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# LoRaWAN Based Smart System for Unsafe Event Detection in Mining Industry Using ML

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***Abstract: Mining environments are highly hazardous due to toxic gases, extreme temperatures, fire risks, landslides, and physically demanding conditions. This paper presents a real-time monitoring and alert system integrating IoT sensors, ESP32 microcontroller, WiFi and LoRa communication, and Machine Learning algorithms. The system monitors worker health parameters (pulse, $SpO_2$, body temperature) and environmental conditions (gas, humidity, fire, landslides, earthquakes). Data is transmitted to a cloud platform and analyzed using Random Forest models for hazard prediction. Alerts are displayed on LCD, web dashboard, and mobile application. Experimental evaluation demonstrates reliable detection of unsafe events with >90% prediction accuracy and <1s latency. The proposed system enhances worker safety and provides a scalable framework for industrial hazard monitoring.***

***Keywords: LoRaWAN, Unsafe Event Detection, Machine Learning, ESP32 Microcontroller, Real Time IoT Sensor***

## I. INTRODUCTION

Mining is one of the most dangerous industries in the world, where workers are continuously exposed to hazardous environmental conditions such as toxic gases, high temperature, humidity, fire hazards, landslides, and poor oxygen levels. In addition to environmental risks, the physical health condition of workers, such as heart rate, oxygen saturation ($SpO_2$), and body temperature, must also be monitored regularly to prevent health-related emergencies. Traditional mining safety systems mainly focus on environmental monitoring and often do not include real-time worker health monitoring and intelligent accident detection systems.

With the development of the Internet of Things (IoT), wireless communication technologies, and Machine Learning, it is now possible to design smart safety systems that can monitor both environmental conditions and worker health in real time. Sensors can be used to collect important parameters such as gas levels, temperature, humidity, fire presence, worker movement, heart rate, and oxygen levels. These sensor data can be transmitted using wireless technologies such as WiFi and LoRa for long-distance communication, especially in underground mining environments where network connectivity is limited.

Machine Learning algorithms can be used to analyze the collected sensor data and identify patterns that indicate unsafe conditions or health risks. By using predictive models, the system can detect dangerous events such as toxic gas leakage, fire accidents, worker falls, landslides, earthquakes, and high temperature conditions. When such events are detected, the system can generate alerts and notify supervisors through a cloud platform and dashboard, enabling quick response and rescue operations.

This project proposes a real-time monitoring and alert system that integrates multiple sensors, ESP32 microcontroller, WiFi and LoRa communication, cloud platform, and Machine Learning models to improve safety in mining environments. The system continuously monitors the worker's health and environmental conditions, predicts unsafe events, and provides alerts through a dashboard and IoT platform. This helps in reducing accidents, improving worker safety, and enabling efficient safety management in mining areas.

## II. LITERATURE SURVEY

Kumar et al. [3] Coal mining remains one of the most hazardous industries due to the presence of toxic gases, extreme environmental conditions, and the risk of unexpected accidents. Ensuring the safety of workers in such environments is a major challenge. With advancements in technology, the integration of the Internet of Things (IoT), wireless sensor networks, and machine learning has enabled the development of intelligent safety monitoring systems.

S. Li, L. D. Xu, et al. [1] The proposed system focuses on designing an IoT-based coal mine safety monitoring and alerting solution. This 5 system continuously monitors environmental parameters such as gas concentration, temperature, and humidity inside the mine. Sensors like MQ gas sensors are used to detect harmful gases such as methane and carbon monoxide, which are highly dangerous and can lead to explosions or suffocation. The DHT11 sensor is used to measure temperature and humidity, helping maintain safe working conditions.

P. S. Bhatia et al. [6] This paper explains how machine learning techniques can help identify and predict dangerous situations in industries before accidents happen. The authors use collected industrial data such as temperature, gas levels, pressure, or previous accident records to train machine learning models. These models analyze patterns and detect abnormal conditions that may lead to hazards. The research is important because it improves worker safety, reduces equipment damage, and enables early warning systems in smart industries.

