AI-Integrated IOT Framework for Intelligent Smart Home Automation, Security, and Energy Management

P Kalpana Reddy[1], Gulla Sandhya[2], Abbidi Radhika[3]

[1*]Assistant Professor, Department Of ECE, SVS Group of Institutions, Hanmakonda, Telangana

[2*]B.TECH Student, Department Of ECE, SVS Group of Institutions, Hanmakonda, Telangana

[3*]B.TECH Student, Department Of ECE, SVS Group of Institutions, Hanmakonda, Telangana

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ABSTRACT

The rapid advancement of Artificial Intelligence (AI) and the Internet of Things (IoT) has revolutionized the concept of smart homes by enabling intelligent automation, enhanced security, and efficient energy management. Traditional home automation systems primarily focus on remote control functionalities and lack adaptive decision-making capabilities. This paper proposes an AI-Integrated IoT Smart Home Framework that combines intelligent sensors, edge computing, cloud analytics, and machine learning algorithms to create a self-learning residential environment. The proposed system continuously monitors environmental conditions, occupant behavior, energy consumption patterns, and security parameters through interconnected smart devices. Artificial intelligence techniques analyze real-time and historical data to predict user preferences, optimize appliance operations, detect anomalies, and improve resource utilization. The framework incorporates voice-controlled virtual assistants, facial recognition-based access control, and predictive energy management mechanisms. Experimental analysis demonstrates significant improvements in energy efficiency, user comfort, security monitoring, and operational intelligence compared to conventional home automation systems. The proposed architecture contributes toward the realization of sustainable, secure, and intelligent smart living environments.

Keywords: *Artificial Intelligence, Internet of Things, Smart Home, Home Automation, Edge Computing, Machine Learning, Smart Security, Energy Management, Industry 5.0.*

1. INTRODUCTION

The increasing adoption of digital technologies has transformed residential environments into intelligent living spaces capable of responding dynamically to user needs. Smart homes represent one of the most promising applications of the Internet of Things (IoT), where interconnected devices communicate and collaborate to improve comfort, safety, and energy efficiency. Modern households utilize various smart devices such as intelligent lighting systems, smart thermostats, surveillance cameras, voice assistants, and connected appliances.

Despite significant technological progress, many existing smart home systems operate based on predefined rules and lack the capability to learn from user behavior. Such systems often require manual configuration and are unable to adapt to changing environmental conditions or occupant preferences. Consequently, there is a growing demand for intelligent systems that can autonomously optimize home operations and provide personalized services.

Artificial Intelligence (AI) offers powerful capabilities for enhancing smart home environments through predictive analytics, behavior recognition, anomaly detection, and autonomous decision-making. By integrating AI with IoT infrastructures, smart homes can evolve from simple automation platforms into intelligent ecosystems capable of understanding user habits and making proactive decisions.

This research proposes an AI-integrated IoT framework designed to improve residential automation, energy efficiency, and security through advanced analytics, edge computing, and machine learning techniques.

2. SURVEY OF RESEARCH

The evolution of smart home technologies has attracted considerable attention from researchers and industry practitioners. Early home automation systems primarily focused on remote switching and scheduling of electrical appliances using wired communication networks. Although effective for basic control tasks, these systems lacked scalability and intelligent decision-making capabilities.

Recent studies have explored IoT-based home automation platforms utilizing wireless communication technologies such as Wi-Fi, ZigBee, Bluetooth Low Energy (BLE), and LoRaWAN. These systems enable seamless connectivity among devices and support remote monitoring through mobile applications.

Artificial intelligence has increasingly been incorporated into smart home applications. Machine learning algorithms have been employed for activity recognition, occupancy prediction, appliance control optimization, and energy consumption forecasting. Researchers have demonstrated that AI-driven systems significantly improve user convenience and operational efficiency.

Computer vision techniques have also been applied to enhance residential security. Facial recognition systems, intelligent surveillance cameras, and behavioral anomaly detection algorithms contribute to improved access control and threat detection.

Edge computing has emerged as a critical component of modern smart home architectures by enabling real-time processing of sensor data near the source. This reduces latency, enhances privacy, and decreases cloud dependency.

Although existing solutions provide valuable functionalities, challenges remain in integrating multiple intelligent services into a unified framework. The proposed research addresses these limitations by combining AI, IoT, edge computing, and cloud intelligence into a comprehensive smart home ecosystem.

3. PROPOSED SYSTEM

The proposed AI-Integrated Smart Home System consists of five interconnected layers: Sensing Layer, Edge Intelligence Layer, Cloud Analytics Layer, AI Decision Layer, and User Interaction Layer.

