IoT Based Low-Cost Fire Detection Alarm System for Safety of Buildings

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ABSTRACT

IoT (Internet of Things) is dominating all over the world for developing technology. It is another information industry following the computer, internet, and mobile connection. In modern society, we must ensure security for leading a comfortable life. Nowadays, security has been affected by different types of matters. Fire and smoke incidents are considered among them. At present, there are many undesirable accidents from Fire and smoke incidents. One way to prevent accidents involving Fire and smoke incidents detection is to affix a Fire and smoke incident detection device at adequate places. Indeed, when the Fire and smoke incidents occurs, then the temperature can be increased naturally. Our proposed work, a simple system using low-cost devices, has been designed to send a phone call, notification to the user via the GSM module in case of any Fire and smoke incidents. It also sends data to the alarm, alerting the users and sending a graphical alert to the server via NodeMCU. This proposed work will contribute if Fire and smoke incidents occur at home, office, shopping malls or in the industry, then people can take the necessary precaution in advance.

Keywords: IOT (Internet of things), low cost, Alarm system, fire and smoke, phone call, water sprinkler.

1. INTRODUCTION

With the rapid growth in population, buildings are also growing vertically due to the shortage of occupancies. However, with these buildings growing vertically, there arise problems regarding the safe evacuation of people during an emergency like a fire. Similarly, with the growth of insulating materials which catch fire easily and their excessive use in building, a threat to the life of building and human is also increasing. Many people are killed every year, and more are hospitalized due to the fire in India. An average of 520 injuries and 40 deaths occurs per year according to the data provided by NFPA.

A fire Accident occurs very rarely, but once it occurs it's consequences will be devastating. As a result, there is substantial attention given by researchers worldwide for the development of intelligent building systems. Many of these casualties can be avoided if we detect a fire early and guide people to a safe location. To build a suitable fire detection and safe evacuation system it is necessary to focus on parameters such as appropriate sensors, software and hardware tools, and combination techniques and at the end effective user interface. This article gives systematic reviews of intelligent fire detection and evacuation system as a combination of fire detection (sensors, technology), evacuation assistance (Static/Dynamic Display) and crowd monitoring and prediction (Video, non-video, GPS, Bluetooth). Besides, the review is evaluated based on (i) fire and building simulation software, (ii) suitable hardware (with their merits and demerits), (iii) fire and smoke detecting sensors, (iv)communication methods and (v) effective user interface for a safe exit.

In this, efforts have been taken to identify research gaps, and suggestions are made to fulfill the need. Further, a novel architecture is recommended for future fire detection and safe evacuation system.

2. LITERATURE SURVEY

Early detection of fires is important to save the life of human beings as well as property. In this case, multiple sensors need to be installed at different places of the building which plays a crucial role [1]. A system based on Lab VIEW is proposed to detect and alert fire events in [2]. A portable community video surveillance system developed in [3] can be used to detect people's motion. Environmental parameters such as temperature, the concentration of toxic gases are measured and monitored in [4] using Node MCU and sensors. In [5], Low-cost IoT based evacuation Service is implemented for real-life situations of Building Automation System (BAS) applications. The Mobile terminal-based system is discussed in [6][8] which provides a 3D interactive model of building and guide evacuees to exit safely. In [9], the author proposed an FPGA based fire warning and multi-door control system which provides the information on the floor where the fire occurred. The integration of IoT with WSN would be effective for fire detection and alerting application [10]. RFID devices and wireless sensors have been used to detect environmental conditions and image identification techniques and digital signage are used to guide people through a safe route [11][13]. To enhance evacuation, plan a Situation-Aware System is used in which end-user specific business rules were created that practically helps actions concerning evacuation plans [14].
Building Information Modelling (BIM) tools can be used to create a virtual environment for fire emergency evacuation [15], [16]. A rescue operation during fire emergency can be fastened using cloud-based Rescue Worker Interface (RWI) which assists rescue warden by proving real-time information of building fire, the flow of fire, people density, and position of remaining warden [17][18]. In [19], the author proposed a system which formulates real-time evacuation path based on real-time data acquisition and calculations of risk distributions. In case of fire events system provides directional guidance concerning the time and location of fire accidents [20]. GIS and IoT technology is used to obtain information about the building. Further, the evacuation path has been estimated using Matlab [21]. ZigBee based fire alarming and prevention system is proposed in[22].In [23], a motion detection sensor based person detection technique is discussed for IoT based fire evacuation assisting system. A sudden change in the motion of an individual in-crowd is detected by the optical flow model [24]. Indoor navigation and evacuation can be improved using a mobile terminal based app like Easy Go [25]. To deal with outdoor evacuation UAV is preferred [26]. LoRa, which is low power and long-range communication technology, is introduced in [27]. In [30], the author suggested a system with a mesh network of fire sensor, and path planning strategy which detects fire event alerts about an emergency to occupants and fire services.
A detailed comparison table is being depicted in Table1.

