BINDURA UNIVERSITY OF SCIENCE EDUCATION

Faculty of Science and engineering

Department of Computer Science (IT Networking)

IOT BASED SMOKE DETECTION AND ALERTING SYSTEM

BY

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APPROVAL FORM

The undersigned certify that they have supervised the student Ali Leo Hassan's dissertation entitled, "Fire detection and alert using sensor fusion and artificial intelligence" submitted in partial fulfillment of the requirements for a Bachelor of Computer Science Honors Degree at Bindura University of Science Education.

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Abstract

The Internet of Things (IoT) has revolutionized the way we interact with technology, and has the potential to greatly improve fire safety systems. In this paper, the researcher presents an IoT-based smoke detection and alerting system using Proteus and Arduino IDE. This system uses a combination of smoke detectors, gas and temperature sensors, microcontrollers, and wireless communication to provide real-time monitoring and alerting capabilities. The researcher begins by discussing the components of the system, including the IOT devices. The paper then describes how these components are integrated into the overall system architecture, and how the system communicates with a central monitoring station. The presentation of the results of the system will be a simulation using Proteus. The Proteus software is used for simulating and testing the circuit before implementation, while the Arduino IDE is used for programming the microcontroller, which demonstrates the effectiveness of this system in detecting smoke and alerting the central monitoring station. The system is able to detect smoke within seconds of it being detected by the smoke detectors, and can send an alert to the central monitoring station in real-time. Overall, the system demonstrates the potential of IoT-based smoke detection and alerting systems to greatly improve fire safety systems, and provides a framework for future research in this area.

Dedication

This work is dedicated to my parents, Memory Murapa and Rhodreck Chawasarira and my grandmother Mrs. Magowa who have been a constant source of support and encouragement during the challenges of graduate school and life. I am truly thankful for having you in my life and for loving me unconditionally. This work is also dedicated to my siblings, whose good examples have taught me to work hard for the things that I aspire to achieve.

Acknowledgements

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Chapter 1: Problem Identification

1.0 Introduction

There has long been a concern with indoor fires. Candles left burning, unattended food cooking in the kitchen, and even electrical problems are all causes of these fires. These small fires typically go unnoticed until they are large enough, making it challenging for the suppression systems to put out the fire or notify the necessary parties in time. It is very vital to have fire alarms in markets, stores, schools, homes and industrial buildings as they play a major role. At an early stage they help to detect smoke before the fire has matured which help in saving lives and damage property. Technological advancements have improved the concept, commercial fire working devices with the aid of a buzzer or siren help provide an alarm signal. This prompted this researcher to develop an IoT based smoke detection and alerting system that is simulated using Cisco Packet Tracer and does not only detect fire and smoke but send relevant information to the concerned individuals.

Sharma, Amit, Singh, Pradeep, Kumar, and Yugal, (2020) developed Systems for conveying information about fires, particularly those that do so using microcontrollers and mobile phones, have been the subject of numerous studies. MQ-2 smoke sensors, UVTRON fire sensors, a mobile phone serving as an information transmitter, and an ATmega32 microcontroller serving as a controller are all utilized as parts of this system. Using the SIM900, MQ-2 smoke sensors, and LM35 temperature sensors, SMS is utilized to alert users of fires. If there is a fire outside the home, the system can alert the owner. All of the components are controlled by an Arduino UNO. This detector's temperature and smoke sensors aid in the early detection of fires. Temperature sensors, smoke sensors, 0809 digital-to-analog converters, system controllers with AT89S52 microcontrollers, and an analogue sensor are among the system's components.

A survey by M. A. Al-Fuqaha et al. (2015) provided a comprehensive overview of the enabling technologies, protocols, and applications of IoT technology, highlighting its potential to revolutionize various industries, including healthcare, transportation, and home automation. The survey identified several key components of IoT systems, including sensors, communication protocols, cloud computing, and data analytics, which are essential for the development of effective IoT-based smoke detection and alerting systems.

The above projects have been focusing on using Arduino UNO and prompted the researcher to design and implement a system that is IOT based for smoke detection and alerting system that will be detecting smoke at a residential place and inform the relevant personnel while providing real-time and quick response time. The project will combine MQ-2 smoke sensors and DHT11 temperature sensors and it also includes an LCD for display, a buzzer for alarming the residents as well as a GSM module. This project will be simulated using Proteus 8 and the code will be written using Arduino IDE.

1.2 Statement of the Problem

Safety is a crucial consideration in the design of residential and commercial buildings to safeguard against the loss of lives and damage of property. National *Fire Protection* Association, (2000) states that most of the indoor fires go undetected until they are sufficiently mature to produce detectable smoke and temperature owing to the mechanisms used in indoor fire systems. The existing fire alerting system is too complex in terms of design and it needs regular maintenance thus involving human intervention.

1.3 Aim of Research

To design and implement an IOT-based smoke detection and alarming system using Proteus 8 and Arduino IDE, to show forth how we can comprehend IOT in networking as a way of appreciating the networking aspect involved in IOT while providing real-time simulations.

1.4 Research Objectives

1. To design and implement an early fire detection system
2. To be able to send real-time alerts to the user's smartphone
3. Evaluate the use of IOT in fire detection.

1.5 Research Questions

1. How is the system going to detect smoke and pick a fire in its infancy stages?
2. How is the system going to notify the habitants and the authorities?
3. How is the use of IOT going to improve system response to developing fire?

1.6 Research Propositions/ Hypothesis

- H_0: The system will be able to detect smoke and pinpoint a fire in its infancy, notify the user and the authorities in time as well as reduce false alarms.
- H_1: The system will fail to detect smoke and pinpoint a fire in its infancy, notify the user and the authority in time as well as reduce false alarms.

1.7 Justification of Research

There are circumstances when natural elements, non-natural factors, or human factors interrupt people's lives and livelihoods and result in fatalities, environmental harm, property losses, and psychological effects. Early fire detection can significantly minimize or even eliminate the number of fatalities caused by carbon monoxide poisoning and other fire-related risks, such as property damage. The number of persons who die in house fires and the losses incurred in property damage due to fire can both be significantly decreased with the development of a fire detection system that is capable of spotting fire in its early stages and alerting the occupants and pertinent authorities. The use of multiple sensors may significantly shorten the time it takes to detect a fire because multiple variables are taken into account before drawing a conclusion. Additionally, the use of multiple variables may help to eliminate false alarms, which typically result in costs to the local authorities as they mobilize to put out the reported fire.

1.7 Assumptions

- The system is designed for indoor use only and is not suitable for outdoor environments.
- The system is designed to detect smoke and gas but may not be able to detect other types of fire hazards such as heat or flames.
- The accuracy of the sensors used in the system may vary depending on the quality and calibration of the sensors

1.9 LIMITATIONS

- The system may not be able to detect smoke or gas in areas where the sensors are not installed or where the concentration of smoke or gas is below the detection threshold of the sensors.
- The system may not be able to provide real-time monitoring of smoke or gas levels, as it relies on periodic sensor readings and alerts.
- The cost of the system may be a limiting factor for some users, particularly if they require multiple sensors or additional equipment for integration with other smart home devices.

1.10 Definition of Terms

1. **Fire** is a rapid oxidation reaction that produces flames, smoke, and heat, and it is sustained by a continuous supply of fuel, oxygen, and heat
2. **Smoke** is a collection of small particles and gases that are produced when a material undergoes combustion or burning.

3. **A sensor** is a device or subsystem that detects or measures physical or chemical changes in the environment and converts them into an electrical or digital signal that can be processed and analyzed by a computer or other electronic system.
4. **A microcontroller** is a small, single-chip computer system that is designed to perform specific tasks and control electronic devices or systems.
5. **A fire alarm** is a device or system designed to detect the presence of fire or smoke and alert people to the danger of a potential fire.
6. **Proteus** is a software tool for electronic circuit simulation, schematic capture, and PCB (printed circuit board) layout design for IoT devices.
7. **Arduino** is an open-source electronics platform based on a microcontroller board, along with a software development environment for creating and programming electronic devices and interactive objects.

Chapter 2: Literature review

2.0 Introduction

While fire detection and alerting systems have evolved over the years, the basic principles remain the same. The goal is to detect fires as quickly as possible and alert people to the danger so that they can evacuate the building safely. In the 1990s, fire detection systems varied depending on the building and its intended use. However, some of the most common fire detection systems in use at the time were smoke detectors, heat detectors, and flame detectors. Smoke detectors were the most widely used fire detection system in the 90s. These devices could detect the presence of smoke in the air and would sound an alarm if a certain threshold was reached. Heat detectors, on the other hand, would sound an alarm if the temperature in a room or area rose above a certain level. Finally, flame detectors were designed to detect the presence of flames and would sound an alarm if a fire was detected.

There were also manual fire detection systems in place in the 90s. These typically included pull stations, which were located throughout a building and could be activated by anyone who noticed a fire. Once activated, the pull station would send an alarm signal to a central monitoring station, where operators would dispatch emergency services.

In terms of alerting people to a fire, there were several methods used. In many cases, buildings were equipped with fire alarms that would sound throughout the building when a fire was detected. In addition, many buildings were also equipped with sprinkler systems, which would activate when a fire was detected. These systems would help to control the fire and prevent it from spreading. People were also alerted to fires through the use of public address systems. In some cases, these systems were used to broadcast evacuation instructions, while in other cases, they were used to provide information about the fire and the location of emergency exits.

