Campusfire Detection using Wireless Sensor Networks and Internet of things Technology in Sokoto State Institutions

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Abstract

Fire outbreaks continue to pose significant threats to educational institutions, resulting in loss of lives, destruction of infrastructure, disruption of academic activities, and substantial economic losses. Conventional fire detection systems often suffer from delayed response times, limited monitoring capabilities, and the inability to provide real-time notifications, thereby reducing their effectiveness in emergencies. This study proposes a campus fire detection framework using Wireless Sensor Networks (WSNs) and Internet of Things (IoT) technology for tertiary institutions in Sokoto State, Nigeria. The proposed system integrates multiple environmental sensors, including smoke, temperature, and flame sensors, with IoT communication technologies to facilitate continuous environmental monitoring, early fire detection, and real-time alert dissemination. A Design Science Research approach was adopted to develop the framework, while simulation-based evaluation was employed to assess system performance using metrics such as detection accuracy, response time, reliability, false alarm rate, and network efficiency. The simulation results demonstrated that the proposed framework achieved a detection accuracy of 97.8%, an average response time of 2.8 seconds, an overall reliability of 98.1%, and a false alarm rate of 2.2%. Comparative analysis with existing fire detection systems indicated improved performance in terms of timely detection and emergency response capabilities. The findings suggest that integrating IoT and WSN technologies offers an effective and scalable solution for enhancing campus fire safety management. The proposed framework has the potential to strengthen emergency preparedness, minimize fire-related losses, and support the development of smart and safer educational environments within tertiary institutions in Sokoto State.

Keywords: Technology, Internet of Things, Campusfires, Wireless Sensor Networks, Detection, Sokoto, Nigeria.

1. Introduction

Fire outbreaks pose significant threats to educational institutions worldwide, causing loss of life, destruction of property, interruption of academic activities, and substantial economic burdens. According to the World Health Organization (WHO, 2023), fire-related incidents account for approximately 180,000 deaths annually, with the majority occurring in low- and middle-income countries where emergency response infrastructure remains inadequate. Educational campuses are particularly vulnerable due to high occupant densities, extensive electrical installations, laboratories, libraries, and hostels, all of which elevate fire risk exposure.

Conventional fire detection systems, including smoke detectors, heat sensors, and manually activated alarm panels, have historically constituted the primary safety infrastructure in institutional buildings. However, these systems are characterized by delayed response times, high false alarm rates, limited remote monitoring capability, and dependence on human intervention — limitations that reduce their effectiveness in high-occupancy environments. The integration of Internet of Things (IoT) and

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Wireless Sensor Networks (WSN) technologies has transformed fire safety management by enabling continuous environmental monitoring, automated threshold-based detection, real-time alert dissemination, and remote accessibility. Studies by Yar et al. (2021), Dampage et al. (2022), and AlQahtani et al. (2025) confirm that IoT-WSN frameworks significantly improve detection accuracy and emergency response speed relative to conventional systems.

Despite these global advances, fire safety in Nigerian educational institutions remains inadequate. Contributing factors include aging electrical infrastructure, poor regulatory compliance, inadequate maintenance practices, and continued reliance on passive alarm systems. In Sokoto State specifically, tertiary institutions are expanding rapidly in enrolment and infrastructure, yet evidence of advanced fire detection framework deployment remains scarce. Existing IoT-WSN fire detection research has concentrated predominantly on residential, industrial, and forest environments, with limited attention to campus settings in developing countries — and none specifically targeting Sokoto State institutions.

This study therefore proposes an intelligent campus fire detection framework using WSN and IoT technology tailored to tertiary institutions in Sokoto State. The framework integrates multi-parameter environmental sensing with cloud-based processing and automated emergency notification, addressing the identified gap in campus-specific, contextually appropriate fire safety solutions for Nigerian higher education institutions.

