# Cloud Computing-Based Advanced Slope Monitoring System for Opencast Coal Mines

Sathish Kumar Mittapally, M Shyam Sunder and
Ram Chandar Karra



February 15, 2023

# Cloud Computing-based Advanced Slope Monitoring System for Opencast Coal Mines

Sathish Kumar Mittapally[1], Shyam Sunder M[2], Ram Chandar Karra[3*]

[1] *Research Scholar, Department of Mining Engineering, National Institute of Technology Karnataka, Surathkal, Mangalore, India; msathishkumar.207mn502@nitk.edu.in*

[2] *Department of Electronics and Communication Engineering, University College of Engineering, Osmania University, Telangana, India: shyamsunder@osmania.ac.in*

[3] *Associate Professor, Department of Mining Engineering, National Institute of Technology Karnataka- Surathkal, Mangalore, India; krc@nitk.edu.in, krc_karra@yahoo.com*

* Corresponding Author

**Abstract**:

Over the past few years, the Internet of Things (IoT) evolved from merely a concept into a growing reality. The Internet of Things and wireless sensor networks with cloud applications are emerging technologies that provide real-time slope monitoring in opencast mines. Wireless Sensor Networks are the fast and more efficient method of slope monitoring compared to many other methods. Development of an advanced slope monitoring system that works on real-time slope data analysis and is equipped with an early warning system against slope failures is crucial for ensuring the safety of manpower and machinery.

This paper introduces an advanced slope monitoring system with an Arduino microcontroller, wireless sensors to measure specific slope parameters and LoRa E32 433 Mhz radio module to transmit sensor data to the receiver. On the receiving side, the Node MCU microcontroller sends sensor data to the Thingspeak cloud platform, which performs data collection, analysis, and early alerts. It is possible to predict slope behavior by monitoring specific slope parameters such as moisture content, intensity of blast vibration, and slope displacement, which are the parameters selected for slope monitoring in this study and measured using respective sensors. The proposed system is installed at an opencast coal mine with two nodes of moisture, vibration, displacement sensors and LoRa RF module.

**Key Words:** Arduino microcontroller, LoRa, Node MCU, Python, Real-time slope monitoring, Thingspeak, Wireless sensor networks.

## I. Introduction:

Mining provides basic raw materials to many industries, such as power, steel, cement, etc., which drives the country's economic development (IBEF, 2023). Coal mines play a significant role in meeting a country's power demand, with the majority of coal production coming from open-cast mines. As near-surface coal deposits are depleting, coal mines delving deeper, which leads to slope stability problems. Director General of Mines Safety (DGMS) made slope monitoring mandatory in Indian opencast mines as per circulars No. 2 and 3 of 2020 to keep the working conditions safe.

Currently, traditional methods such as Total station, LiDAR, and SSR are being used in opencast coal mines to monitor slopes. However, these methods have their own limitations, such as high cost, complex operations, irregular monitoring and inability to provide automated early predictions and warnings of slope movements. These limitations can have a negative impact on the efficiency and safety of the mining operations, making it important to explore new and more advanced technologies that can overcome these issues. Wireless sensor networks and cloud computing technologies have the potential to address the limitations of traditional methods used in opencast coal mines. These technologies can provide a cost-effective and efficient solution for monitoring slope movements, as well as providing early predictions and warnings of potential instability. Wireless sensor networks can be used to install sensors in key areas of the mine and transmit data in real-time to a central location for analysis (Ciampalini et al., 2021). Cloud computing can then be used to process and analyse this data, providing valuable insights into the stability of the mine and helping to prevent potential disasters. This can greatly increase the safety and efficiency of mining operations, making wireless sensor networks and cloud computing a valuable tool for opencast coal mines.

According to Dorthi et al (2020), a wireless sensor network is deemed to be a more appropriate method for continual monitoring due to its cost-effectiveness, capability for two-way communication, and the ability to furnish real-time monitoring and analysis of data. One of the main advantages of using MEMS sensors is their low cost, which makes them more accessible and cost-effective than traditional sensors. Additionally, MEMS sensors are lightweight, which makes them easy to handle and install. They also consume less power than traditional sensors, making them more energy-efficient and longer-lasting (Khoshnoud & de Silva, 2012). Various research studies on the integration of Wireless Sensor Networks (WSNs) and slope monitoring have revealed new potential and opened up paths for future growth and development. Dorthi & Karra (2017; 2018; 2022) developed an integrated wireless data acquisition system, to assess the slope stability and it is validated the same with conventional slope monitoring instruments and numerical modelling.