According to a report by MarketsandMarkets (MarketsandMarkets, 2019), the global IoT-based fire detection market is expected to grow from $494 million in 2018 to $1.5 billion by 2024, at a CAGR of 20.2% during the forecast period (1). This growth is driven by the increasing adoption of IoT-based fire detection systems in various industries, such as healthcare, manufacturing, and residential. The smoke detection sensors used in IoT-based systems are typically photoelectric or ionization sensors. Photoelectric sensors detect smoke by using a light source and a photodetector, while ionization sensors detect smoke by using a radioactive source and an ionization chamber. Both types of sensors have their advantages and disadvantages, and the choice of sensor depends on the specific requirements of the application.

2.1 Fire

The National Fire Protection Association (NFPA) defines fire as "a chemical reaction involving rapid oxidation of a fuel, usually accompanied by the release of heat and light in the form of flames and smoke". The United States Fire Administration (USFA) describes fire as "a rapid oxidation process that produces heat and light". Therefore, fire is a chemical reaction that occurs when a fuel source (such as wood, paper, or gasoline) combines with oxygen and is ignited by a heat source (such as a spark or flame). The reaction releases energy in the form of heat and light, which can cause damage to property and harm to living beings

2.1.0 Fire Growth and Behavior

Fire growth and behavior refer to the way in which fires develop and spread, including factors such as fuel type, heat release rate, and ventilation. The National Wildfire Coordinating Group's "Wildland Fire Behavior: Understanding the Basics" publication, provides an introduction to wildland fire behavior and discusses factors such as weather, topography, and fuel characteristics that influence fire growth and behavior.

2.1.1 The 4 Stages of a Fire

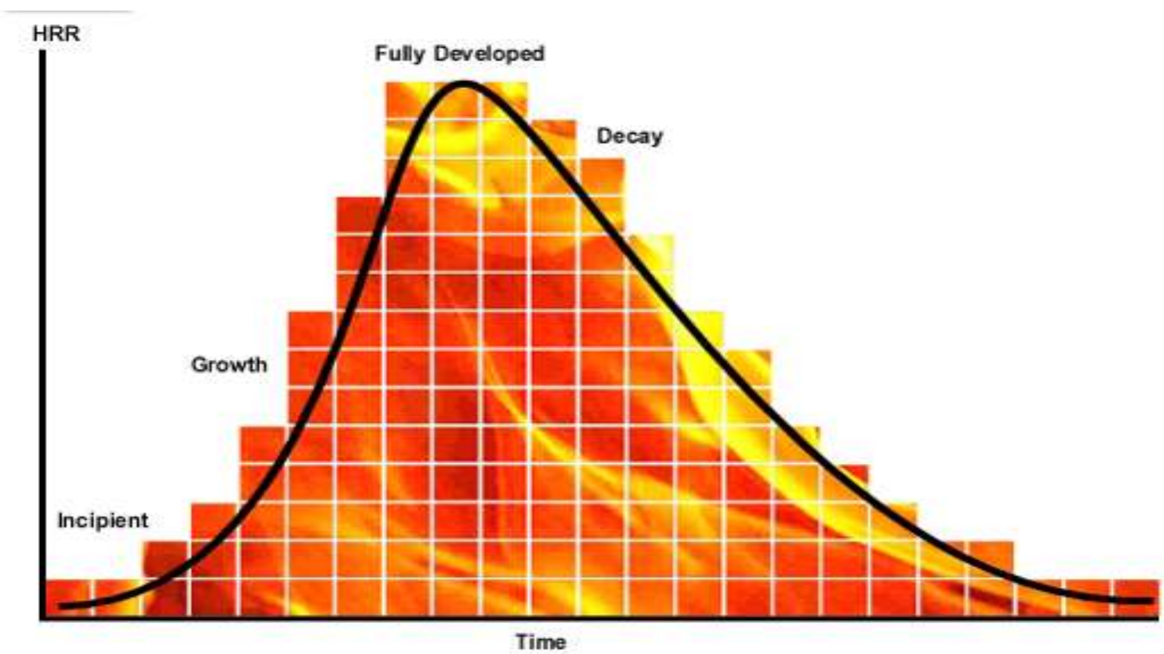

Figure 1: Heat Release Rate (HRR) and Fire Development (Josh, 2010)

There are four stages of a fire development which include:

(a) Incipient:

This is the initial stage of fire, where a heat source meets a fuel source and a chemical reaction occurs, resulting in the release of heat, light, and gases. The incipient stage is typically brief and can be caused by various sources, such as electrical sparks, open flames, or friction.

(b) Growth:

In this stage, the fire spreads rapidly as the heat generated by the fire causes nearby fuel to ignite. The growth stage is characterized by increasing flames, smoke production, and heat release. The fire may also begin to produce dangerous gases, such as carbon monoxide and hydrogen cyanide.

(c) Fully developed:

At this stage, the fire has reached its maximum size and intensity, and the available fuel has been consumed or removed. The fully developed stage is often the most dangerous, as the high temperatures and toxic gases can pose a significant threat to occupants and firefighters.

(d) Decay:

In this final stage, the fire begins to diminish as the available fuel is depleted and the heat and flames subside. The decay stage may still pose a risk of re-ignition or smoldering, and firefighters must remain vigilant to prevent further damage or injury.

2.1.2 Production of Smoke in Fire

Smoke is a visible collection of a variety of solid, liquid, and gas particles left unburned during the combustion process (Figure 2) It is possible for smoke to contain a large number of different chemicals and fumes, although visible smoke is mostly carbon or soot, tar, oils, and ash. Smoke is produced in a fire as a result of incomplete combustion of the fuel, and can contain a variety of toxic and harmful substances. This simply means that there is not enough oxygen present when the material is burned to completely burn the fuel. Instead of only carbon dioxide and water vapor being created, incomplete combustion can result in the production of soot, smoke, and ash.

Figure 2: Production of smoke

2.1.3 Impacts of fire outbreaks

Fire outbreaks can have significant impacts on people, property, and the environment. They can have devastating impacts on individuals, communities, and the environment. It is essential to take steps to prevent fires and to be prepared to respond quickly and effectively in the event of a fire emergency. Some of the impacts of fire outbreaks include:

1. Loss of life:

Fire outbreaks can result in the loss of human life, either directly through burns or smoke inhalation, or indirectly through structural collapse or other hazards.

2. Property damage:

Fires can cause significant damage to buildings, homes, and other structures, resulting in costly repairs and rebuilding efforts.

3. Environmental damage:

Fires can also have a significant impact on the environment, destroying habitats, polluting air and water, and releasing harmful chemicals and gases.

4. Economic losses:

Fire outbreaks can have a significant economic impact, causing businesses to shut down, disrupting supply chains, and reducing property values.

5. Psychological trauma:

Fire outbreaks can also have long-lasting psychological impacts on survivors and witnesses, causing anxiety, depression, and post-traumatic stress disorder.

2.2 Fire detectors

Fire detectors are devices used to detect the presence of fire or smoke in a building. There are several types of fire detectors in use today, including smoke detectors, heat detectors, and flame detectors. Fire detectors are an important part of any building's fire safety system. By detecting the presence of fire or smoke, these devices can help to alert occupants to the danger and prevent the spread of fire. According to NEDCC (Northeast Document Conservation Center), the key aspect of fire protection is to identify a developing fire emergency in a timely manner, and to alert the building's occupants and fire emergency organizations. This is the role of fire detection systems and alarm systems. When present, humans can be excellent fire detectors. The healthy person is able to sense multiple aspects of a fire including the heat, flames, smoke, and odors. For this reason, most fire alarm systems are designed with one or more manual alarm activation devices to be used by the person who discovers a fire. Unfortunately, a person can also be an unreliable detection method since they may not be present when a fire starts, may not raise an alarm in an effective manner, or may not be in perfect heath to recognize fire signatures. It is for this reason that a variety of automatic fire detectors have been developed. Automatic detectors are meant to imitate one or more of the human senses of touch, smell or sight. Thermal detectors are similar to our ability to identify high temperatures, smoke detectors replicate the sense of smell, and flame detectors are electronic eyes.

2.2.0 Fire detectors types

2.2.1 Manual fire detection

According to NEDCC (Northeast Document Conservation Center), manual fire detection is the oldest method of detection. In the simplest form, a person yelling can provide fire warning. In buildings, however, a person's voice may not always transmit throughout the structure. For this reason, manual alarm stations are installed. The general design philosophy is to place stations within reach along paths of escape. It is for this reason that they can usually be found near exit doors in corridors and large rooms.

The advantage of manual alarm stations is that, upon discovering the fire, they provide occupants with a readily identifiable means to activate the building fire alarm system. The alarm system can then serve in instead of the shouting person's voice. They are simple devices, and can be highly reliable when the building is occupied. The key disadvantage of manual stations is that they will not work when the building is unoccupied. They may also be used for malicious alarm activations. Nonetheless, they are an important component in any fire alarm system.

2.2.2 Smoke detectors

According to National Fire Protection Association, (2016), smoke detectors are the most widely used type of fire detector. These devices work by detecting the presence of smoke in the air and sounding an alarm when a certain threshold is reached. There are two main types of smoke detectors: ionization and photoelectric. Ionization smoke detectors are more responsive to flaming fires, while photoelectric smoke detectors are more responsive to smoldering fires. The National Fire Protection Association (NFPA) recommends that both ionization and photoelectric smoke detectors be used in homes and buildings (NFPA, 2019). The NFPA also recommends that smoke detectors be installed in every bedroom, outside each sleeping area, and on every level of the home or building.