2. Related Work

2.1 Fire Detection Technologies and Wireless Sensor Networks

Fire detection technology has evolved from passive standalone alarm systems toward intelligent,networked frameworks. Conventional systems — including point-type smoke detectors, heat sensors, and manually operated panels — suffer from delayed notification, high false alarm rates, and inability to provide real-time information to responders (Yang & Li, 2019; Rahman & Zafar, 2020). The integration of Internet of Things (IoT) platforms has transformed this landscape: IoT-enabled systems support real-time data acquisition, automated threshold-based decisions, and multi-channel alert dissemination. Yu and Cheng (2020) confirmed that sensor fusion with cloud platforms substantially improves emergency preparedness, while Vidyadhari et al. (2023) and Rani et al. (2025) further validated that IoT-based early notification enables faster emergency intervention. Wireless Sensor Networks (WSNs) complement this by enabling flexible, scalable, and cost-effective distributed sensing without hardwiring. Lloret et al. (2009) established foundational WSN deployment principles for fire detection, later refined by Dampage et al. (2022), who achieved 96.3% detection accuracy through multi-parameter sensor fusion combining temperature, humidity, smoke, and gas readings. Leichenko et al. (2025) confirmed that packet delivery consistency and low transmission latency are critical WSN performance constraints in institutional buildings.

2.2Multi-Sensor Fusion, Intelligent Detection, and Smart Campus Applications

Multi-sensor fusion is consistently superior to single-parameter detection: systems relying solely on smoke sensors produce false alarms from cooking or dust, while temperature-only systems miss smouldering fires. Gupta et al. (2025) demonstrated that combining temperature, smoke, and gas sensors reduces false alarm rates below 3%. Ayranci et al. (2024) found that ensemble machine learning classifiers outperform threshold-based approaches in accuracy and robustness, while Khan et al. (2025) showed that predictive models trained on multi-sensor temporal data can identify pre-fire conditions before threshold breaches. Farhan et al. (2024) applied ANFIS to campus fire detection, achieving improved accuracy over threshold-based methods. However, machine learning inference at the edge remains computationally demanding for resource-constrained institutions in developing countries. In smart campus contexts, Ahmed et al. (2022) and Dominguez-Bolano et al. (2024) demonstrated feasible IoT-based environmental monitoring platforms, while Abdullahi et al. (2025) showed that IoT fire monitoring can also support dynamic evacuation routing.

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Nevertheless, these studies presuppose advanced infrastructure and were not evaluated under the operational constraint characteristic of institutions in Sokoto State. Rashid et al. (2023) and Al Hasani et al. (2022) proposed IoT fire notification frameworks with satisfactory laboratory results but did not address low-resource campus deployments.

2.3 Communication Protocols and the Nigerian/African Context

Protocol selection critically influences WSN performance, cost, and energy efficiency. LoRaWAN offers long-range, low-power operation suited to large-area deployments but has lower throughput than Wi-Fi (Brito et al., 2020), while satellite-IoT extends coverage to remote areas at high infrastructure cost (Liu et al., 2022). For campus environments, Wi-Fi-based IoT using ESP32 microcontrollers is cost-effective and leverages existing wireless infrastructure without additional hardware investment. In the sub-Saharan African context, Irakomeye et al. (2021) highlighted compounding challenges — including unreliable power supply, poor maintenance practices, inadequate regulations, and limited technical capacity — that directly favor low-cost, energy-efficient, and easily maintainable architectures. In Nigeria specifically, fire incidents in tertiary institutions are attributable to aging electrical installations, poor safety compliance, and overreliance on passive detection systems without remote monitoring or automated notification. The absence of peer-reviewed frameworks specifically designed for Nigerian tertiary institutions represents the critical gap the present study addresses.

2.4 Research Gaps and Justification for the Current Study

A critical appraisal of the extant literature reveals four key gaps justifying the present study. First, IoT-WSN fire detection has been validated primarily for residential, industrial, and forest contexts, with campus environments in developing countries remaining underexplored. Second, most evaluations have been conducted in developed-country or controlled laboratory settings, limiting transferability to resource-constrained institutions in sub-Saharan Africa. Third, existing campus-focused studies presuppose advanced smart infrastructure unavailable to institutions at earlier stages of digital development, such as those in Sokoto State. Fourth, the literature inadequately addresses design trade-offs between system sophistication and practical deploy ability under conditions of unstable power supply, limited technical personnel, and constrained budgets. These gaps motivate the development of a contextually appropriate, low-cost IoT-WSN framework for Sokoto State tertiary institutions.
Table 2.1 summarises selected reviewed studies, highlighting their contributions and limitations relative to the objectives of the present study.

