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Design and Implementation of an IoT-Driven Smart Home Intrusion Detection System using PIR Sensor and Cloud Alerts

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ABSTRACT: The increasing trend toward smart home automation has created a need for efficient, economical, and real-time security solutions. Conventional CCTV and alarm systems are often costly and require complex installation. To address these limitations, this research proposes an Internet of Things (IoT)-based home intrusion detection system that utilizes a Passive Infrared (PIR) sensor and a NodeMCU ESP8266 microcontroller to monitor human motion and transmit instant alerts through a cloud platform. The system connects to the user's smartphone through a cloud server, enabling remote surveillance and instant notifications. Experimental observations show that the proposed model provides quick detection, low latency alerts, and reliable performance, making it suitable for homes, small offices, and closed environments. The results indicate that the system is practical, cost-effective, and adaptable for future enhancements, including camera modules and AI-based classification.

KEYWORDS: IoT, Intrusion Detection, PIR Sensor, ESP8266, Cloud Monitoring, Smart Home Security.

I. INTRODUCTION

In recent years, the concept of smart homes has advanced significantly due to rapid developments in IoT devices and wireless communication technologies. One of the core components of smart home systems is security, which ensures the safety of property and occupants. Traditional home security solutions such as CCTV cameras, wired alarm systems, and manual surveillance demand high installation cost, skilled personnel, and continuous power backup, making them less practical for small households.

With the availability of low-cost microcontrollers and cloud platforms, IoT-based security solutions have emerged as efficient alternatives. These systems integrate sensors, Wi-Fi modules, and cloud servers to detect intrusions and provide event-based alerts to users regardless of their physical location.

The proposed system in this research focuses on developing a portable, user-friendly, and cost-effective smart home security model that combines a PIR sensor for motion detection with a cloud connectivity interface using the ESP8266 NodeMCU module. The system is designed to immediately detect unusual motion and send alerts to the user's smartphone via a cloud service. Unlike conventional surveillance systems, this design reduces complexity, improves accessibility, and enhances monitoring efficiency.

II. LITERATURE REVIEW

Various works have demonstrated how IoT can improve home security, each using different sensing mechanisms and communication modules. Some studies have focused on camera-based systems that detect intruders using image processing techniques, but these require high computational power and have privacy concerns. GSM-based systems have also been developed, but SMS delivery is often delayed, and the operational cost increases with frequent alerts.

Researchers have explored PIR sensors to detect human movement due to their low cost, reliability, and low power consumption. However, most of the previous designs either depend solely on local buzzers or lack proper mobile notifications. Additionally, several studies did not integrate real-time cloud dashboards, which restricts remote monitoring.



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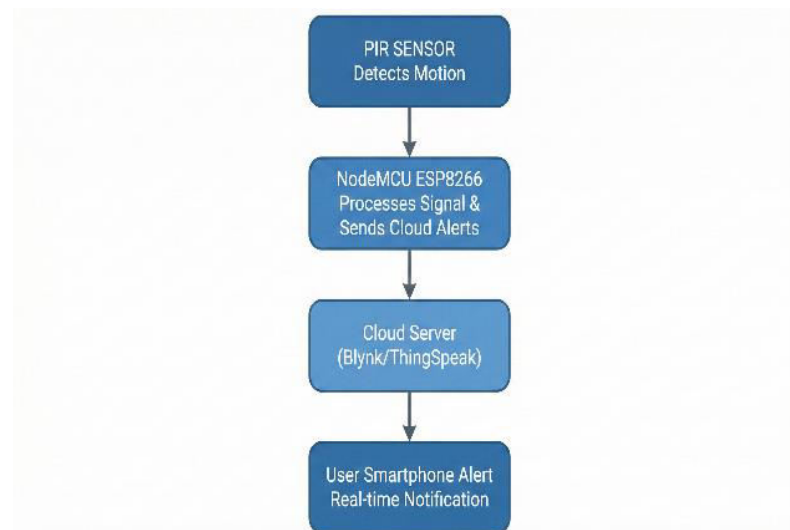
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This research fills these gaps by integrating a PIR sensor with a cloud-based IoT service, enabling the user to monitor intrusion events in real time from anywhere. The proposed system also introduces a lightweight architecture that ensures fast processing, instant connectivity, and energy-efficient operation.

