Intelligent Fire Alarm System with Node Communication

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Abstract—**Fire accidents can cause significant loss of life and property if they are not detected at an early stage. To address this challenge, this paper presents the design and implementation of an Intelligent Fire Alarm System with node-based communication for real-time monitoring and early fire detection. The proposed system employs an ESP32 microcontroller integrated with temperature, smoke, and flame sensors to continuously monitor multiple cabins or zones. Sensor data are acquired and processed in real time to identify abnormal conditions accurately while minimizing false alarms.**

When fire-related parameters exceed predefined threshold values, the system activates an audible buzzer to provide an immediate warning. In addition, the embedded Wi-Fi capability of the ESP32 enables remote access through a web-based interface, allowing authorized users to monitor system status and deactivate the alarm when necessary, without being physically present at the installation site. A regulated power supply is incorporated to ensure reliable and stable operation under varying electrical conditions.

The developed system is cost-effective, compact, and easy to implement, making it suitable for small and medium-sized facilities. Experimental results demonstrate that the proposed system provides rapid response and reliable detection of fire incidents, thereby enhancing safety and enabling timely preventive action.

Index Terms—**IOT, Fire Detection, ESP32, Smoke Sensor, Temperature Sensor, Alarm System**

I. INTRODUCTION

Fire accidents pose a significant threat to human life and property, particularly when they are not detected at an early stage. In many practical situations, conventional fire alarm systems provide only local audible alerts, requiring personnel to be physically present to hear and respond to the warning. This limitation can lead to delayed intervention and increased damage during emergency situations. Consequently, there is a growing need for intelligent fire detection systems capable of continuously monitoring environmental conditions and providing remote access for timely response [1], [3], [4].

This paper presents the design and development of a multi-zone Intelligent Fire Alarm System based on the Espressif Systems ESP32 microcontroller. The proposed system integrates temperature, smoke, and flame sensors to continuously monitor multiple cabins or zones for potential fire hazards [2], [5], [8]. Sensor data are acquired and processed in real time to detect abnormal conditions such as excessive temperature, smoke concentration, or the presence of flame. When any parameter exceeds predefined threshold values, the system immediately activates an audible buzzer to alert nearby occupants.

To enhance functionality and user convenience, the ESP32's built-in Wi-Fi capability is utilized to provide a web-based interface for remote monitoring and control. Through this interface, authorized users can view the status of each monitored zone and deactivate the alarm when necessary without being physically present at the installation site [3], [6]. This feature significantly improves operational flexibility and facilitates prompt decision-making during emergency situations.

The proposed system is compact, cost-effective, and easy to implement, making it suitable for small-scale applications such as offices, laboratories, classrooms, and residential buildings. Experimental results demonstrate that the system offers rapid response and reliable fire detection performance, thereby improving safety and reducing the risk of extensive damage caused by fire incidents.

II. OBJECTIVES

1. To design and develop a multi-zone fire detection system capable of monitoring multiple cabins or areas simultaneously.

2. To integrate temperature, smoke, and flame sensors for the reliable detection of various fire indicators.
3. To implement the system using an Espressif Systems ESP32 microcontroller for real-time data acquisition and processing.
4. To generate an immediate audible alarm through a buzzer when abnormal or potentially hazardous conditions are detected.
5. To provide a web-based remote monitoring and control interface that enables users to supervise the system and deactivate the alarm from any authorized device.
6. To develop a simple, cost-effective, and practical fire alarm solution suitable for small- and medium-scale applications.

III. METHODOLOGY

1. System Architecture

The proposed system architecture as shown in Figure 1 is designed to provide efficient multi-zone fire monitoring while maintaining simplicity and ease of implementation. Each cabin or monitoring zone is equipped with temperature, smoke, and flame sensors to detect different indicators of a potential fire. These sensors continuously measure environmental conditions and transmit their outputs to the Espressif Systems ESP32 microcontroller, which serves as the central processing unit of the system.

