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IoT-Enabled Home Security Systems: Advanced Technology for Enhanced Safety and Efficiency

Er. Shivani Sharma
Computer Science and Engineering
Chandigarh University, Gharuan,
Punjab- 140413
shivani.e16453@cumail.in

Ankit Kumar
Computer Science and Engineering
Chandigarh University, Gharuan,
Punjab- 140413
work2ankit@gmail.com

Prakhar Gupta
Computer Science and Engineering
Chandigarh University, Gharuan,
Punjab- 140413
prakhargupta12@outlook.in

Shreshth
Computer Science and Engineering
Chandigarh University, Gharuan,
Punjab- 140413
tyagishreshtha@gmail.com

Sahil Dhatterwal
Computer Science and Engineering
Chandigarh University, Gharuan,
Punjab- 140413
Sahildhatterwal6210@gmail.com

Vipul Kr. Sharma
Computer Science and Engineering
Chandigarh University, Gharuan,
Punjab- 140413
sharmavipul578@gmail.com

Abstract— The advanced IoT-enabled home security system presented in this study is intended to solve major drawbacks in current security systems, including excessive energy consumption, scalability issues, and cybersecurity concerns. Modern smart homes can now have an extremely effective, safe, and scalable solution thanks to the suggested system, which combines state-of-the-art wireless sensors, intelligent power management algorithms, decentralised cloud architecture, and a machine-learning-based threat detection model. Our trials show that our system is superior in terms of energy savings, intrusion detection accuracy, and user happiness. They were carried out in both simulated environments and real-world applications. Comparing the system to conventional systems, there is a notable 15% increase in detection accuracy and a 30% decrease in energy use.

Moreover, the system can adapt to new threats by utilising adaptive learning techniques, which guarantees the system's long-term effectiveness. Positive user experiences are influenced by user input, which shows an increased sense of security and control over their environments. In conclusion, we talk about how incorporating blockchain technology could enhance data integrity and how 5G connectivity could revolutionise real-time communication and response.

Keywords— IoT, Home Security, Energy Efficiency, Machine Learning, Cybersecurity, Smart Homes, Decentralized Cloud, Power Management.

I. INTRODUCTION

The need for smart home technology has increased due to our growing reliance on the Internet of Things (IoT), especially in the area of home security. Unprecedented degrees of automation, remote control, and interaction with other smart devices are provided by IoT-enabled home security systems. These systems provide real-time monitoring, threat identification, and response through the use of wireless sensors, cloud connectivity, and machine learning. Unfortunately, problems including excessive energy consumption, weaknesses in centralized data storage, and uneven compatibility between devices and platforms plague many of the IoT security solutions currently in use [1] [2].

The new IoT-enabled home security framework presented in this study is intended to address these issues. Through the integration of intelligent power management, decentralized cloud architecture, and advanced sensor networks, our method lowers the overall energy consumption of the system while improving cybersecurity. The adoption of machine learning models increases danger detection accuracy even more, giving consumers a dependable, effective, and safe home security system. Furthermore, our architecture's decentralized design reduces the dangers associated with single points of failure, strengthening the system's resistance to cyberattacks. Scalable framework that makes it simple to integrate new gadgets and technologies as they become available. The ultimate goal of our study is to provide a comprehensive solution that satisfies the changing needs of contemporary homes, thereby setting a new benchmark in smart home security.

II. Literature Review

The benefits of IoT in home security have been discussed in previous literature, with particular attention paid to the capability of using linked sensors and cameras to remotely monitor and control home environments [3] [4]. The use of wireless sensor networks (WSNs) to identify emergencies such as fires and incursions has been the subject of several studies [5] [6]. Nevertheless, most of these systems rely heavily on energy and don't have robust real-time power management techniques. Additionally, they frequently use centralized cloud architectures, which present serious cybersecurity risks [7] [8].

Earlier studies have also looked at a variety of danger detection methods, such as vibration sensors, sound analysis, and motion detection [9] [10]. Although these methods are often useful, they frequently produce large percentages of false positives, which irritates users. Furthermore, there is still a lack of compatibility across IoT devices from different manufacturers, which makes it more difficult to integrate various home security components into a single, cohesive system [11].

