Research Trends International Journal of Technology and Innovation
An International Peer-Reviewed, Refereed & Open-Access Journal
ISSN : 3144-3273
Available Online at : https://rtijti.com/
doi : https://doi.org/10.5281/zenodo.23624599

IoT-Based Fire Detection and Management System with Automatic Water Sprinkling and Mobile Alert

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A R T I C L E I N F O

Article History:
Received : 23-10-2026
Accepted : 24-10-2026
Published : 25-10-2026

Publication Issue
Volume 1, Issue 4
October – December 2026

Page Number
15-19

A B S T R A C T

Fire incidents can cause injury, loss of life, and damage to property when they are not detected and addressed quickly. This report presents the proposed design of an IoT-Based Fire Detection and Management System with Automatic Water Sprinkling and Mobile Alert. The system uses a flame sensor to detect a possible fire and an ESP32 microcontroller to process the sensor signal. When fire is detected, the ESP32 can activate a relay-controlled water pump and a buzzer/LED warning. A servo motor is proposed to move the sprinkler nozzle left and right, helping direct water toward the detected fire area. The ESP32's built-in Wi-Fi capability supports a mobile monitoring interface that can display fire status, pump status, and alerts over a network. The design is divided into four modules: mobile application and monitoring, fire detection and sensing, fire direction and nozzle control, and automatic water suppression. This document describes the proposed architecture and planned evaluation. Performance measurements are not claimed because they must be obtained after implementation and testing.

Index Terms - Internet of Things (IoT), ESP32, Flame Sensor, Fire Detection, Automatic Water Sprinkling, Servo Motor, Relay Module, Wi-Fi, Mobile Alert.

I. INTRODUCTION

Fire is a serious safety risk in homes, laboratories, offices, workshops, educational institutions, and industrial environments. Fire accidents can cause damage to human life, buildings, electrical equipment, and valuable materials. If a fire is not detected at an early stage, it can spread quickly and become difficult to control. Conventional fire alarm systems provide warnings to nearby people, but they may not automatically activate a fire-suppression mechanism or provide remote monitoring. Therefore, an IoT-based fire detection system can help improve fire monitoring and provide a faster initial response.

The Fire Detection Management System with Mobile Application is an IoT-based project designed to detect flames, activate a warning system, control water sprinkling, and provide fire-status information through a mobile application. The system uses a flame sensor as the primary fire-detection component and an ESP32 microcontroller as the main control unit. The flame sensor continuously monitors the surrounding area within its detection capabilities and sends signals to the ESP32. The controller processes these signals according to the programmed conditions and operates the connected devices when a flame is detected.

When the configured fire condition is detected, the ESP32 activates a buzzer and an LED to provide a local warning. It also sends a control signal to a relay module, which switches on the water pump. The pump supplies water through a pipe connected to a sprinkler nozzle. A servo motor helps change the direction of the nozzle so that water can be directed toward the target area. These components work together to demonstrate automatic fire detection and a water-based response mechanism.

The system also uses Wi-Fi communication to connect the ESP32 with a mobile application. The application can display important information such as normal system status, fire detected, fire cleared, and water pump

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ON/OFF status. This feature allows users to monitor the system remotely when the required network connection and application communication service are available. The project involves hardware connections, ESP32 programming using the Arduino IDE, sensor interfacing, relay control, servo motor operation, and mobile application integration. It helps students understand embedded systems, automation, wireless communication, and Internet of Things technology.

The main objective of this project is to demonstrate an affordable and automated approach to flame detection, local warning, water-pump control, nozzle direction adjustment, and remote monitoring. The system can serve as an educational prototype for understanding the application of IoT in fire safety. However, a flame sensor has limitations related to detection range, lighting, orientation, and environmental conditions. Water is not suitable for every type of fire, particularly certain electrical and flammable-liquid fires. Therefore, the prototype must be tested under safe and supervised conditions and must not replace certified fire alarms, approved fire-suppression equipment, or established emergency procedures.

The rest of the paper is organized as follows. Section II reviews the literature related to IoT-based fire detection and management systems. Section III describes the methodology of the proposed system, which consists of four modules: mobile application and monitoring, fire detection and sensing, fire direction and nozzle control, and automatic water suppression. Section IV discusses the expected benefits, planned evaluation, and feasibility of the proposed system. Section V presents the conclusion and future scope of the project.