The ESP32 periodically acquires and analyses sensor data in real time to identify abnormal conditions such as elevated temperature, excessive smoke concentration, or the presence of flame. When any sensor reading exceeds the predefined threshold values, the microcontroller immediately activates an audible buzzer to alert occupants and initiate a rapid response.

The built-in Wi-Fi capability of the ESP32 enables remote monitoring and control through a web-based interface. Authorized users can access the interface to view the status of all monitored cabins and acknowledge alarm conditions by remotely deactivating the buzzer when appropriate. This functionality enhances operational flexibility and allows system supervision even when personnel are not physically present at the installation site.

A regulated power supply is incorporated to provide stable and reliable operation of the sensors, microcontroller, and communication modules. The overall architecture is compact, cost-effective, and straightforward to implement. In addition, the modular design allows the system to be easily expanded by adding additional cabins or monitoring zones without significant modifications to the core hardware or software architecture.

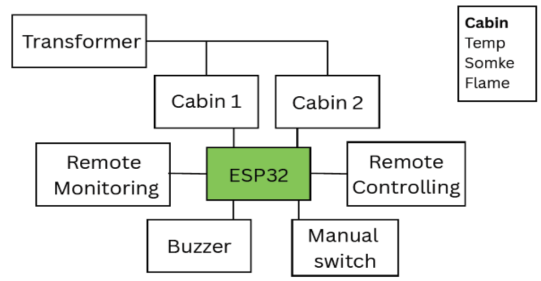


Figure 1: Block Diagram

2. Hardware

The system is made with parts that are easy to find. This is done to make sure the system is reliable and not too costly. The ESP32 microcontroller is at the heart of the system. The ESP32 microcontroller handles everything, including reading sensor data processing the sensor data and controlling the outputs when they are needed. The ESP32 microcontroller also has built-in Wi-Fi which makes it possible to monitor and control the system remotely without adding any parts. For sensing the temperature, a DS18B20 sensor is used [2]. The DS18B20 sensor gives accurate temperature readings and it works with just one wire, which makes the wiring a bit easier. A 4.7kΩ pull-up resistor is added to the DS18B20 sensor to make sure the communication with the DS18B20 sensor stays stable. Otherwise the DS18B20 sensor can behave a little strangely sometimes. For detecting smoke MQ6 gas sensor is used [2], [5]. The MQ6 gas sensor can sense smoke and gases that are in the air. The MQ6 gas sensor has an output that is connected to the ESP32 microcontroller so the values, from the MQ6 gas sensor can be checked all the time. The system also has an IR flame sensor, which directly detects if there is a fire [5].

When the system detects something that's not normal a 5V buzzer is used to give an alert. Since the ESP32 microcontroller works on 3.3V a transistor is added between the ESP32 microcontroller and the 5V buzzer to drive the 5V buzzer safely. This is done to avoid damaging the ESP32 microcontroller. There is also a

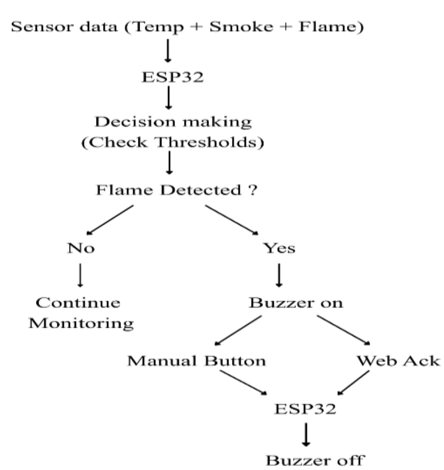
switch so the alarm can be turned off locally if it is needed. At the time there is a remote option to turn off the alarm through Wi-Fi.
For power a regulated supply is used. The regulated supply has a transformer, a rectifier, a filter and a regulator, which provide 5V and 3.3V. Overall the design of the system is simple and it works well for practical use. The system is of modular which is a good thing.

3. Software
The system software keeps checking the surroundings and responds based on how serious the fire risks. It is written in Arduino IDE. Runs on the ESP32. The ESP32 continuously reads data from all sensors again and again.
The idea is to not react to every small change. Instead it understands the situation step, by step.