## II. Field investigations and methodology

In this research study, to detect and observe the slope behaviour, three key parameters of the slope were selected for monitoring, that are moisture content, intensity of blast vibration and displacement. These parameters provide important information about the stability and movement of the slope. The FC-28 MEMS moisture sensor (Figure 1) is utilized to measure the moisture content in the slope. It operates on the principle of a variable resistor, which adjusts its resistance based on the moisture present in the soil, as described by Bhardwaj (2021). To detect vibration SW- 420 MEMS vibration sensor (Figure 2) is used. It employs a piezoelectric element, which when subjected to mechanical stress due to vibration, produces a voltage. The spring-loaded mass attached to this element produces voltage that is then converted into an electrical output signal. A slider potentiometer of 10 ohms resistance (Figure 3) is used to measure displacement. This is also a variable resistor that features a slider that moves along a resistive element. The position of the sliding contact along the resistive element determines the resistance of potentiometer, which is then produced into an electrical signal. By analysing the electrical signal produced by the potentiometer, the resistance and position of the slider can be determined. By obtaining the movement of the slider, which is attached to the sliding part of the slope, the displacement of the slope can be measured.

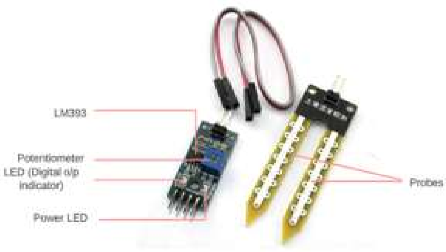


Figure. 1 FC-28 Soil moisture sensor

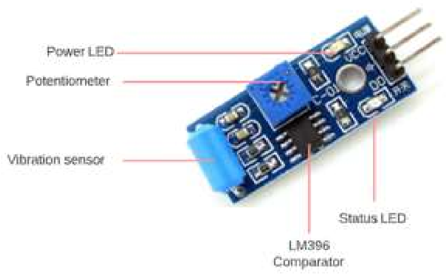


Figure. 2 Vibration sensor SW420

Figure.3 Potentiometer type displacement sensor

In this study, Arduino UNO and NodeMCU (Figure 4 & 5) are utilized as the CPU for operating the sensors. The Arduino UNO is a microcontroller board based on Atmega328P that has 14 digital input/output pins, 5 analogue inputs, a USB connection, and a power jack. On the other hand, NodeMCU is a microcontroller that comes with built-in support for Wi-Fi connectivity, as well as various input/output pins. Both of these boards can be programmed using the open-source Arduino IDE. The process of ensuring the accuracy and reliability of sensor data, and calibration of the sensors are accomplished through a laboratory experiment the result of which are published in the research paper by Dorthi & Karra (2022).

