

# Data integration in multi-sensor smart home systems based on Internet of Things technology

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**Abstract**—As sensor technologies advance, their applications across various fields are rapidly expanding. Current sensor systems often operate separately, collecting overlapping data on environmental conditions, which limits their effectiveness and resource utilization. This paper proposes an integrated approach based on Internet of Things (IoT) technology to enhance the awareness, robustness, and reliability of sensor systems through their integration. Specifically, the study looks at connecting two existing subsystems — a fire alarm system and a temperature monitoring system — both of which use temperature and humidity sensors to monitor similar environmental data. By integrating these systems into the ThingSpeak IoT platform, their local data resources are used to create a common structure that improves the functionality and resilience of individual subsystems. The simulation results demonstrate that the integrated system significantly improves robustness and operational reliability compared to traditional separate systems, which provides a compelling case for data fusion in intelligent environments.

**Keywords** — multi-sensor smart home systems, IoT technology, data integration.

## I. INTRODUCTION

Recent advancements in sensor technologies have led to their widespread application in various fields, including the development of smart home systems. These systems rely on sensors to collect and analyze environmental data, enabling real-time monitoring and detection of changes. Despite the availability of similar data across different systems, sensors often operate independently, limiting the effective utilization of data resources. This fragmented approach hinders the development of more robust and reliable systems. Integrating these isolated systems using IoT technology can overcome this challenge by facilitating data fusion and system integration.

The IoT enables real-time data fusion, cloud storage, autonomous decision-making, and user interaction via remote interfaces. Through communication between devices, IoT systems reduce the complexity and cost of managing multiple devices simultaneously. In recent years, IoT technology has been applied to a wide range of fields, including robotics, autonomous vehicles, healthcare, and smart home systems. Smart home systems, in particular, benefit from the ability to control, monitor, and automate household functions, offering improvements in efficiency, comfort, and safety.

An IoT based smart home system consists of control, monitoring, and automation devices.

In its application, a smart home can be connected via a wired or wireless network. The use of wired connection is

usually applied for local networks, in the sense that control, monitoring, and automation are performed in close proximity to the house. In contrast, wireless network is connected to a local network or the internet which can be implemented using Wi-Fi, Bluetooth, NodeMCU, and Zigbee [1].

In the past few decades many studies and researches have taken place in order to improve IoT based smart home systems and to increase their level of effectiveness.

## II. IOT-BASED SMART HOME SYSTEMS

Home automation has gained increasing popularity due to advancements in IoT technology, which simplifies everyday life by enabling real-time monitoring and control of home functions. Sensor data retrieval has become easier and more accessible, leading to the digitalization and automation of various household tasks. In recent years, several IoT-based home automation systems have been proposed by researchers.

In the research papers [2] and [3], IoT-based fire alarm systems have been developed using Arduino controllers, DHT11 temperature sensors, Wi-Fi, and GSM modules to provide real-time responses to fire incidents. For example, stand-alone fire alarm systems equipped with temperature sensors are typically installed in individual rooms, as illustrated in Figure 1.

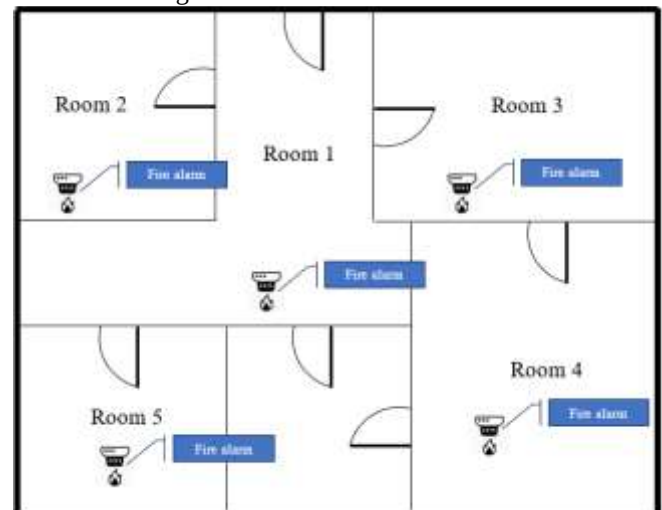


Fig. 1. Standalone fire alarm system.

