



Landslide & Rockfall Monitoring System Using NodeMCU Sensor Node with LoRa Communication and Thingspeak IoT

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Abstract: A LoRa-based Wireless Sensors Network (WSN) for rockfall and landslide monitoring is an innovative solution designed for real-time, remote detection and early warning of geohazards, especially in challenging or inaccessible regions. LoRa (Long Range) communication technology enables the deployment of autonomous, low-power sensor nodes that can monitor key indicators of rockfall and landslide activity, such as soil moisture, ground tilt, temperature, rainfall, and vibration. These sensors are distributed in a star or mesh topology and communicate over long distances to a central gateway, which aggregates and transmits data to a server for analysis. The system allows rapid detection of critical ground movements, providing timely alerts and supporting mitigation efforts. Portable LoRa WAN-based assemblies powered by solar energy make these networks cost-effective and suitable for remote and rugged terrain. Real-world deployments have shown the feasibility of continuous data collection, energy efficiency, and reliable performance, enhancing safety and disaster preparedness in vulnerable areas. This approach makes use of dedicated hardware (such as HC12 modules and NodeMCU) and software platforms (like Arduino IDE, Nodejs), and is scalable for integration of weather and ground sensors. It facilitates effective disaster management by offering high accuracy and rapid response times even in areas without traditional communications infrastructure.

Index Terms - : Landslides, Rock fall detection, Remote sensing, NodeMCU ADXL345, GIS

I. INTRODUCTION

Landslides and rockfalls are significant natural hazards that can lead to loss of life, infrastructure damage, and economic disruption, especially in regions with steep slopes, weak geological formations, or intense rainfall. With growing populations settling in vulnerable zones and climate change increasing the frequency of extreme weather events, the threat posed by these geohazards is rapidly rising. Recent advances in wireless sensor networks (WSNs), particularly those leveraging LoRa (Long Range) communication technology, have paved the way for cost-effective and energy-efficient solutions to this problem. LoRa-based networks enable low-power sensors to be deployed across vast and difficult terrains, gathering real-time data on indicators such as soil moisture, ground tilt, vibrations, and environmental conditions. This data is transmitted wirelessly over long distances to a central gateway for analysis and alert generation. The ease of sensor deployment, flexibility of network architecture, and minimal infrastructure requirements make LoRa-based WSNs especially suited for continuous, autonomous monitoring in challenging geographies.

II. LITERATURE REVIEW

Mattia Ragnoli has published the paper “LoRa-Based Wireless Sensors Network for Rockfall and Landslide Monitoring: A Case Study in Pantelleria Island with Portable LoRaWAN Access”[1]. In this paper wireless sensor network based rockfall and landslide detection done by monitoring the axial accelerations, temperature, barometric pressure, altitude, relative humidity, gas resistance for air AQI, and battery level[1]. In this paper author concluded that the future development will be in the optimization of packet transmission in terms of packet loss. Another development can be in sensor node by introduction of different sensors.

Ioannis Farmakis published paper “Rockfall detection using LiDAR and deep learning”[3]. The outcome of this research is promising regarding the potential for AI to be applied to attempt to prevent property and life loss from rockfalls in the future [3]. study shows that it is challenging to achieve generalization in rockfall detection even with DL, which has proven its strengths in vision problems for other types of datasets. There might be a need for more and diverse training data to tackle the generalization challenge [3].

“A critical analysis using remote sensing and GIS techniques for spatial distribution and macro-morphological analyses of rockfalls in the Golden Gate Highlands National Park, South Africa”[4]. Published by Hugo Jose De Lemos concluded that rockfalls in the GGHP shows the potential of remote sensing and GIS techniques to be used for extracting rockfall characteristics from remotely sensed imagery and analysing them in relation to topographic variables derived from remotely sensed imagery [4]. Another major limitation noted in this study is that the use of environmental variables derived through a 20 m DEM is not ideal for the assessment of micro-scale rockfall [4]. Marius Schneider, published paper “Rockfall monitoring with a Doppler radar on an active rockslide complex in Brienz/Brinzauls (Switzerland)”[5]. Author investigated a new rockfall data set recorded by a Doppler radar at the active landslide complex of Brienz/Brinzauls in the Swiss Alps. This is the first complete rockfall time series recorded during 4 years for events of about 1m³ in size and larger. Fausto Guzzetti, published paper Geographical landslide early warning systems[6]. Author concluded that operational forecasting of weather-induced landslides is possible and feasible and it can contribute to mitigate landslide risk, reducing fatalities and economic losses. However operational landslide forecasting a difficult and uncertain task [6].