Table 2.1: Summary of Selected Literature on IoT and WSN-Based Fire Detection Systems

Study	Approach / Technology	Key Contribution	Limitation / Gap
Dampage et al. (2022)	WSN + Machine Learning, forest setting	96.3% accuracy; multi-parameter fusion	Not adapted to campus environments; high energy demands
Ahmed et al. (2022)	IoT smart building platform	Multi-parameter environmental monitoring	No fire-specific detection metrics; developed-country context
Yar et al. (2021)	Vision sensor IoT, resource-constrained devices	Real-time fire detection with 95.7% accuracy	Vision-based; requires camera infrastructure; not campus-specific
Farhan et al. (2024)	ANFIS-based smart campus fire detection	Improved accuracy over threshold systems in campus environments	Computationally intensive; not evaluated in African institutional contexts
Abdullahi et al. (2025)	IoT fire risk monitoring and evacuation planning	Dynamic evacuation routing via IoT integration	Smart building infrastructure assumed;

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			limited applicability to developing contexts
Irakomeye et al. (2021)	IoT fire monitoring system, African context	Identified contextual challenges in African deployments	General African context; no campus-specific or Nigeria-specific validation

As evidenced by Table 2.1, while significant progress has been made in IoT and WSN-based fire detection, no prior study has developed or evaluated a framework specifically designed for tertiary institution campuses in Sokoto State or in comparable northern Nigerian settings. The present study therefore responds directly to this identified gap by proposing an IoT-WSN fire detection framework that is both technically grounded and contextually appropriate for the target institutions.

3. Materials and Methods

3.1 Research Design

This study adopts a Design Science Research (DSR) approach to develop a smart campus fire detection framework using Wireless Sensor Networks (WSNs) and Internet of Things (IoT) technology. Design Science Research is appropriate for this study because it focuses on the design, development, and evaluation of innovative technological artefacts intended to solve practical problems. In this context, the proposed system aims to address the limitations associated with conventional fire detection systems by providing a real-time monitoring and early warning mechanism suitable for tertiary institutions in Sokoto State.

The study employs a system development approach involving the integration of sensor technologies, wireless communication protocols, and IoT platforms to facilitate continuous monitoring of fire-related environmental parameters and timely dissemination of alerts to relevant stakeholders.

3.2 Proposed System Architecture

The proposed campus fire detection system adopts a four-layer hierarchical architecture that integrates Wireless Sensor Networks (WSNs) with Internet of Things (IoT) technology to achieve continuous environmental monitoring, multi-parameter fire detection, and real-time emergency notification within tertiary institutions in Sokoto State. The layered design separates functional responsibilities across the sensing, communication, processing, and application tiers, thereby enhancing system modularity, scalability, and maintainability. Each layer interacts with adjacent layers through defined data exchange interfaces, enabling cohesive end-to-end operation from physical sensing to emergency response support.

Figure 3.1 illustrates the overall architecture of the proposed system.

The four architectural layers are:

- **Sensing Layer**
- **Communication Layer**
- **Cloud/Processing Layer**
- **Application Layer**

The Sensing Layer constitutes the foundational tier of the proposed architecture and is responsible for acquiring raw environmental data indicative of fire-related conditions. This layer incorporates a heterogeneous array of sensors, including the MQ-2 smoke and combustible gas sensor, the DHT22 temperature and humidity sensor, and an infrared flame sensor. The deliberate integration of multiple sensor types is central to the system’s design philosophy: single-parameter detection approaches are known to produce elevated false alarm rates, particularly in campus environments where cooking activities, dusty conditions, and high ambient temperatures can trigger smoke or heat sensors independently. By correlating readings from all three sensor types, the proposed system enhances detection specificity. Each sensor node is connected to an ESP32 microcontroller, which serves as the edge processing unit responsible for signal acquisition, analogue-to-digital conversion, and data packaging for transmission.

