Improved Fire Safety and Protection Model for Smart Buildings with Internet of Things

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ABSTRACT

The expansion of smart cities around the world in recent years has necessitated the protection of building infrastructure and the environment from the possibility of a fire outbreak. Existing fire safety and protection systems have to be upgraded for optimal usage with Internet of Things-enabled equipment in smart buildings, necessitating the creation of a better fire safety and protection model for smart buildings in the context of smart cities. Sensors detect and report conditions surrounding a fire occurrence in this project, which uses Internet of Things-enabled devices to provide fire safety and protection services for smart buildings. In order to determine the fire state in real time, flame and gas sensors were put in the smart building. The design was modelled, simulated, and constructed using Proteus software with code written in Arduino IDE, and the data gathered from the design was evaluated using ThingSpeak, which has MATLAB software capability. After demonstrating this upgraded model in a 3600m × 3600m smart room, the result obtained shows that within the temperature of 21 to 37^{o}C, there was no fire detected in the building, whereas, temperature above 53.5 to 58^{o}C indicate the presence of fire in the building. Similarly, the smoke sensor value at 24ppm shows that there is no smoke in the building, while at 56ppm and above indicates that there is smoke in the building. An attempt will be made to demonstrate it in a huge smart city environment.

CCS CONCEPTS

- **Hardware Sensing System; Deployments of Sensors; Fire Safety and Protection; Internet of Things**;

KEYWORDS

Fire safety, Fire protection, Improved Model, Internet of Things, Smart buildings

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1 INTRODUCTION

A fire breakout results in significant loss of life and property valued in the millions of naira. A little flame can quickly grow into a huge inferno and spread throughout a building in minutes. This can be mitigated or avoided if flames are identified early and the appropriate procedures to extinguish them are taken. Early identification of emergent fires, as well as informing building inhabitants of the need to evacuate and notifying emergency fire response groups, are all aided by fire detection and alarm systems. The endeavor to build automatic fire detection systems has been expanded in recent years, and sensor-based detection has become a popular way of fire detection [1].

By detecting the presence of fire or smoke and sending warnings to building inhabitants and fire emergency services, the Internet of Things (IoT) allows fire detection devices to collect data from their immediate surrounding. As a novel technology, the IoT is being used in smart city fire safety and prevention [2]. Although house constructions can utilize a simple fire detection system, smart buildings require sophisticated fire and smoke detectors that respond to the smoke or gas created by a fire [3].

The major goal is to develop a smart building fire prevention and protection plan. The sub-tasks listed below helps to create a fire detection system that uses IoT-enabled devices, as well as a system that can extinguish flames if fire occurs. Also, it enables real-time monitoring of the state of the smart building via a mobile application, construct a signal transfer mechanism for fire control agency assessment, evaluate and analyze the fire prevention and protection strategy for smart buildings design performance.

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2 RELATED WORK

[4] opined that a system based on a network of several interconnected nodes distributed throughout a house is simple to develop and install. Each node could contain a microcontroller with embeded devices (Wi-Fi) connected to detect flame, smoke, temperature, CO_2, and humidity sensors that continuously sense the environment for the presence of fire is simple to develop and install. The interlinked nodes in their model constituted a Wi-Fi network, and the Raspberry Pi microcontroller with a 4G module was designed to communicate with a centralized node linked to the sensing nodes via a bridge node. When a node detects a fire outbreak, the system sends a text message to the owner and the fire department, albeit there is no remote access for users (mobile app) because all existing access points are web based. [5] designed and constructed a wireless sensor network with many sensors for early detection of residential fires. For notification messages, a Global System for Mobile Communication (GSM) was implemented into the design. Overall, the system was able to identify fires early, even when the sensors were not operating, while maintaining the energy usage of all sensors within acceptable ranges. [7] investigated the design and implementation of a system that takes readings from the microcontroller and uses the GSM communication module to notify users and fire service workers of the presence of a fire. In comparison to traditional wireless fire alarms, the proposed method was less expensive and redundant.