These systems monitor the ambient temperature in the relevant areas and detect the presence of a fire. When sensors detect a temperature above a preset threshold, the system activates buzzers while sending a fire alert notification to the user's smartphone or computer. This system allows users to respond quickly to fire emergencies. However, if one of the

sensors malfunctions or fails, the system may be unable to detect a fire at its early stage, posing a significant safety risk. This highlights the inherent vulnerability of standalone fire alarm systems to single-point failures, which can compromise the system's reliability.

In these research papers [4] and [5], IoT-based temperature control systems use Arduino controllers, DHT11 temperature sensors, and ESP8266 Wi-Fi modules to send sensor data to the cloud. The data is retrieved by IoT platforms for real-time analysis and control. Users can monitor temperature conditions remotely via smartphones or computers and control home actuators, such as air conditioners, if needed. In Figure 2, the conventional temperature control system, equipped with temperature sensors, as suggested by [4] and [5], is installed in each of the five rooms.

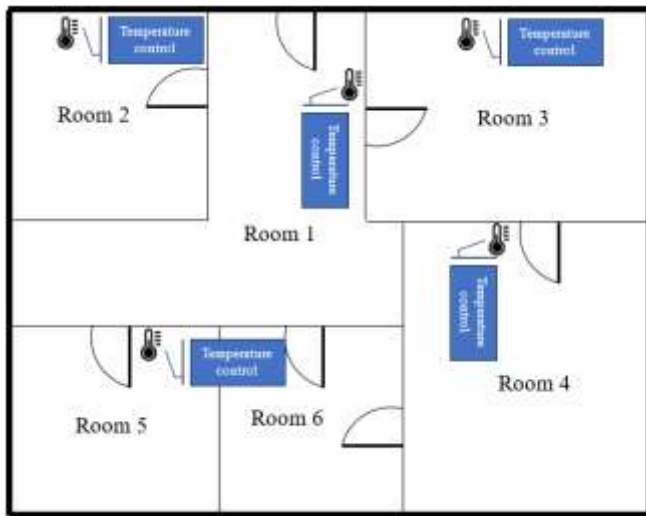


Fig. 2. Traditional temperature control system.

Despite the benefits offered by these systems, their reliance on individual sensors makes them vulnerable to failures. A single sensor malfunction can disrupt the entire system's operation. As fire alarm and temperature control systems collect the same environmental data, the sensors of temperature control system can also detect a potential fire by identifying a sudden and abnormal rise in temperature in the room. By integrating these systems through IoT-based data fusion, it is possible to mitigate the risk of sensor failure and enhance system reliability. Furthermore, fusion of sensor data can provide a more comprehensive view of the environment by extending the coverage of smart home systems. By combining data of multiple sensors, the systems can generate a more accurate and reliable understanding of the environment than what could be achieved using individual sensors alone. With this method, sensor fusion can enhance their perception, decision-making capabilities, and overall accuracy [6].

To achieve the described benefits of data fusion, this paper proposes a connected IoT-based system consisting of two subsystems, a fire alarm system and a temperature control system.

### III. DEVELOPMENT AND IMPLEMENTATION OF AN INTEGRATED SYSTEM

To achieve correct fusion of sensor data, all subsystems must have similarities such as data sources or sensor types. Otherwise, integration would merely provide convenience control.

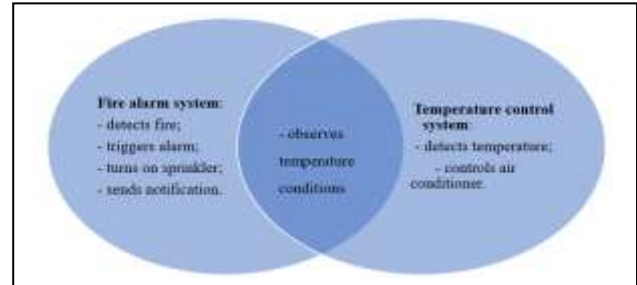


Fig. 3. Information commonality between connecting subsystems.

Figure 3 illustrates the information commonality of connecting subsystems. Both subsystems observe the surrounding temperature using identical sensors, which collect similar environmental data. By combining these data sources, the subsystems can complement each other, ensuring continued functionality even if one system fails. This interconnected structure can enhance the system's robustness and reliability.

#### A. Architecture of the Connected System

The house prototype designed for this study includes fire alarm and temperature control subsystems installed in five separate rooms. A total of 10 sensors (two in each room) are used to monitor temperature conditions. The fire alarm subsystem detects fire incidents by collecting room temperature data, while the temperature control subsystem monitors room conditions to regulate temperature.