Table1. Comparison of hardware, fire sensing devices, simulation software, communication technology and user interface used by various researchers

Source	Hardware/Technology	FireSensing Devices	Simulation Software	Communication Technology	User Interface
[1]	Raspberry Pi	LM 35Smoke SensorGas Sensor (MQ9)	FDS	GSM	No work on evacuation
[3]	nRF24L01 transceivers, Laptopwith Arduino	IR Flame Sensor	PythonMATLAB's roboticsPackage	RF transceivers	HTML/CSS based website
[5]	Ardunio	RFM23B RFID, LM35, HC-05,PIR Sensor	BIM	Bluetooth	Audio Signal, SMS on user mobile.
[4]	Mobile Phone with RFIDReader capability	RFID tags	Path Planner, Viewpoint Calculator, and MobiX3D	RFID technology	Mobile phone-based App
[7]	Mobile Phone with NFC and RFID reader	Active temperature and RFID sensor tags	MobiX3D, Viewpoint Calculator	RFID, Cloud Computing	Mobile Phone
[9]	FPGA, Microcontroller	Temperature Sensor	TimeNET	Wireless Transceiver	Direct Alarm System is provided at each floor
[12]	Zigbee, RFID	Temperature, Humidity, and Light	MySQL Database	WSN Technology	LCD Display
[17]	Microcontroller	Smoke	BAS(Building Automation System)	Cloud	App on Smartphone
[21]	IoT, Arduino	LM35, HC-05, PIR Sensor	BIM	Bluetooth, RF Communication	Audio Signal, SMS on user mobile.
[31]	Turtlebot2, Parrot AR. Drone 2.0& DJI Phantom 4	Illuminance sensor, Arduino Uno as a sensor	Google Map	Wireless	Application Mobile
[50]	IoT, Microcontroller	Temperature, CO, OpticalDensity Sensor	GIS, Matlab	wireless sensor Network	Fire Alarm, Emergency Lightening system

3. DEVELOPMENT IN FIRE DETECTION AND EMERGENCY EVACUATION

3.1. Fire sensing, sensors and devices

It involves a Multi-sensor module for sensing parameters like heat, smoke, flame, gas etc.as depicted in Figure 1, with signal conditioning, amplifier circuit, processing unit, alarm system, and safe evacuation path display [33].