Figure 3: Smoke Detectors

2.2.3 Heat detectors

Heat detectors are another type of fire detector. These devices work by detecting changes in temperature and sounding an alarm when a certain threshold is reached. There are two main types of heat detectors: fixed temperature and rate-of-rise. Fixed temperature heat detectors activate when the temperature in a room or area rises above a certain level, while rate-of-rise heat detectors activate when the temperature rises rapidly over a short period of time (National Fire Protection Association, 2016).

According to the National Fire Protection Association (NFPA), heat detectors are best suited for environments where smoke or dust is present, or where smoke detectors may be prone to false alarms (NFPA, 2019). Heat detectors are commonly used in areas such as kitchens, attics, and mechanical rooms. NIST (2010) conducted a study on heat detectors and found that rate-of-rise heat detectors were more effective at detecting fires in their early stages than fixed temperature heat detectors. However, they also noted that both types of detectors were effective in detecting fires once they had reached a certain size.

Figure 4: Heat Detectors

2.2.4 Flame detectors

Flame detectors are designed to detect the presence of flames and sound an alarm when a fire is detected. These devices work by detecting the ultraviolet or infrared radiation given off by flames. There are several types of flame detectors, including ultraviolet, infrared, and multi-spectrum detectors (National Fire Protection Association, 2016). UV flame detectors sense the ultraviolet radiation emitted by flames, while IR flame detectors sense the infrared radiation emitted by flames. Combined UV/IR detectors use both types of sensors to provide more reliable flame detection. According to the National Fire Protection Association (NFPA), flame detectors are best suited for environments where smoke or dust is present, or where smoke detectors may be prone to false alarms (NFPA, 2019). Flame detectors are commonly used in areas such as chemical plants, refineries, and aircraft hangars. A study conducted by the National Institute of Standards and Technology (NIST) found that UV flame detectors were effective at detecting small fires, while IR flame detectors were more effective at detecting larger fires (NIST, 2010). They also noted that combined UV/IR detectors were the most effective at detecting a wide range of fires.

Figure 5: Flame Detectors

2.2.5 Temperature sensors

Temperature sensors are devices that measure temperature and convert the measurement into an electrical signal. There are several types of temperature sensors, including thermocouples, resistance temperature detectors (RTDs), and thermistors. Thermocouples are made from two different types of metal wire that are joined together at one end. When the joined end is exposed to heat, a voltage is generated that is proportional to the temperature difference between the joined end and the other end of the wires. Thermocouples are commonly used in industrial applications due to their durability and wide temperature range. RTDs are sensors made from a length of wire that has a resistance that changes with temperature. As the wire is exposed to heat, the resistance changes, which can be measured and used to calculate the temperature. RTDs are commonly used in scientific and laboratory applications due to their accuracy and stability.

Thermistors are sensors made from a material that has a resistance that changes with temperature. As the material is exposed to heat, the resistance changes, which can be measured and used to calculate the temperature. Thermistors are commonly used in consumer electronics and automotive applications due to their low cost and fast response time.

Figure 6: Temperature Sensors

2.3 Global System for Mobile Communications

(Garg, 2010), define GSM (Global System for Mobile Communications) as a standard developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second-generation (2G) digital cellular networks used by mobile devices. The GSM architecture consists of several components that work together to provide mobile communication services.

Integrating GSM on an IoT-based smoke detection and alerting system using Cisco Packet Tracer can provide an additional layer of redundancy and improve the reliability of the system. In case of a fire, the system can send alerts to the user's mobile device using both Wi-Fi and GSM connectivity, ensuring that the user receives the alert even if Wi-Fi connectivity is lost. Here are the steps to integrate GSM on an IoT-based smoke detection and alerting system using Cisco Packet Tracer:

2.3.1 GSM Features

1. Digital voice transmission:

GSM uses digital modulation techniques to transmit voice, which results in better voice quality and reduced interference compared to analog systems.

2. International roaming:

GSM is a global standard that is used in over 200 countries, allowing users to roam internationally with their mobile devices.

3. Short message service (SMS):

GSM supports SMS, which allows users to send and receive short text messages using their mobile devices.

4. Caller ID:

GSM supports caller ID, which allows users to see the phone number of the person who is calling them.

5. Data services:

GSM supports data services such as circuit-switched data (CSD) and packet-switched data (GPRS), which allow users to access the internet and other data services using their mobile devices.

6. Security:

GSM provides security features such as authentication and encryption to protect the privacy and security of user communication.

7. SIM card:

GSM uses a SIM (Subscriber Identity Module) card that contains the user's subscriber information, such as their phone number and network authentication key.

8. Call forwarding and call waiting:

GSM supports call forwarding and call waiting, which allows users to forward incoming calls to another phone number or receive incoming calls while on another call.

2.4Micro-Controller

A microcontroller is a small integrated circuit designed to control the operation of an embedded system; typically, a processor, memory, and input / output peripherals are included on one chip; however, these days, they can only have input / output ports for you to plug in devices. These computers are used in many industries and applications, including domestic and commercial building automation, manufacturing, robotics, and automotive.

2.4.1Arduiono Uno

According to the Arduino Family (Arduino, 2011), Arduino is an open-source electronics platform that is based on easy-to-use hardware and software. Building on it has proven to be a choice of many people from novice to experts in as much as simplicity, portability and cost are concerned. Uno board is a popular choice for IoT projects because of its low cost, ease of use, and compatibility with a wide range of sensors and actuators. It is a versatile platform that can be used for prototyping and testing IoT systems before they are deployed in the real world (A.

A. Al-Fuqaha et al, 2015). The Arduino Uno board is compatible with a wide range of sensors and actuators, making it ideal for a variety of projects, such as robotics, home automation, and data logging. The board can be programmed using the Arduino Integrated Development Environment (IDE), which is based on the C programming language

2.5 Proteus simulator

Proteus is a software simulation tool that is specifically designed to simulate and test electronic circuits and microcontroller-based systems before they are physically implemented. Proteus provides a virtual environment where the designer can test and debug the system without the need for physical hardware. In this research of an IoT-based smoke detection and alerting system using Arduino IDE and Proteus, the virtual environment provided by Proteus can be used to simulate the entire system. The smoke sensor module and buzzer module can be simulated using Proteus' extensive library of electronic components and devices. The Arduino board and Wi-Fi module can also be simulated using Proteus' microcontroller simulation capabilities (Labcenter Electronics Ltd, 2021). The simulation allows the researcher to test the system's functionality and performance under different scenarios and conditions. The simulation can also be used to test the system's ability to handle different types of alerts, such as email alerts or mobile notifications. Once the simulation is complete, the designer can analyze the results and make any necessary adjustments to the system before physically implementing it. This can save time and resources by identifying potential problems and addressing them in the simulation phase, rather than during the physical implementation phase.