1. The system follows a stage approach.
2. First it monitors the temperature sensor. If it goes beyond a set limit it gives a warning. This means something might be starting.
3. Next the smoke sensor comes into picture and tries to detect the smoke. If smoke is detected, the risk level increases.
4. Finally the flame sensor checks critical stage as a fire.

The buzzer turns on when a flame is detected, because fire is confirmed by flame sensor [5]. This helps avoid false alarms. Unnecessary alarms can be annoying.
The ESP32 uses its Wi-Fi feature to provide access. A simple web page is used to check the system status [3], [6]. It can also turn off the buzzer if needed even when the user is not nearby.

4. Flowchart Figure 2: Flowchart or Work Flow



The intelligent fire alarm system keeps monitoring everything. It starts when the system gets power from a supply and then the ESP32 gets all the sensors and communication parts ready.

It keeps collecting data from the temperature sensor, smoke sensor and flame sensor in both cabins at the time. The data is read all the time and compared with the set limits. The system does not react away. Instead it checks in following stages.

1. First it checks the temperature. If it rises fast it gives an early warning that something might be wrong.
2. Then it checks for smoke or gas. This makes it more concerned.
3. Finally the flame sensor detects fire. Then does the buzzer go off. This way unnecessary alarms are avoided.

The ESP32 also uses its Wi-Fi to make a web interface. This lets the user check the system status from away and turn off the buzzer if needed.

There is also a switch to stop the alarm locally. Both options work separately making the system flexible. The whole process runs in loop: continuous monitoring, checking and responding. This helps detect fire conditions and deal with them in time.
The ESP32 and the sensors keep working to ensure the system is always on the lookout, for potential fires. This Intelligent Fire Alarm System is designed to be reliable and efficient. It uses the ESP32 to monitor and respond to fires. The system is always ready to respond.

IV. RESULTS AND DISCUSSIONS

The result of this project shows that the system is able to detect fire conditions in a reliable and fairly quick manner, which was kind of the main goal. During testing, the sensors responded properly to changes in temperature, presence of smoke, and flame detection, each stage working as expected.

The temperature sensor gave early signs when heat increased, while the smoke sensor added another level of confirmation, and finally the flame sensor ensured that the buzzer was triggered only in actual fire-like situations.

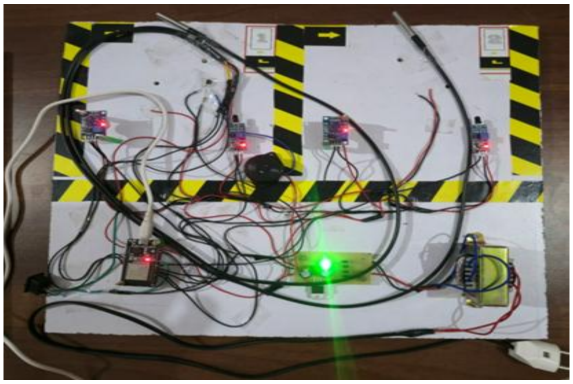


Figure 3: System Hardware

One thing that stood out was how the staged detection helped in reducing false alarms [2], [5]. The system didn't react to minor changes or noise, which is important because too many false alerts can make a system less useful over time. The buzzer response was immediate once the flame was detected, so the alert part worked well.

The remote monitoring feature also performed quite smoothly. The web interface allowed checking the system status and turning off the buzzer from a distance, which adds a lot of convenience, especially when no one is nearby. The manual switch also worked without any issues, giving a backup control option.

There were a few small limitations noticed, like sensor sensitivity depending on surroundings or slight delays in some conditions, but nothing too major. Overall, the system behaves in a stable and predictable way. It is simple, cost-effective, and suitable for small-scale use, and with a few improvements it could be made even more efficient and scalable.

V. FUTURE SCOPE

The proposed Intelligent Fire Alarm System offers significant potential for further enhancement and large-scale deployment. Although the current implementation provides reliable fire detection using temperature, smoke, and flame sensors, several additional features can be incorporated to improve system performance, functionality, and applicability.

