

Article

A Systematic Review on Firefighting Systems Based on IoT

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Abstract. Firefighting is a very important aspect to consider in the modern world to protect against loss of life, property, and damage to infrastructure. This can be done securely using improved firefighting systems. As modern technologies continue to rise, firefighting systems based on IoT can be applied in various fields to create awareness in times of fire outbreaks. With IoT, Various sensors can be deployed in the wireless sensor network to provide real-time signals and accuracy in fire detection.

These tiny, low-power sensor devices can sense their surroundings, detect, and collect fire-related information that usually includes flames, abnormal temperatures, and early signs of smoke. The fire detection systems then use the collected data to provide quick signals as a medium of alert, indicating their potential to offer an important benefit of real-time monitoring. This paper aims to explore the existing research about firefighting systems and the various techniques applied based on IoT to make fire detection easier.

The researchers concluded that in order to develop modern and more efficient firefighting systems, IoT needs to be combined with other technologies such as embedded systems, image processing, Message Queuing Telemetry Transport protocol (MQTT) protocol, BIM, AI, and GIS technologies. This not only helps to produce real-time systems but also ensures the accuracy of the developed firefighting systems.

Keywords: Fire, Firefighting, Firefighting Systems, IoT.

Introduction

Firefighting systems are systems specifically developed to assist in fire outbreak situations. These systems work by detect early signs of smoke and the sensors included within the system such as heat sensors can detect abnormal temperatures thus can be able to give alerts to the responsible personnel, giving them a chance to recover the cause or perform a safe evacuation.

As The world continues to get modernised every single day, increased industrialization (Majdalani et al., 2025), the introduction of tall buildings (Ivanov & Chow, 2023) ,(Khan et al., 2023) forest conservation, modernisation of Agriculture, smart transportation (T. Deng et al., 2025), and so many others has led to the need of advanced technologies to protect these infrastructure against several disasters, for being of them.

Fire is a very hazardous disaster that does not only lead to loss of people's lives but also destroys expensive property that may require large sums of money from the responsible governments for replacement and this may hinder development. In the modern world, the introduction of new technologies

continues to assist in firefighting thereby performing early detection, as well as avoiding its occurrences. Specifically, the use of Internet of Things (IoT) systems for fire detection has gained significant attention due to its potential to enhance safety and response times. These fire detection systems have the potential to offer numerous benefits, such as real-time monitoring, remote management, and data-driven insights (Singh et al., 2025a).

Several researchers have shown an extra effort in developing systems that can be used for firefighting. (Y. Zhang et al., 2021) proposed a model that detects the fire outbreak for smart cities and the model showed 98.4% of accuracy and just 0.14% minimal error rate. This is because Artificial Intelligence continues to prove as one of the best key research techniques for several researchers in improving the performance of detecting fire hazard in smart cities.

This systematic review paper therefore aims at exploring the existing research about firefighting systems with an aim of getting answers to the research questions and to also find out the various technologies that can be combined with IoT to make fire detection easier and more efficient.

Literature Review

- **Fire and Its Causes**

Fire can be defined as a rapid oxidation of a fuel in the exothermic chemical process of combustion, releasing heat, flames, and various reaction products. This disaster is considered dangerous because it may lead to severe injuries and loss of human lives (C. Chen et al., 2023), lead to destruction of environmental and natural resources (Sivrikaya & Demirel, 2025), impact ecosystem services (Bajinath-Rodino et al., 2023), pollute the environment and water bodies (Araujo et al., 2025), cause outages in industries (Szabó et al., 2024), and also lead to loss of expensive property and infrastructure.

This dangerous disaster may occur in different areas due to various factors such as the type of materials used in construction. In tall buildings, the concrete's low thermal conductivity and thermal expansion properties play a crucial role during a fire (Hamidi et al., 2025). As the steel section loses strength and stiffness under high temperatures, the load is effectively transferred to the concrete core.

In addition to the above, in residential buildings or homes, fire can be caused by population density and underground car parks. (Raposo et al., 2025) also carried out a related research that in addition to the above identified construction problems, materials used, and heat sources as some of the responsible causes of fire incidents in homes.