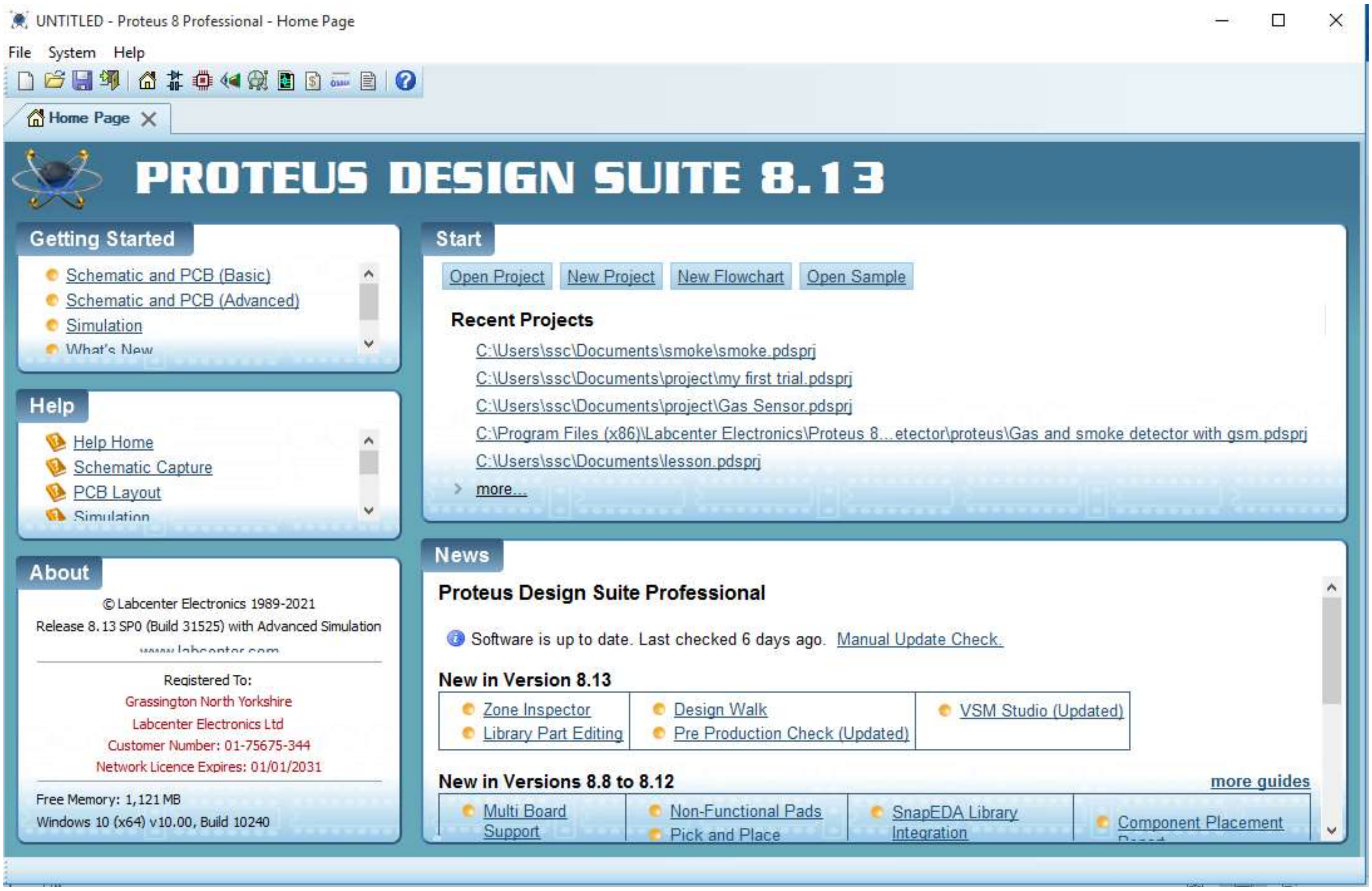

Figure 7: Screenshot of Proteus Simulator

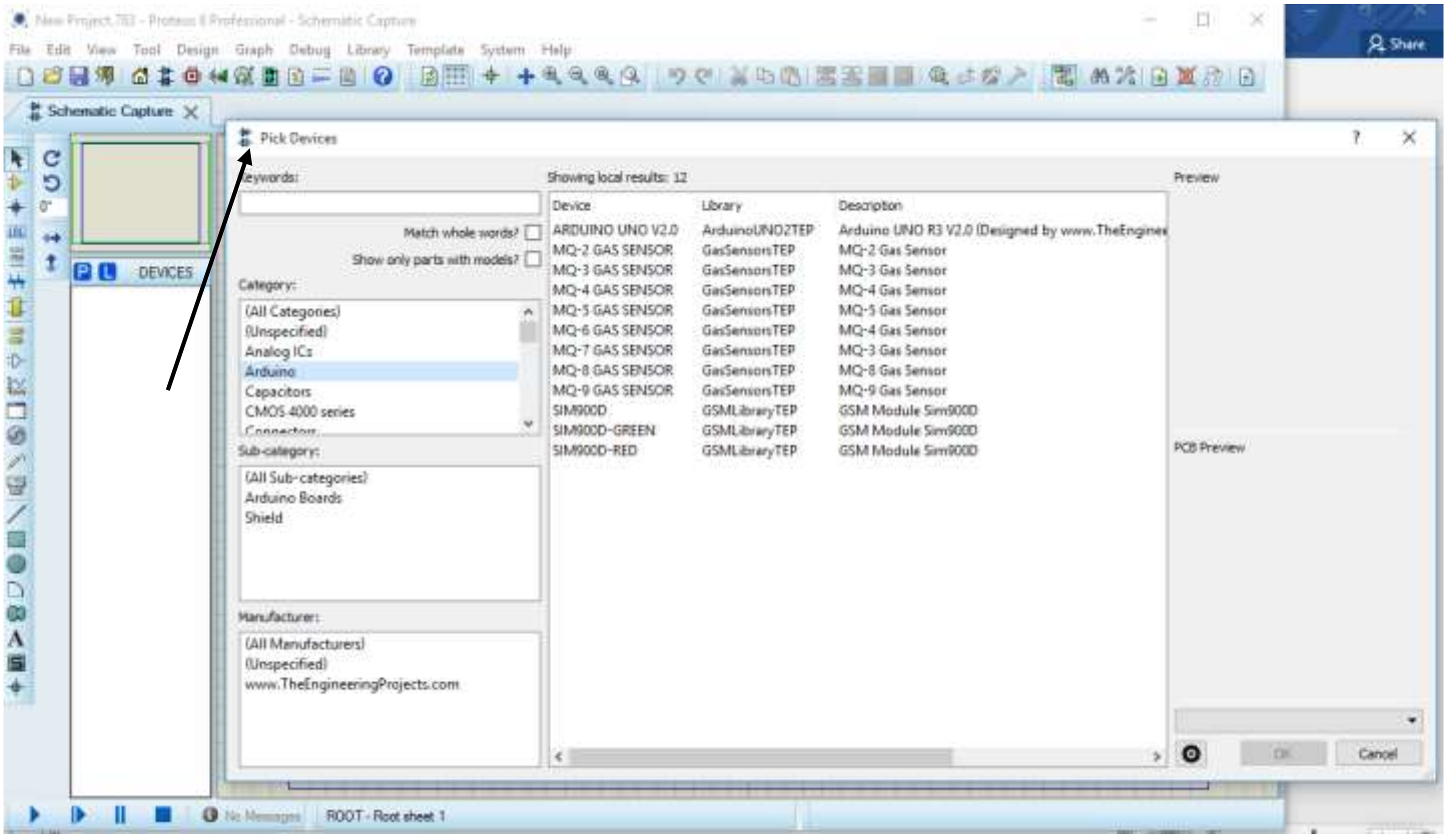

Figure 8: Screenshot of components selection in Proteus

Chapter 3: Design and Methodology

3.0 Introduction

Determining the validity of your study is anchored on your research paper's methodology. According to Somekh and Lewin (2005), a research methodology is both "the collection of methods or rules" you apply to your research, as well as the "principles, theories, and values" that support your research approach. Simply put, a research paper's methodology section must shed light on how you were able to collect or generate your research data and demonstrate how you analyze them (SHU Library, 2020).

3.1 Research Design

A research design is the overall strategy that a researcher chooses to integrate the different components of a research study in a coherent and logical way. It outlines the procedures and methods that will be used to collect and analyze data, as well as the theoretical framework and research questions that will guide the study.

3.1.1 Requirements Analysis

The requirements analysis is a crucial step in the development of any system, as it helps to identify the needs and expectations of the stakeholders. In the case of the IoT-based smoke detection and alerting system, the requirements analysis involves identifying the functional and non-functional requirements of the system. Overall, the requirements analysis for the IoT-based smoke detection and alerting system is critical to ensure that the system meets the needs and expectations of the stakeholders. By identifying the functional and non-functional requirements, the development team can design and implement a system that is effective, efficient, and reliable (Javed, M. A., & Rathore, M. M, 2018).

3.1.1.1 Functional Requirements

Functional requirements refer to what the system should do.

- Smoke detection: The system should be able to detect smoke in real-time and accurately.

- Alerting: The system should be able to alert the relevant authorities that is building occupants, in case of a fire.

- Automatic shut-off: The system should be able to automatically shut off the power supply in case of a fire to prevent further damage.

- Remote monitoring: The system should allow for remote monitoring of the building's status and the system's performance.

3.1.1.2 Non-Functional Requirements

- The system ought to be able to detect a fire as quickly as possible
- The system should be highly reliable, with minimal downtime.
- The system is supposed to be easy to install and use and understand for the building occupants and maintenance personnel.
- The system should be available all the time and should be able to detect fire anytime.
- The system should be prepared to use all the detectors accessible for decision-making
- The system should be cost-effective, with minimal maintenance and operating costs.

3.1.1.3 Hardware Requirements

- Personal computer

3.1.1.4 Software Requirements

- Windows 10 Operating system
- Cisco Packet Tracer
- Proteus
- Arduino IDE

3.2.1 System Development tools

In computer science, a methodology is a framework for organizing, scheduling, and managing the steps involved in developing an information system. Numerous frameworks for various projects have been identified by researchers, and each framework has pros and cons depending on how it will be used. The waterfall approach, spiral model, and progressive (prototyping) model are a few of these frameworks. Given that the project is very modest and has a fixed deadline, the author chose to utilize the waterfall methodology because of its simplicity. The waterfall model is the ideal option for a project of this nature because all the project's criteria have been determined and all the necessary tools are available.

3.2.2 Waterfall Model

According to (Jones, R. T., & Smith, J. K. , 2018), the Waterfall Model is a traditional software development approach that consists of a linear and sequential process where each phase of the development process must be completed before the next phase can begin. The five phases of the Waterfall Model are: requirements Analysis, system design, implementation, testing, and maintenance

