

Design of a Smart Fire Monitoring and Alert System for Industrial Warehouses Using IoT

ABSTRACT

Fire incidents in industrial warehouses pose serious threats to human life, property, and production continuity. Traditional fire detection systems often rely on passive mechanisms and lack the ability for remote monitoring and early warning. To address these limitations, this study proposes the design and development of a smart fire monitoring and alert system based on Internet of Things (IoT) technology. The system utilizes various sensors — including temperature, smoke, and gas detectors — to detect early signs of fire in real time.

Data from the sensors is processed by an ESP32 microcontroller and transmitted to an IoT cloud platform for real-time monitoring and alerting. When abnormal conditions are detected, the system automatically sends notifications to users via mobile applications or email, allowing for immediate response. Experimental testing in a simulated environment confirms that the system operates reliably, with fast response and easy user interaction. The proposed solution offers a cost-effective and scalable fire safety approach, particularly suitable for small and medium-sized industrial warehouses.

Keywords: IoT; Fire detection; Smart monitoring; Industrial safety; ESP32; Temperature sensor; Smoke sensor; Real-time alert; Cloud-based system; Warehouse fire prevention

I. INTRODUCTION

Industrial warehouses are environments where large quantities of goods, equipment, and combustible materials are stored and operated. These settings often involve high electrical loads, flammable chemicals, and minimal human supervision during off-hours, making them especially vulnerable to fire hazards. Fire incidents in such environments can cause severe damage — not only in terms of property loss but also through disruption of business continuity and potential harm to human life. Therefore, the development of early fire detection and warning systems is critical for industrial safety and risk mitigation.

Traditional fire detection systems are often limited to standalone smoke or heat sensors connected to a central alarm. These systems typically operate in a reactive manner, relying on human intervention and lacking the ability to monitor environmental conditions continuously or from a distance. Moreover, in large-scale industrial setups, a single-point failure or delayed response may lead to uncontrolled fire spread before appropriate action can be taken.

The advent of smart sensing technology and the rise of the Internet of Things (IoT) have opened new opportunities to design intelligent monitoring systems with real-time capabilities. Among various microcontroller platforms available for embedded system development, the STM32 series stands out due to its high processing power, low energy consumption, and rich peripheral support. STM32 microcontrollers are highly suitable for industrial applications that require fast data acquisition, real-time response, and flexible integration with external communication modules.

In this research, we propose the design and implementation of a smart fire monitoring and alert system for industrial warehouse environments using an STM32 microcontroller as the core processing unit. The system integrates a range of sensors — including temperature sensors, smoke detectors (e.g., MQ-2), and gas detectors (e.g., MQ-135) — to monitor environmental parameters continuously. When abnormal conditions indicative of fire are detected, the system triggers local alerts through buzzers and visual

indicators (LEDs). Simultaneously, the system transmits real-time data and alert messages to remote users using a wireless communication module such as ESP8266 (Wi-Fi) or SIM800L (GSM/GPRS).

The goal of this study is to develop a low-cost, scalable, and reliable solution that enhances fire safety in industrial settings, particularly for small and

medium-sized enterprises (SMEs) that may not have access to advanced commercial fire protection systems. Through experimental validation in a simulated warehouse model, the system's performance will be evaluated in terms of accuracy, response time, and usability. The proposed system aims to contribute toward the growing trend of digital transformation and smart automation in industrial safety systems.

II. MATERIALS AND DISCUSSION

Overview of IoT Technology and Fire Detection Systems

Internet of Things (IoT) in Industrial Applications

The Internet of Things (IoT) refers to a network of interconnected physical devices capable of collecting, transmitting, and acting upon data through the internet. In industrial settings, IoT plays a transformative role by enabling real-time monitoring, automation, and predictive maintenance across various domains such as production, logistics, energy management, and safety systems.

IoT-based safety systems use sensors, microcontrollers, and communication modules to detect environmental changes and trigger automated responses. These systems offer advantages including remote accessibility, scalability, data logging, and faster response time compared to traditional monitoring methods. Cloud integration and mobile applications further enhance the usability and management of these systems.