One important area for future development is the integration of additional sensors, such as humidity, carbon monoxide, and combustible gas sensors [4], [8]. These sensors can provide more comprehensive environmental monitoring and improve the accuracy and reliability of fire detection while further reducing the possibility of false alarms. The system architecture is inherently scalable and can be extended to monitor a larger number of cabins or zones, making it suitable for deployment in large buildings, industrial facilities, and commercial complexes.

Another potential enhancement is the implementation of real-time notification services, including mobile application alerts, Short Message Service (SMS) [3], [6]. These features would enable users and emergency personnel to receive immediate warnings regardless of their location, thereby facilitating faster response during critical situations. A dedicated mobile application could also provide a more convenient and intuitive interface for monitoring and control compared with a standard web-based interface.

The graphical user interface can also be enhanced using engineering software platforms such as LabVIEW developed by National Instruments, enabling more interactive visualization, real-time dashboards, and advanced supervisory control functions [7].

Overall, the proposed system provides a robust and flexible foundation for the development of advanced fire safety solutions. With the integration of additional sensors, cloud connectivity, mobile applications, and enhanced visualization tools, the system can be transformed into a comprehensive and intelligent fire monitoring platform suitable for a wide range of real-world safety applications.

VI. CONCLUSION

In the end, this project shows that a simple and low-cost fire alarm system can still work in a reliable and practical way. The system was able to monitor multiple cabins and detect fire conditions using temperature, smoke and flame sensors, each playing its part in the process. The step-by-step detection helped in avoiding unnecessary alarms, which was actually important for making the system more usable, not just reactive.

The ESP32 handled the sensing and control quite well, and the Wi-Fi feature added that extra flexibility of checking and controlling the system remotely. The buzzer alert worked instantly when a real fire condition was detected, and both manual and remote acknowledgement made it easier to manage in different situations.

There were a few small limitations, like sensor sensitivity and minor delays, but overall the system performed in a stable way. It's simple, easy to build and doesn't cost much, which makes it suitable for small-scale use.

REFERENCES

[1] A. Verma, S. Kulkarni, and R. Patil, "IoT-based intelligent fire detection and alarm system using ESP32," Int. J. Innov. Res. Electr. Electron. Instrum. Control Eng., vol. 10, no. 4, pp. 112–118, Apr. 2022.

[2] P. Sharma and M. Joshi, "Multi-sensor fire monitoring system using smoke, temperature and flame sensors," J. Embedded Syst. Appl., vol. 7, no. 2, pp. 54–60, Jun. 2021.

[3] R. Singh, A. Gupta, and V. Mehra, "Wireless fire alarm and remote monitoring system using ESP32 and Wi-Fi technology," in Proc. Int. Conf. Smart Electron. Commun. Technol., Hyderabad, India, Sept. 2022, pp. 201–206.

[4] K. Patel and N. Shah, "Design and implementation of smart fire detection system using IoT," Int. J. Comput. Appl. Technol. Res., vol. 11, no. 5, pp. 97–103, May 2022.

[5] S. Iyer and P. Nair, "Real-time smoke and flame detection system for industrial safety applications," J. Electr. Electron. Eng. Res., vol. 9, no. 3, pp. 41–47, Mar. 2020.

[6] D. Kumar, R. S. Chauhan, and H. Patel, "Web-based remote acknowledgement system for smart fire alarms," in Proc. IEEE Int. Conf. Commun. Signal Process., Chennai, India, Jul. 2021, pp. 455–460.

[7] M. Ali and T. Joseph, "Low-cost intelligent fire safety system using embedded controllers," Int. J. Eng. Res. Technol., vol. 8, no. 9, pp. 320–325, Sept. 2019.

[8] V. Rao and S. Deshmukh, "Implementation of multi-zone fire detection system using wireless sensor networks," J. Adv. Smart Syst. Technol., vol. 6, no. 1, pp. 15–22, Jan. 2023.