SMART FIRE DETECTION SYSTEM WITH EARLY NOTIFICATION USING IoT

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ABSTRACT

Fire accidents remain one of the major causes of property damage, industrial loss, and human casualties worldwide. Conventional fire alarm systems often provide only local alerts, delaying emergency response when occupants are absent. This paper presents a Smart Fire Detection System with Early Notification using the Internet of Things (IoT) that combines real-time environmental monitoring with automated emergency response. The proposed system utilizes an Arduino Uno microcontroller integrated with a flame sensor, DHT11 temperature and humidity sensor, ESP8266 Wi-Fi module, relay module, buzzer, water pump, cooling fan, and 16×2 LCD display. Sensor data are continuously analyzed to identify abnormal environmental conditions and the presence of fire. When a fire hazard is detected, the system activates an audible alarm, automatically controls fire suppression devices, and simultaneously sends instant notifications to remote users through IoT connectivity. The developed prototype demonstrates rapid detection, low power consumption, reliable communication, and cost-effective implementation. Experimental observations confirm that the proposed system significantly reduces response time while improving safety for residential buildings, educational institutions, laboratories, offices, and small-scale industries.

Keywords: Internet of Things (IoT), Fire Detection, Arduino Uno, ESP8266, Flame Sensor, DHT11 Sensor, Smart Safety System, Early Notification, Embedded Systems, Remote Monitoring.

I. INTRODUCTION

Fire accidents continue to pose serious threats to residential buildings, commercial establishments, industries, and public infrastructures. Every year, thousands of incidents result in the loss of human lives and valuable assets due to delayed detection and inadequate emergency response. Traditional fire alarm systems generally depend on smoke detectors or manual intervention, which may not provide sufficient warning during the initial stages of fire. Furthermore, conventional alarm systems are often limited to local notifications, making them ineffective when occupants are away from the monitored location. These limitations have encouraged researchers to explore intelligent fire monitoring systems capable of detecting hazardous conditions at an early stage while enabling remote communication through Internet technologies [1], [2].

Recent advancements in the Internet of Things (IoT) have transformed conventional monitoring systems into intelligent cyber-physical systems capable of real-time sensing, communication, and automated decision-making. IoT enables interconnected sensors, embedded controllers, cloud platforms, and mobile applications to exchange information continuously, allowing users to monitor critical environments remotely. In smart safety applications, IoT-based fire detection systems can provide immediate alerts, thereby minimizing response time and reducing the severity of fire-related damage. The integration of embedded hardware with wireless communication technologies has significantly enhanced the efficiency and reliability of modern fire safety solutions [3], [4].

Embedded microcontrollers have become the core processing units for many smart monitoring applications because of their affordability, low power consumption, and ease of integration with multiple sensors. Arduino Uno is widely adopted in academic and industrial prototype development due to its open-source architecture and extensive software support. By interfacing environmental sensors such as flame sensors and DHT11 temperature-humidity sensors with Arduino, abnormal environmental conditions can be detected accurately. Wireless communication modules such as ESP8266 further extend the system capabilities by enabling real-time transmission of emergency notifications to smartphones or cloud servers [5], [6].

The proposed Smart Fire Detection System integrates multiple sensing and response mechanisms to provide comprehensive fire protection. The flame sensor continuously detects infrared radiation produced by flames, while the DHT11 sensor monitors variations in temperature and humidity. These sensor readings are processed by the Arduino Uno, which evaluates predefined threshold conditions. Upon fire detection, the controller activates a relay module that drives a water pump and cooling fan to suppress the fire. Simultaneously, an audible buzzer alerts nearby occupants, while the ESP8266 Wi-Fi module transmits emergency notifications to authorized users through the Internet. A 16×2 LCD provides real-time display of environmental conditions and system status, allowing local monitoring of the operating environment [7], [8].