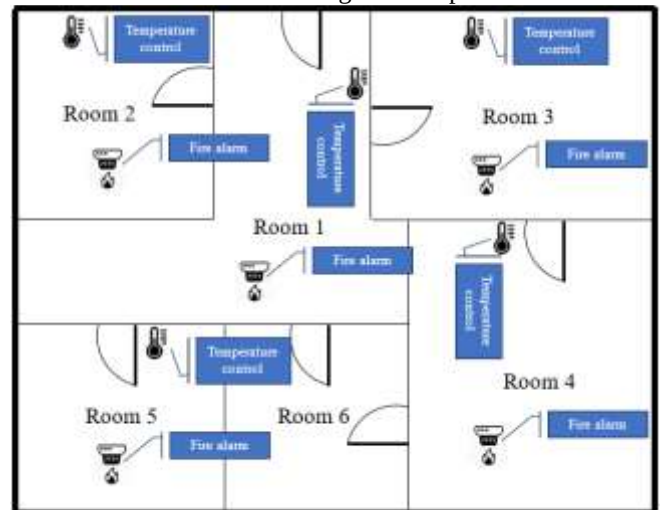


Fig. 4. Design of the smart house prototype.

In real-world environments, sensors are susceptible to noise and interference, which can degrade performance. By integrating multiple sensors and combining their data, the connected system becomes more resilient to environmental noise and more precise in monitoring conditions. As shown in Figure 4, fusion of sensor data expands the coverage and

enhances the accuracy of the connected system compared to standalone systems.

### B. Implementation of data collection in the system

Figure 5 shows the overall design of the proposed connected system. The subsystems are connected to an IoT platform through Wi-Fi modules. Once connected, the subsystems transmit the collected sensor data to a web server, which acts as the central unit. The web server processes the data, enabling users to remotely monitor and control the system. By integrating sensor data on the web server, the connected system can continue to function even in the event of subsystem or sensor failure, thereby increasing system robustness.

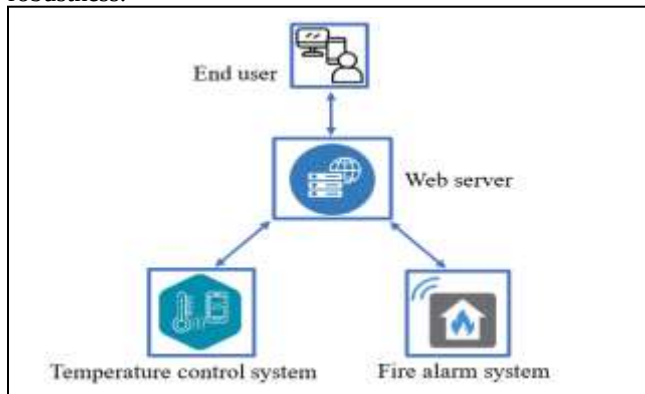


Fig. 5. Overall design of connected system.

### C. Hardware of the systems being connected

Figure 6 provides an overview of the hardware components used in the fire alarm and temperature control subsystems. Both systems use Arduino Uno controllers to manage sensors, Wi-Fi modules, and actuators. DHT11 sensors collect temperature data, which is transmitted via ESP8266 Wi-Fi modules to the IoT platform, ThingSpeak.

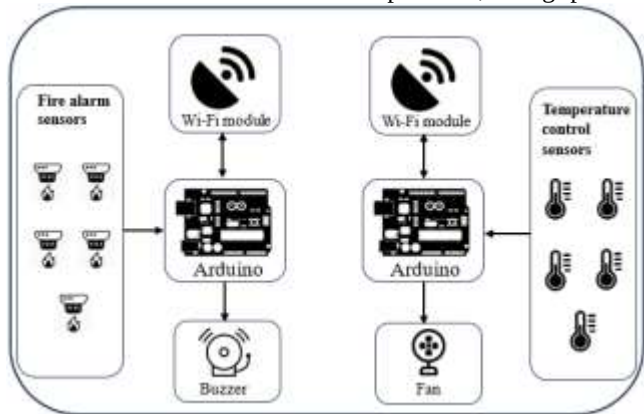


Fig. 6. Hardware components for fire alarm and temperature control subsystems.