In residential areas with underground car parks, If the park walls and ceiling are built with poor concrete, the building can seriously get damaged in case of a fire outbreak in the underground car parking due to thermal spalling of poor concrete (Kowalski et al., 2025). It is therefore important to consider reinforced concrete structures due to their nature of resistance to fire compared to timber and steel.

In the transportation industry, fire can be caused by accidents such as cars and trucks hitting each other in transportation tunnels, thus also easy to derive from single-source fire to multi-source fire (Xiao et al., 2024). This is very dangerous as the high temperature, strong thermal radiation and toxic gas can cause great harm to human body.

In forests, fires can be caused by socioeconomic factors and a lack of knowledge and awareness of the risks involved in the use of fire (Ferreira et al., 2024). This leaves a need for integrated fire management approaches.

On the other hand, fires can be caused by overheating in industries. Overheating of machines in industries due to heavy and continuous work may

lead to fire explosion (Szabó et al., 2024). This not only leads to the destruction of the plant, forced shutdown, serious personal injuries or deaths but also as severe outages that may end up affecting the business world and the economy at large.

Over all, regardless of where the fire disaster hits, several damages are usually caused due to late detection of the fire and most likely due to the lack of fire alarm system (Kowalski et al., 2025). The deployment of new intelligent technologies is therefore significant in ensuring accurate fire detection while fronting safe and timely evacuation activities.

- **Fire Detection**

Fire detection relies on the collection of fire-related information that usually includes flames, increasing heat and smoke. In the present world, a lot is being done to protect against fire disaster. In an effort to succeed, various infrastructures are equipped with fire alarm and detection systems. These systems can detect early signs of smoke and the sensors included within the system such as heat sensors can detect abnormal temperatures (Wu et al., 2022).

Currently, several researches have been done about fire detection. This has shown great importance because if not fully controlled, fire may result into loss of lives, environmental damage, and financial losses. A research carried out by (Park et al., 2023) analysed fire-signal characteristics in a fire accident that occurred in an area with an IoT-based fire-detection system. The researchers applied fuzzy logic to the output signals of detectors to distinguish genuine fire and false fire-alarm signals in order to improve reliability. Wild fires are another significant natural hazard.

The issue of sudden fire outbreaks has raised the need to monitor potential risk areas and also perform early fire detection with an aim of reducing the

potential damage. Fortunately, IoT can also be used to detect and prevent the wild fires thus helping to conserve the environment. This advanced technology has modernised the world and overtaken previous approaches applied by governments to detect wildfires such as the use of satellite imagery and drone-borne sensing.

(Nakau et al., n.d.) made a system to detect automatically detect forest fires daily for Alaska area during the entire summer. Another similar research proposed a novel airborne UAV-based IoT (UIoT) system for wildfire sensing, detection, and extinguishing. The researchers aimed at presenting a design of low-cost and low-maintenance fire-detecting IoT nodes for large-scale deployment (Ramadan et al., 2024).

Methodology

A systematic review approach is used in this research paper with an aim of exploring the existing data about firefighting systems based on IoT. This approach was chosen due to its strict requirements for search strategy and selecting articles for inclusion in the review. Systematic reviews are effective in synthesizing what the collection of studies are showing in a particular question and can provide evidence of effect that can inform policy and practice (Snyder, 2019).

The chosen approach intends to answer the research questions and fulfil gaps in the existing studies of the chosen field. The research questions of this study as identified by researchers are;

Q1: What are the common causes of fire that necessitate intelligent firefighting systems?

Q2: In which areas/fields are firefighting systems commonly applied?

Q3: What are the existing challenges, and benefits of firefighting systems based on IoT?

The Search Strategy

The researchers followed a specific strategy to search for the existing related studies to firefighting systems based on IoT. To get the latest work in the field, we used specific related search terms to be able to exploit different resources of data.

Resources such as Science direct database, Google scholar, IEEE, Scopus, ResearchGate, and Springer were fully searched to filter out the latest papers with the most related information to backtracking of relevant References was also done from the most relevant articles but researchers ensured that their years of publication still fell within the required time of 10 years. The researchers mainly used Journal articles within a period of 10 years (2015 -2025) but highly considered latest articles concentrating more ie; the ones published between 2020 and 2025 while looking at the trending firefighting systems based on IoT.