For the fire alarm system, [8] attempted developing fire detecting system by utilizing Arduino and Raspberry Pi. This method proved effective in detecting and notifying the impacted area of the fire. The device can also alert the fire department if there is a rise in fire activity, which can assist in the early suppression of the fire. [2] employed a method that worked well in giving real-time notification to homeowners and firefighting authorities via distress sound, light alarm, and SMS messaging. The system was quite effective and efficient in detecting fires, but it was also quite costly. [9] employed an ATEMega8 microprocessor with audio/video receiver, as well as fire sensors and a computer architecture with a smaller instruction set. The prototype was a success, according to the findings of a test conducted in the most optimal manner feasible, based on a near-real situation. However, improved sensors and server functions were required to meet a wider range of Internet of Things requirements.

High cost of refurbishing structural infrastructures and the facilities around industrial building after fire outbreak necessitates the need to develop a sophisticated system capable of monitoring the building against and also protecting the system in case of unforeseen fire occurrence among other already existing schemes. This research demonstrates the capability of deploying IoT in fire safety and protection scheme accurately.

This improved fire safety and protection model for smart buildings incorporates features such as real-time updates of the state of the smart building in the mobile app, the system also depicts the exact location of the fire by displaying the coordinates of the location to the fire safety agency, and also shows the fastest route possible to get there using Google Maps.

3 SYSTEM DESIGN

The creation of a fire safety and protection model for smart buildings proposed in this paper uses an experimental approach. Hardware components used in the development of the system, includes Atmega 328P, Flame sensor, Gas sensor, water pump, resistors, relay, and Wifi-Module. Proteus, Arduino IDE, and Android Studio are some of the programs used in simulation and circuit design of the proposed system.

Figure 1 shows the system's block diagram and demonstrates how various sub-units are linked together to build a fully functional system. For the fire prevention and protection strategy for smart buildings, these are separated into sections that work both independently and collectively. The sensing unit is made up of sensors that detect flames or gases in the environment. The temperature sensor, measures the temperature value of the smart building, this is also included in the sensing area. The sensors give data to an IoT-enabled microcontroller, which then sends notifications to the smartphone. The actuating unit contains the water pump for extinguishing the flames, when needed, as well as the buzzer, which emits a ringing sound to alert the building's occupants.

3.1 The Electrical Design

This system is built with three sensors (gas, flame, and temperature) and is programmed so that if any of the sensors detect conditions surrounding a fire, the controller activates and deploys the protection system, which greatly reduces the intensity of the flames while also sending notifications to appropriate authorities.

The model was simulated in Proteus, with the smoke and flame sensors returning values when smoke or gas was detected in the environment as shown in Figure 2. The green LED shows a safe environment, whereas the red LED indicates the presence of conditions around a fire (smoke and gas). An alert is triggered, and the pump is turned ON/OFF to lower the intensity of the flames by pouring flame retardant substance on the fire source. Notifications are also transmitted to the smartphone application, allowing firefighters to respond quickly. Figure 3 shows the sequence of operations of the improved fire safety system as it deploys the IoT capability in fire management in smart building.

3.2 Mobile Application Interface design

The built Android mobile application for users and the Fire Service agency is shown in Figure 4. In this design, the user must register with the building's resident information verification is then sequentially handled for security reason using their email address and password. The mobile application displays information on the buildings once a user has logged in. In the Android Studio IDE, the mobile application was created using Cascaded Style Sheets (CSS), Hypertext Mark-up Language (HTML), and JavaScript.