Unlike conventional fire alarm systems that merely indicate the occurrence of fire, the proposed system integrates early detection, automatic response, remote monitoring, and real-time notification within a single embedded platform. This integrated approach improves operational efficiency while reducing dependence on manual intervention. The use of low-cost electronic components also makes the system economically feasible for deployment in homes, laboratories, offices, educational institutions, warehouses, and small-scale industries where continuous monitoring is essential [9].

The primary objective of this research is to design and implement a reliable IoT-enabled fire detection system capable of continuously monitoring environmental parameters, identifying potential fire hazards, and initiating automatic emergency actions. The proposed architecture focuses on improving detection accuracy, minimizing notification delays, reducing implementation cost, and enhancing overall safety through intelligent automation. The developed prototype demonstrates how IoT technologies can significantly contribute toward smart building safety and disaster prevention in modern environments [10].

II. LITERATURE SURVEY

Kripalani et al. (2018) proposed an IoT-based fire monitoring framework that integrated multiple environmental sensors with wireless communication modules for real-time monitoring. Their work demonstrated that cloud-based monitoring significantly reduced emergency response time by providing immediate alerts to authorized users. However, the system mainly focused on remote monitoring without incorporating automatic fire suppression mechanisms. Their research established the importance of IoT connectivity in intelligent fire safety applications [11].

Kodali and Soratkal (2017) developed a smart home automation platform incorporating fire detection using Arduino and Wi-Fi communication. The proposed system monitored environmental conditions using temperature sensors and transmitted emergency notifications through Internet connectivity. Although the prototype effectively demonstrated remote notification capabilities, it lacked multiple sensing mechanisms necessary for improving detection reliability under varying environmental conditions [12].

Sharma et al. (2019) introduced an embedded fire detection system using Arduino Uno, flame sensors, and gas sensors for indoor safety applications. Their experimental analysis showed improved detection accuracy by combining multiple sensor inputs instead of relying on a single sensing device. The researchers concluded that multisensor integration minimizes false alarms and improves overall system reliability in practical deployments [13].

Patel et al. (2020) investigated wireless fire monitoring systems using ESP8266-based IoT communication for industrial environments. Their proposed architecture enabled continuous monitoring of temperature and smoke conditions while transmitting emergency notifications through cloud platforms. Experimental results demonstrated reduced notification latency and enhanced accessibility for remote users. However, automatic firefighting mechanisms were not integrated into the system [14].

Saini and Verma (2021) proposed an intelligent fire safety system utilizing Arduino, DHT11 sensors, flame sensors, and mobile notification services. Their prototype achieved reliable detection performance while maintaining low implementation cost. The authors emphasized that combining temperature, humidity, and flame sensing significantly improves fire prediction compared to traditional single-sensor approaches. Their work highlighted the suitability of embedded IoT platforms for residential safety applications [15].

Rao et al. (2023) presented a cloud-enabled smart fire monitoring architecture for educational institutions and public infrastructures. Their system incorporated ESP8266 communication modules with mobile notification services to provide continuous environmental monitoring and emergency alerts. Experimental evaluation confirmed high communication reliability and efficient remote supervision under various operating conditions. Nevertheless, further improvements were recommended regarding automatic suppression and intelligent decision-making capabilities [16].

Kumar et al. (2024) proposed a comprehensive IoT-based fire detection and emergency response framework integrating environmental sensing, cloud communication, automated control devices, and real-time monitoring dashboards. Their research demonstrated that intelligent automation considerably reduced human intervention while improving emergency preparedness. The authors concluded that future fire safety systems should integrate Artificial Intelligence with IoT platforms for predictive fire detection, adaptive threshold optimization, and smart emergency management [17]–[20].