The elimination strategy included papers that were relevant but did not fall into a period of 10 years, papers which indicated improper citation, and those that were not yet published but were just upload to the internet and research platforms like ResearchGate.

To fully exploit the above-mentioned sources, the researchers used search strings such as (Firefighting) AND (IoT OR alert systems OR intelligent monitoring OR smart monitoring) AND (smart fire management OR control) AND (automation OR fire prediction).

To avoid excluding very important information and related articles to firefighting based on IoT, we finally applied a search on a full text. This was considered because some studies may be related but may not have the main search strings (Lynn et al., 2020).

- **Fire Fighting**

IoT can be defined as the ‘Internet of Things’. The system deals with remote monitoring and integration of diverse hardware and software elements

to provide secure, seamless and reliable services. It also requires components such as sensor nodes, actuators, network protocols, and gateway nodes to ensure that these systems are secure and fully function (Mishra & Mishra, 2025). This technology can be used in fighting fires in homes (Y. C. Zhang & Yu, 2013), offices (Hu et al., 2021), airports (Yulong et al., 2025) and, forests (Ramadan et al., 2024). This has been driven by the advances in IT therefore enabling researchers to realize digital fire-alarm systems applying IoT technology.

Previously, traditional measures of reliability for fire detection include a raise in the temperatures within the building, smoke detection in the environment and all these have been assisted by analogy fire-alarm systems in the event of a fire. These methods are not reliable enough to protect against the overwhelming harm caused by fire in case of an incident. Thanks to the rise of IoT that has triggered and advancement to IoT-based fire-detection strategies and systems (Y. C. Zhang & Yu, 2013). With IoT, the output signal of a detector is analysed to classify fires and false alarms can be ignored.

Various sensors can be deployed in the wireless sensor network to provide, real-time signals and accuracy in fire detection. These tiny, low-power sensor devices have the ability to sense their surroundings and provide quick signals as a medium of alert. Within the IoT technology, reducing the number of false alerts can be done by the use of Global System for Mobile Communications (GSM). The GSM strategy is desirable due to its ability to cope up with incidents of sensor malfunctions. Therefore, over the past years, IoT and its systems has showed great reliability for fire detection and its advancement rapidly continues to evolve due its countless advantages such as remote management, real-time monitoring, and data-driven insights.

Despite all the above, the success of these IoT systems heavily relies on various factors such as the technology implied, implementation measures, and maintenance techniques setup (Singh et al., 2025a).

Applications of IoT in fire fighting

- *Buildings, malls, offices*

The growth and development of the world has accelerated the need for tall buildings with better designs. However, some of their designs and interior finishing products are highly flammable and this raises the need for modern methods to protect the buildings against sudden fires, and also to prevent fire from rapid spread in case of the incident (Liu et al., 2025). These tall buildings include places like offices, malls all which need protection due to the important materials that they contain.

Due to their height and population density, when tall buildings go under fire disaster, there is a high risk of losing people's lives and significant property (Kim et al., 2024). Therefore, personal safety for people within the dangerous environment, fire fighters, and property protection must be highly considered during the plan of fire disaster prevention (Khan et al., 2022). Thorough methods to create alerts to help people evacuate the buildings and escape to safer and secure areas must be carefully considered. However, the timeliness of evacuation and rescue advice directly determine the outcome of the fire disaster (Hsiao & Hsieh, 2023a). This can be properly done by real time systems.

Several researches have been done on how these buildings can be protected using intelligent technologies and have shown good results in providing real-time fire protection systems and rescue operations in tall and busy buildings. According to the existing research, it has been found out that IoT can be used to monitor fire outbreak signs and provide early warning of fires in modern tall buildings (Hsiao & Hsieh, 2023b), (Shen et al., 2025),

(Z. Zhang et al., 2024) proposed the IoT-based DWM-Evac model for fire emergency evacuation path planning. The model implied IoT technology by using various sensors placed inside buildings to monitor fire incidents and spread in real-time, collecting critical data such as temperature, smoke concentration, and flame location. The research confirmed that the

application of IoT in managing fire improves response speed, optimizes path planning, and enhances personnel safety.