The reviewed studies clearly indicate that LoRa-based IoT systems outperform older wireless technologies like GSM or ZigBee in terms of range, energy efficiency, and scalability.

NodeMCU-based systems are especially suited for low-cost academic and field prototypes, allowing easy integration with multiple sensors and ThingSpeak cloud visualization.

However, gaps remain in:

- Battery sustainability for long-term operation,
- Integration of predictive algorithms for early alerts, and
- Deployment of multi-node mesh networks for large-area monitoring.

The proposed NodeMCU + LoRa system aims to address these challenges by combining long-range communication, low power usage, and real-time cloud-based data visualization to create an effective early warning tool.

III. METHODOLOGY

The system development for a LoRa-based Wireless Sensors Network (WSN) designed for rockfall and landslide monitoring involves creating a robust, real-time, and scalable architecture to detect and report geological hazards in challenging environments.

Transmitter Node (Sensor Unit):

Equipped with NodeMCU, LoRa module, temperature sensor, accelerometer, and GPS module. Continuously reads sensor data. Sends the data wirelessly to the receiver node through LoRa.

Receiver Node (Gateway): Receives LoRa data from transmitter. Uploads it to ThingSpeak cloud using Wi-Fi. Displays real-time plots such as temperature vs. time, vibration vs. time.

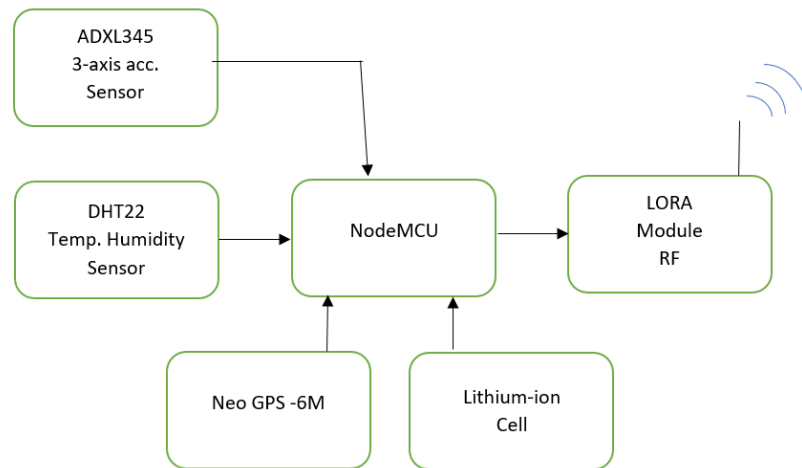


Figure 1 Block diagram of LORA- Based Wireless Sensor Network monitoring system for rockfall and landslide

The accelerometer measures any vibration or movement of the slope surface. The GPS module detects any displacement of the monitored area. The temperature sensor tracks environmental changes that might trigger landslides. NodeMCU collects all sensor readings and transmits them via LoRa. The receiver uploads data to ThingSpeak, where graphs are plotted in real-time. If sensor readings cross certain thresholds (e.g., sudden high vibration or displacement), an alert can be generated.