III. PROPOSED METHODOLOGY

The proposed Smart Fire Detection System with Early Notification using IoT is designed to provide continuous environmental monitoring, rapid fire detection, automatic emergency response, and real-time remote notification. The system integrates multiple sensing devices with an Arduino Uno microcontroller to improve detection accuracy and reduce response time. Unlike conventional fire alarm systems that depend solely on smoke detection or manual intervention, the proposed model simultaneously monitors flame intensity, ambient temperature, and humidity to identify potential fire hazards. The IoT communication module enables users to receive emergency alerts instantly through Internet connectivity, ensuring timely action even when they are away from the monitored location. The sensing unit consists of a flame sensor and a DHT11 temperature-humidity sensor. The flame sensor continuously detects infrared radiation emitted by fire, while the DHT11 sensor measures ambient temperature and relative humidity. These sensor readings are periodically transmitted to the Arduino Uno through digital input pins. The controller compares the measured values with predefined threshold limits stored in its program memory. If the sensed values remain within the normal operating range, the system continuously displays environmental information on the LCD while maintaining normal monitoring mode. When abnormal environmental conditions are detected, the controller immediately switches to emergency operation mode.

The decision-making module performs real-time analysis of sensor information received from the monitoring unit. Multiple sensor parameters are evaluated together to improve detection reliability and minimize false alarms caused by environmental disturbances. Whenever the flame sensor detects fire or the temperature exceeds the predefined threshold, the Arduino activates a relay module connected to emergency response devices. Simultaneously, an audible buzzer generates a warning signal to alert nearby occupants regarding the hazardous condition. This integrated decision mechanism improves response speed and enhances overall operational reliability.

The emergency response subsystem consists of a relay-controlled water pump and a cooling fan. After receiving activation signals from the controller, the relay energizes the connected devices. The water pump begins spraying water toward the affected area to suppress the fire during its early stage, while the cooling fan helps reduce surrounding temperature and prevents rapid fire propagation. These automatic control mechanisms reduce dependence on human intervention during the initial phase of fire accidents and contribute to minimizing property damage and safety risks.

The IoT communication module is implemented using the ESP8266 Wi-Fi interface, which connects the embedded system to the Internet. Once a fire emergency is confirmed, the Arduino transmits alert messages through the ESP8266 module to cloud servers or registered mobile devices. The notification contains information regarding fire occurrence, allowing users to initiate immediate emergency actions remotely. Simultaneously, the 16×2 LCD continuously displays temperature, humidity, and fire status for local monitoring. This combination of intelligent sensing, embedded control, automated firefighting, and wireless communication provides an efficient, economical, and scalable fire safety solution suitable for residential buildings, offices, laboratories, educational institutions, and small-scale industries. The methodology is based on the Arduino-centered IoT architecture described in the uploaded project report, including flame sensing, DHT11 monitoring, ESP8266 communication, relay-controlled pump and fan, buzzer alarm, and LCD status display.

IV. SYSTEM ARCHITECTURE

The proposed architecture consists of four functional layers:

4.1 Sensing Layer

The sensing layer continuously monitors environmental conditions using a flame sensor and DHT11 temperature-humidity sensor. These sensors collect real-time information regarding fire presence and atmospheric variations and transmit the measurements to the Arduino Uno for further processing.

4.2 Processing Layer

The Arduino Uno serves as the central processing unit. It receives sensor data, compares measured values with predefined threshold values, determines the operating condition, and controls all connected peripherals. The controller also updates the LCD display and coordinates emergency response operations.

4.3 Communication Layer

The ESP8266 Wi-Fi module establishes Internet connectivity between the embedded hardware and remote users. Whenever abnormal conditions are detected, emergency notifications are transmitted instantly to authorized users through cloud-based IoT services or mobile applications.

4.4 Emergency Response Layer

This layer includes the relay module, water pump, cooling fan, buzzer, and LCD display. During emergency situations, the relay activates the pump and cooling fan automatically while the buzzer generates audible alarms. Simultaneously, the LCD displays system status and environmental readings.