In addition to the above, (Saini et al., 2022) presented an intelligent evacuation system that combines Internet of Things (IoT), fog layer, and cloud layer. The system applied IoT technologies to capture environmental information, and the location of occupants to track their movements while the Fog layer was employed to detect emergency events using Support Vector Machine and the result indicated that the simulations of framework could efficiently and accurately guide evacuees to a safer location thus reducing direct fire exposure.

Furthermore, in tall buildings, IoT can be used to increase the use of automatic feature learning and multi-fusion systems, which has demonstrated significant improvements in detection accuracy. These automatic features for smoke and fire detection are widespread in residences, businesses, and shopping centres (Beyond Boundaries Advancements in Fire and Smoke Detection for Indoor and Outdoor Surveillance Feeds, n.d.).

- *Homes fire warning systems*

The rise of smart homes due to urbanization has improved living standards. However, home environments have high-risk zones for fire hazards due to their dense occupancy patterns and complex structural configurations. This pauses the need for modern methods in fire-detection and early fire-warning systems in intelligent building management platforms. The technology enables real-time monitoring, predictive analytics, and automated emergency response mechanisms, thereby significantly improving fire prevention capabilities. When properly deployed in smart homes, IoT-enabled fire-detection systems can create building protection solutions, integrate with other safety protocols, and, enhance system reliability (Strand & Kristensen, 2024), (Alam et al., 2024).

Currently, IoT can be applied in homes to protect homes and save people's lives in times of fire outbreaks by providing warnings and alarms in

case of fire outbreaks. Some IoT systems can power a smart home with just a simple tap from a human finger and can also serve as a self-powered switch for fire warning (Rana et al., 2021). (Shi et al., 2022) developed a system that can manage home automation, real-time monitoring for fire, smoke, gas leaks, network scans, anomaly detection, appliance usage tracking, and cloud data backup.

Other researchers considered the fact that the kitchen is one of the most crucial spaces in a house and rises safety issues caused by fire usage for cooking. The issues considered included uncontrolled fire, gas leakage and extreme temperatures. The researchers considered how to address these issues based on IoT technologies (L.-W. Chen et al., 2024).

- *Industrial fire warning systems*

Urbanization in the present world has led to the rise of many industries. These industrial areas contain dangerous components in case of fire break out such as Liquid storage tanks which are usually located in important areas of a city

Due to their importance, these tanks are usually placed in industrial areas or ports, and in the event of a fire, it may affect all aspects of the city by spreading to the surrounding residential areas, commercial districts and transportation arteries (Dong et al., 2023), (Abbassi et al., 2015).

Relying on the Internet of Things perception and identification technology to improve the intelligent level of fire protection facilities improves the reliability of the system, and effectively controls disaster accidents and enhances early emergency response capabilities (L. Deng et al., 2025).

- *Forests fire warning systems*

Environment is a very important resource to human beings as part of the ecosystem, and is beneficial to the universe as a whole. This is because these forests act as habitat for wild animals and also help to improve the universe's weather. Any threat of forest fires poses severe risks to the ecosystems and human habitats, primarily due to the greenhouse effect and sudden climate

changes (Jaber & Alkhatib, 2025). Therefore, there must be modern ways to detect and control these sudden fires.

Currently researchers continue to focus on forest fires using trending technologies. A research carried out by (Lertsinsrubtavee et al., 2023) focused on the use of IoT air quality sensors to detect forest fire incidents by focusing on an area affected by forest fires. An existing number of hotspots reported through satellite and human observations was used to identify forest fire incidents. The data analysis revealed three distinct periods with forest fires and three periods without fires (non-forest fires).

As a matter of significance, avoiding forest fires is vital as forest fires and agriculture-related burning poses significant health and respiratory risks to millions of people (Lertsinsrubtavee et al., 2023). The fires are a hazardous and destructive disaster that may cause economic and ecological damage. When let to occur, local ecological conditions such as weather, water and soil are out of balance and often take decades to centuries to recover (Zhan et al., 2022).