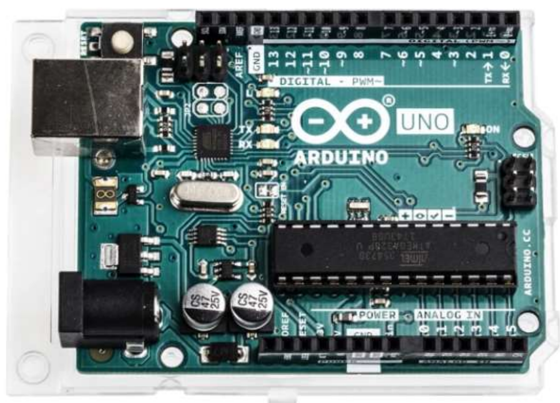


Figure.4 Arduino Board

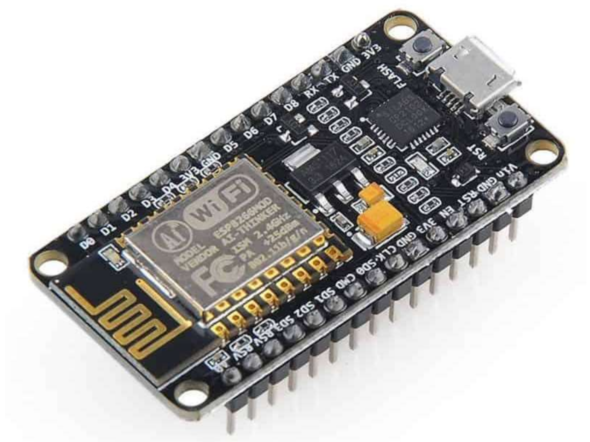

Figure. 5 NodeMCU ESP8266 pinouts

In this section, an advanced slope monitoring system is architectured with WSN and cloud computing that triggers Email and SMS alerts when the specific parameters of the slope that are being measured exceeds a certain threshold. As mentioned earlier the key parameters are the moisture content of the slope, intensity of the vibration and slope displacement. The Lo-Ra E32 400 MHz module is used for data communication in this system. It is a wireless communication device that utilizes Lo-Ra technology to enable data transfer over extensive distances. Operating within the 400 MHz frequency band, this module consumes less power while providing long-range wireless transmission with a reach of up to 9km. Figure 6 shows the image of Lo-Ra E32 400MHz module with 2.4GHz 2db antenna. Two sets of sensor nodes are arranged and fixed in benches, which serve as transmitters that send the sensor data obtained to the receiving station.

Figure 6. Lo-Ra E32 400MHz module

The sensor node equipped with an FC-28 soil moisture sensor, a SW-420 vibration sensor, a 10 ohms slider potentiometer, an Arduino UNO microcontroller and a Lo-Ra transmitter module with the cables extending out from the node is installed in the bench. Figure 7 shows the process of installation of sensor node into the bench. These sensor nodes transfer sensor data with the help of Lo-Ra transmitter to the receiver at the receiving station. A receiver node, that includes a Lo-Ra receiver and is controlled by a NodeMCU microcontroller, is set up at the receiving station. The receiving station is facilized with internet access via Wi-Fi, and through the use of the NodeMCU Wi-Fi module, sensor data sensor data is uploaded to the Thingspeak cloud platform using Thingspeak write API.

Figure. 7 Installation of sensor nodes on the slope benches

ThingSpeak is a cloud-based platform that enables the collection, storage, and real-time analysis of sensor data. It provides the capability to create customized dashboards and generates alerts based on the data collected. However, in this research study, for increased system flexibility, a Python program hosted on a cloud platform called PythonAnywhere retrieves sensor data from the ThingSpeak feed using the ThingSpeak read API and analyses the data to trigger alerts. The system methodology described above is depicted in a visual representation in Figure 8.