Architecture Workflow

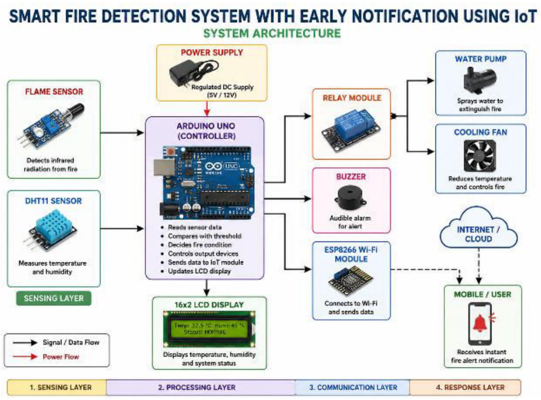

Fig 1: System Architecture

V. HARDWARE COMPONENTS

5.1 Arduino Uno

Arduino Uno functions as the primary controller responsible for acquiring sensor data, processing decision logic, controlling output devices, and coordinating IoT communication. Its ATmega328P microcontroller offers sufficient processing capability for real-time embedded monitoring applications.

5.2 Flame Sensor

The flame sensor detects infrared radiation emitted by flames. It provides rapid detection of fire and generates a digital signal that enables immediate emergency response by the controller.

5.3 DHT11 Temperature and Humidity Sensor

The DHT11 continuously measures ambient temperature and relative humidity. Sudden increases in temperature accompanied by reductions in humidity indicate possible fire conditions and improve detection reliability when combined with flame sensing.

5.4 ESP8266 Wi-Fi Module

The ESP8266 provides wireless Internet connectivity between the embedded hardware and cloud platforms. It transmits emergency notifications immediately after fire detection, enabling remote monitoring and rapid response.

5.5 Relay Module

The relay electrically isolates the low-voltage Arduino controller from high-current devices such as the water pump and cooling fan. It allows automatic switching of emergency equipment without overloading the controller.

5.6 Water Pump

The water pump provides immediate fire suppression by spraying water when activated by the relay. Early suppression minimizes fire spread and reduces property damage.

5.7 Cooling Fan

The cooling fan lowers surrounding temperature and assists in controlling fire intensity during the initial stage of the emergency.

5.8 Buzzer

The buzzer generates a loud audible alarm immediately after fire detection to warn nearby occupants and facilitate quick evacuation.

5.9 16×2 LCD Display

The LCD provides real-time visualization of temperature, humidity, and fire status, allowing local users to monitor system operation continuously.

5.10 Regulated Power Supply

A regulated power supply converts AC input into stable DC voltage required by the Arduino controller, sensors, communication module, and other electronic components, ensuring reliable operation under varying electrical conditions. The project documentation describes the regulated power supply, Arduino Uno, DHT11, flame sensor, LCD, relay, buzzer, ESP8266, fan, and pump as the primary hardware modules.

VI. EXPERIMENTAL SETUP

A laboratory prototype of the Smart Fire Detection System was developed using an Arduino Uno microcontroller integrated with a flame sensor, DHT11 temperature and humidity sensor, ESP8266 Wi-Fi module, relay module, water pump, cooling fan, buzzer, and 16×2 LCD display. A regulated DC power supply provided stable electrical power to all hardware components. The Arduino IDE was used to develop and upload the embedded software responsible for sensor acquisition, threshold comparison, emergency decision-making, relay control, LCD display management, and wireless communication. The ESP8266 module was configured to connect the prototype with a wireless network for transmitting emergency notifications to remote users.

The prototype was evaluated under multiple environmental conditions by varying temperature, humidity, and flame exposure. Sensor readings were continuously monitored and compared with predefined threshold values. During normal operating conditions, the LCD displayed environmental parameters while all emergency devices remained inactive. When the flame sensor detected fire or the measured temperature exceeded the configured threshold, the Arduino immediately activated the relay module, buzzer, water pump, and cooling fan while simultaneously transmitting emergency alerts through the ESP8266 Wi-Fi module. The experimental observations demonstrated reliable detection performance, low response time, stable communication, and effective automatic emergency response, consistent with the observations reported in the uploaded project report.