- *Airports fire warning systems*

Airports are a very sensitive place that accommodates a lot of travellers both day and night. These infrastructure face fire risks due to a combination of flammable materials, complex structures, and heavy operational equipment. Such a busy place needs to be secured from any disaster in an effort to protect people's lives and property. This is more driven by the evolving landscape of aviation and increasing passenger expectations that necessitate a proactive approach to fire safety.

Keeping such an environment safe does not only need a physical security but more effort must be applied in employing intelligent systems. This is because aviation transport infrastructure is essential in international commerce and cultural exchange thus, any emergency may cause major impacts on the society (Yulong et al., 2025).

Airports usually have complex structures due to the high-rise buildings, large open spaces, underground infrastructures with diverse functions, and a high population density requiring safer measures for exit in case of disasters (Wong et al., 2025). If not carefully planned with clear emergency exit sign systems, the complexity of the built environment puts the occupants lives at high risk during emergencies, particularly in fire incidents.

An existing study used a case study of the waiting hall of a Chinese airport to analyse major factors such as fire, personnel, exit, and path, and predicted evacuation time for different exits (Junpeng et al., 2017). The findings indicated that an intelligent decision-based model can evenly distribute evacuees in the space; in an environment with all exits open. The researchers further confirmed that the evacuation time could be reduced by 27.75% and the maximum difference in evacuation time between exits became only 16.03s thus making it possible to save more lives in case of a fire outbreak.

- *Transportation fire warning systems*

In the present word, transportation ranges from transporting people to goods and services. Different modes of transportation can be used such as buses, air, trains, lorries and trucks for transporting cargo (Paś et al., 2022a). While performing their services these categories need protection against any disasters, fire inclusive (Paś et al., 2022b). Intelligent techniques can therefore provide strategic benefits in smart city systems and improve various aspects of urban life (Cengiz et al., 2025), (Sourav et al., 2020).

More so in cities, high traffic flow in a confined tunnel makes fire safety a critical issue (X. Zhang et al., 2024). IoT has be used to utilize dynamic sensor data and AIoT technologies to create frameworks for tunnel fire safety management in real-time. One of the existing researches used an AI model in predicting the tunnel fire scenarios and attained an overall accuracy of 98% (Wu et al., 2022).

Other existing frameworks include a digital twin framework for tunnel fire safety management in real-time (X. Zhang et al., 2024). These intelligent digital twin systems can be used to collect, manage, process and visualize the tunnel fire information (Wu et al., 2022). Apart from being applied in transportation, the digital twin framework can also be applied in different areas such as agriculture, aerospace, cities, electricity, construction, supply chain, offshore, healthcare and manufacturing services to simulate and create connection between real mentioned fields and virtual fields mostly during fire events. This helps for real time fire safety management by the help of sensor data and IoT technologies (X. Zhang et al., 2024). According to existing studies, IoT works well in firefighting if implemented with other technologies, such as AI and embedded systems to produce more advanced systems. The different fields can be illustrated as shown in figure 1.