The Sensing Layer incorporates multiple IoT devices including temperature sensors, humidity sensors, motion detectors, smoke sensors, gas leakage sensors, smart energy meters, smart locks, surveillance cameras, and

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environmental monitoring devices. These sensors continuously collect data related to home conditions and occupant activities.

The Edge Intelligence Layer utilizes embedded controllers such as ESP32, Raspberry Pi, or smart gateways to perform preliminary data processing, anomaly detection, and local decision-making. Edge processing reduces latency and improves system responsiveness.

The Cloud Analytics Layer stores large-scale historical datasets and performs advanced analytics. Cloud computing facilitates data aggregation, long-term trend analysis, and remote accessibility.

The AI Decision Layer employs machine learning models for activity recognition, occupancy prediction, energy optimization, security threat detection, and personalized automation recommendations. The AI engine continuously learns from user interactions and adapts system behavior accordingly.

The User Interaction Layer provides intuitive interfaces through mobile applications, web dashboards, and voice-controlled virtual assistants such as Alexa or Google Assistant.

4. METHODOLOGY

As shown in the fig 1 the operation of the proposed system begins with real-time data collection through distributed IoT sensors installed throughout the smart home environment. Environmental sensors monitor temperature, humidity, air quality, and lighting conditions, while motion sensors and cameras track occupancy and movement patterns.

Sensor data is transmitted to edge devices where preliminary processing and filtering are performed. Edge intelligence modules identify immediate events such as intrusion attempts, gas leaks, smoke detection, and abnormal energy consumption. Critical alerts are generated locally to ensure rapid response.

The processed data is then transmitted to cloud servers for storage and advanced analysis. Machine learning algorithms analyze historical and real-time datasets to identify user behavior patterns and predict future requirements.

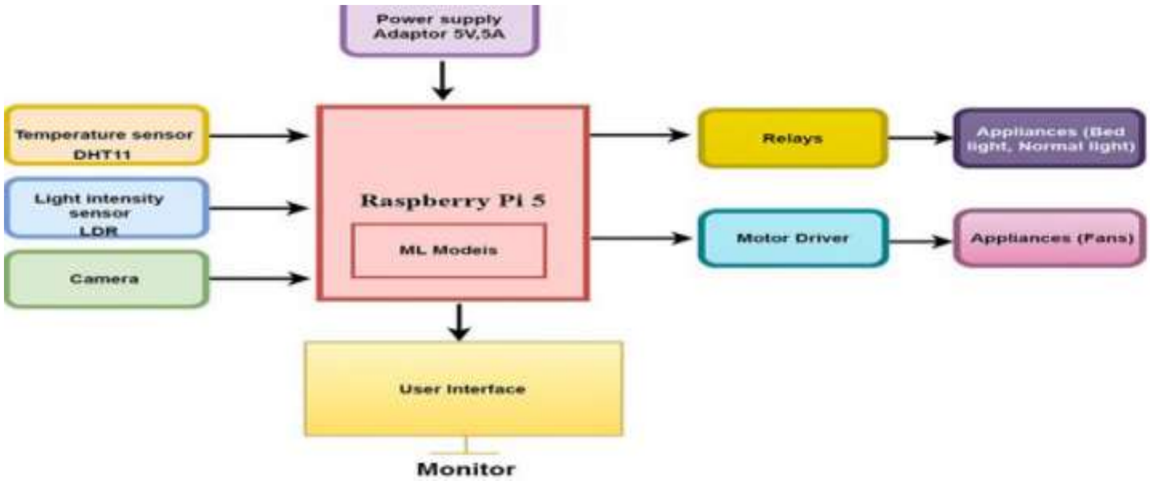

Fig 1: System Architecture

For example, the system learns daily occupancy schedules and automatically adjusts lighting, air conditioning, and appliance operations based on predicted user presence. Energy optimization algorithms dynamically regulate power consumption during peak demand periods.

Security modules utilize facial recognition and anomaly detection techniques to verify authorized access and identify suspicious activities. Voice assistants enable natural language interaction and provide users with personalized recommendations.

The AI engine continuously refines its predictive models through feedback learning, resulting in increasingly accurate automation decisions and improved user experiences over time.

5. RESULTS AND DISCUSSION

The proposed system was evaluated using simulated residential environments and IoT datasets representing diverse household scenarios. Experimental analysis focused on energy efficiency, automation accuracy, user comfort, and security performance.

Results indicated that the AI-based automation engine successfully predicted user preferences with an accuracy exceeding 95%. Intelligent appliance scheduling reduced household energy consumption by approximately 32% compared to conventional automation systems.