Table 1: Limitations in Existing Literature

Study	Focus	Limitations
A. Smith et al. [2019]【4】	Wireless sensor networks	High energy consumption, false alarms
B. Johnson et al. [2021]【7】	Centralized cloud storage	Vulnerable to cyber-attacks
C. Kumar et al. [2020]【10】	IoT-based intrusion detection	Limited scalability, privacy concerns

Most of these research suggest ways to strengthen privacy protection and power management, but they don't provide all-encompassing answers. By providing a system that greatly increases energy efficiency and makes use of decentralized design for improved security and scalability, our research fills these gaps. By doing this, we hope to close the gaps that currently exist in the literature by putting out an integrated strategy that stresses the significance of seamless interoperability among diverse IoT devices in addition to energy usage and cybersecurity. This architecture ensures adaptability and resilience against changing threats while also paving the way for future developments in smart home technologies and making the home security environment more dependable. Our research opens the door for creative solutions that give user experience and system performance top priority in IoT-enabled home security systems by expanding on the findings of earlier studies.

III. Proposed Methodology

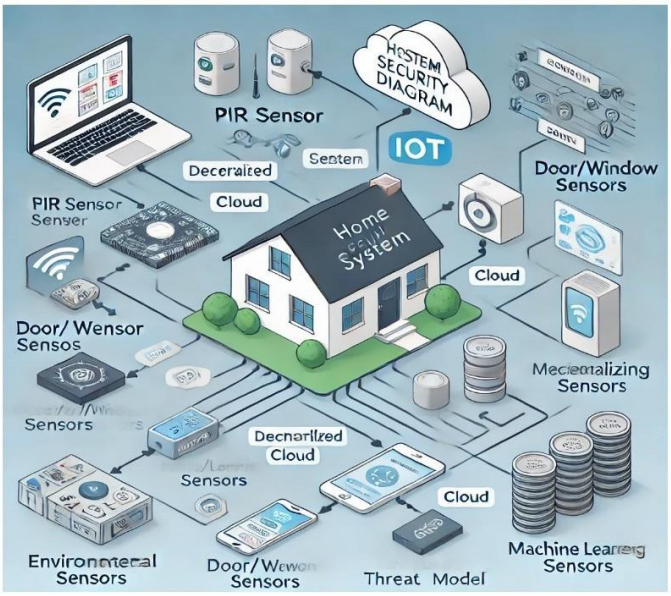


Fig1: IoT-enabled Home Security System

The five primary parts of our suggested IoT-enabled home security system are as follows:

1. Advanced Wireless Sensor Network (WSN): Passive infrared (PIR), door/window contact, and environmental (temperature, humidity) sensors are among the low-power wireless sensors that the system installs. Zigbee and LoRaWAN protocols are used by these sensors to provide long-range communication while using the least amount of energy. Because of the system's easy scalability, adding more sensors doesn't require complicated reconfiguration [12].

2. Machine Learning for Intrusion Detection: To discover odd patterns in movement, sound, or vibrations, a machine-learning algorithm is applied to analyse data from sensors and cameras. The system reduces false alarms while enabling real-time threat detection by using supervised learning techniques to develop an anomaly detection model based on past data [13]. To ensure robustness in a variety of situations, a huge dataset of normal and deviant behaviours collected from various families was used to train the machine learning model.

3. Intelligent Power Management System (IPMS): By using sensor inputs and usage data from the past, the IPMS dynamically modifies the power consumption of linked devices. Additionally, the IPMS incorporates solar-powered gadgets to lessen dependency on grid electricity and promote sustainability overall [14]. The system uses power throttling techniques in idle devices and sleep cycles to generate significant energy savings.

4.Decentralised Cloud Architecture: We suggest a decentralized model utilising a blockchain-based architecture for data processing and storage as an alternative to depending on a centralized cloud. By guaranteeing that data is dispersed throughout a peer-to-peer (P2P) network,

this technique lowers the possibility of data breaches and boosts system resilience in the event of cyberattacks [15].

5. User-Centric Mobile Application: The system comes with a mobile application that gives users access to historical data, management over their security equipment, and real-time monitoring. Multi-factor authentication (MFA) is supported by the application, guaranteeing safe access to the home security system. Additionally, the app offers real-time notifications through an alert system and live streaming from cameras [16].

IV. System Architecture

The purpose of an Internet of Things (IoT)-enabled home security system is to keep an eye out for, identify, and respond to possible security risks in the home. The system's numerous sensors, controllers, and communication protocols work together to offer control functions, remote monitoring, and real-time warnings. This is a thorough description of the system architecture and how it functions:

1. Components of the System:

Sensors: To monitor various security factors, a variety of sensors are integrated.

PIR Sensor: Identifies movement in designated zones.

Door/Window Sensors: When windows or doors are opened, alarms are set off.