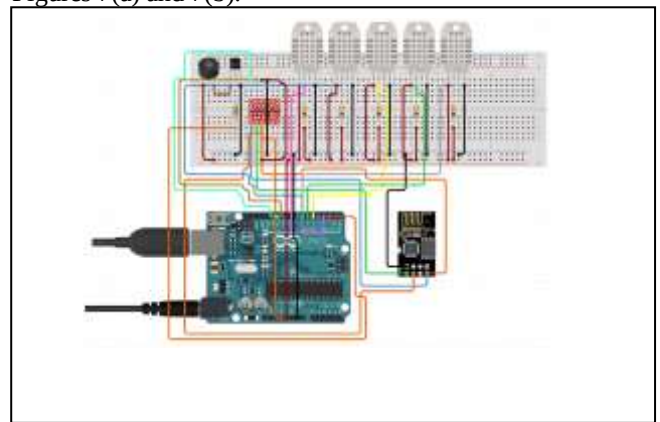
ThingSpeak is an IoT analytics platform service that allows to aggregate, visualize and analyze live data streams in the cloud. It provides instant visualizations of data posted by devices to it. With the ability to execute MATLAB code in ThingSpeak, users can perform online analysis and processing of the data as it comes in. It enables automatic actions on

collected data by using third-party services like E-mail and X(Twitter).

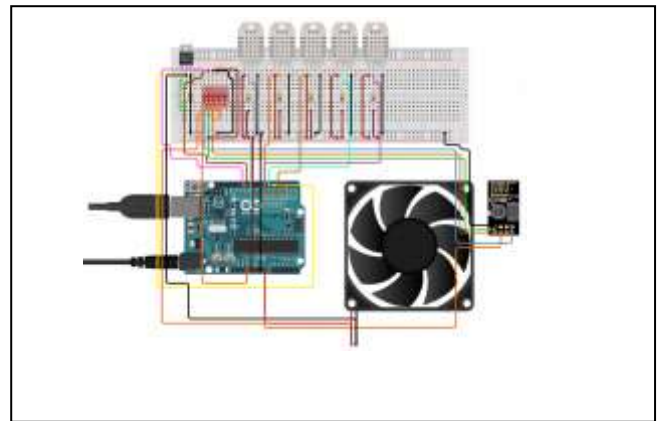
### D. Operating Principles of the Subsystems

The fire alarm and temperature control subsystems follow a similar process to communicate with the IoT platform. Both subsystems first connect to ThingSpeak platform using Wi-Fi modules and then collect temperature data from DHT11 sensors. The collected data is sent to ThingSpeak platform. The fire alarm subsystem activates when the temperature exceeds 50°C, signaling a potential fire and triggering an alert. Similarly, the air conditioning fan is ON when room temperature is above 30°C and is OFF when temperature reaches below 30°C by analyzing data from temperature control subsystem.

The circuit diagrams for each subsystem are shown in Figures 7(a) and 7(b).



(a)



(b)

Fig. 7. Circuit diagrams: (a) fire alarm subsystem; and (b) temperature control subsystem.

## IV. PRACTICAL TESTS AND RESULTS

The platform then consolidates the data from each room, displaying it on a control panel for real-time monitoring by the user, as shown in figure 8.

Upon receiving temperature data from the subsystems, ThingSpeak stores the data in cloud storage.

As discussed in Section II, sensor systems are vulnerable to single-point failures, where the malfunction of a sensor can disrupt the system's functionality. As shown in Figure 9(a), the

temperature control subsystem in Room 1 ceased transmitting temperature data, likely due to a sensor failure or a network connection issue. Consequently, the air conditioning unit in Room 1 stopped operating. However, as shown in Figure 9(b), the temperature data from Room 1 is still being provided by the fire alarm subsystem.

