simulates small-scale earthquake vibrations, essential for detecting minor tremors and providing early warnings, allowing prompt shelter before a major quake occurs.

TABLE IV.
FINAL TEST

Distance	Feedback		
	1 kg	2 kg	3 kg
10 cm	Not Detected	Not Detected	Detected
20 cm	Not Detected	Not Detected	Detected
30 cm	Not Detected	Not Detected	Not Detected

After hardware testing, the next step is to check how notifications appear in the Telegram application. The author took screenshots of received notifications and checked the Serial Monitor to ensure the notification text matches the programmed message.

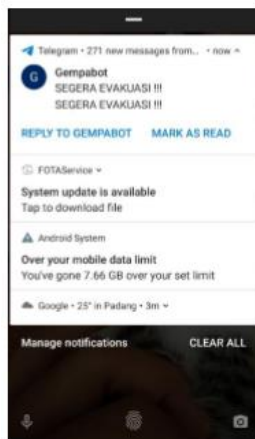


Fig 19. Telegram Alert

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Y : -0.90
Z : -10.90
X : -1.00
Y : -1.00
Z : -10.90
X : -0.70
Y : 1.10
Z : -11.50
SEGERA EVAKUASI !!!
X : -1.00
Y : -1.00
Z : -11.00
X : -1.00
Y : -1.00
Z : -11.00
    
```

Fig 20. Serial Monitor

The notification message received in the Telegram application matches what was programmed on the NodeMCU ESP8266 board.

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