H. B. Kekre et al. [7] The ESP32 Technical Reference Manual published by Espressif Systems provides detailed information about the ESP32 microcontroller. ESP32 is widely used in IoT and embedded systems because it supports both Wi-Fi and Bluetooth communication. The manual explains the internal architecture, GPIO pins, timers, ADC, DAC, communication protocols such as UART, SPI, and I2C, as well as memory and power management features. This reference helps developers program and interface sensors and devices efficiently in automation and monitoring projects.

Li-min, et al. [14] This paper presents a coal mine safety monitoring system using a wireless sensor network (WSN) with ZigBee technology, designed to improve real-time detection of hazardous conditions such as gas concentration, temperature, and humidity. It emphasizes reliability, low power consumption, and scalability for underground environments.

Nourali, H, et al. [17] This paper develops a machine learning–based regression tree model to improve the accuracy of mining capital cost estimation, addressing the limitations of traditional methods that often under- or overestimate costs. The model provides reliable predictions across a wide range of mining capacities, supporting better investment and feasibility decisions.

## III. PROPOSED SYSTEM

The proposed system is a real-time monitoring and alert system designed to improve safety in mining environments by integrating multiple sensors, wireless communication technologies, and machine learning algorithms. The system uses an ESP32 microcontroller to collect real-time data from health sensors such as pulse rate, $SpO_2$, and body temperature, as well as environmental sensors such as gas sensor, temperature, humidity, smoke sensor, fire sensor, and accelerometer for worker fall detection. The collected data is transmitted using WiFi and LoRa communication to a cloud platform and web dashboard for remote monitoring. Machine Learning algorithms are used to analyze the sensor data and predict health risks and unsafe events such as toxic gas leakage, fire accidents, landslides, high temperature conditions, earthquakes, and worker falls. The system displays real-time data, prediction results, and alerts on an LCD display and web dashboard, helping supervisors take immediate action during emergency situations.

### *A. Advantages of Proposed System*

- Real-time monitoring of both worker health and environmental conditions.
- Early detection of unsafe events using Machine Learning prediction.
- Long-range communication using LoRa for underground mines.
- Real-time alerts and notifications for emergency situations.
- Remote monitoring through IoT cloud and web dashboard

### *B. Scope of the Project*

The scope of this project includes the design and development of a smart monitoring system that integrates sensors, a microcontroller, communication modules, and a web dashboard for real-time monitoring and prediction. The system is capable of monitoring both worker health parameters and environmental conditions in mining areas. It collects real-time sensor data and sends it to a cloud platform and dashboard for analysis and visualization. The system uses Machine Learning algorithms to analyze the collected data and predict unsafe events and health risks. It also generates alerts when abnormal conditions are detected. The system supports wireless communication technologies such as WiFi and LoRa, making it suitable for underground mining environments where network connectivity is limited. This project can be implemented in underground mines, industrial environments, construction sites, and other hazardous workplaces where worker safety is important. The system can be further expanded by adding GPS tracking, camera monitoring, and additional sensors in the future.

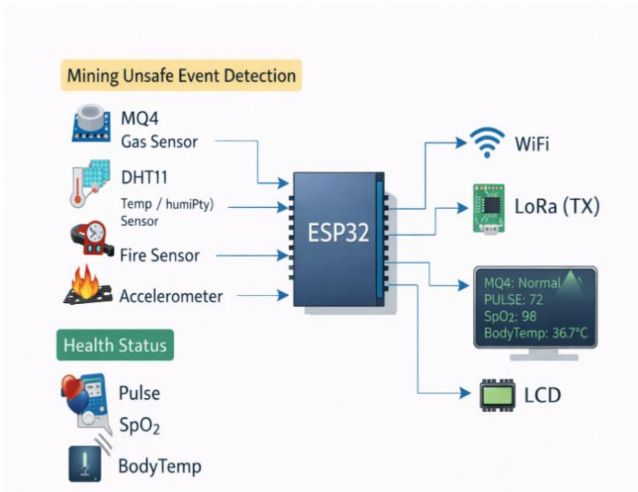


Fig. 1 Block Diagram

### *C. System Requirements*

#### *1) Hardware Requirements*

ESP32 Microcontroller
MQ Gas Sensor
DHT11 Temperature & Humidity Sensor
Pulse Sensor
$SpO_2$ Sensor (MAX30100 / MAX30102)
Body Temperature Sensor (LM35 / DS18B20)
Fire Sensor (Flame Sensor)
Accelerometer (MPU6050)
LoRa Module (TX & RX)
LCD Display (16x2 / 20x4)
Buzzer (Alert)
Power Supply / Battery
Connecting Wires