Fig. 1: Applications of IoT in firefighting

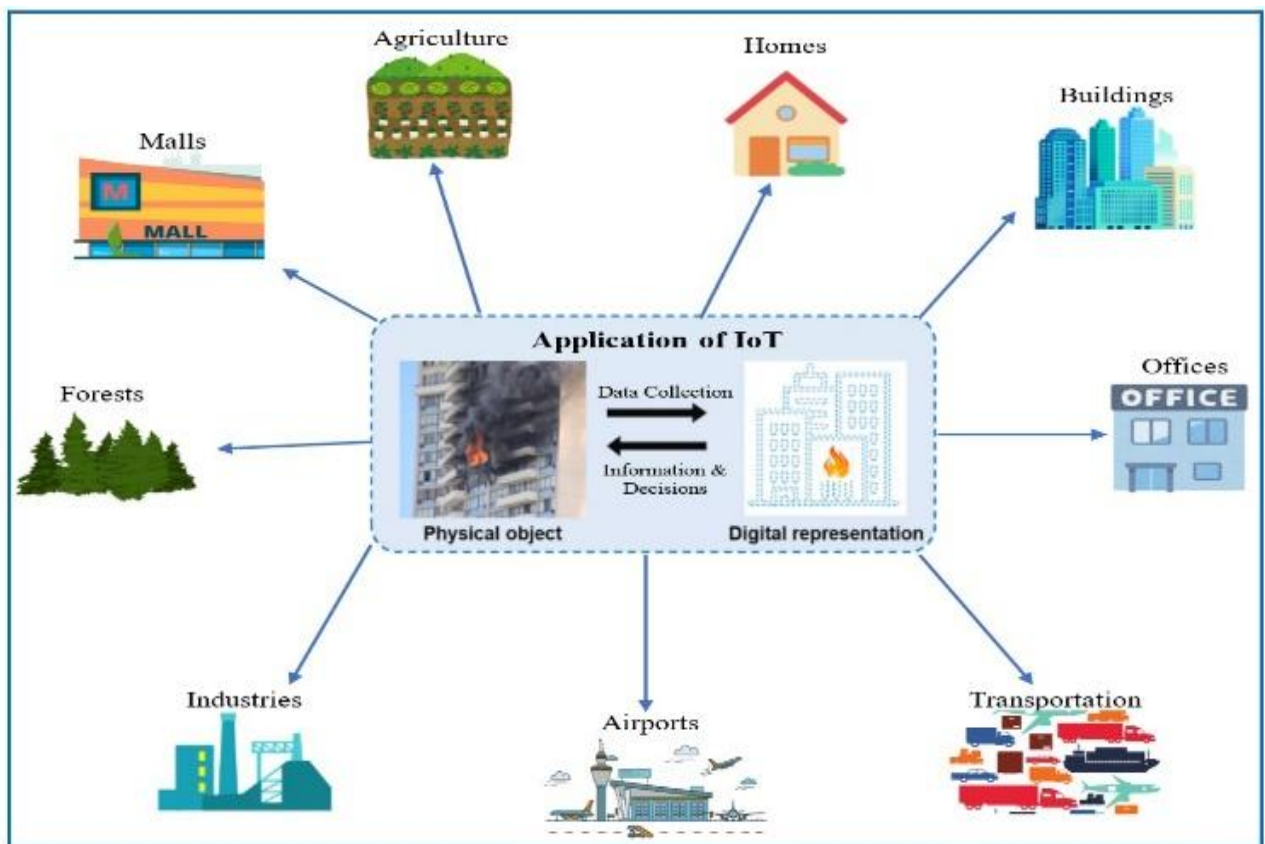


Table 1. A summary of the recent research papers that focus on firefighting based on IoT.

Year	Area	Contribution	Reference
2025	Agriculture	Developed a fire detection and anti-fire security system in smart agriculture using IoT and an embedded system.	(Morchid et al., 2025)
2024		Presented an advanced IoT system architecture for early fire detection, enabling real-time collection and analysis of environmental data.	(Morchid, Oughannou et al., 2024)
		Developed and implemented a real-time fire detection system tailored for smart agriculture.	(Morchid, Jebabra, Ismail, et al., 2024)
		Introduced a fire detection system with the use of IoT and Message Queuing Telemetry Transport protocol.	(Morchid, Jebabra, Qjidaa, et al., 2024a)
2025	Aviation/ Airports	Developed an integrated system for enhancing the resilience of airport firefighting in modern airports	(Yulong et al., 2025)
2017		Built a fire-evacuation digital twin system and put forth a digital-twin-based airport-terminal-fire-scene modelling theory from four perspectives.	(Junpeng et al., 2017)
2025	Tall buildings	Proposed a concept of smart firefighting that integrated fire sensors with IoT to enable intelligent fire monitoring.	(Shen et al., 2025)
2023		Proposed and prototyped a real-time fire protection system architecture for disaster prevention, evacuation, and rescue operations in buildings.	(Hsiao & Hsieh, 2023b)