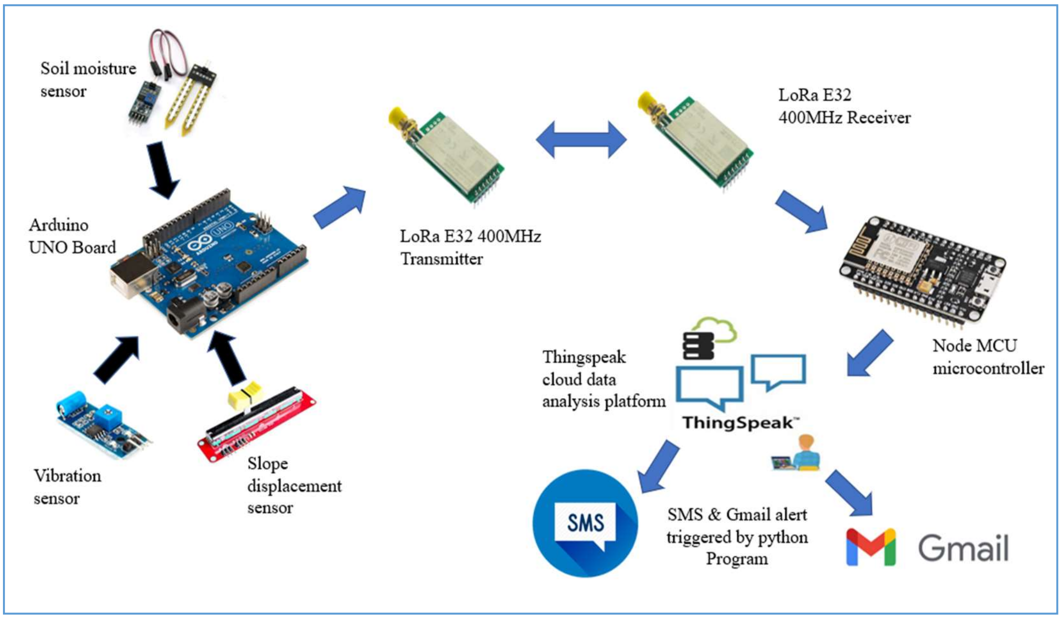


Figure. 8 The proposed system methodology visual representation

## III Result & Discussion

The sensor nodes are installed in the crust and toe of a bench as shown in Figure 10. Appropriately monitoring a slope requires a thorough understanding of the geological and geo-mechanical characteristics of the slope. This includes determining the number and positioning of necessary monitoring nodes. However, this study is specifically focused on identifying potential challenges and errors that may arise during field implementation. In other words, the field experiment conducted is a crucial step in the development and refinement of the monitoring design. Given that, there are only two nodes and the threshold for triggering alert is an approximate value determined by both the moisture and displacement sensors. The transmitter and receiver nodes were powered by a 12V battery, which provides a runtime of 6-8 hours when fully charged. The sensors transmit data which is recorded in the Thingspeak database and displayed in the form of graphs for observation. The installation position of Nodes 1 and 2 in the bench can be seen in Figure 9. Figure 10 shows the recorded data from the moisture sensor, while Figure 11 and 12 depict the vibration and displacement sensor data, respectively. The moisture and vibration sensor were buried along the node, while the displacement sensor was mounted on the surface. The base of the displacement sensor was fixed to the surface, and a rod extending from the sliding part of the slope face and toe was attached to the sliding knob of the sensor.