Fire Detection Technology: Traditional vs. Smart Systems

Traditional fire detection systems typically use standalone smoke detectors, heat sensors, or sprinkler activation mechanisms. While effective to some

extent, they often suffer from limitations such as:

- Lack of remote notification capability
 - Delayed response due to manual inspection or passive detection
 - Inability to log environmental data for analysis
 - No integration with modern communication or automation infrastructure
- In contrast, smart fire detection systems combine embedded sensing hardware with IoT communication protocols to enable:
- Real-time environmental sensing (temperature, smoke, gas)
 - Local and remote alerts via buzzer, SMS, app notifications, etc.
 - Historical data storage for trend analysis or accident investigation
 - Remote supervision and management from mobile devices or control centers

Role of Microcontrollers in IoT-Based Fire Detection

Microcontrollers serve as the central processing units in smart fire detection systems. They collect sensor data, perform threshold-based decision making, and handle communication with external systems. For this project, the STM32 microcontroller is selected due to its:

- High processing speed suitable for real-time monitoring

Low power consumption for long-term deployment
 Multiple analog/digital interfaces for sensor integration
 Compatibility with wireless modules (e.g., ESP8266, SIM800L)
 Together with temperature sensors (like DHT11/DHT22), smoke sensors (MQ-2), and gas sensors (MQ-135), the STM32 enables a modular and scalable architecture for warehouse fire monitoring.

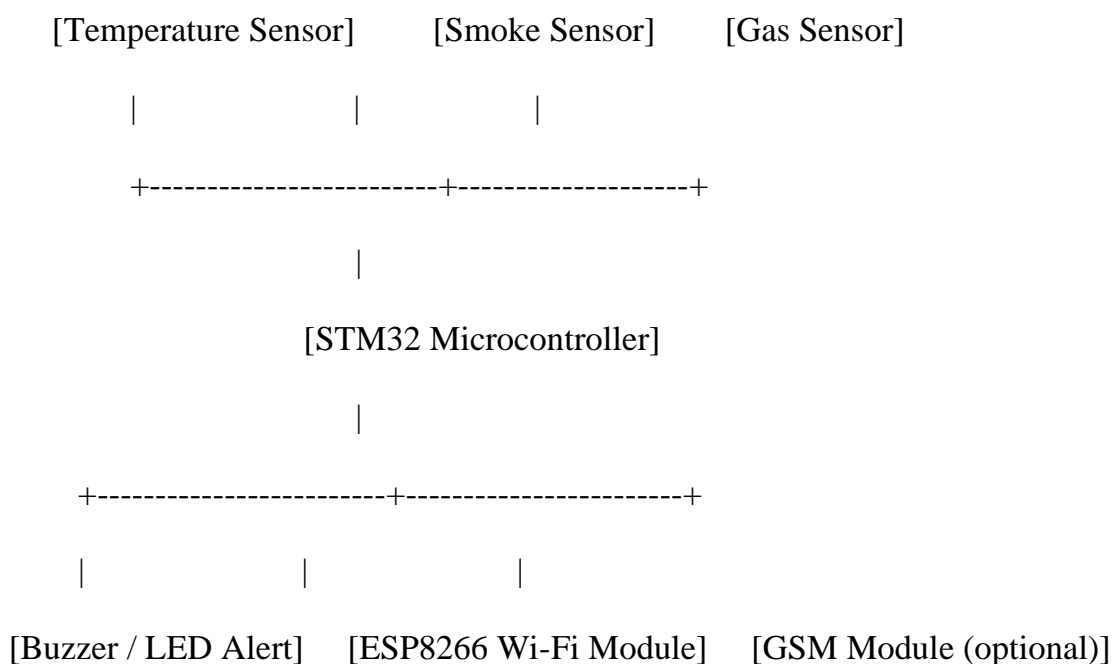
To deliver real-time alerts, the system requires wireless communication. The two main approaches include:
 Wi-Fi-based modules (e.g., ESP8266): suitable for environments with stable internet connectivity
 GSM-based modules (e.g., SIM800L): ideal for remote areas with cellular coverage but no Wi-Fi
 These modules allow the STM32 to send alerts and data to cloud platforms such as Firebase, ThingSpeak, or MQTT brokers. Users can then monitor conditions via web dashboards or mobile applications.

Wireless Communication and Cloud Integration

SYSTEM DESIGN

The smart fire monitoring and alert system is designed based on a modular architecture that integrates multiple sensors, a central microcontroller (STM32), communication modules, and cloud connectivity. This section presents the system's block diagram, hardware components, and software workflow, illustrating how they work together to achieve real-time fire detection and warning.

Diagram 1 System Block Diagram



SIM800L sends SMS to pre-registered phone numbers with fire alert messages.

Remote Monitoring Interface: A mobile app or web dashboard visualizes real-time and historical data.

4.4 Functional Workflow

System Initialization: STM32 configures peripherals and checks sensor readiness.

Real-Time Monitoring: Sensors continuously collect environmental data

Danger Detection: If any parameter exceeds a threshold, an interrupt is triggered.

Alert Generation:

Local: Buzzer and LEDs signal in the factory.

Remote: Alerts are sent to the cloud or phone via the communication module.

Data Logging: Optional – data can be stored to analyze trends and conditions.

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