2024		Proposed an IoT-based DWM-Evac model for fire emergency evacuation path planning.	(Z. Zhang et al., 2024)
		proposed a novel AIoT-integrated Digital Twin system for a full-scale multi-floor building to manage the dynamic fire information.	(AIoT-Powered Building Digital Twin for Smart Firefighting and Super Real-Time Fire Forecast, n.d.)
2025	Construction Industry	Integrated IoT, BIM, and GIS technologies, especially in construction resource monitoring, to fight disasters like sudden fires.	(Liu et al., 2025)
2024	Transportation	Developed an AIoT model for predicting and real-time managing fire locations in transportation tunnels.	(X. Zhang et al., 2024)
2022		Proposed an intelligent system and digital twin to collect, manage, process, and visualize the tunnel fire information	(Wu et al., 2022)
2024	Forests/ environment	Introduced a concept of a fire detection system with the use of (MQTT) protocol and IoT.	(Morchid, Jebabra, Qjidaa, et al., 2024b)
2020		Developed a forest fire detection system using wireless sensor networks and Unmanned Aerial Vehicles based on IoT and image processing.	(An Integrated Fire Detection System Using IoT and Image Processing Technique for Smart Cities, n.d.)
2023		Demonstrated the use of IoT air quality sensors to detect forest fire incidents.	(Lertsinsrubtavee et al., 2023)

Table 1. Some of the latest and most related research papers that have proposed and developed firefighting systems based on IoT and other combined technologies.

The benefits of using IoT in firefighting

The incorporation of the Internet of Things (IoT) in firefighting comes with various advantages that improve fire detection, prevention, and response efficiency. Fire detection systems powered by IoT incorporate real-time data collection from sensors like smoke and flame detectors to enhance the early warning capabilities (Morchid et al., 2025). As a result, alerts can be sent to household owners, service emergency providers, or even farm owners immediately, thus eliminating substantial damage. IoT monitoring also allows the tracking of environmental parameters, which is important in identifying potential threats before they turn into emergencies (Khan et al., 2022).

The use of IoT protocols such as MQTT enables the real-time transmission of data from sensors to cloud platforms from where the response teams can access it thus, promoting swift action (Morchid, Jebabra, Qjidaa, et al., 2024b). Furthermore, the modularity of these systems permits the addition of new fire monitoring equipment without compromising the already existing structures (Singh et al., 2025b).

The application of the Internet of Things is an effective tool for boosting agricultural sustainability and food security. The automation of some responses such as sprinkler activation ensures rapid fire outbreak control thus ensuring smart agricultural (Morchid, El Alami, et al., 2024). These IoT based fire detection systems work in a way that aids in preventing wildfires that may lead to losing agricultural resources.

Challenges of firefighting using IoT

The process of fire detection using IoT involves the collection and transmission of sensitive data. Therefore, ensuring data security and privacy is essential to protect against unauthorized access and potential cyber-attacks. On the other hand, the process involves several challenges that act as a standing block to successful firefighting. First, IoT devices rely on stable and reliable connectivity to transmit data. Network failures or communication issues can

lead to delayed or missed fire detection alerts, compromising system effectiveness (Singh et al., 2025a).

Ensuring interoperability between different IoT devices and platforms can be challenging, especially when integrating multiple vendors' solutions. Standardization efforts are crucial to foster seamless integration. IoT fire detection systems should be designed to minimize false alarms caused by environmental factors, device malfunctions, or other non-fire-related events. Frequent false alarms can lead to complacency and reduce the system's credibility. Regular maintenance and timely software updates are essential to keep IoT fire detection systems functioning optimally. Balancing the benefits against the cost is essential to justify the adoption of such systems.

Discussion and Conclusion

In this review paper, the researchers aimed at reviewing firefighting systems based on IoT. The review was aimed at understanding the common causes of fire that necessitate intelligent firefighting systems, the various areas/fields in which firefighting systems are commonly applied and, the existing challenges, and benefits of firefighting systems based on IoT. The research found out that these systems can be applied in various fields such as agriculture, construction industry, transportation, aviation, and smart city.

The researchers concluded that in order to develop modern and more efficient firefighting systems, IoT needs to be combined with other technologies such as embedded systems, image processing, Message Queuing Telemetry Transport protocol (MQTT) protocol, BIM, and GIS technologies. This not only helps to produce real time systems but also ensures accuracy of the developed systems.

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