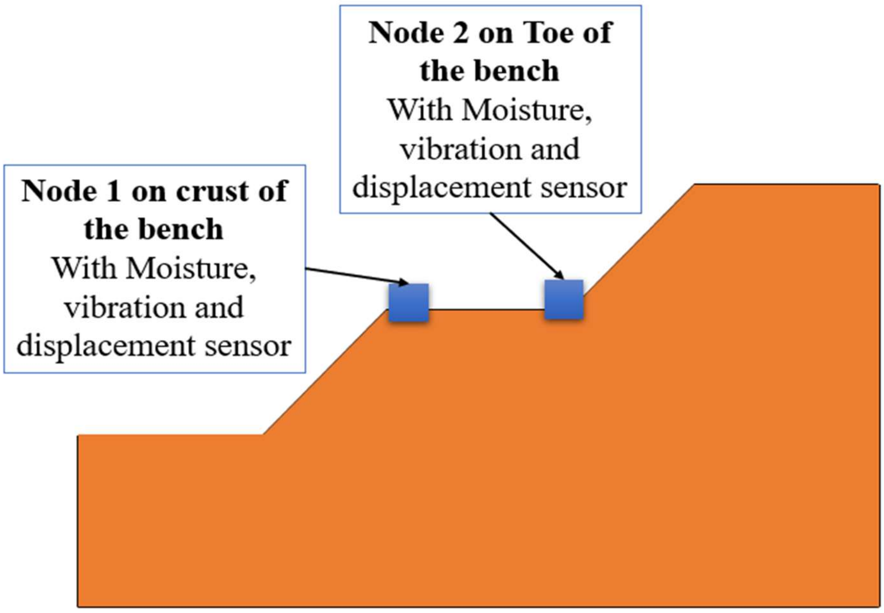


Figure 9. Installed nodes position in the slope benches

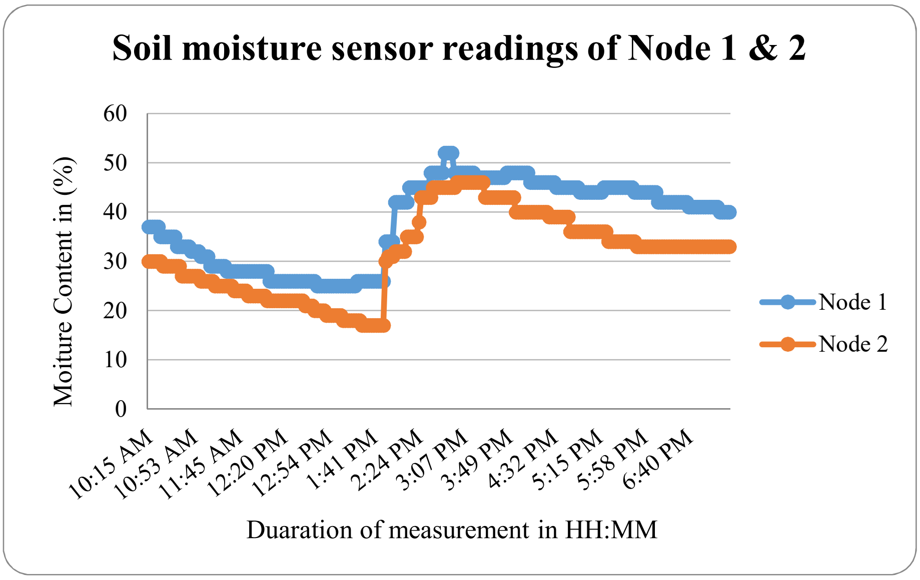


Figure 10. Moisture sensors readings

As seen in Figure 10, the data shown in the figure provides and insight into the moisture level of the slope at various times throughout the day, measured by Nodes 1 and 2. Initially, the moisture level was 38% at node 1 and 30% at node 2, measured at 10:15 AM, and it gradually decreased until 2:00PM. At a point, the slope received enough rainfall to wet the surface. The threshold for moisture was set at 40%, and as the moisture level reached this threshold at approximately 2:00 - 2:15 PM, and the system triggered email alert. The email alert was generated using the smtp library of Python, which is known for its flexibility and ease of use.

The text alert can be sent using webhooks from IFTTT web service, which automates web-based tasks. However, it should be noted that while there are many apps that support this feature, they can be quite expensive.

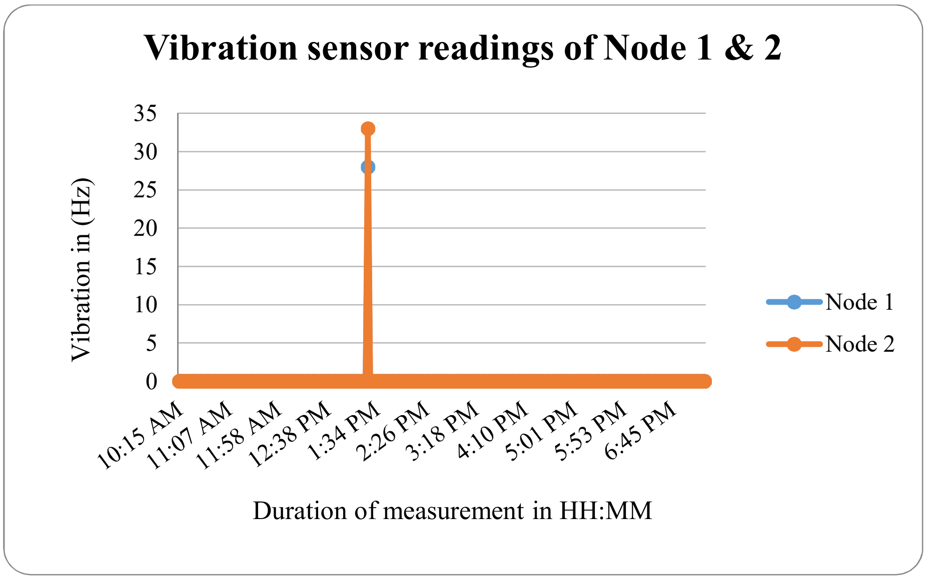


Figure 11. Vibration sensor readings

The SW-420 vibration sensor is non-directional and detect vibrations of all axes, but incapable of providing output for each individual direction. The vibration sensor was intended to detect vibration caused by vehicle or fleet movement and blasting, but since there was no fleet movement present on the day of measurement, it detected the blast vibration from a blast that occurred 1km away. The blasting occurred at 1:25PM, and as shown in the Figure 11, the vibration sensor at node 1 detected it a 28Hz while the sensor at node 2 detected it at 34 Hz.