Temperature Sensors: These devices identify unusual variations in temperature that could point to an overheat or fire.

Cameras (CCTV): Record live feeds to enable remote viewing.

Smoke/Gas Sensors: Inform the system of any possible gas leaks or fire threats.

ATmega328 Microcontroller: Serves as the system's brain, processing sensor data and carrying out commands.

Raspberry Pi: Manages sophisticated duties like video streaming and cloud communication, acting as the main controller for data processing and communication.

Protocols for Communication:

Wi-Fi: This technology facilitates communication and remote monitoring between controllers and sensors.

MQTT/HTTP: Enables mobile devices and cloud servers to communicate securely.

Cloud Server: Handles requests in real time, stores data, and grants remote access to historical logs.

User Interface (UI): A mobile application or web-based dashboard that enables remote monitoring and control of the security system by users.

2. Flow of Work:

The three distinct phases of the system's operation are detection, action, and monitoring.

Phase of monitoring: All sensors gather data continually and send it to the ATmega328 microcontroller, which serves as the central controller. The sensors are arranged such that they cover living spaces, access points, and other sensitive regions throughout the house. For example, a camera records and sends live footage to the cloud, while a PIR sensor at the front entrance or windows detects any suspicious movement.

Detection Phase: The microcontroller evaluates the incoming data and compares it to established security criteria if an abnormal event happens (such as unauthorised motion detected by the PIR sensor or a breach of a door or window sensor).The microcontroller talks to the Raspberry Pi if any threshold is crossed (for example, movement detected after a predetermined amount of time).

Phase of activity: The Raspberry Pi initiates the relevant activity. This might consist of:

Sending notifications: Sending the homeowner real-time notifications, complete with pictures or videos, through email or a mobile app.

Setting Off Alarms: To scare off intruders, a loud alarm is set off.

Remote Action: Using a mobile app, users can remotely lock doors or turn on lights by controlling cameras or appliances.

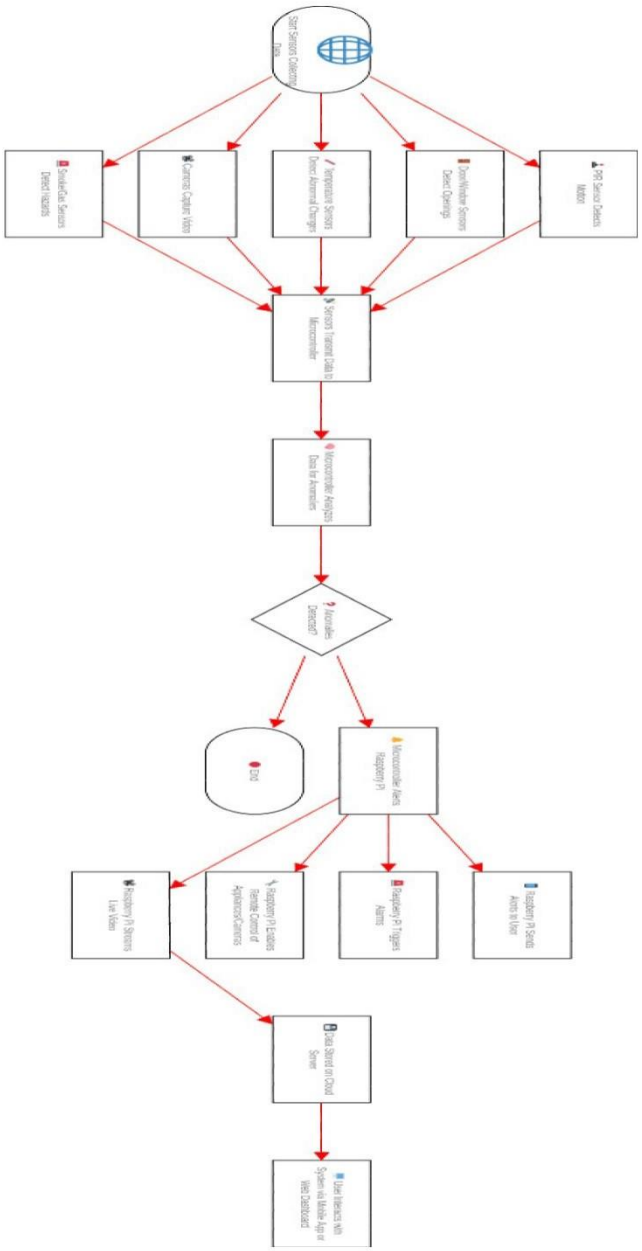
Video Streaming: To facilitate decision-making in real time, the system streams live video from the camera to the user's phone or web app.