II. LITERATURE REVIEW

Prof. Mohd Kashif AR et al. [1] proposed a solar-powered automatic firefighting robot for detecting and suppressing small fires. The system uses an Arduino Nano, flame sensors, an ultrasonic sensor, a relay-controlled water pump, and a servo motor to direct the water nozzle. A solar panel and a 12V battery provide power. The study demonstrates automatic fire detection and water spraying. However, detection may be affected by ambient light, and minor navigation errors were observed. Unlike this system, our proposed project uses an ESP32 with Wi-Fi and a mobile application for remote fire alerts and system-status monitoring.

Ervin F. Raquin et al. [2] proposed an Automated Fire Suppression System using an Arduino Uno R3 and a flame sensor to detect fire. Servo motors direct the water nozzle, while a relay-controlled water pump sprays water toward the fire. The study reported a 100% response rate within a testing range of 30 cm to 80 cm. However, the system may have difficulty detecting small flames at greater distances and may produce false triggers due to sunlight or other infrared sources. This research supports the use of flame sensors, water pumps, and servo motors for automatic fire suppression. Our project improves remote monitoring by using an ESP32, Wi-Fi connectivity, and a mobile application to provide fire alerts and system-status updates.

Devansh V. Desai et al. [3] proposed a Fire Fighting Robot using an Arduino Uno for automatic fire detection and suppression. The system uses flame sensors to detect fire, a servo motor to control the direction of the water nozzle, and a DC water pump to spray water on the fire. The robot can move toward the fire and operate the water-spraying mechanism automatically. The study reports that the prototype detected flames at approximately 0.8 meters under the tested conditions. This research demonstrates the usefulness of flame sensors, microcontrollers, servo motors, and water pumps in automatic fire suppression. Unlike this system, our proposed project uses an ESP32 with Wi-Fi connectivity and a mobile application for remote fire alerts and system-status monitoring.

Juliaz and Maulana [4] proposed a Design of Fire Detector with Water Sprinkler Based on Internet of Things (IoT) using a NodeMCU ESP8266 microcontroller for fire detection, automatic water sprinkling, and remote monitoring. The system uses fire and smoke sensors to detect fire, a relay module to control the water sprinkler, and an LCD to display the system status. The Blynk mobile application is used for remote monitoring and fire notifications, while email alerts provide additional information to users. The study demonstrates that IoT technology can improve fire monitoring, response speed, and safety in residential, commercial, and industrial buildings. However, the system uses both fire and smoke sensors. Our proposed project uses only a flame sensor with an ESP32, a relay-controlled water pump, and a servo motor to direct the water nozzle. It also uses Wi-Fi connectivity and a mobile application for fire alerts and system-status monitoring.

Alqourabah et al. [5] proposed a Smart Fire Detection System Using IoT Technology with Automatic Water Sprinkler to detect fire and provide an automatic response. The system uses an Arduino microcontroller, flame sensor, temperature sensor, gas sensor, Wi-Fi module, relay, water pump, LED, and buzzer. The Ubidots IoT platform is used to monitor sensor readings and send SMS alerts to property owners. When a fire is detected, the relay activates the water pump, which supplies water to the sprinkler. The researchers reported an average response time of approximately 5 seconds for fire detection and notification. However, the study uses multiple sensors and its flame sensor performance depends on the detection distance. Our proposed project uses only a flame sensor with an ESP32, a relay-controlled water pump, and a servo motor to direct the water nozzle. It also uses Wi-Fi connectivity and a mobile application for fire alerts and system-status monitoring.

III. METHODOLOGY

The proposed system follows a modular approach in which each module performs a specific function and communicates with the other modules to achieve automatic fire detection, water suppression, and mobile monitoring. It combines flame sensing, ESP32-based control, servo-operated nozzle direction, relay-controlled water pumping, and Wi-Fi communication. The system is organized into four modules: mobile application and monitoring, fire detection and sensing, fire direction and nozzle control, and automatic water suppression. The ESP32 processes the flame sensor signal, activates the required warning and suppression devices, and provides system status to the mobile application through Wi-Fi.