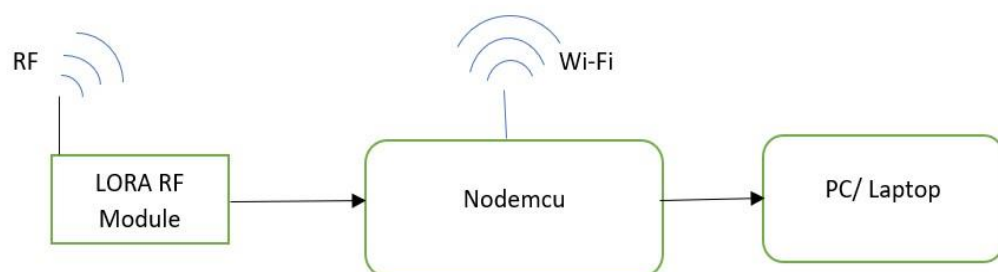


Figure 2 Receiver Node

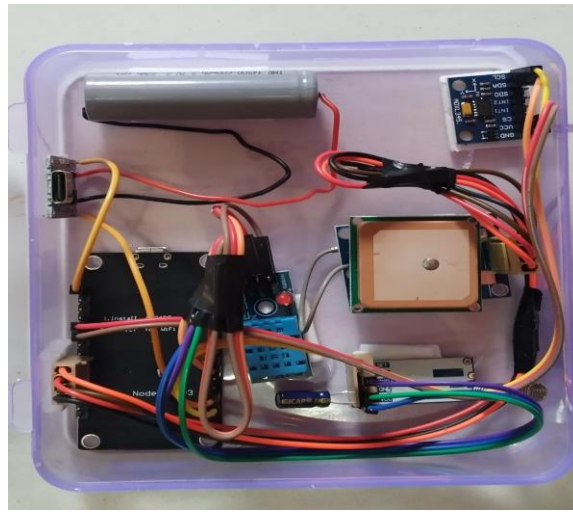


Figure 3 Photograph of Wireless Sensor Network-Based Rockfall and Landslide Monitoring Systems

All data from the sensors are uploaded to ThingSpeak using an API key. The following parameters are plotted:

- Temperature vs Time
- Vibration (Acceleration) vs Time
- GPS coordinates (Latitude, Longitude)
- This visualization helps identify unusual patterns and trigger early alerts.