3.3 Implementation of an Improved Fire Protection and Safety Scheme for Smart Buildings

Figure 5 depicts the improved fire safety and protection model created for smart buildings; this was demonstrated the model with three sensors in a 3600m x 3600m apartment. The model was created

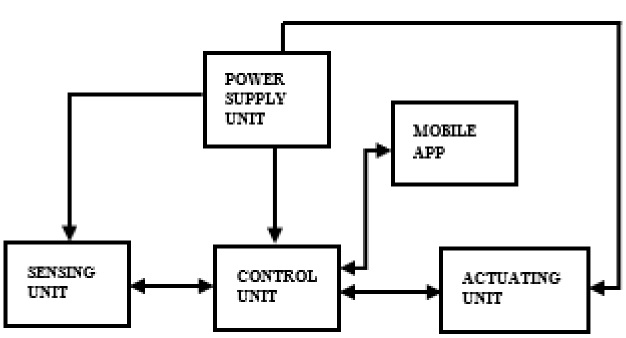


Figure 1: Block diagram of the Improved Fire Safety and Protection Model for Smart Buildings

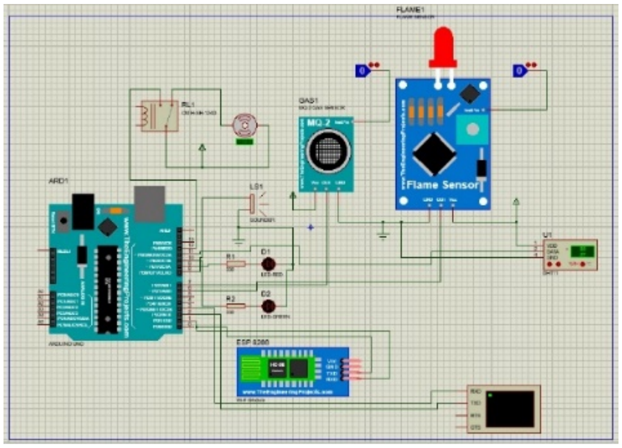


Figure 2: Circuit diagram of smart IoT system for fire safety applications

to detect the presence of fire or smoke generated by igniting a flammable material and transit to the controller from any of the gas or flame sensors. The data received from the sensors was then transmitted over the internet to the mobile application, where an alert notification was retrieved on the phone.

Similarly, by detecting the degree of temperature in the smart building, the model uses the temperature sensor to improve system performance. This system detects a temperature three times that of the room and predicts a fire.

Although, the already fire safety and protection scheme seems not to have accurately suffice the incidence of fire outbreak completely. Hence, requires an enhanced model proposed in this research work with IoT capabilities. Sensors are deployed to determine the smoke and fire status of the smart building with the status referring options for the occupants and fire combating agency.

4 RESULT DISCUSSIONS AND DESIGN VALIDATION

When the system was tested and presented, the experimental approach used in the creation of the Improved Fire Protection and Safety Scheme for Smart Buildings yielded results.

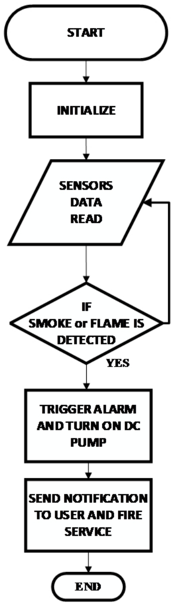


Figure 3: Flowchart of the Improved Fire Protection and Safety Scheme for Smart Buildings

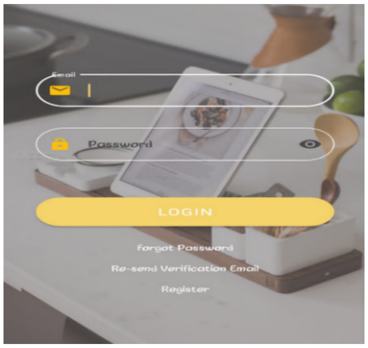


Figure 4: Mobile Application Interface Improved Fire Protection and Safety Scheme for Smart Buildings

Figure 5: Prototype Improved Fire Protection and Safety Scheme for Smart Buildings

4.1 The Electrical System design result of the Improved Fire Protection and Safety Model for Smart Buildings

Five sampling intervals were used to test the sensors' ability to detect fire, smoke, and temperature in the smart building. A smart building fire data status under test was retrieved from the sensors, as shown in Table 1 and Figure 6. For the initial demonstration, smoke levels were 10 parts per million, the temperature was 21 degrees Celsius, and no flame was identified, indicating that there was no fire in the smart building.