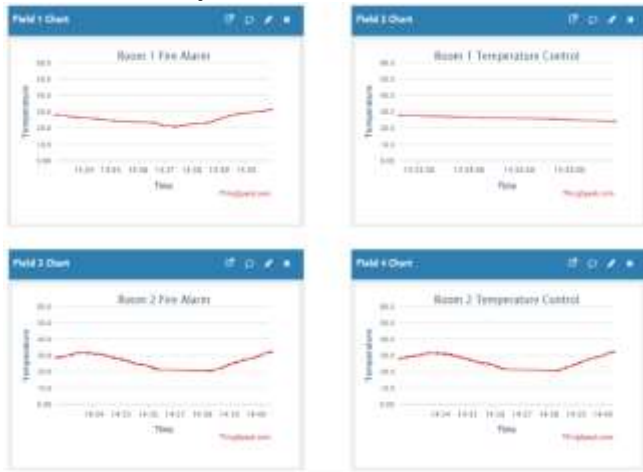
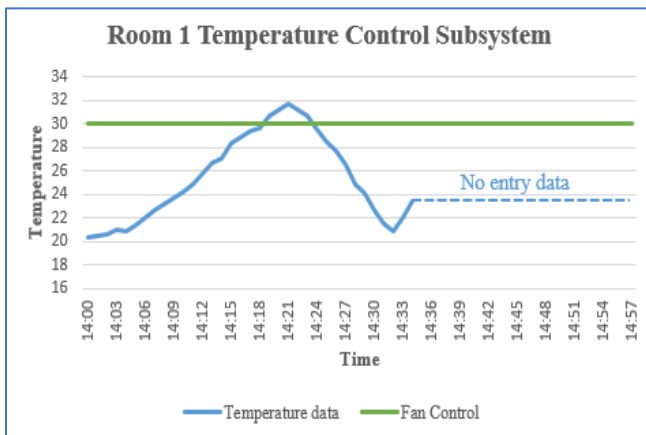
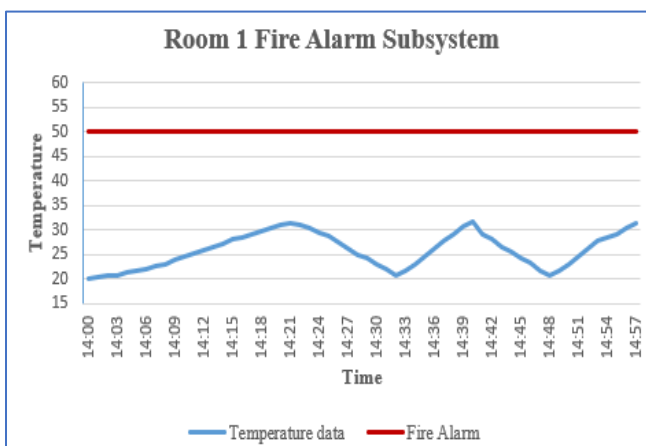


Fig. 8. ThingSpeak control panel of connected system.



(a)



(b)

Fig. 9. Room 1 temperature data sent by temperature control (a) and fire alarm subsystems (b).

In such a scenario, ThingSpeak can respond to the data provided by the fire alarm subsystem. When the platform

detects the absence of input from the temperature control subsystem in Room 1, using its React function, it can analyze the data transmitted by the fire alarm subsystem. Upon identifying that the room temperature has exceeded 30°C, ThingSpeak can send an HTTP request to activate the air-conditioning unit, as illustrated in Figure 10.