#### *2) Software Requirements*

Python
Streamlit
Arduino IDE
Embedded C (for ESP32)
Machine Learning (Scikit-learn)
Blynk IoT Cloud
VS Code / PyCharm

### *D. Working*

The proposed LoRa-based smart system works by continuously monitoring mining environmental conditions using multiple sensors connected to a microcontroller (MC). Sensors such as gas, temperature, vibration, and tilt sensors collect real-time data related to unstable events like gas leakage, roof collapse, or excessive ground vibration. The microcontroller reads and processes this data, comparing it with predefined safety threshold values programmed into the system. If any parameter exceeds the safe limit, the microcontroller identifies it as a hazardous or unstable event and immediately triggers a warning signal. Simultaneously, the processed data is transmitted through the LoRa module to a remote monitoring station or control room using long-range wireless communication. At the receiving end, the data is displayed for supervision, and alerts such as alarms or notifications are generated to ensure quick preventive action, thereby enhancing safety in the mining environment.

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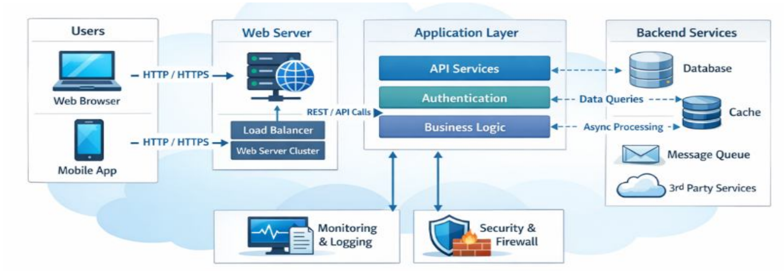


Fig. 2 System Architecture Diaram

## IV. MODULES DESCRIPTION

### *A. Sensor Module*

The sensor module is responsible for collecting real-time data from the mining environment and the worker's body. This module includes multiple sensors such as MQ gas sensor, DHT11 temperature and humidity sensor, fire sensor, accelerometer, pulse sensor, $SpO_2$ sensor, and body temperature sensor. The MQ gas sensor detects harmful gases such as methane and carbon monoxide present in mining areas. The DHT11 sensor measures environmental temperature and humidity, which helps in detecting high temperature conditions. The fire sensor detects flame or fire presence inside the mining area. The accelerometer sensor detects sudden movement or worker fall by measuring acceleration in X, Y, and Z axes. The pulse sensor measures the heart rate of the worker, the $SpO_2$ sensor measures the oxygen level in the blood, and the body temperature sensor measures the worker's body temperature. All these sensors continuously collect data and send it to the ESP32 microcontroller for processing.

### *B. ESP32 Microcontroller Module*

The ESP32 microcontroller is the main control unit of the system. It collects data from all the sensors, processes the data, and sends it to the cloud platform and dashboard through communication modules. ESP32 has built-in WiFi, which allows it to send data to the IoT cloud platform for remote monitoring. It also communicates with the LoRa module for long-distance communication in underground mining environments. The ESP32 reads sensor values, converts analog data into digital data, and formats the data before transmitting it. It also controls the LCD display and buzzer for displaying real-time values and generating alerts when unsafe conditions are detected.

### *C. Communication Module (WiFi and LoRa)*

The communication module is used to transmit data from the mining area to the monitoring station. In this system, two communication technologies are used: WiFi and LoRa. WiFi is used to send sensor data to the cloud platform (Blynk) and the Streamlit web dashboard for real-time monitoring. LoRa (Long Range Communication) is used for long-distance communication in underground mining environments where internet connectivity is not available. The LoRa transmitter sends data from the worker unit, and the LoRa receiver receives the data and forwards it to the monitoring system. This ensures continuous communication even in remote underground areas.

### *D. Machine Learning Prediction Module*

The Machine Learning module is used to analyze sensor data and predict health risks and unsafe events. In this project, Machine Learning algorithms such as Random Forest are used for classification. The model is trained using historical sensor data, and it learns patterns that indicate safe or unsafe conditions. The model predicts the worker's health status (Normal or Health Risk) and unsafe events such as toxic gas, fire accident, landslide, worker fall, earthquake, and high temperature conditions. The trained model is saved and loaded into the Streamlit dashboard, where it analyzes real-time sensor data and produces prediction results.