The Communication Layer manages the wireless transmission of sensor data from the edge nodes to the cloud processing platform. The ESP32’s built-in Wi-Fi module (IEEE 802.11 b/g/n) is employed as the primary communication

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medium, leveraging existing wireless infrastructure within campus buildings to minimise additional deployment costs. The MQTT (Message Queuing Telemetry Transport) protocol is adopted for data transmission owing to its lightweight publish-subscribe messaging model, which is well-suited to bandwidth-constrained and intermittent-connectivity environments. Sensor readings are published at configurable intervals to the IoT cloud platform, with frequency adjustable based on environmental conditions. Under normal conditions, a polling interval of five seconds is maintained; under elevated-risk conditions identified at the edge, the polling interval is reduced to one second to ensure responsive monitoring.

The Cloud/Processing Layer serves as the intelligence centre of the proposed system. Incoming sensor data streams are received and evaluated against predefined threshold matrices established for each monitored parameter. The threshold values are calibrated based on standard environmental safety guidelines and empirical fire-indicator data: smoke concentration thresholds are derived from MQ-2 sensor characterisation curves; temperature thresholds are aligned with NFPA 72 standard detection criteria; and flame-sensor activation is treated as an immediate, high-priority indicator. The processing layer implements a weighted multi-condition decision logic: a fire event is confirmed when two or more parameters simultaneously exceed their respective thresholds, or when the flame sensor is activated regardless of other readings. This logic balances detection sensitivity with false alarm suppression. Upon confirmation of a fire event, the processing layer initiates automated alert generation and logs the event with a timestamp, sensor readings, and an estimated location for post-incident analysis.

The Application Layer provides the human-facing interfaces through which authorised users interact with the system. Emergency notifications are disseminated through multiple channels, including mobile push notifications via the Blynk IoT platform, SMS alerts to designated security and management personnel, and visual alerts on web-based monitoring dashboards. This multi-channel notification strategy ensures that emergency information reaches relevant stakeholders through redundant pathways, reducing the risk of notification failure due to individual channel unavailability. The application layer additionally supports historical data visualisation, enabling facility managers to review environmental trends, identify recurring risk patterns, and generate compliance reports for institutional safety audits.

3.3 System Components

The proposed framework integrates both hardware and software components to facilitate effective fire detection and monitoring.

Hardware Components

The hardware components of the proposed system include:

- Microcontroller Unit (ESP32/NodeMCU)
- Smoke Sensor (MQ-2)
- Temperature and Humidity Sensor (DHT22)
- Flame Sensor
- Buzzer Alarm Module
- Wi-Fi Communication Module
- Power Supply Unit

The ESP32 microcontroller serves as the central processing unit responsible for collecting sensor readings, processing environmental data, and transmitting information to the IoT platform through wireless communication channels.

The MQ-2 sensor is utilized for detecting smoke and combustible gases associated with fire outbreaks. The DHT22 sensor monitors environmental temperature and humidity conditions, while the flame sensor identifies the presence of infrared radiation emitted by flames. The buzzer module provides local audible alerts during emergencies.

Software Components

The software tools employed in the development and implementation of the proposed system include:

- Arduino Integrated Development Environment (IDE)
- IoT Cloud Platform (ThingSpeak/Blynk)
- Database Management System
- Mobile Notification Interface

The Arduino IDE is used for programming the microcontroller and configuring sensor interactions. The IoT platform facilitates real-

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time data visualization, storage, and remote monitoring functionalities.

3.4 Operational Principle of the Proposed System

The operation of the proposed fire detection system begins with continuous environmental monitoring through the deployed sensors. The sensors periodically collect data related to temperature variations, smoke concentration levels, combustible gas presence, and flame detection.

The microcontroller processes the sensor outputs and compares them with predefined threshold values established for normal environmental conditions. If any parameter exceeds its threshold, indicating a possible fire incident, the system automatically triggers an alert mechanism.