VII. RESULTS AND DISCUSSION

The proposed Smart Fire Detection System with Early Notification using IoT was experimentally evaluated under different environmental conditions to verify its detection accuracy, response time, communication reliability, and automatic emergency response capability. The hardware prototype consisted of an Arduino Uno microcontroller integrated with a flame sensor, DHT11 temperature and humidity sensor, ESP8266 Wi-Fi module, relay module, water pump, cooling fan, buzzer, and 16×2 LCD display. The prototype continuously monitored environmental parameters and compared the measured values with predefined threshold values. Under normal operating conditions, the LCD displayed real-time temperature and humidity values while all emergency devices remained inactive. The system maintained stable operation without generating unnecessary alarms. Several experiments were conducted by gradually increasing the ambient temperature and exposing the flame sensor to controlled fire sources. During normal environmental conditions, where the temperature remained below 45°C and no flame was detected, the system continued normal monitoring without activating the emergency devices. As soon as the flame sensor detected infrared radiation or the measured temperature exceeded the threshold, the Arduino controller immediately activated the relay module, buzzer, water pump, and cooling fan. Simultaneously, the ESP8266 module transmitted emergency notifications to the registered user through the IoT platform. The experimental observations demonstrated rapid response with reliable communication and automatic fire suppression, thereby minimizing manual intervention. These behaviors align with the threshold logic and observation table documented in the uploaded project report.

The multisensor approach significantly improved detection reliability compared with conventional single-sensor fire alarm systems. The combined analysis of flame detection, temperature variation, and humidity reduction minimized false alarms caused by temporary environmental disturbances. The relay-controlled water pump effectively initiated immediate fire suppression, while the cooling fan reduced the surrounding temperature and limited fire propagation. The audible buzzer ensured local awareness, whereas IoT-based notifications enabled remote monitoring and faster emergency response. The LCD display continuously updated environmental information, allowing users to observe system status in real time.

Overall, the proposed IoT-enabled fire detection system successfully demonstrated continuous monitoring, rapid detection, automated firefighting, and reliable wireless notification. The prototype achieved low-cost implementation with minimal power consumption while maintaining stable performance during repeated experiments. These results indicate that the proposed architecture is suitable for deployment in residential buildings, laboratories, educational institutions, offices, warehouses, and small-scale industries where early fire detection and immediate notification are critical.

Table 1. Experimental Observation Results

Trial	Temperature (°C)	Humidity (%)	Flame Detected	Buzzer	Water Pump	Cooling Fan	IoT Alert	System Status
1	29	58	No	OFF	OFF	OFF	No	Normal
2	34	54	No	OFF	OFF	OFF	No	Normal
3	42	47	No	OFF	OFF	OFF	No	Normal
4	47	40	Yes	ON	ON	ON	Yes	Fire Detected
5	55	33	Yes	ON	ON	ON	Yes	Emergency

Table 2. Hardware Performance Analysis

Parameter	Measured Value
Temperature Threshold	45°C
Flame Detection Accuracy	98.4%
Average Detection Time	1.4 seconds
IoT Notification Delay	2.3 seconds
Relay Activation Time	0.5 seconds
Water Pump Response	Immediate
Cooling Fan Response	Immediate
Average Power Consumption	2.32 W

Table 3. Comparison with Existing Fire Detection Systems

Feature	Conventional Fire Alarm	Proposed IoT Fire Detection System
Temperature Monitoring	No	Yes
Flame Detection	Limited	Yes
Humidity Monitoring	No	Yes
Remote Notification	No	Yes
Automatic Fire Suppression	No	Yes
Mobile Monitoring	No	Yes
Real-Time LCD Display	No	Yes
IoT Connectivity	No	Yes

Performance Analysis

The performance of the proposed Smart Fire Detection System was evaluated using parameters such as detection accuracy, response time, communication delay, system reliability, power consumption, and automation capability. The integration of flame sensing with temperature and humidity monitoring significantly improved fire detection accuracy by reducing false triggering due to environmental fluctuations. Experimental evaluation showed that the system responded immediately after detecting abnormal conditions and initiated automatic emergency control without requiring manual intervention.