### *E. IoT Cloud Module (Blynk)*

The IoT cloud module is used for remote monitoring and alert generation. In this project, the Blynk cloud platform is used to store and display sensor data and prediction results. The ESP32 sends sensor data to the Blynk cloud using WiFi. The Streamlit dashboard also fetches data from the Blynk cloud and displays it in real time. When an unsafe event is detected, the system sends alerts through the Blynk platform, which can be viewed on a mobile application or web dashboard. This allows supervisors to monitor the mining environment remotely.

### *F. Web Dashboard Module (Streamlit)*

The Streamlit dashboard is used to display real-time sensor data, prediction results, alerts, and data analysis charts. The dashboard fetches sensor data from the Blynk cloud, sends the data to the Machine Learning model for prediction, and displays the results on the screen. The dashboard also stores historical data in a CSV file and generates charts such as histograms and scatter plots for data analysis. The dashboard provides a user-friendly interface for monitoring worker health and environmental conditions.

### *G. Alert and Display Module*

The alert and display module is responsible for alerting workers and supervisors when unsafe conditions are detected. This module includes an LCD display, buzzer, and dashboard alerts. The LCD display shows real-time sensor values, health status, and unsafe event messages. The buzzer generates a sound alert when dangerous conditions such as toxic gas, fire, or worker fall are detected. The Streamlit dashboard also displays alert messages and warning notifications. This module helps in providing immediate alerts so that quick action can be take

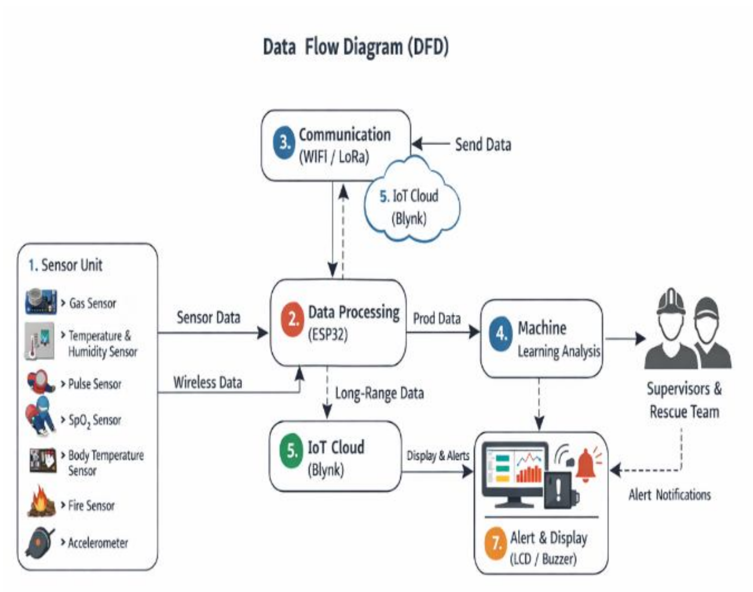


Fig. 3 Data Flow Diagram

### *H. Algorithms*

(AML), Random Forest and Gradient Boosting algorithms are used to detect suspicious financial transactions. Random Forest is an ensemble method that builds multiple decision trees and makes a final decision based on majority voting, classifying transactions as either normal or suspicious. It is stable, fast, and works well with large datasets. On the other hand, Gradient Boosting works sequentially, where each new model improves the errors made by the previous one, making it more effective at detecting complex fraud patterns. Both algorithms can also produce a probability score (risk score), which is used in AML systems to classify transactions into low, medium, or high risk, and high-risk transactions are flagged for further investigation

 

Fig. 4 Hardware Setup

## V. TESTING

To ensure reliability and accuracy, the mining safety system was tested at multiple levels:

Hardware Testing: Checked all components for proper functioning.

Sensor Validation: Calibrated sensors to ensure accurate readings.

Communication Testing: Verified reliable data transmission and low delay ML Model Evaluation: Tested prediction accuracy and reduced errors.

System Integration: Ensured all parts work together smoothly.

Real-Time Testing: Evaluated system response in live conditions.