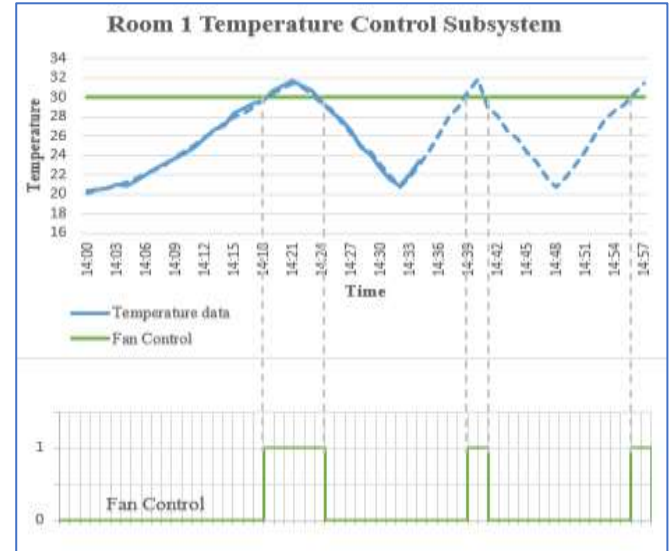
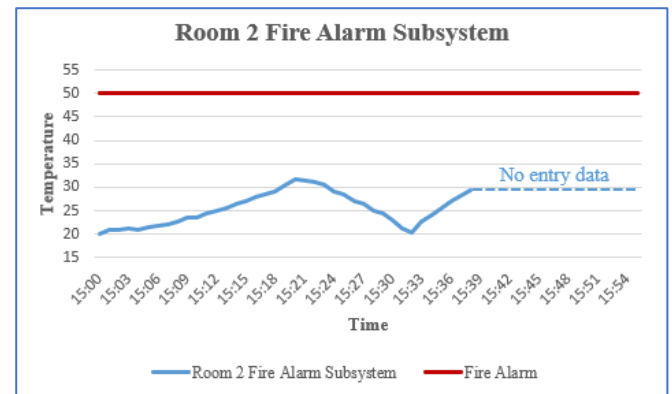
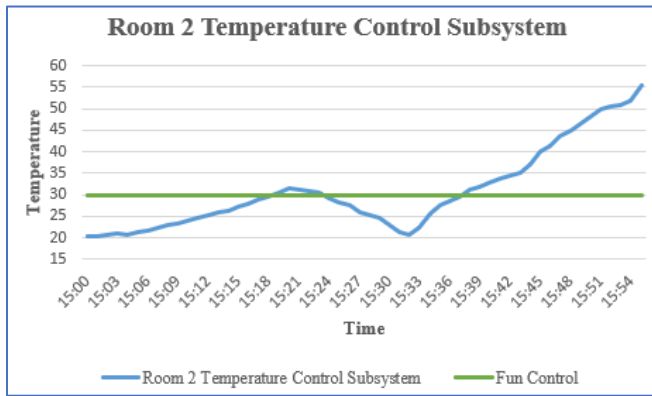


Fig. 10. The temperature data from fire alarm subsystem supports the functionality of temperature control subsystem.

This demonstrates that the connected system is capable of maintaining the functionality of the temperature control subsystem despite its failure. As a result, the integrated system exhibits greater robustness compared to standalone systems, because of its additional data resources.



(a)



(b)

Fig. 11. (a) Room 2 fire alarm subsystem stopped working; and (b) temperature control subsystem detects potential fire accident.

The analysis of the collected data, presented in Figure 11(a) and 11(b), reveals that when the fire alarm subsystem in Room 2 fails to detect a potential fire incident, the temperature control subsystem detects a sudden rise in room temperature. This analysis of data indicates that the temperature control subsystem is aware of the fire event. By utilizing the additional data source, the fire alarm subsystem's robustness can be enhanced, and the overall connected system can benefit significantly from the integration of these two subsystems, resulting in improved reliability in detecting and responding to fire emergencies. Figure 12 shows that temperature control subsystem can effectively respond to critical fire incidents in cases where the fire alarm subsystem malfunctions. In addition, if the temperature in either of subsystems exceeds 50°C, the IoT platform triggers an alert and notifies the user. This demonstrates how the integration of the temperature control subsystem can complement the fire alarm subsystem, allowing for more accurate decision-making in the event of a fire by using additional data resource.

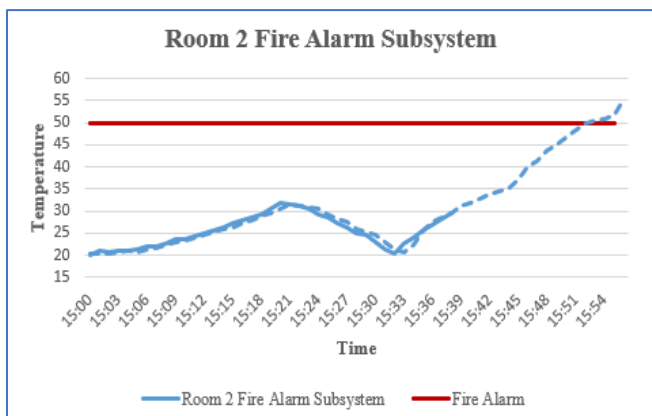


Fig. 12. The temperature data from temperature control subsystem can help to continue the functionality of fire alarm subsystem.

## V. CONCLUSION

The results of this study show that integrating smart home systems using IoT technology improves their reliability and sustainability. By combining sensors and data, a connected IoT-based system provides a more complete picture of the environment than standalone systems. The integration of subsystems supported by IoT platforms ensures continuous system operation even in the event of a subsystem or sensor failure. This approach improves the overall reliability of smart home systems, offering increased functionality and fault tolerance.

Our future work will focus on investigating the efficiency of integrating other smart home components such as security, lightning and water supply subsystems.

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