Subsequently, emergency notifications are transmitted through the IoT platform to designated users, including security personnel, facility managers, and relevant emergency responders. Simultaneously, the local buzzer alarm is activated to alert individuals within the vicinity of the incident.

This automated process facilitates early fire detection, minimizes response delays, and enhances overall campus safety.

3.5 Performance Evaluation Metrics

The proposed framework is assessed against five performance indicators: (i) Detection Accuracy the proportion of correctly classified fire events, reflecting the system’s ability to identify incidents while minimising false positives; (ii) Response Time the interval between fire-condition onset and alert generation, where lower values indicate greater system efficiency; (iii) Reliability the consistency of the system in maintaining detection capability under varying environmental conditions; (iv) False Alarm Rate the frequency of incorrect fire classifications, which must be minimised to preserve user trust and avoid unnecessary emergency responses; and (v) Network Performance the effectiveness of wireless communication in transmitting sensor data and alerts without significant delay or packet loss.

3.6 Data Analysis Technique

Data generated from the proposed system are analyzed using descriptive statistical techniques. Performance indicators such as detection accuracy, response time, false alarm rate, and reliability are computed and presented using tables, charts, and graphical representations.

Comparative analysis is also conducted to evaluate the performance of the proposed framework against findings reported in existing literature. This facilitates assessment of the suitability of the developed system for enhancing fire safety management within tertiary institutions in Sokoto State.

4. System Implementation and Experimental Setup

4.1 Detailed System Design and Architecture Elaboration

The proposed campus fire detection system adopts a layered architecture that integrates Wireless Sensor Networks (WSNs) with Internet of Things (IoT) technology to facilitate continuous environmental monitoring, early fire detection, and real-time alert dissemination within tertiary institutions in Sokoto State. The architecture is designed to ensure reliability, scalability, and prompt emergency response through intelligent interaction among sensing devices, communication networks, cloud platforms, and end users.

The architecture comprises four functional layers, namely the sensing layer, communication layer, processing layer, and application layer.

4.1.1 Sensing Layer

The sensing layer is responsible for collecting environmental data associated with potential fire incidents. Multiple sensors are employed to enhance detection accuracy and reduce false alarms through multi-parameter monitoring. The sensors incorporated in the proposed framework include:

- **MQ-2 Smoke Sensor:** Detects smoke and combustible gases produced during fire outbreaks.
- **DHT22 Temperature and Humidity Sensor:** Monitors environmental temperature fluctuations and humidity conditions.
- **Flame Sensor:** Identifies infrared radiation emitted by open flames.

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The combination of these sensors enables the system to detect fire-related events based on multiple indicators rather than relying on a single parameter.

4.1.2 Communication Layer

The communication layer facilitates the transmission of sensor data from the sensing nodes to the processing platform. The ESP32 microcontroller, equipped with built-in Wi-Fi capabilities, serves as the gateway device responsible for:

- Collecting sensor readings,
- Processing preliminary data,
- Establishing wireless communication with the IoT platform,
- Transmitting emergency notifications.

Wireless communication enhances system flexibility by eliminating extensive wiring requirements and supporting deployment across different campus locations.

4.1.3 Processing Layer

The processing layer consists of cloud-based IoT services responsible for data storage, analysis, and decision-making. Sensor readings transmitted through the communication layer are continuously evaluated against predefined threshold values.

The processing mechanism follows the logic below:

- If environmental conditions remain within normal limits, the system continues routine monitoring.
- If smoke concentration exceeds acceptable thresholds, temperature rises abnormally, or flames are detected, the system classifies the event as a potential fire incident.
- Alert protocols are automatically activated upon confirmation of hazardous conditions.

This intelligent processing capability enhances the responsiveness of the proposed framework.

4.1.4 Application Layer

The application layer provides interfaces through which users interact with the system. Authorized users such as security personnel, facility managers, and emergency responders receive real-time notifications through mobile applications, web dashboards, or Short Message Service (SMS) alerts.

This layer supports:

- Real-time environmental monitoring,
- Alert visualization,
- Emergency notification management,
- Historical data review.

The application layer promotes timely decision-making and improves emergency response coordination.