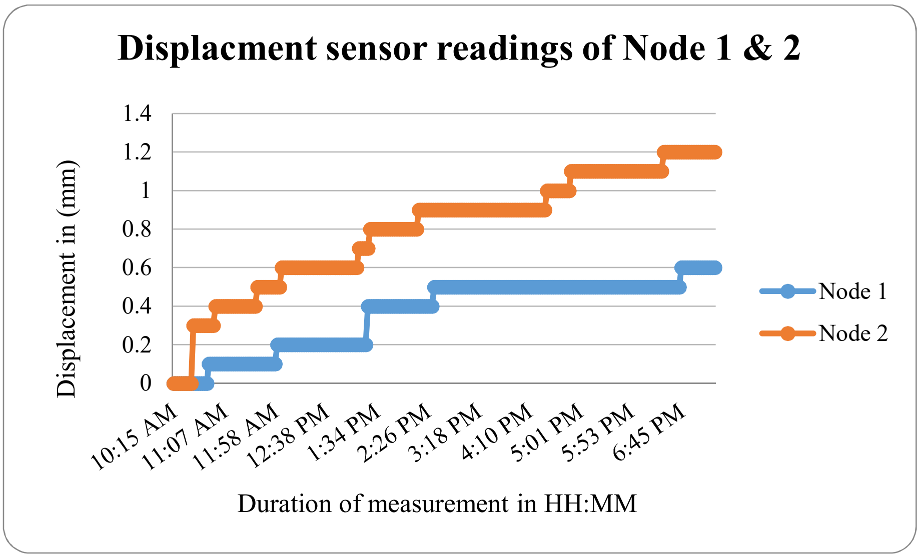


Figure 12. displacement sensor readings

For the displacement sensor, the threshold for displacement was set at 1mm. The initial reading for the displacement sensor was set to zero for both the nodes. The maximum displacement recorded during the entire day of measurement was 1.2 mm at node 1 and 0.6 mm at node 2. Node 1, which was installed at the bench toe, did not experience any displacement greater than 1 mm during the entire day, whereas node 2 detected a displacement of 1 mm at around 4:30 PM an triggered an email alert as a result. The image of the Thingspeak platform dashboard for both node 1 and node 2 is depicted in Figure 13. Figure 14 shows the alert messages triggered by the python program.

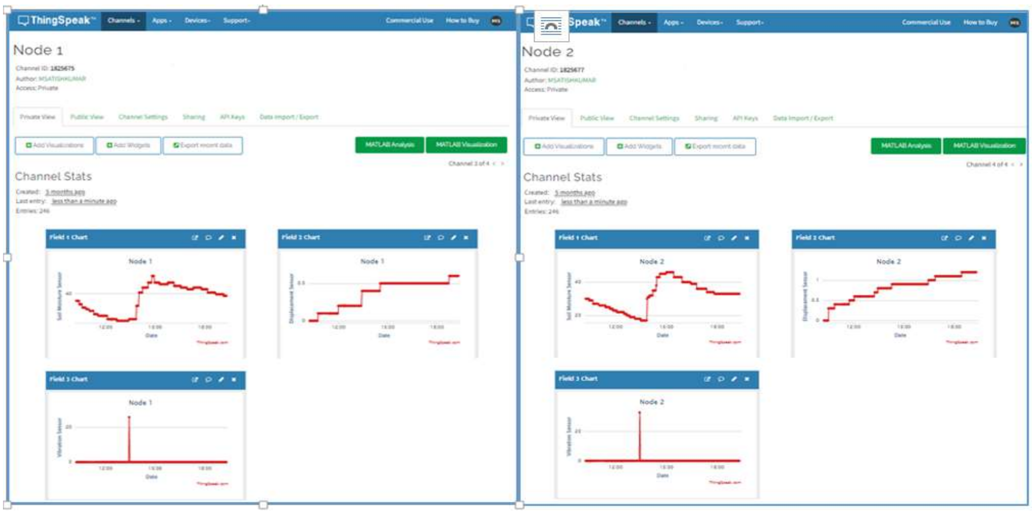


Figure 13. Dashboard of Thingspeak platform of Node 1 and Node 2

The Lo-Ra E32 400mh module, when the transmitter and receiver are in a direct and unobstructed line of sight, can transmit data over a distance of up to 9km. However, in the testing area the range of the Lo-Ra E32 400mh may be limited by various factors. One of the main factors that can affect the range of Lo-Ra module is the presence of obstacles such as buildings, trees, or other structures that can block the line of sight between the transmitter and receiver. In this case, the transmitter and receiver broke the line of sight when it reached a distance of 1500m. This suggests that the range of the Lo-Ra module in this particular testing area is limited by the presence of obstacles that block the line of sight between the transmitter and receiver.