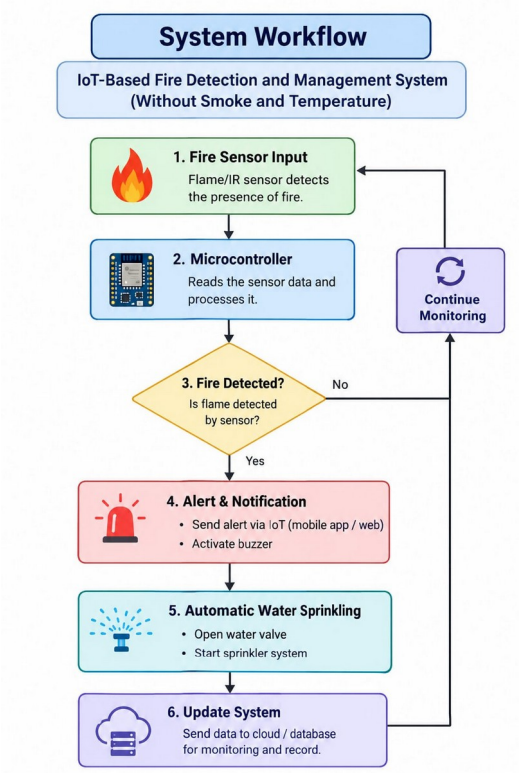


Figure 1. Block diagram of the proposed IoT-Based Fire Detection and Management System, showing flame detection, automatic water sprinkling, and mobile alerts.

Table 1. Summary of the Four Modules

Module	Function	Key tools
1. Mobile Application and Monitoring	Displays fire alerts and system status remotely	Mobile application, ESP32, Wi-Fi
2. Fire Detection and Sensing	Detects fire and sends the sensor signal to the controller	Flame sensor, ESP32
3. Fire Direction and Nozzle Control	Moves the water sprinkler nozzle left and right	Servo motor, ESP32
4. Automatic Water Suppression	Activates the water pump and provides local warnings	Relay module, water pump, pipe, nozzle, buzzer, LED

3.1 Module 1: Mobile Application and Monitoring

This module provides a mobile application through which users can receive fire alerts and monitor the system status remotely using Wi-Fi. The application communicates with the ESP32 through the selected network communication method and displays information about fire detection, water pump operation, and the current system status.

Mobile Application Interface: The mobile application provides a simple interface for users to monitor the fire detection system. It displays the fire status, such as fire detected or fire cleared, and the water pump status, such as ON or OFF.

Wi-Fi Communication: The ESP32 uses its built-in Wi-Fi capability to communicate with the mobile monitoring interface. When the system detects a fire or changes its operating status, the corresponding information can be sent to the application, provided the network and communication service are available.

Fire Alerts and Monitoring: The application is designed to inform users about fire detection and system operation. This helps users monitor the system remotely without being physically present near the prototype. The delivery of alerts depends on the implemented software and network connection.

3.2 Module 2: Fire Detection and Sensing

This module detects fire using a flame sensor and sends the sensor signal to the ESP32 microcontroller for processing. The ESP32 evaluates the sensor input and initiates the appropriate actions when the configured fire-detection condition is met.

Flame Detection: The flame sensor monitors its surroundings for a flame within its detection capabilities. When a flame is detected, the sensor produces an output signal that is read by the ESP32.

Signal Processing: The ESP32 receives the sensor output and checks whether the configured fire-detection condition has been satisfied. Based on the sensor reading and control logic, the microcontroller determines whether to activate the warning and water-suppression mechanisms.

Fire Status Update: When fire is detected, the ESP32 updates the system status and initiates the configured response. The fire status can also be communicated to the mobile application through Wi-Fi. Sensor readings may be affected by lighting, distance, flame orientation, and environmental conditions; therefore, the detection system must be tested under different conditions.

3.3 Module 3: Fire Direction and Nozzle Control

This module controls the direction of the water sprinkler nozzle using a servo motor. The servo motor moves the nozzle left and right according to the programmed control mechanism, helping direct the water toward the intended area.

Servo Motor Control: The ESP32 sends control signals to the servo motor to move the nozzle to predefined positions. The movement range is determined by the mechanical arrangement and the servo motor's operating limits.

Nozzle Direction Control: The servo motor rotates the nozzle left and right to change the direction of water flow. This movement is intended to improve the coverage of the sprinkler mechanism.