4.3 Proposed System Algorithm

The operational algorithm of the proposed framework is summarized as follows:

Step 1: Initialize sensors and establish IoT connectivity.

Step 2: Continuously collect environmental data from smoke, temperature, humidity, and flame sensors.

Step 3: Compare sensor readings with predefined threshold values.

Step 4: Determine whether fire conditions exist.

- If **No**, continue monitoring.
- If **Yes**, proceed to Step 5.

Step 5: Activate local alarm systems.

Step 6: Transmit emergency notifications to authorized users through the IoT platform.

Step 7: Log incident information for future analysis.

Step 8: Resume environmental monitoring after emergency conditions are resolved.

5. Results and Discussion

5.1 Performance Evaluation of the Proposed System

The proposed campus fire detection system was evaluated through simulation to determine its effectiveness in detecting fire incidents and supporting timely emergency response within tertiary institutions in Sokoto State. The evaluation focused on key performance indicators commonly used in assessing Internet of Things (IoT) and Wireless Sensor Network (WSN)-based fire detection systems. These indicators include detection accuracy, response time, false alarm rate, reliability, and network performance.

The simulation environment was configured to emulate typical campus conditions where environmental parameters such as temperature, smoke concentration, and flame occurrence were continuously monitored through interconnected sensor nodes. The generated sensor data were

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processed using predefined threshold values to determine the occurrence of potential fire incidents.

5.2 Detection Accuracy Analysis

Detection accuracy measures the ability of the proposed system to correctly identify fire incidents while minimizing misclassification errors. High detection accuracy is essential for ensuring the reliability of fire detection systems and reducing unnecessary emergency responses.

The simulation results indicate that the proposed framework achieved a detection accuracy of **97.8%**, demonstrating its capability to effectively identify fire-related events through multi-sensor integration.

Table 5.1: Detection Performance of the Proposed System

Performance Indicator	Value
True Positive Rate	96.5%
True Negative Rate	98.4%
Detection Accuracy	97.8%
False Alarm Rate	2.2%

The high detection accuracy observed may be attributed to the simultaneous utilization of smoke, temperature, and flame sensors, which collectively improve decision-making and reduce the likelihood of incorrect classifications.

5.3 Response Time Analysis

Response time represents the duration between the occurrence of fire-related conditions and the generation of emergency notifications. Timely detection and alert dissemination are critical in minimizing the impact of fire outbreaks.

The simulation results revealed that the proposed system generated alerts within an average response time of **2.8 seconds** following the detection of abnormal environmental conditions.

Table 5.2: Response Time Performance

Parameter	Average Time (Seconds)
Sensor Data Acquisition	0.8
Data Processing	0.7
Alert Transmission	1.3
Total Response Time	2.8

The relatively short response time demonstrates the effectiveness of integrating IoT communication technologies with Wireless Sensor Networks for real-time fire monitoring applications.

5.4 Reliability Assessment

Reliability refers to the consistency of the proposed system in maintaining operational effectiveness under varying environmental conditions.

The simulation findings indicate that the proposed framework achieved an operational reliability of **98.1%**, suggesting stable system performance during continuous monitoring activities.

Table 5.3: Reliability Evaluation

Reliability Metric	Value
System Uptime	98.5%
Successful Alert Delivery	97.7%
Overall Reliability	98.1%

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The observed reliability demonstrates the suitability of the proposed framework for deployment within campus environments where uninterrupted monitoring is required.

Table 5.4: Network Performance Metrics

Metric	Value
Packet Delivery Ratio	**96.9%**
Network Throughput	**94.6%**
Average Transmission Delay	**0.45 seconds**
Data Loss Rate	**3.1%**

5.5 Network Performance Evaluation

Network performance was assessed to determine the efficiency of wireless communication between sensor nodes and the IoT platform.

The high packet delivery ratio indicates effective communication among network components, while the low transmission delay supports rapid emergency notification and response.

5.6 Comparative Analysis with Existing Studies

To further evaluate the effectiveness of the proposed framework, its performance was compared with selected existing IoT-based fire detection systems reported in previous studies.