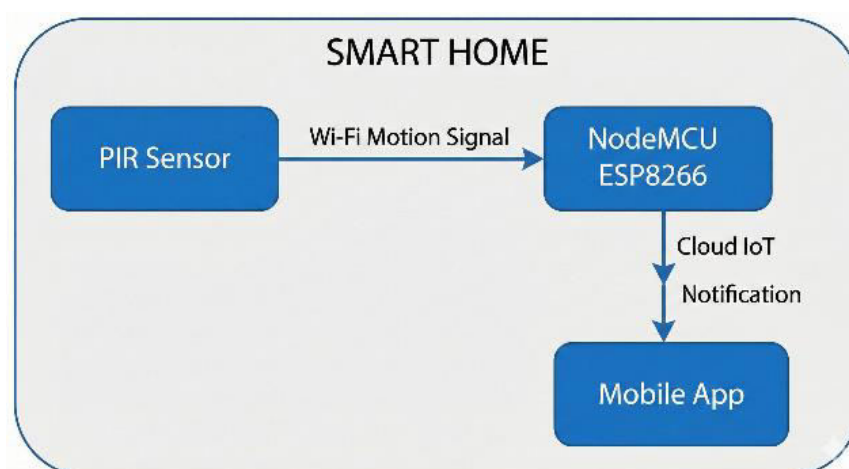
III. SYSTEM ARCHITECTURE

The proposed system consists of a PIR sensor, a NodeMCU ESP8266, a buzzer, and a cloud dashboard. The PIR sensor continuously monitors the surroundings for infrared radiation changes caused by movement. When the sensor detects motion, it transmits a signal to the NodeMCU. The microcontroller processes this signal and sends alert data to the cloud platform through Wi-Fi. The cloud platform then triggers a notification that instantly reaches the user's smartphone.

IV. BLOCK DIAGRAM



V. ARCHITECTURE DIAGRAM



VI. METHODOLOGY

The system follows a structured flow to detect and report intrusion events. The PIR sensor operates on the principle of detecting changes in infrared radiation emitted by human bodies. When a human enters the sensor's field of view, the infrared pattern changes suddenly, causing the sensor to output a HIGH signal.



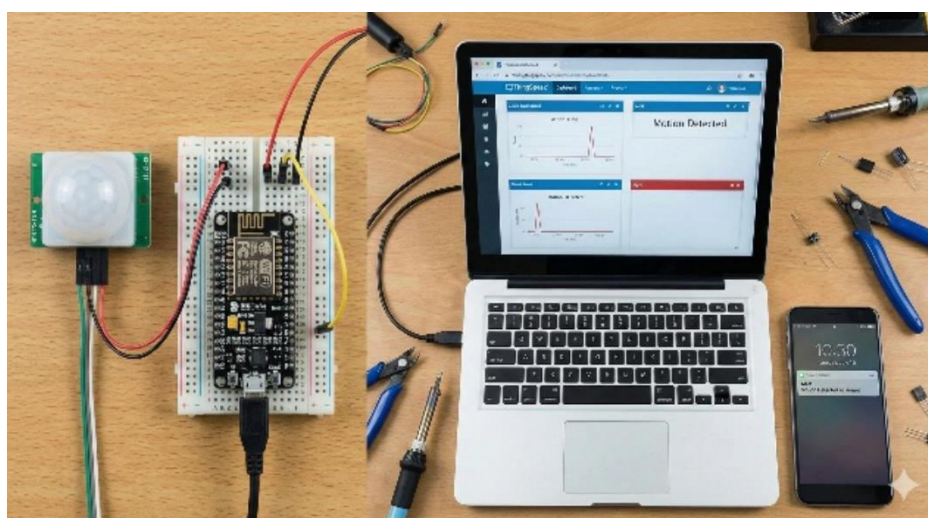
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The NodeMCU, continuously reading the sensor output, immediately identifies this change and activates the next steps in the workflow. This includes switching on the buzzer for local alerting and simultaneously executing the cloud communication routine. The NodeMCU connects to a Wi-Fi network and transmits the alert message to the assigned cloud server. Upon receiving the message, the cloud server updates the intrusion status on the user's mobile dashboard and triggers a notification.

This process typically takes less than one second from motion detection to mobile alert, ensuring real-time monitoring. The system remains active continuously, making it suitable for 24/7 surveillance.

VII. IMPLEMENTATION AND EXPERIMENTAL RESULTS



The proposed system was assembled using a PIR sensor placed at an optimal height of approximately 1.5 meters to ensure accurate detection. The NodeMCU was configured using the Arduino IDE, and the PIR sensor was connected to one of the GPIO pins. During testing, the system was placed inside a controlled indoor environment. When a person entered the monitored region, the PIR sensor detected the movement almost instantly, and the NodeMCU transmitted the alert to the cloud server without delay. The buzzer activated immediately, providing local indication of intrusion.

During repeated experiments, the system consistently detected movement within one to two seconds, and the notification reached the user's smartphone with minimal latency. The Wi-Fi-based alerts proved faster and more reliable than SMS-based systems. The overall performance validated the efficiency of the IoT-based intrusion detection model and confirmed its suitability for practical applications.

VIII. ADVANTAGES

The proposed system is highly reliable, affordable, and easy to install. It consumes low power and requires minimal maintenance. The cloud platform eliminates the need for expensive hardware like DVRs and CCTV cameras. The PIR sensor provides accurate detection with low false triggers when placed correctly. Users can monitor intrusions from anywhere in the world using their smartphone, making the system ideal for remote monitoring.

IX. APPLICATIONS

This system can be used in homes, apartments, banks, shops, storage rooms, laboratories, offices, warehouses, and other restricted areas. It is also suitable for rental houses and small-scale business establishments where cost-effective security solutions are needed.



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X. CONCLUSION

This research successfully demonstrates a functional IoT-based intrusion detection system that integrates PIR sensor technology with cloud-based alert mechanisms. The system is economical, reliable, easy to deploy, and offers real-time monitoring through mobile notifications. Compared to traditional systems, the model requires less hardware, lower installation cost, and minimal maintenance. Future improvements may include integrating an IP camera for visual evidence, AI-based human detection, GPS-based remote alerts, and GSM backup communication for scenarios without Wi-Fi.

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