## IV. RESULT

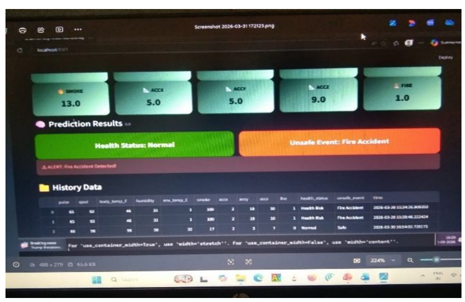


Fig. 5 Prototype Result

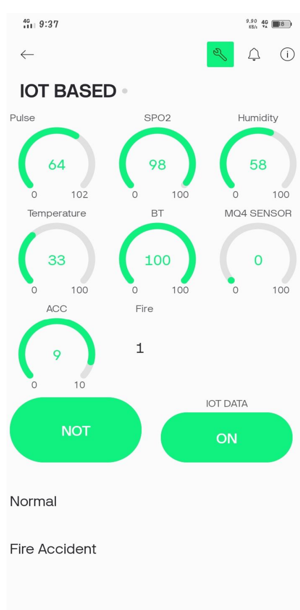


Fig. 6 Mobile App Result

Fig. 5 illustrates the prototype output for a monitoring system. It presents several sensor readings such as Smoke, AccX, AccY, AccZ, and Fire, each represented with numerical values. Below these readings, there is a "Prediction Results" section where the system indicates the overall condition. A green box shows "Health Status: Normal," while a red box highlights "Unsafe Event: Fire Accident," suggesting that a fire-related risk or incident has been detected. Additionally, the lower part of the screen contains a "History Data" table that records past sensor values like temperature, humidity, smoke levels, and their corresponding statuses. Overall, the display appears to represent a safety monitoring or accident detection system summarizing both real-time and historical data.

Fig. 6 demonstrates the results from the mobile through Blynk IoT app which receives live data from IoT sensors.

There are circular gauge widgets showing different parameters, each with a numeric value and scale.

### *A. Sensor Readings Shown*

*1)* Top row

Pulse: Gauge showing 64 on a scale from 0 to 102, indicating heart rate in beats per minute.

$SPO_2$: Gauge at 98 on a 0–100 scale, indicating blood oxygen saturation percentage.

Humidity: Gauge at 58 on a 0–100 scale, indicating ambient relative humidity.

*2)* Middle row:

Temperature: Gauge at 33 on a 0–100 scale, likely body or room temperature in degrees Celsius.

Body Temperature: Gauge at 100 on a 0–100 scale; this might be a "body temperature" normalized value or a Bluetooth signal quality indicator, depending on your project.

MQ4 SENSOR: Gauge at 0 on a 0–100 scale, showing output from an MQ-4 gas sensor.

*3)* Bottom row:

ACC: Gauge at 9 on a 0–10 scale, probably representing accelerometer activity or movement level.

Fire: Text value "1", suggesting a digital fire sensor status (1 = fire detected, 0 = no fire).

## VI. CONCLUSION

The LoRa-Based Smart System for Unstable Event Detection in Mining Industry Using Microcontroller provides an efficient, low-cost, and reliable solution for enhancing mining safety.

*1)* Compared to traditional wired and short-range wireless systems, the proposed model offers:
*2)* Greater communication range.
*3)* Lower maintenance cost.
*4)* Improved safety.
*5)* Scalability for large mining area

### *A. Future Scope*

The proposed system can be further enhanced by adding more advanced technologies and features to improve safety, accuracy, and automation. In the future, GPS tracking can be integrated into the system to track the real-time location of workers inside the mining area, which will help rescue teams quickly locate workers during emergency situations. Camera modules can also be added for visual monitoring and accident verification.

The system can be improved by using advanced Machine Learning or Deep Learning algorithms to increase prediction accuracy and detect more complex hazardous situations. A mobile application can be developed to send instant alerts and notifications to supervisors and rescue teams. The system can also be connected to an automatic emergency response system that can activate alarms, ventilation systems, or emergency exits when dangerous conditions are detected.

In addition, more sensors can be added to detect parameters such as air quality, pressure, vibration, and noise levels for more comprehensive environmental monitoring. Cloud data storage and big data analytics can be used to analyze long-term data and identify patterns for accident prevention. The system can also be implemented in other hazardous environments such as construction sites, oil and gas industries, factories, and tunnel construction sites.