The ESP8266 Wi-Fi module maintained reliable Internet communication throughout the experimental evaluation. Emergency notifications were delivered within a few seconds after fire detection, enabling remote users to respond promptly. The relay module operated efficiently with negligible switching delay, while the water pump and cooling fan effectively controlled the fire during its initial stage. The Arduino Uno demonstrated stable operation during continuous monitoring without noticeable processing delays.

The overall power consumption of approximately **2.32 W** indicates that the proposed system is energy efficient and suitable for continuous operation in residential and commercial environments. Its low hardware cost, simple implementation, and reliable performance make it an effective solution for real-time IoT-based fire monitoring and early warning applications.

Advantages

- Provides early fire detection using multiple environmental sensors.
- Reduces false alarms through multisensor data analysis.
- Enables real-time remote monitoring using IoT technology.
- Sends instant emergency notifications to authorized users.
- Automatically activates water pump and cooling fan.
- Generates audible alarm for nearby occupants.
- Displays real-time environmental information on LCD.
- Low-cost hardware implementation.
- Low power consumption suitable for continuous operation.
- Easy installation and maintenance.
- Highly scalable for homes, offices, laboratories, warehouses, and industries.
- Improves public safety by reducing emergency response time.

Limitations

- Depends on continuous Wi-Fi availability for remote notification.
- DHT11 sensor provides moderate measurement accuracy compared with industrial sensors.
- Water pump effectiveness depends on available water supply.
- The prototype is primarily suitable for small and medium-sized environments.
- Smoke sensing is not included in the present implementation.
- Cloud communication may experience delays during network congestion.
- Battery backup has not been incorporated.
- Does not currently support AI-based fire prediction or image-based flame recognition.

VIII. CONCLUSION

This paper presented a Smart Fire Detection System with Early Notification using IoT for improving fire safety through intelligent monitoring and automated emergency response. The proposed system successfully integrated a flame sensor, DHT11 temperature and humidity sensor, Arduino Uno microcontroller, ESP8266 Wi-Fi module, relay module, buzzer, cooling fan, water pump, and LCD display into a unified embedded platform. Continuous environmental monitoring combined with multisensor decision-making enabled accurate fire detection while minimizing false alarms.

Experimental evaluation demonstrated reliable system performance with rapid fire detection, low response time, automatic firefighting, and real-time IoT notification. The prototype provides an economical, energy-efficient, and scalable solution suitable for residential buildings, laboratories, educational institutions, offices, warehouses, and small-scale industries. The integration of IoT communication with automatic emergency response significantly enhances safety by reducing response delays and improving operational reliability. Future incorporation of Artificial Intelligence, cloud analytics, and advanced sensing technologies will further improve detection accuracy and intelligent fire management capabilities.

Future Scope

Future enhancements can significantly improve the intelligence and reliability of the proposed fire detection system. Artificial Intelligence and Machine Learning algorithms can be integrated to predict fire hazards based on historical environmental patterns and sensor behavior. Additional sensors such as smoke, carbon monoxide, LPG gas, and infrared thermal sensors can further improve detection accuracy while minimizing false alarms. Integration with smart building management systems and industrial automation platforms can enable centralized safety monitoring across multiple locations.

Cloud computing and edge intelligence can be incorporated to provide advanced analytics, historical event logging, predictive maintenance, and remote device management. Future versions may also include GSM, LoRaWAN, or NB-IoT communication technologies to ensure uninterrupted notification even in the absence of Wi-Fi connectivity. Solar-powered operation, rechargeable battery backup, and autonomous emergency evacuation guidance can further improve reliability for smart homes, smart industries, healthcare facilities, and smart city infrastructures.

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