Figure 14. Email alerts triggered by python program

**Conclusion:**

This research presented a cloud computing-based real-time monitoring system for slope stability designed specifically for open-cast coal mines. The system has been tested and installed at an opencast coal mine, and it has been shown that it is possible to predict slope behavior by monitoring specific slope parameters such as moisture content, the intensity of blast vibration, and slope displacement. This system utilises a combination of three sensors, IoT devices, WSN and cloud computing technologies to provide real-time monitoring and analysis of slope stability, enabling early detection of potential hazards and allowing for prompt and effective mitigation measures to be taken. Once the moisture content reaches 42% at node 1 at 2:02 PM, 40% at node 2 at 2:30 PM, and displacement of 1 mm at node 2 at 4:30 PM from the slopes of mine triggers an email and SMS alert to the administrator for immediate monitoring and preventive measures. Overall, the proposed system demonstrates the potential for using cloud computing technologies to improve safety and efficiency in open-cast coal mines to save the lives of the mine as well as equipment nearby to the slopes.

**References:**

1. Bhardwaj, R. B. (2021), ‘Landslide detection system: Based on IoT’, International Journal for scientific research & development, Vol. 9, No. 1, pp. 54 – 59.
2. Ciampalini, A., Farina, P., Lombardi, L., Nocentini, M., Taurino, V., Guidi, R., Pina, F. D., and Tavarini, D. (2021). Integration of Satellite InSAR with a Wireless Network of

Geotechnical Sensors for Slope Monitoring in Urban Areas: The Pariana Landslide Case (Massa, Italy). Multitemporal Remote Sensing: Methods and Application for Geomorphology and Engineering Geology, vol. 13, no. 13, pp. 2534–2535. https://doi.org/10.3390/rs13132534.

3. Director General of Mines Safety (DGMS) Technical, Circular No. 2 of 2020, "Guidelines for Systematic Monitoring of Slopes in Opencast Coal and Metalliferous Mines".
4. Director General of Mines Safety (DGMS) Technical, Circular No. 3 of 2020, "Guidelines for Scientific Study under Regulation 106 of CMR, 2017".
5. Khoshnoud, F., de Silva, C. W. (2012). Recent advances in MEMS sensor technology-mechanical applications. IEEE instrumentation and measurement magazine, 15(2), 14-24. Doi:10.1109/mim.2012.6174574
6. S.K. Mittapally & R.C. Karra (2022). Functions and performance of sensors for slope monitoring in opencast coal mines – laboratory experimentation, Petroleum science and Technology, Taylor & Francis Online. (under press).
7. Kumar, D., & Ram Chandar, K., (2020). Zigbee Based Wireless Data Acquisition System for Monitoring of Partition Stability above old Underground Coal workings. Arabian Journal of Geosciences, 13, 307 (2020). https://doi.org/10.1007/s12517-020-5255-6
8. Kumar, D., and Ram Chandar K (2022). Integrated Slope Monitoring System for Slope Stability Over Old Underground Galleries During Surface Mining Operations Using Internet of Things. Jl. Geotechnical and Geological Engineering. 10.1007/s10706-022-02369-2
9. Kumar, D., and Ram Chandar, K., 2017. Computer Aided Slope Stability Monitoring. Disaster Advances, Vol. 10, Issue 12, (2017), 37-51.
10. Kumar, D., and Ram Chandar, K., 2018. Slope Stability Monitoring in Opencast Coal Mine based on Wireless Data Acquisition System- A Case Study. International Journal of Engineering and Technology, Vol. 7, No. 2, 24-28. DOI: 10.14419/ijet.v7i2.21.11829.
11. Metals & Mining Industry in India: Overview, market size & growth: IBEF, India Brand Equity Foundation. (n.d.). https://www.ibef.org/industry/metals-and-mining (accessed January 27, 2023).