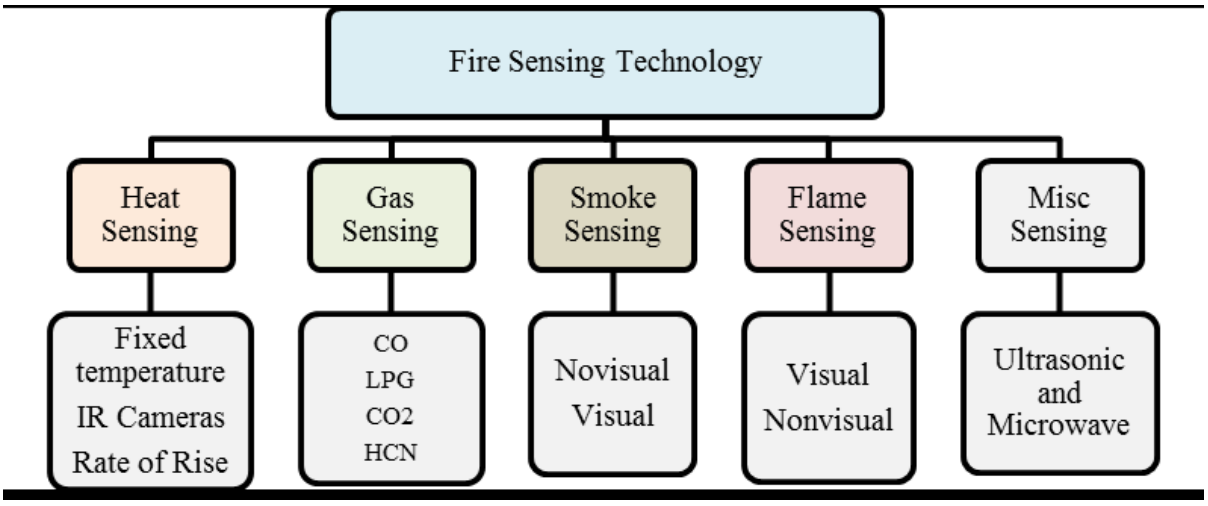

Figure 1. Fire sensing technologies[31]

3.2. Hardware platforms

After detecting a fire event it needs to be processed for further course of actions, for which effective hardware platform plays a key role. Figure 2 shows the block diagram of the fire alarm system. Many hardware devices are used by researchers till now.

3.3 Simulation tools

3.3.1. BIM

Building Information Modeling (BIM) provides the facility to make a layout in three-dimension (3D) and carry out disaster prevention activities. Specifically, it is used in the design of fire sprinklers and an alarming system. e.g. BIM 360, AutoCAD, Revit, etc. A 3-dimensional building evacuation and guidance system overcomes the problem of poor visibility in 2 dimensional based systems. The basic use of BIM technology is the exchanging and processing of building information, so the architecture of the fire evacuation system can be designed. BIM-based 3-dimensional model is very close to a real-time scenario and it is proven that this model helps to provide information such as rescue conditions, evacuation paths, etc[35].

3.3.2. GIS

Spatial or geographical information can be achieved through a software tool such as a geographic information system (GIS)[36]. It contains activities such as capture, store, manipulate, analyzes, manage, and present. GIS and CAD integration helps to visualize geospatial information from various locations of the building during a fire emergency. The GIS is used to simulate evacuation environment and to visualize evacuation process. In [37], the author presented a multi-agent-based fire evacuation model, in which GIS is used to capture the geospatial data of agents and trace its location and provide a safe exit path.

3.3.3. FDS

Fire Dynamics Simulator (FDS) is a fire-driven fluid flow model with computational fluid dynamics. It is a sort of a simulation tool developed by NIST's Building Fire Research Laboratory. FDS can analyze three-dimensional fires very quickly [38]. This enables simulation of smoke and heat transfer from fire, besides, FDS provides a fire detector and water sprinkler analysis. Pyro Sim is a kind of simulation tool can be used as a Fire Dynamic Simulator (FDS). It can also be used to simulate the motion of people.

3.3.4. MATLAB

MATLAB based image processing can be used to detect a fire accident. Any CCTV camera mounted in the building premises will take the input image for the device from video in real-time. Initially, we need to separate the fire and background from the received image using the color segmentation method. Further, fire growth is estimated by comparing two consecutive fire images. If fire growth continues over certain images, the emergency alarm is switched on and the computer screen displays the real-time video with the fire indication in red color. MATLAB robotics package has been used to perform path planning. MATLAB AHP toolbox can be used to calculate available evacuation paths and avoid high-risk ones based on the information of the properties, people density, and evacuation distance. Figure 3 displays color segmentation with a five frame difference in the image processing methodology adopted for fire detection based on MATLAB.

4. RESEARCH GAP AND SUGGESTIONS

4.1. Long range communication technology

Connected devices have so far running on traditional protocols like Bluetooth, Wi-Fi, and Cellular Network, etc. But embedded sensors and other IoT devices have different network requirements like low power, long-range, etc. The basic architecture of LoRa can be seen in Figure 5. To meet these requirements one can go for LPWAN, LoRa. LoRa is a Long Range, low power wireless, low data rate communication protocol built to construct an IoT network [40]40[41]. LoRa uses sub-gigahertz radio frequency bands which are license-free. It provides long-range transmissions (1-15 km) with low power consumption.