Similarly, the smoke status in the second and fourth demonstrations is 24ppm and 30ppm respectively. Although the temperature status is 31^{o}C and 37^{o}C, and the model saw no fire, implying that there was no fire in the smart building. However, the third and fifth demonstrations show smoke levels of 56ppm and 62ppm respectively. While the temperature levels are 52.50^{o}C and 58.50^{o}C, and the developed model detected the presence of flame, implying that a fire occurred in the smart building, triggering the use of flame retardant material to mitigate the effects of the fire.

4.2 The Mobile Application Interface design result of the Improved Fire Protection and Safety Model for Smart Buildings

The mobile application for the system was developed for both fire service agency and owners of smart buildings mainly to receive alert notifications when conditions surrounding a fire incident are detected in a smart building.

Figure 7(a) shows the android interface for the smart building dwellers. 7(b) shows the android interface for the Fire Service Agency operator and Figure. Figure 7a shows the profile of the smart building occupants in the mobile application with the temperature and location of the building, such that when the fire safety and protection model detect conditions as in Table 1 and Figure 6, an alert notification is sent to the occupants of the smart building and also to fire service agency. Figure 7b shows the profile of the fire service agency when a fire alert notification is received (Table 1 and Figure 7a depicts the profile of smart building occupants in the mobile application, along with the building's temperature and location, so that when the fire safety and protection model detect the conditions shown in Table 1 and Figure 6, an alert notification is sent to the smart building's occupants as well as the fire service agency. When a fire alert notification is received, Figure 7b depicts the profile of the fire service agency (Table 1 and Figure 6). Once a fire incident has been recorded, the details of the location and shortest route to the building are displayed on the mobile application for fire service agencies to respond quickly.

Table 1: Sensors Readings

	Smoke (ppm)	Temperature (°C)	Flame	Fire Status
1	10	21.00	NO	NO FIRE
2	24	31.00	NO	NO FIRE
3	56	52.50	YES	FIRE DETECTED
4	30	37.00	NO	NO FIRE
5	62	58.00	YES	FIRE DETECTED

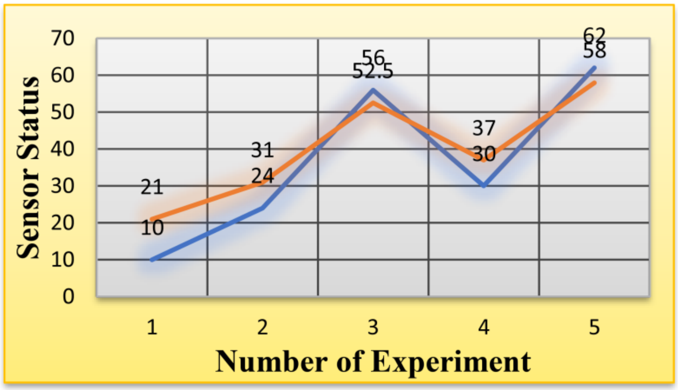
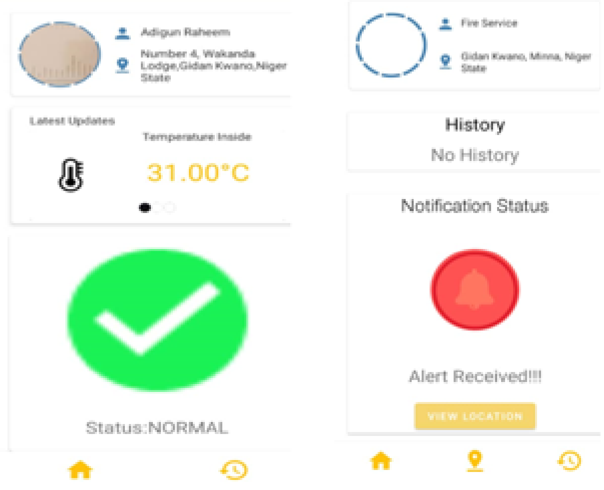
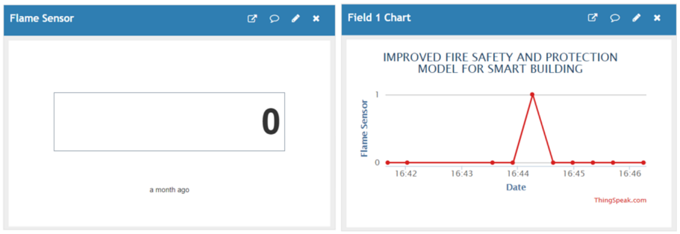