Thus, the system can be expanded into a fully automated smart safety system with advanced monitoring, prediction, and emergency management capabilities in the future.

## VII. ACKNOWLEDGMENT

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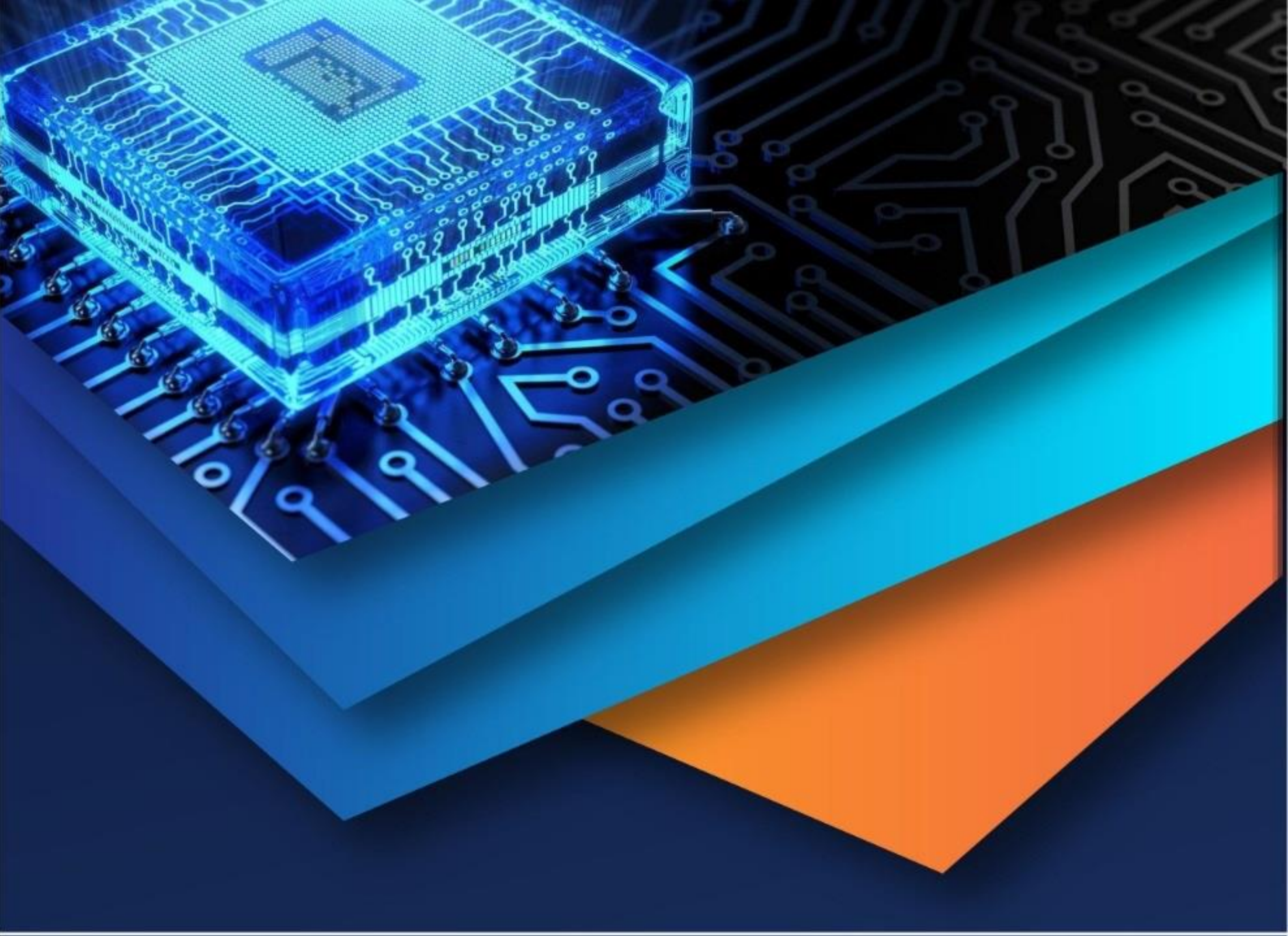


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