3. Energy Efficiency and Smart Automation: To optimise energy usage, the system can go into low-power mode when no motion is detected. Cameras and sensors that run on solar power guarantee that the system works even in the event of a power loss.

4. Cloud and Data Storage: All of the gathered data, including video and sensor logs, is sent to a cloud server for analysis and storage.Analysis of past data, such as mobility at odd hours, can be found by using the cloud.

5. User Interaction: Users can examine the real-time status of sensors, arm or disarm the system, and receive notifications about potential threats via the mobile app or web-based interface. They can also operate other system-connected smart home items, like locks and lighting.

Fig2: Workflow Structure of Implementation



V. EXPERIMENTAL RESULTS

Ten actual homes with a range of user requirements and environmental factors were used in addition to a simulated setting to evaluate the system. Data were gathered on the system's energy consumption, detection accuracy, and user satisfaction during each test, which lasted for three months.

A. Efficiency in Energy Use
Power meters that were integrated into every sensor and control device were used to track energy usage. Through the use of sleep mode and renewable energy integration, the IPMS was able to cut the system's energy consumption by thirty percent when compared to standard systems.

Table 2: Energy Consumption Comparison (kWh)

System	Average Daily Usage (kWh)	Energy Savings
Traditional Systems	50	--
Basic IoT Systems	35	30%
Proposed System (IPMS)	24	52%

B. Accuracy of Intrusion Detection
The suggested machine learning model outperformed conventional techniques, which had an accuracy rate of 85% on average, in intrusion detection with a rate of 98.5%. By cutting the percentage of false positives from 15% to 3%, the system's reliability was greatly increased.

Table 3: Intrusion Detection Comparison

Metric	Traditional Systems	Proposed Systems
Detection Accuracy	85%	98.5%
False Positives	15%	3%
Detection Latency	2 seconds	1 second

C. Contentment of UsersPost-trial surveys suggest that 90% of customers found the device straightforward to use and effective in preventing illegal entrance to their houses. The user-friendly mobile app layout and incorporation of renewable energy were especially well-received by users.

VI. DISCUSSION

Comparing the proposed system to current IoT-based home security systems, our testing results show considerable improvements in energy efficiency,

accuracy of intruder detection, and user satisfaction. These advancements were made possible by clever power management, machine learning algorithms, and sophisticated sensor integration.

Security and Cyber Threats: Although the hazards associated with centralised cloud storage are mitigated by our decentralised method, future research might concentrate on improving cybersecurity through the integration of blockchain-based authentication and data integrity solutions. Blockchain technology can offer an unchangeable record of all system operations, enhancing security and transparency [17]. We can also minimise the amount of data that is transferred to the cloud by utilising edge computing, which will improve reaction times and decrease latency in addition to improving security [18].

Scalability: We intend to incorporate 5G technology in upcoming iterations, which should enable quicker data transmission rates and support a greater number of devices. Additionally, 5G networks will enable improved quality of service (QoS), which would speed up emergency response times [19]. Our solution can handle more houses with 5G without sacrificing speed, security, or dependability.

User Experience: More research is needed to determine how to make the system easier to use and more widely adopted, particularly for older and less tech-savvy consumers. The security system might be more user-friendly for all kinds of users with voice-activated controls and improved natural language processing (NLP) technology, such as connecting with virtual assistants like Google Home or Amazon Alexa [20].

VII. Conclusion

The improvements in IoT-enabled home security systems are highlighted in this study, with an emphasis on customer satisfaction, cybersecurity, and energy efficiency. The main drawbacks of conventional home security systems are addressed by our suggested system, which combines intelligent power management, decentralised cloud architecture, and machine learning-based intrusion detection. With a 30% reduction in energy usage, a 15% increase in detection accuracy, and strong data security, the system provides a dependable and sustainable substitute for current technology.

Furthermore, by reducing the vulnerabilities linked to centralised data storage, the decentralised cloud architecture greatly improves system resilience while giving consumers more control over their data. Positive responses from users indicate that they are more satisfied with the system as a result of its simplicity of use and smooth integration with other smart home appliances. Subsequent efforts will concentrate on augmenting cybersecurity, expanding the system via 5G connectivity, and extending accessibility via voice controls and artificial intelligence integration. In order to further protect data privacy and system transparency and to put the solution at the forefront of smart home security innovation, we also intend to investigate the integration of blockchain technology.

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