Coordination with Fire Detection: The nozzle movement is coordinated with the fire-detection and suppression logic. The system must use a defined movement strategy to select the nozzle direction. Since a single flame sensor does not necessarily identify the precise direction of a fire, the actual direction-control capability must be verified during testing.

3.4 Module 4: Automatic Water Suppression

This module automatically activates the relay module and water pump when fire is detected. The ESP32 controls the relay according to the programmed logic, allowing the pump to supply water through a pipe and nozzle toward the intended fire area. A buzzer and LED provide additional local warnings.

Relay Control: When the ESP32 identifies the configured fire condition, it sends a control signal to the relay module. The relay switches the water pump circuit according to the system design.

Automatic Water Pump Activation: The water pump starts when the relay is activated and supplies water through the connected pipe and sprinkler nozzle. This mechanism demonstrates automatic water suppression for suitable, controlled test conditions.

Buzzer and LED Alert: The buzzer produces an audible warning, while the LED provides a visual indication when fire is detected. These alerts help indicate the system's operating condition to people nearby.

System Reset and Testing: When the fire condition clears, the ESP32 follows the programmed control logic to update the system status and stop the pump when appropriate. The pump, relay, buzzer, LED, and nozzle must be tested to verify their correct operation and coordination.

Water suppression must not be used on energized electrical equipment or fires for which water is unsuitable. This prototype is intended for academic demonstration and is not a replacement for certified fire-protection equipment.

IV. EXPECTED BENEFITS AND EVALUATION PLAN

4.1 Expected Benefits

Based on the proposed design, the IoT-Based Fire Detection and Management System is expected to detect fire using a flame sensor, provide local alerts through a buzzer and LED, automatically activate the water pump, and control the sprinkler nozzle using a servo motor. The system is also expected to provide remote fire alerts and system status monitoring through a mobile application using Wi-Fi. These features may help improve fire awareness, support a quicker response, and demonstrate automated fire suppression at a low cost. These are expected benefits and have not yet been confirmed through experimental testing.

4.2 Planned Evaluation

After implementation, the proposed system will be evaluated based on the following measures:

- Fire Detection Accuracy: Testing the flame sensor under different conditions to check its ability to detect fire;
- Response Time: Measuring the time taken to activate the alert system and water pump after fire detection;
- Alert System Testing: Checking the proper functioning of the buzzer and LED during fire detection;
- Water Pump Operation: Verifying the correct activation of the relay and water pump when fire is detected.

4.3 Feasibility and Scope

The proposed IoT-Based Fire Detection and Management System is technically feasible because it uses commonly available components such as an ESP32, flame sensor, relay module, water pump, servo motor, and Wi-Fi technology. Its economic feasibility depends on component costs, power requirements, and mechanical setup, while operational feasibility depends on a user-friendly mobile application, reliable wiring, and easy maintenance. The scope includes flame detection, buzzer and LED alerts, automatic water pumping, servo-controlled nozzle movement, and remote monitoring through a mobile application, excluding water-level monitoring. However, the flame sensor may not detect every type of fire, Wi-Fi alerts depend on network availability, and a single sensor may not accurately identify the fire's direction or size. Water is unsuitable for certain fires, especially those involving energized electrical equipment. Therefore, the prototype is intended for academic demonstration and is not a replacement for certified fire-safety equipment.

V. CONCLUSION

This report presents the proposed design of an IoT-Based Fire Detection and Management System with Automatic Water Sprinkling and Mobile Alert. The architecture combines a flame sensor and ESP32 with local warnings, relay-controlled pumping, servo-based nozzle movement, and Wi-Fi mobile monitoring. The modular structure supports independent development and integration testing. Since implementation results have not been provided, the effectiveness of the system must be

established through measured trials before any performance claims are made.

Future improvements may include additional sensing for better confirmation, improved direction estimation, secure remote communication, event logging, backup connectivity, and integration with certified alarm systems. Any such features should be added only after requirements, cost, and safety implications are evaluated.

ACKNOWLEDGMENT

The authors thank their project guides, Dr. C. P. Divate and Ms. N. R. Bhokare, and the Department of Computer Engineering, Sanjay Bhokare Group of Institute, Miraj, for their guidance and support.

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