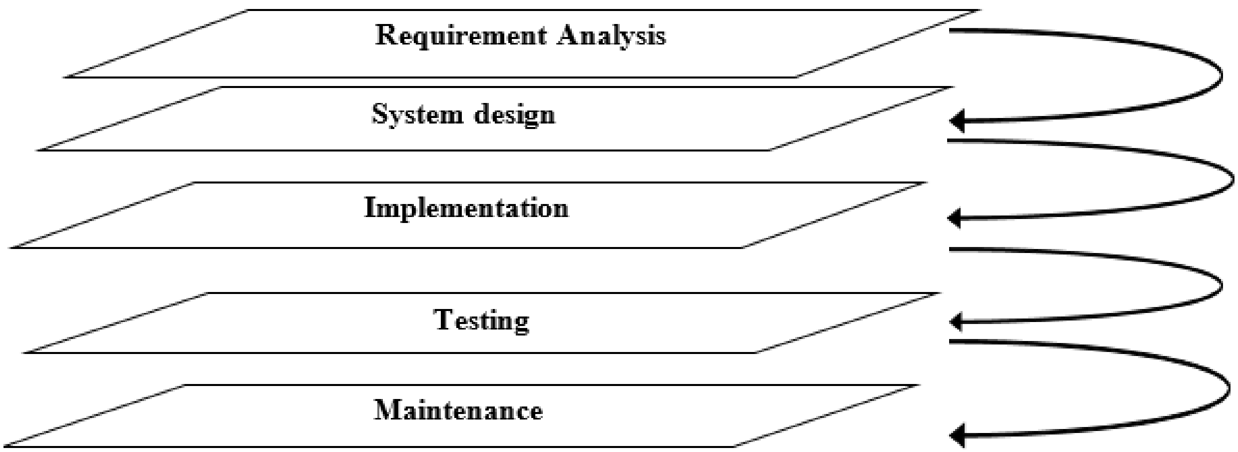

Figure 9: Waterfall Model

3.3Summary of how the system works

The IoT-based smoke detection and alerting system using Arduino IDE and Proteus is designed to detect smoke in real-time and alert the relevant authorities in case of a fire. The system consists of various components, including smoke and temperature sensors, Arduino board, Wi-Fi module, and a buzzer. The system works by using the smoke sensor to detect smoke in the environment as well as the temperature sensors that senses the change of temperature in the environment. The smoke sensor is connected to the Arduino board, which processes the data from the sensor and sends it to the Wi-Fi module. The Wi-Fi module is used to connect the system to the internet, allowing for remote monitoring and control of the system. When the smoke sensor detects smoke, the Arduino board sends a signal to the buzzer, which alerts the occupants of the building. Proteus is used in the development of the system to simulate the behavior of the system before it is implemented in the real world. This helps to identify any potential issues or problems with the system before it is deployed. (Javed, M. A., & Rathore, M. M, 2018)

In summary, the IoT-based smoke detection and alerting system using Arduino IDE and Proteus works by using smoke sensors to detect smoke, Arduino board to process the data and send signals, Wi-Fi module to connect the system to the internet, and a buzzer to alert the occupants of the building. Proteus is used to simulate the behavior of the system before it is deployed in the real world.

3.3System Design

The system design for the IoT-based smoke detection and alerting system using Arduino IDE and Proteus involves the integration of hardware and software components to detect smoke in real-time and alert the relevant authorities in case of a fire. The system consists of various components, including smoke sensors, Arduino board, Wi-Fi module, and a buzzer.

3.3.1Data Flow Diagram

The data flow diagram consists of two main components: the smoke detection system and the alerting system. The smoke detection system includes a smoke sensor module connected to an Arduino board. The sensor module detects the presence of smoke and sends a signal to the Arduino board. The Arduino board processes the signal and sends it to the Wi-Fi module (GSM), which is also connected to the board. The alerting system includes a buzzer module which is also connected to the Arduino board. When the smoke sensor module detects smoke, the Arduino board sends a signal to the buzzer module to sound an alarm. The Wi-Fi module sends a notification to the cloud server, which can then send an alert to the designated recipient's mobile device through an SMS.