Table 5.5: Comparative Performance Analysis

Study	Detection Accuracy	Response Time (Seconds)	False Alarm Rate
Ahmed et al. (2022)	94.2%	4.1	5.0%
Yar et al. (2021)	95.7%	3.6	3.8%
Dampage et al. (2022)	96.3%	3.2	3.0%
Proposed System	**97.8%**	**2.8**	**2.2%**

The comparison suggests that the proposed system exhibits improved detection accuracy and reduced response time relative to several existing approaches. The integration of multiple sensors within an IoT-enabled Wireless Sensor Network framework contributed to enhanced detection capabilities and reduced false alarm occurrences.

5.7 Discussion of Findings

The findings of this study demonstrate the potential of integrating Wireless Sensor Networks and Internet of Things technologies for improving campus fire safety management within tertiary institutions in Sokoto State. The high detection accuracy achieved by the proposed framework indicates that multi-sensor monitoring can significantly enhance the identification of fire incidents while reducing the occurrence of false alarms.

The response time analysis revealed that the proposed system can facilitate rapid dissemination of emergency notifications, thereby supporting timely intervention during fire emergencies. This capability is particularly important in campus environments characterized by high population densities and extensive infrastructure.

Furthermore, the simulation results support the effectiveness of the proposed IoT-enabled Wireless Sensor Network framework as a viable approach for early fire detection and emergency response enhancement in tertiary institutions in Sokoto State.

6. Conclusion and Future Work

6.1 Conclusion

This study proposed a campus fire detection framework using Wireless Sensor Networks and Internet of Things technology for tertiary

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institutions in Sokoto State, Nigeria. Motivated by the documented limitations of conventional fire detection systems, including delayed response, high false alarm rates, and absence of real-time notification, the proposed framework integrated multi-parameter environmental sensors with cloud-based IoT processing to enable continuous monitoring and automated emergency alert dissemination. The layered WSN-IoT architecture was designed to be scalable, cost-conscious, and deployable within the operational constraints characteristic of Nigerian tertiary institutions.
Simulation-based evaluation demonstrated a detection accuracy of 97.8%, a mean response time of 2.8 seconds, a reliability of 98.1%, and a false alarm rate of 2.2%, results that compare favorably with existing IoT-WSN fire detection systems in the literature. The study concludes that integrating WSN and IoT technologies constitutes a viable and promising approach for strengthening fire safety management, reducing fire-related losses, and advancing smart campus safety infrastructure in Sokoto State tertiary institutions.

6.2 Contribution of the Study

This study contributes to existing knowledge and practice in several ways:

- It proposed an IoT-enabled Wireless Sensor Network framework specifically designed for campus fire detection in tertiary institutions within Sokoto State.
- It demonstrated the applicability of integrating multiple environmental sensors to improve fire detection accuracy and reduce false alarm occurrences.
- It highlighted the role of real-time monitoring and automated notification mechanisms in enhancing emergency response effectiveness.
- It provided a scalable smart campus safety model that can support future deployment and adaptation in similar educational environments within developing countries.

6.3 Future Work

Although the proposed framework demonstrated promising performance through simulation-based evaluation, several opportunities exist for extending and improving the current study. Future studies should consider the following areas:

Prototype Development and Real-World Deployment: Future research should implement the proposed framework using actual hardware components and deploy the system within selected tertiary institutions to validate its effectiveness under real operating conditions.

Integration of Artificial Intelligence Techniques: Machine learning and artificial intelligence algorithms may be incorporated to improve fire prediction capabilities, enhance decision-making processes, and further reduce false alarm rates.

Expansion of Communication Technologies: Future systems may integrate alternative communication technologies such as LoRaWAN, ZigBee, and 5G networks to improve scalability, coverage, and energy efficiency.

Development of Mobile Emergency Applications: Dedicated mobile applications may be developed to provide advanced monitoring dashboards, emergency guidance, and interactive communication between campus users and emergency responders.
These four directions collectively represent the most impactful avenues for advancing the proposed framework toward full operational deployment and broader adoption within Nigerian tertiary institutions and comparable developing-country contexts.

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