Figure 6: Sensor Status and Numbers of Experiment



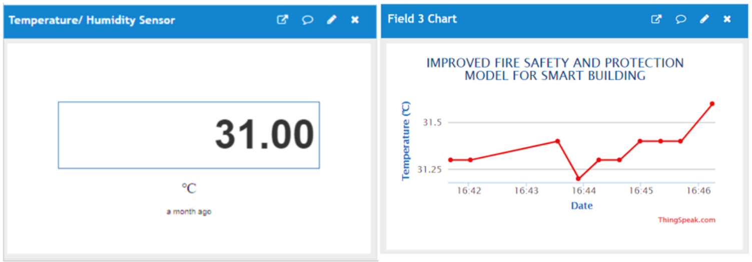
(a.) (b.)

Figure 7: Mobile Application Interface for the improved fire safety and Protection Model



(a) (b)

Figure 8: Flame Sensor Value



(a) (b)

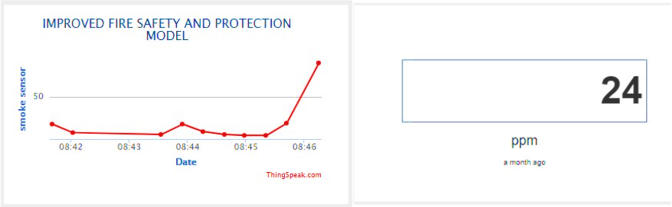
Figure 9: Temperature Sensor Value

4.3 Results of the Prototype demonstration with Thingspeak Platform

The ThingSpeak platform was used to demonstrate the produced prototype model of the enhanced fire safety and protection strategy for smart buildings, as well as the outcome analysis. The data is displayed at each level of the system's performance to portray the values shown in Table 1 and Figure 6

Figure 8a represents the flame sensor value when there is absence of flame in the smart building (0) and in 8b when there is presence of flame in the smart building, the sensor value changes to (1).

Figure 9a represents the temperature sensor value in the smart building (31°C) and figure 9b shows temperature readings in the smart building at varying time intervals, the sensor value also changes and rises to about 53.50 to 58.00°C.



(a) (b)

Figure 10: Smoke Sensor Value

Figure 10a shows smoke sensor readings in the smart building at varying time intervals, the sensor value changes in accordance to the concentration of smoke in the smart building with 56 parts per million (ppm) and above. Figure 10b represents the smoke sensor value detected (24ppm), this indicates that there is no fire detected because of its little concentration in the smart building. The location of the fire incident can be traced using google maps, from the developed app. This is one of the major advancements that the system has contributed to knowledge.

5 CONCLUSION

The improved fire safety and protection model for smart buildings was designed, simulated, built, and tested. The model used sensors to detect fire incident parameters, introduce a fire prevention mechanism, alert the fire service agency, and provide location information. The developed model was successful in identifying circumstances (fire and smoke) and alerting authorities for response, according to the results of the testing.

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