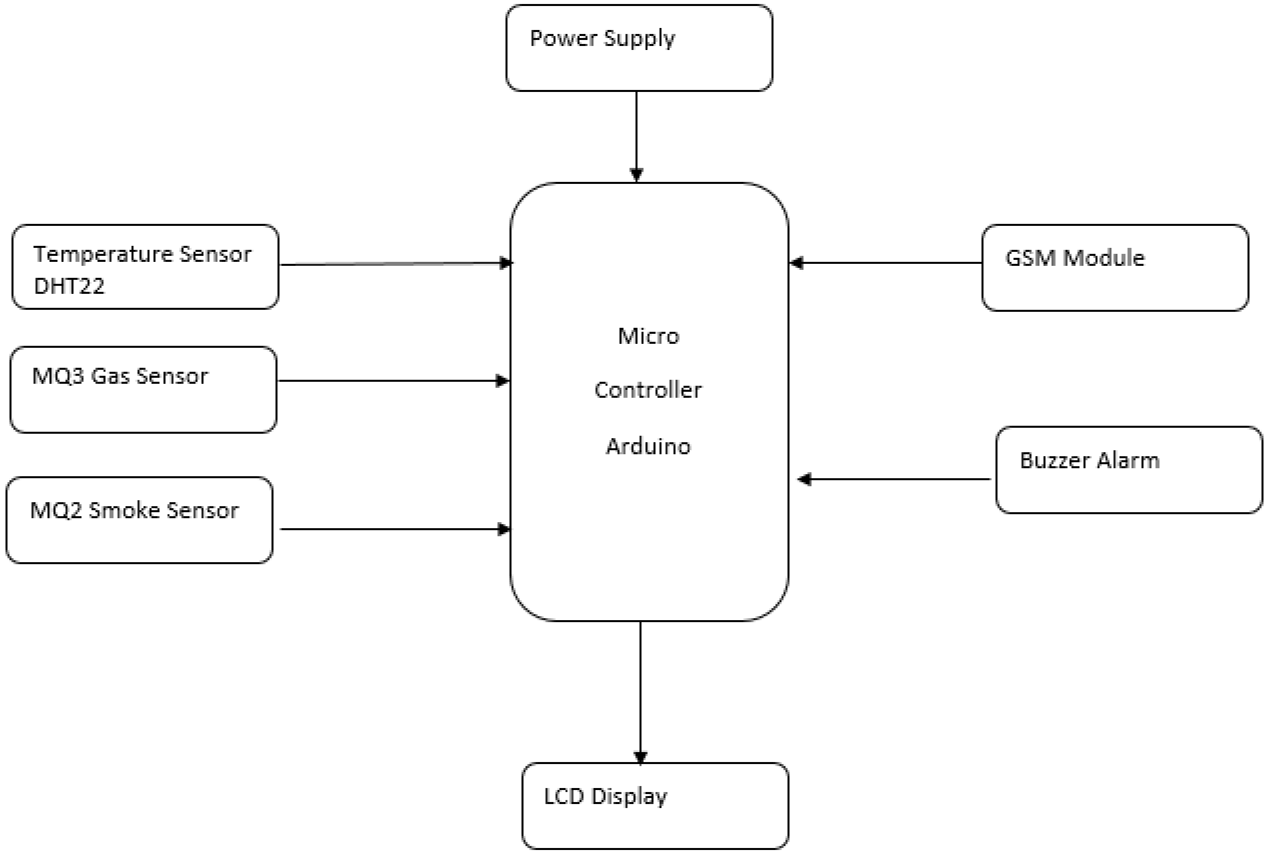

Figure 10: Data Flow Diagram

3.4.2SystemFlowChart

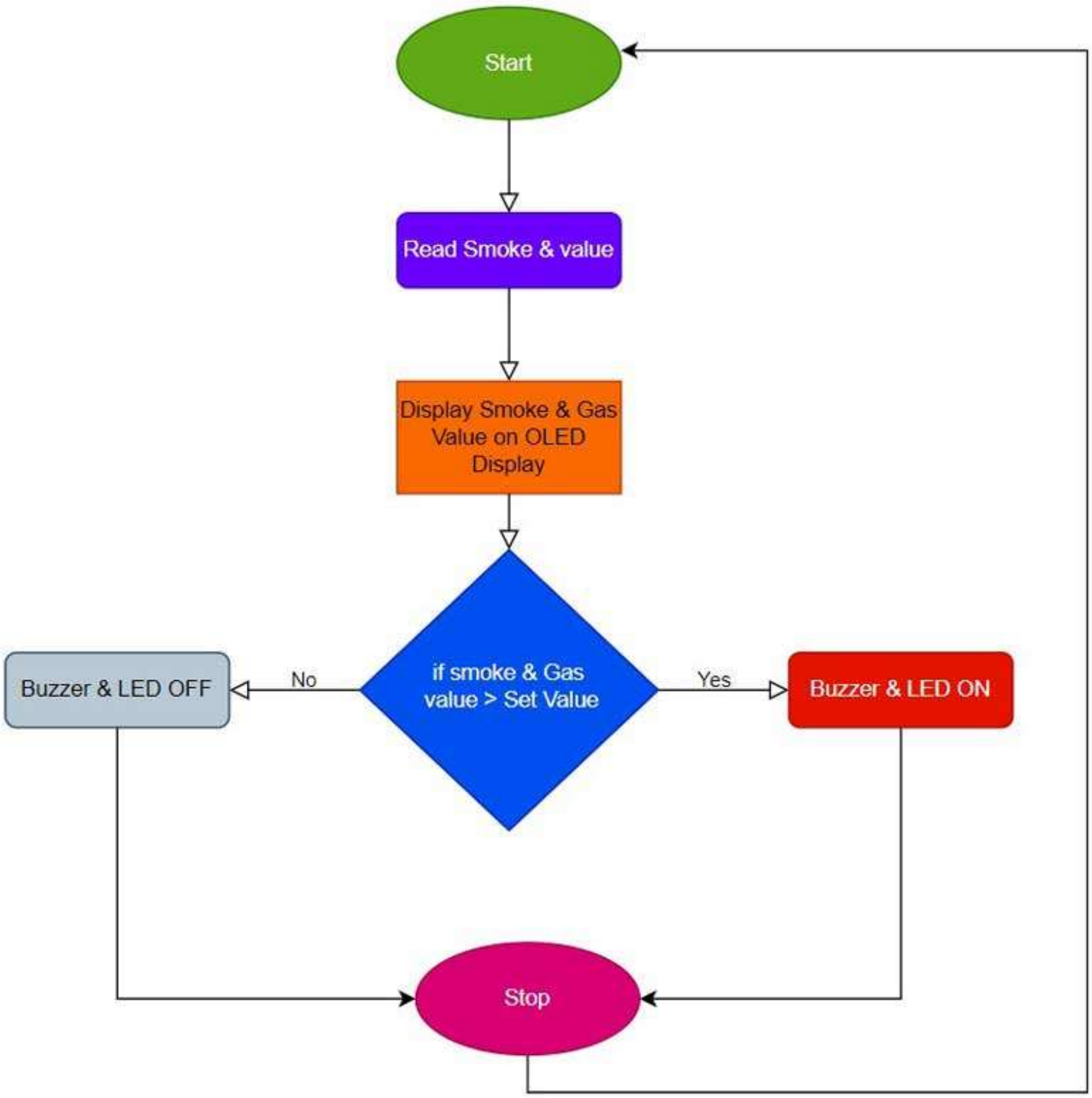

Figure 11: Flow Chart

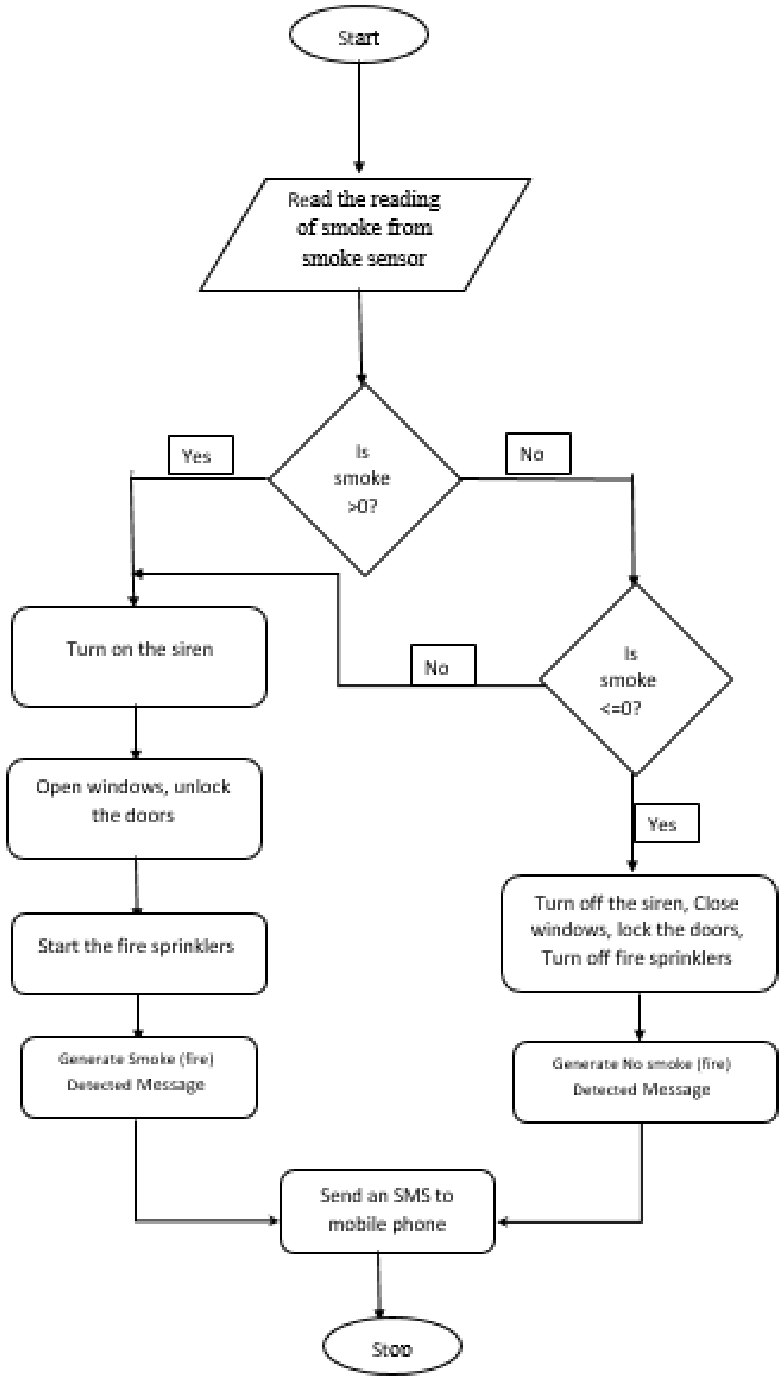

Figure 12: Flow Chart

3.5 Overall view of the system

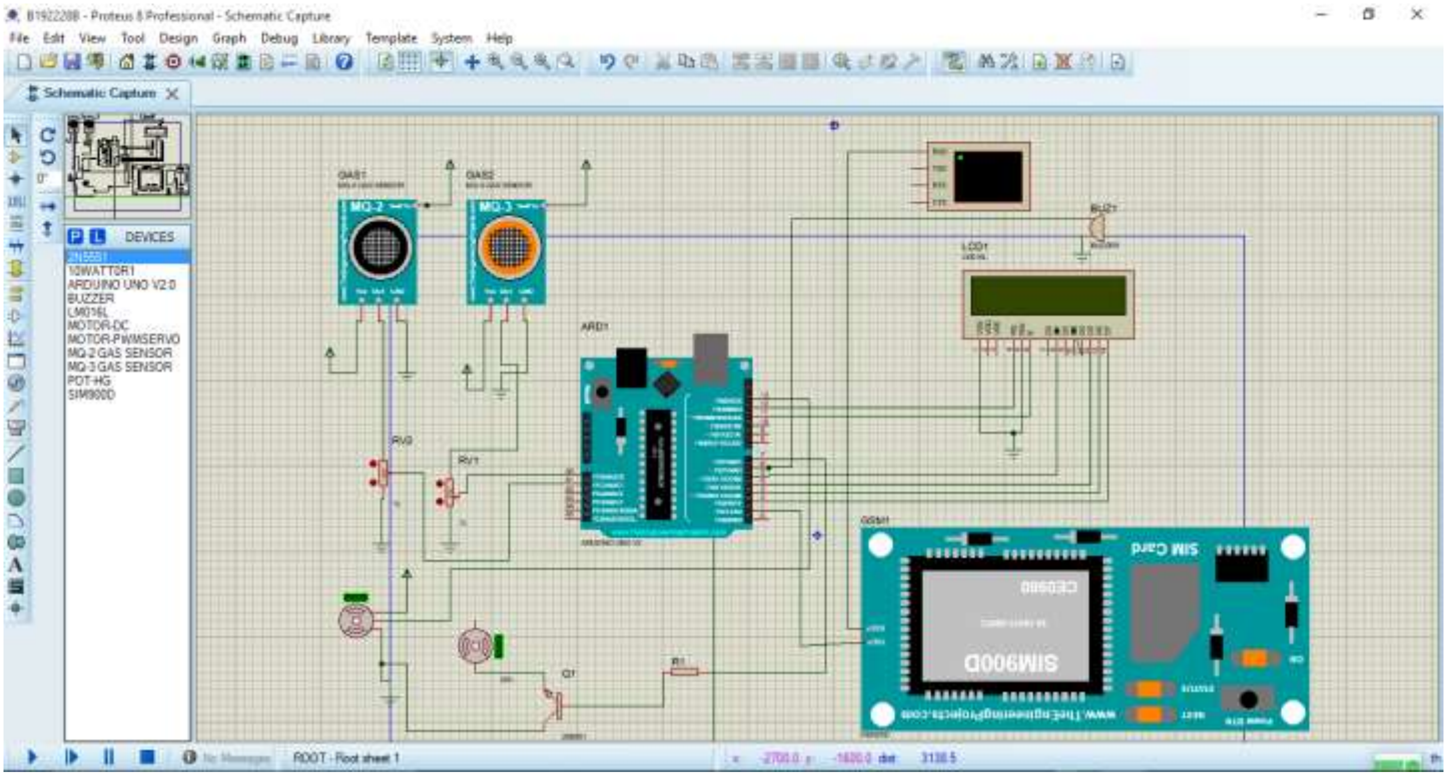

Figure 13: Screenshot of the simulation in Proteus

CHAPTER 4: RESULTS

4.0 Introduction

The aim of this chapter is to evaluate the performance of the system and verify that it meets its intended requirements. In this chapter, the testing process, test results, and analysis should be presented. This chapter is important as it provides insight into the system's performance and can help identify potential issues that need to be resolved. The system should be tested using a range of test cases that cover different scenarios and use cases. The test cases should cover areas such as smoke detection, alert triggering, alert notification, and response to alert. The results of the testing should be presented in this chapter, including any issues that were identified during the testing process (al S. R., 2018).

4.1 Testing

Testing for an IoT based smoke detection and alerting system involves verifying that the system functions as expected and meets its intended requirements. This typically involves a combination of black box and white box testing. Both black box and white box testing are important for ensuring the quality and reliability of an IoT based smoke detection and alerting system. By thoroughly testing the system's functionality and internal workings, you can identify and resolve issues before they impact the system's users.