5. NOVEL ARCHITECTURE FOR FIRE DETECTION AND EVACUATION

Early detection of fire helps to reduce major casualties and saves the life of human beings and property. In the view of this general architecture of smart fire detection and evacuation system is suggested in Figure 7. It is constituted by end devices, Controlling unit, Central Controlling Unit, and End-user Interface. Popular communication technologies such as Bluetooth, wifi, LoRA, etc. are used in the proposed system.

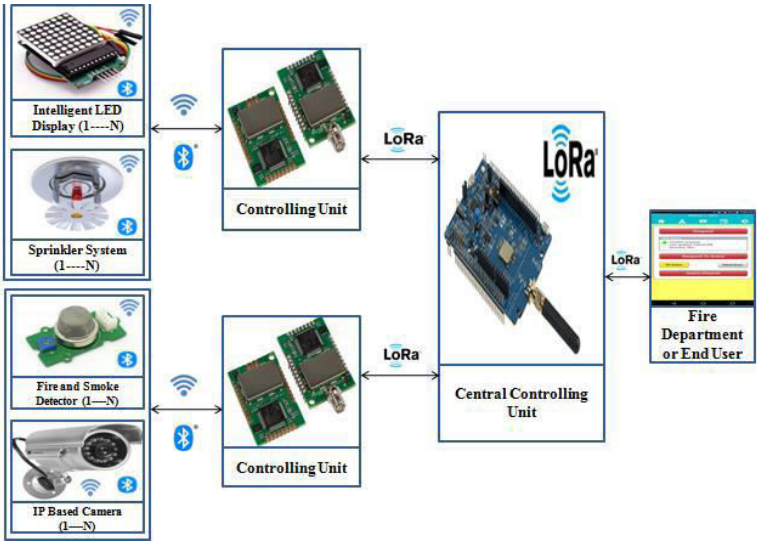

Figure 7. A novel architecture for fire detection and evacuation system

5.1. End devices

The key component of our system is end devices, which play the role of collecting valuable data. The collected data like temperature, humidity can be used to decide the fire accident and take further action. These end devices involve sensors such as temperature sensor, smoke sensor, humidity sensors, actuators such as sprinkler system for controlling fire, IP based CCTV for finding the flow of fire and detecting number people inside the building and led display for guiding people to safe exit [47]7[48].

5.2. Controlling unit

These devices are controlling the end devices through Wi-Fi and or Bluetooth. They are capable to collect data from sensors and cameras and further based on programming it will actuate the sprinkler system and LED display accordingly. The controlling unit can be of any microcontroller/Microprocessor-based system such as Arduino, Raspberry Pi, ESP8266, etc. It is enabled with a wireless protocol such as ZigBee [49].

5.3. Central controlling unit

It acts as a mediator between the controlling unit and the end-user application. In this case, to communicate with end-user such a fire department we need long-range communication technology. LoRa is a long-range communication technology that contains Long Range communication capability hardware.

5.4. End-user interface

End-user such people inside the building should know the status of fire accidents on their mobile phones. It is possible through a mobile-based Android app [32]. It is also necessary to inform the authorized fire department regarding fire accident with live status and location. Mobile or desktop-based applications will act as a user interface for the evacuee and fire department [50].

6. CONCLUSION

With the rapid growth in technology, the life of human beings is changing enormously as things are becoming smarter. In the era of modern technology and lifestyle, we should think about human safety and security in an emergency condition. Fire accident is one of the dangerous events which need to be addressed effectively with the help smart technology. Because of this, we have surveyed the available methods and systems for fire detection and evacuation systems. Detail analysis is done according to parameters such as sensors, hardware platforms, software tools, and user interface for safe exit during an emergency.
We have identified some areas where still improvement is possible, and it can be done with advanced methods such as (i) LoRa for long-range communication, (ii) customized hardware for more reliability,(iii) Dynamic display guide, and (iv)people density for safe evacuation are suggested. To overcome the issues with the existing system we have proposed a novel architecture for smart fire detection and evacuation. The proposed architecture involves accurate and early sensing of a fire event, IP cameras for tracing people inside building under fire, LoRa for long communication, Zigbee for inter-node communication, actuators to enable sprinkler system and effective user interface.

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