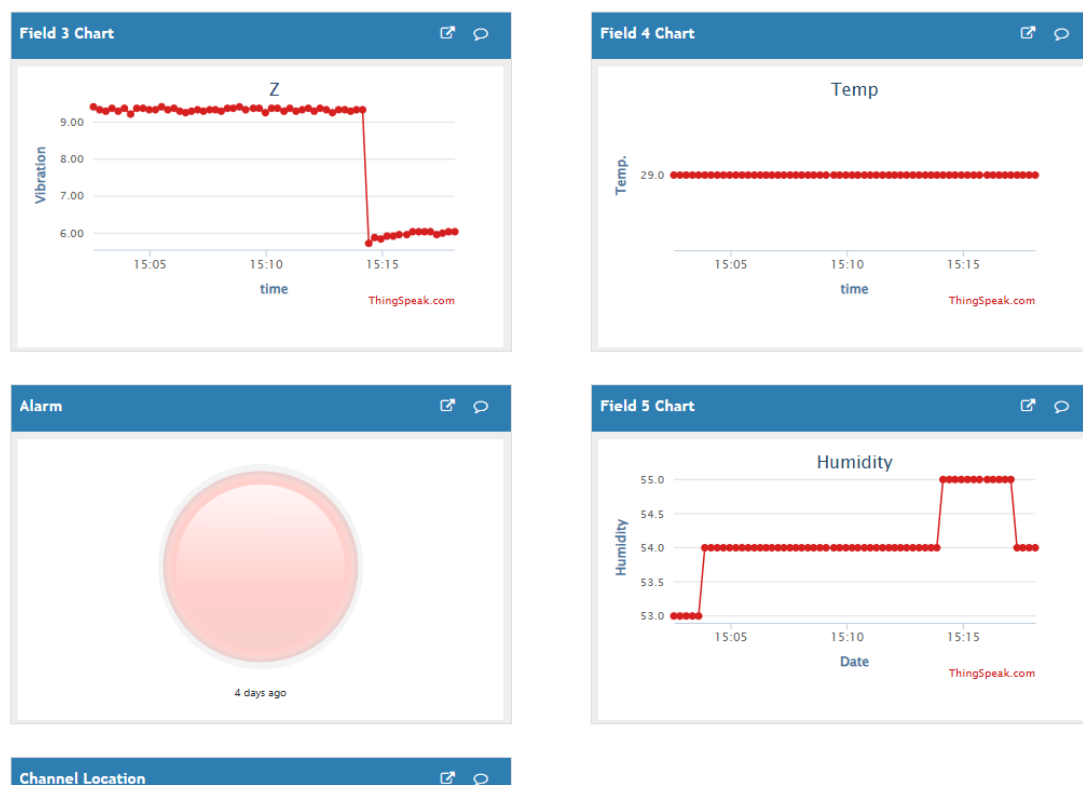


Figure 4 Under normal condition Result graph on Thingspeak

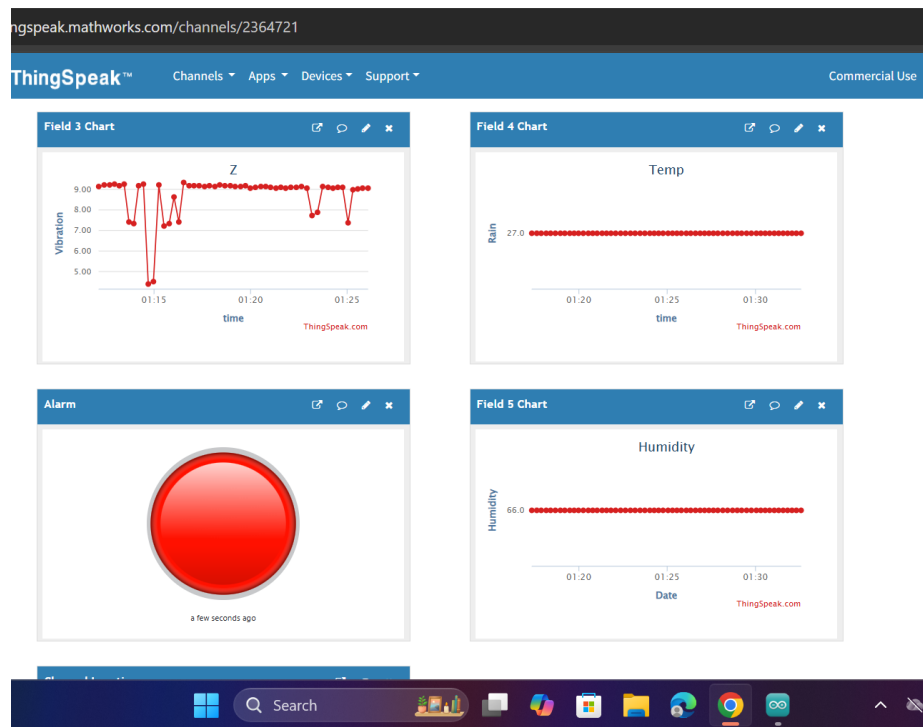


Figure 5 Alarm triggered after vibration threshold limit crossed

	A	B	C	D	E	F	G
	created_at	entry_id	X	Y	Z	TEMP	HUMIDITY
1	2025-10-17 09:22:08 UTC	184	-0.54917	-0.23536	9.41438	29	54
2	2025-10-17 09:22:24 UTC	185	-0.54917	-0.23536	9.41438	29	54
3	2025-10-17 09:22:40 UTC	186	-0.5884	-0.19613	9.33593	29	54
4	2025-10-17 09:22:56 UTC	187	-0.54917	-0.23536	9.45361	29	54
5	2025-10-17 09:23:12 UTC	188	-0.54917	-0.19613	9.37516	29	54
6	2025-10-17 09:23:28 UTC	189	-0.54917	-0.23536	9.2967	29	54
7	2025-10-17 09:23:43 UTC	190	-0.50995	-0.23536	9.41438	29	54
8	2025-10-17 09:24:00 UTC	191	-0.50995	-0.19613	9.33593	29	54
9	2025-10-17 09:24:15 UTC	192	-0.5884	-0.19613	9.37516	29	54
10	2025-10-17 09:24:31 UTC	193	-0.54917	-0.15691	9.41438	29	54
11	2025-10-17 09:24:46 UTC	194	-0.50995	-0.27459	9.45361	29	54
12	2025-10-17 09:25:02 UTC	195	-0.54917	-0.23536	9.41438	29	54
13	2025-10-17 09:25:18 UTC	196	-0.54917	-0.23536	9.41438	29	54
14	2025-10-17 09:25:33 UTC	197	-0.50995	-0.27459	9.33593	29	54
15	2025-10-17 09:25:49 UTC	198	-0.54917	-0.23536	9.33593	29	54
16	2025-10-17 09:26:04 UTC	199	-0.54917	-0.23536	9.2967	29	54
17	2025-10-17 09:26:20 UTC	200	-0.5884	-0.19613	9.33593	29	54
18	2025-10-17 09:26:36 UTC	201	-0.54917	-0.27459	9.2967	29	54
19	2025-10-17 09:26:51 UTC	202	-0.54917	-0.31381	9.37516	29	54
20	2025-10-17 09:27:07 UTC	203	-0.5884	-0.23536	9.37516	29	54

Figure 6 Data record in CSV file format

IV. CONCLUSION

A LoRa-based Wireless Sensor Network (WSN) monitoring system for rockfall and landslide represents a robust, energy-efficient, and scalable solution for real-time geohazard detection and disaster risk management. Its architecture allows autonomous, wireless sensor nodes—powered by renewable sources—to continuously monitor critical parameters like ground inclination, vibration, soil moisture, and rainfall in both urban and remote areas. Data is transmitted via LoRaWAN to gateways and centralized servers, enabling instant analysis, warnings, and data-driven intervention by authorities.

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