4.1.1 Black box Testing

Black box testing involves testing the system's functionality without knowledge of its internal workings. This type of testing helps ensure that the system meets its intended requirements and functions as expected from a user's perspective (R. S. Pressman and B. Maxim, 2015). Black box testing for an IoT based smoke detection and alerting system involves testing the sensors and devices used to detect smoke, verifying that alerts are triggered correctly, and checking that the system responds appropriately to alerts. Black box testing is a type of software testing that evaluates the functionality of a software application without knowledge of its internal workings or code. It is also known as functional testing or specification-based testing. The aim of black box testing is to verify that the software application functions as intended and meets its intended requirements. Black box testing is useful for detecting issues related to user interface, functionality, and usability. It can also be used to evaluate the system's performance and compatibility with different hardware, software, and operating systems. However, black box testing may not detect issues related to code quality, security, and performance.

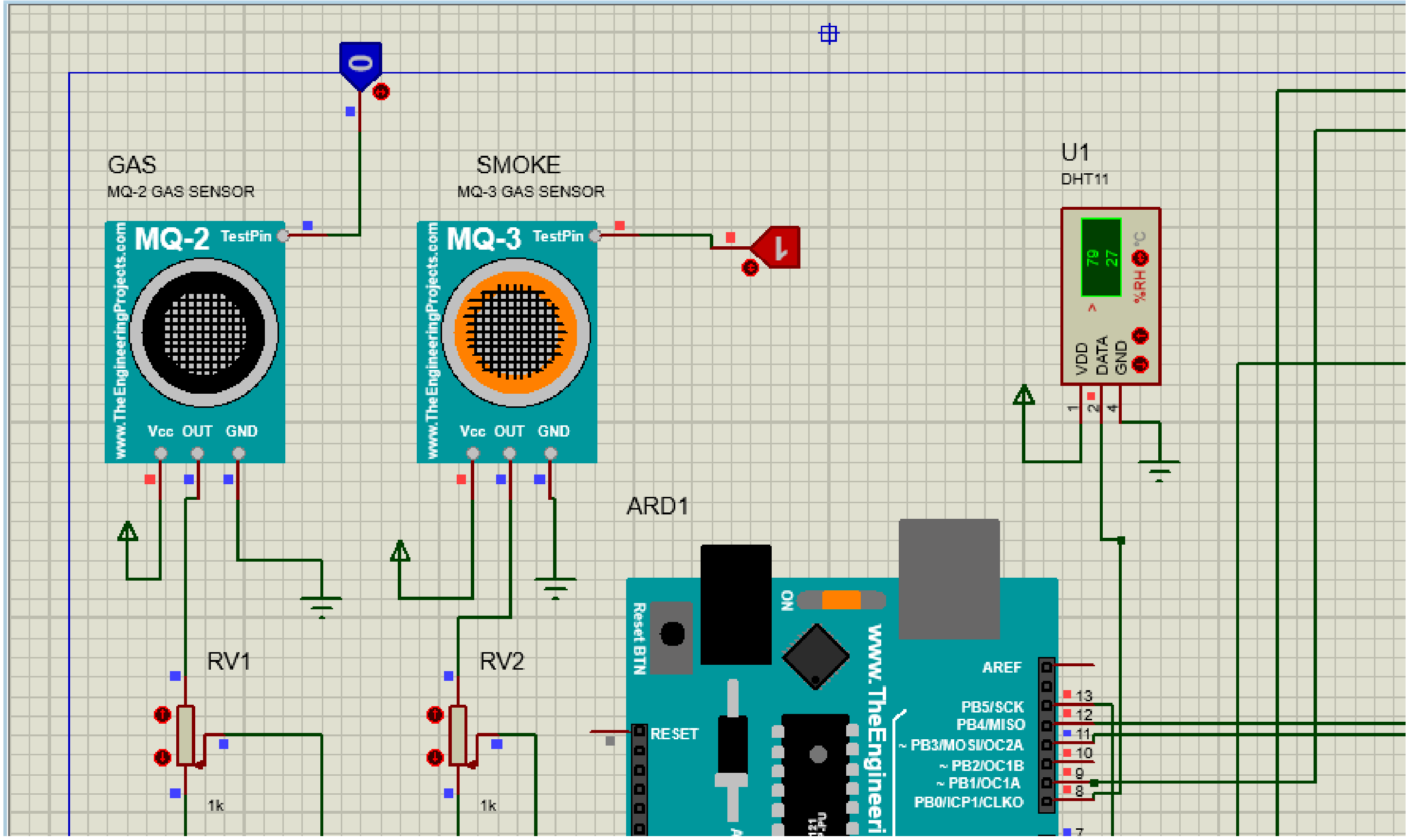

Figure 14: Running the simulation showing the sensors connected together with the test pins

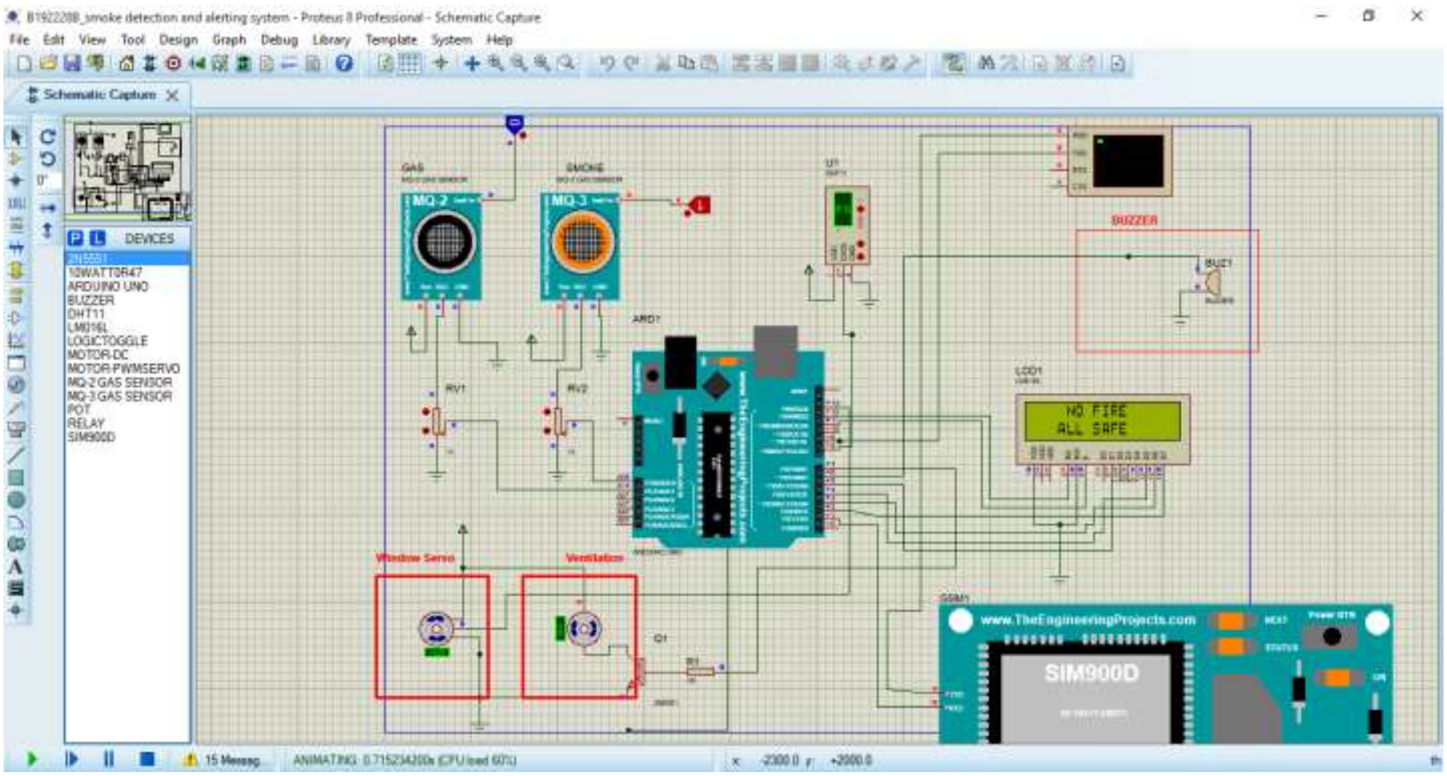

Figure 15: Running the simulation without fire

4.1.2 White box Testing

According to (R. S. Pressman and B. Maxim, 2015), white box testing is a type of software testing that involves testing the internal workings and code of a software application code to ensure that it meets its intended requirements and functions as expected. This type of testing helps identify and resolve issues that may not be apparent through black box testing. It is also known as structural testing or code-based testing. The aim of white box testing is to verify that the software functions as intended and meets its intended requirements. In white box testing, the tester has knowledge of the internal structure and code of the software application. This allows the tester to create test cases that target specific areas of the code and identify potential issues. White box testing is typically performed by developers or quality assurance engineers who have knowledge of programming languages and software development practices. White box testing is useful for detecting issues related to code quality, security, and performance. It can also be used to evaluate the system's scalability and maintainability. However, white box testing requires a deep understanding of the system's architecture and code, which can make it more time-consuming and expensive than black box testing. White box testing for an IoT based smoke detection and alerting system involves testing the code structure, communication protocols, and interactions between system components.

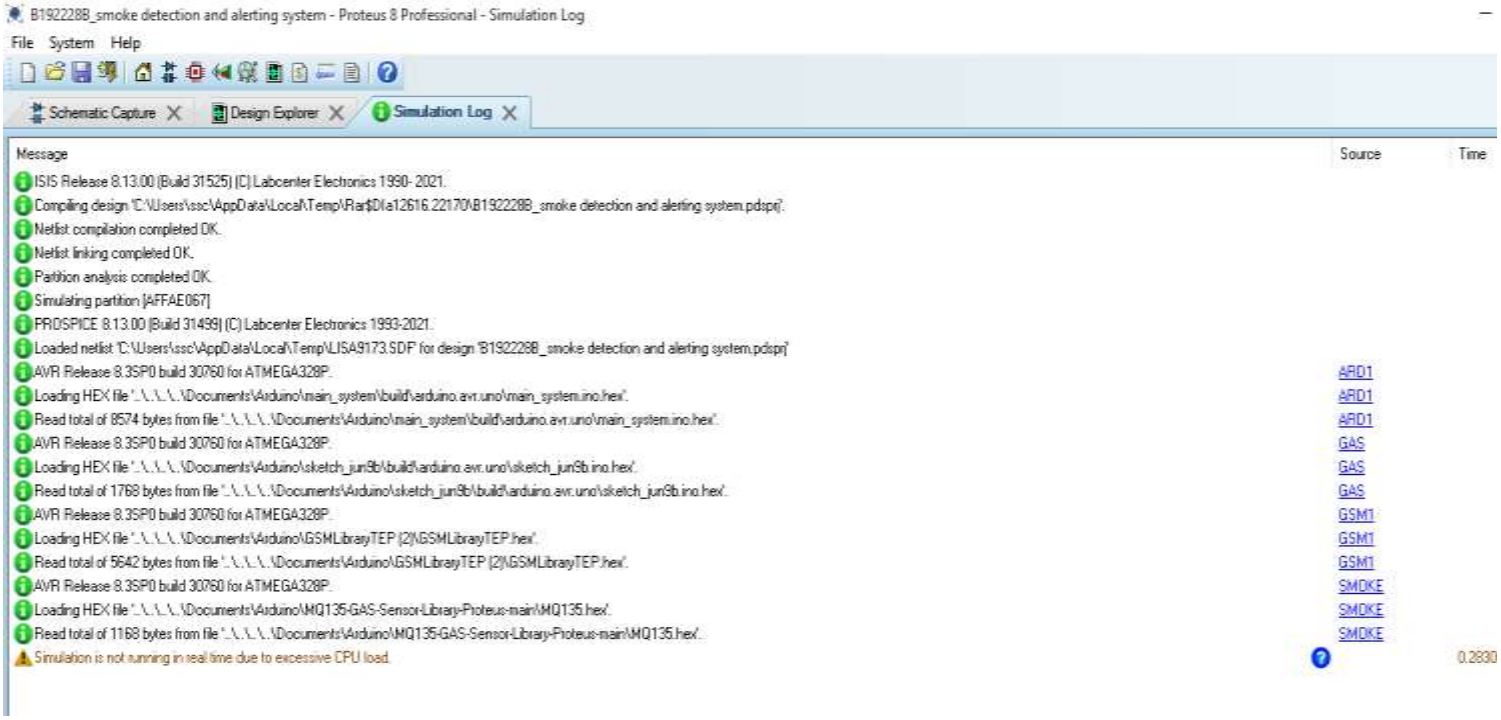

Figure 16: simulation log

4.2 Evaluation Measures and results

In this chapter, the performance of the system is going to be evaluated based on different metrics and criteria. Some evaluation measures for the smoke detection and alerting system include: Detection accuracy where we check the percentage of times the system correctly detects smoke. Alert response time, through checking the time taken by the system to send an alert after detecting smoke. The percentage of times the system sends an alert when smoke is detected which determines the alert reliability. False positive rate: The percentage of times the system sends an alert when there is no smoke. The amount of power consumed by the system during operation so as to have detailed information on the power consumption. System availability, the percentage of time the system is operational and available for use. The results can then be analyzed to identify any issues or areas for improvement. For example, if the detection accuracy is low, the system's smoke detection algorithm could be improved. If the alert response time is high, the system's communication protocol could be optimized to reduce latency.

The effectiveness of the smoke detection and alerting system can be assessed, and potential areas for improvement can be found, by employing a confusion matrix and computing evaluation measures. This may enhance the system's ability to detect smoke and issue alerts while maintaining reliability.

Table 1 Confusion Matric

	Smoke Present	No Smoke Present
Smoke Detected	True Positive	False Positive
No Smoke Detected	False Negative	True Negative

4.2.1 Accuracy

Accuracy is a measure of how well the system is able to correctly identify the presence or absence of smoke. It is calculated as the number of correct predictions divided by the total number of predictions. In this case, the accuracy of the system can be calculated as:

Accuracy = (TP + TN) / (TP + FP + TN + FN)

where TP is true positive, TN is true negative, FP is false positive, and FN is false negative.

Precision is a measure of how well the system is able to correctly identify the presence of smoke. It is calculated as the number of true positives divided by the total number of positive predictions. In this case, the precision of the system can be calculated as:

Precision = TP / (TP + FP)

Recall is a measure of how well the system is able to correctly detect the presence of smoke. It is calculated as the number of true positives divided by the total number of actual positives. In this case, the recall of the system can be calculated as:

Recall = TP / (TP + FN)

F1 score is a measure of the system's overall performance, taking into account both precision and recall. It is calculated as the harmonic mean of precision and recall. In this case, the F1 score of the system can be calculated as:

F1 score = 2 * (Precision * Recall) / (Precision + Recall)

4.2.2 Response Time

The response time is the time interval between the detection of smoke and the triggering of the alert. It is used to measure the time it takes for the system to detect smoke and trigger an alert. The response time of the system can be affected by several factors, such as the sensitivity of the smoke sensor, the processing speed of the microcontroller, and the communication speed between the microcontroller and the alerting devices. To measure the response time, the system should be tested using a range of test cases that cover different scenarios and use cases. The test cases should include different levels of smoke concentration and different distances between the smoke sensor and the alerting devices.

4.3 Conclusion

Conclusion: In order to assess the effectiveness of an IoT-based smoke detection and warning system employing Proteus, testing, results, and analysis have been crucial components. Through testing, several use cases and situations were examined, and the system's accuracy and response time were gauged. To find any problems or potential areas for improvement, the test results were recorded and examined. The study can assist in identifying the underlying causes of any problems and possible remedies to enhance system performance. Conclusion: In order to assess the effectiveness of an IoT-based smoke detection and warning system employing Proteus, testing, results, and analysis have been crucial components. Through testing, several use cases and situations were examined, and the system's accuracy and response time were gauged. To find any problems or potential areas for improvement, the test results were recorded and examined. The study can assist in identifying the underlying causes of any problems and possible remedies to enhance system performance.

CHAPTER 5: RECOMMENDATIONS AND FUTURE WORK

5.1 Introduction

The researcher focused on findings presentation and data analysis in the preceding chapter. The recommendations and future work for an IoT-based smoke detection and warning system using Proteus and the Arduino IDE will be the main focus of this chapter. The recommendations and future work are aimed at improving the performance, functionality, and reliability of the system, as well as expanding its capabilities to meet the evolving needs of users.

5.2 Aims and Objectives Realisation

The main objectives of the system were to design and implement an early fire detection system, to be able to send real-time alerts to the user's smartphone and to evaluate the use of IOT in fire detection. To this end, the researcher developed a system that used IoT devices for fire detection and simulated the obtained data using Proteus which indicated that the system had in fact reduced late and false alarms and to alert the inhabitants.

5.3 Conclusion

In conclusion, the recommendations and future work for an IoT based smoke detection and alerting system using Proteus and Arduino IDE are aimed at improving the system's performance, functionality, and reliability.

The recommendations include improving accuracy and reliability, expanding functionality, enhancing alerting mechanisms, developing mobile applications, incorporating battery backup and redundancy, and conducting long-term testing. These recommendations are based on the evaluation of the system's performance, which was conducted through testing and analysis. By implementing these recommendations, the system can be improved to provide a more effective and reliable response to potential fire hazards. The recommendations aim to improve the system's accuracy, reliability, and response time, as well as to expand its capabilities to meet the evolving needs of users.

5.4 Recommendations

The recommendations and future work for an IoT based smoke detection and alerting system using Proteus and Arduino IDE are aimed at achieving the following aims and objectives:

Improve system performance: The primary aim of the recommendations is to improve the performance of the system by enhancing its accuracy, reliability, and response time. By implementing more sensitive smoke sensors, optimizing the code, and improving communication speed, the system can more accurately detect smoke and trigger alerts in a timely manner.

Enhance system functionality: The recommendations also aim to expand the functionality of the system by incorporating additional features, such as real-time monitoring and reporting, machine learning algorithms, and integration with other home automation systems. These enhancements can improve the system's capabilities and provide a more comprehensive solution for fire safety.

Improve user experience: The recommendations also aim to enhance the user experience by providing more intuitive and informative alerts, developing mobile applications for remote access and control, and incorporating voice alerts or alerts with visual cues.

Ensure system reliability: The recommendations aim to ensure system reliability by incorporating battery backup and redundancy, which can ensure that the system remains operational in the event of power outages or component failures.

Conduct long-term testing: Finally, the recommendations aim to conduct long-term testing to evaluate the system's performance over an extended period of time and to identify any issues that may arise as the system is used over time.

5.5 Future Work

Some future work that can be done for an IoT based smoke detection and alerting system using Proteus and Arduino IDE are cloud connectivity whereby the system can be connected to the cloud to enable remote monitoring and control. This can allow users to receive alerts and control the system from anywhere in the world, as well as developing mobile applications to provide users with a more intuitive and user-friendly interface for monitoring and controlling the system.

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