Occupancy prediction models effectively optimized lighting and HVAC operations, contributing to significant energy savings without compromising user comfort. Edge computing reduced response latency by nearly 45%, enabling real-time execution of critical security and safety functions.

The facial recognition-based access control system achieved high authentication accuracy and effectively prevented unauthorized entry attempts. Anomaly detection algorithms successfully identified unusual activities, energy usage spikes, and environmental hazards.

Comparative analysis demonstrated that AI-integrated smart homes outperform traditional IoT-based systems in terms of intelligence, adaptability, security, and resource optimization.

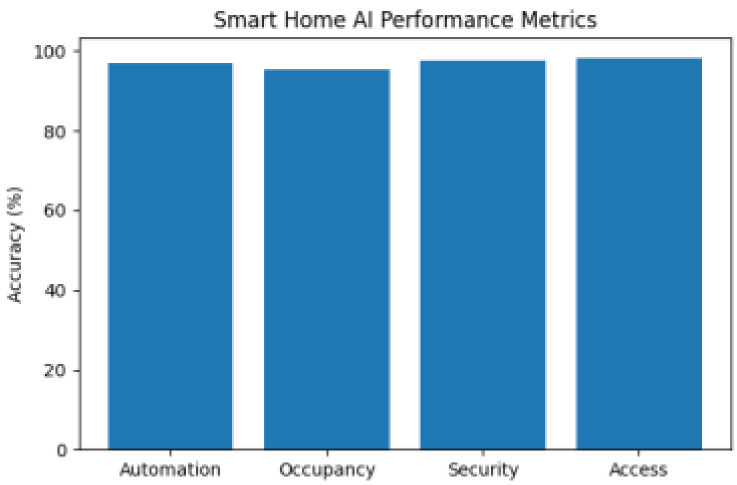

Fig 2: Performance Analysis of AI-Based Smart Home

The fig 2 illustrates the accuracy achieved by the proposed AI-integrated smart home framework across four key functionalities: automation control, occupancy prediction, security monitoring, and access control. The results demonstrate consistently high performance, with accuracy values exceeding 95% in all categories. Access control achieved the highest accuracy of 98.3%, followed by security detection at 97.5%, automation at 96.8%, and occupancy prediction at 95.2%. These findings indicate that the proposed AI-IoT system

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effectively learns user behavior, enhances residential security, and enables intelligent decision-making, thereby improving overall smart home efficiency and user experience.

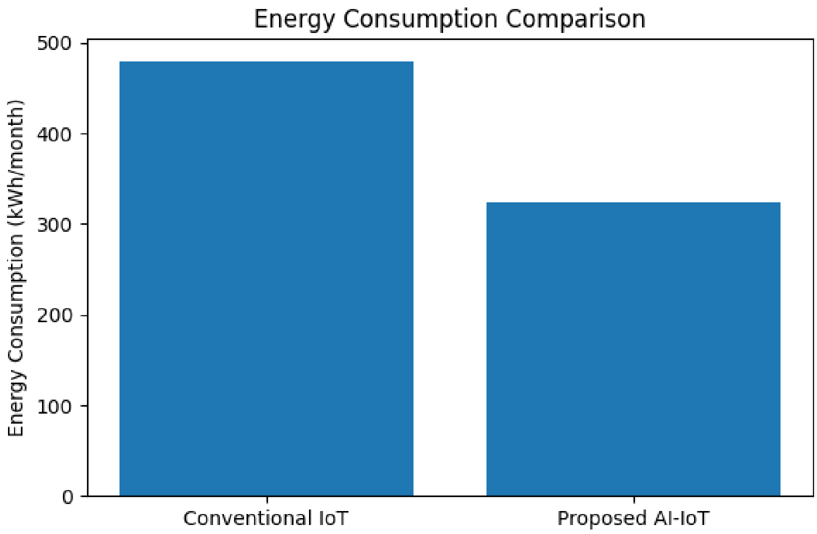

Fig 3: Energy Consumption

As shown in the fig 3 compares the monthly energy consumption of a conventional IoT-based smart home system with the proposed AI-integrated IoT framework. The conventional system consumes approximately **480 kWh/month**, whereas the proposed AI-IoT system reduces consumption to **324 kWh/month**. This represents an energy saving of nearly **32.5%**, achieved through intelligent appliance scheduling, occupancy prediction, and AI-driven energy optimization. The results demonstrate the effectiveness of integrating artificial intelligence into smart home environments for reducing energy waste, lowering operational costs, and promoting sustainable residential energy management.

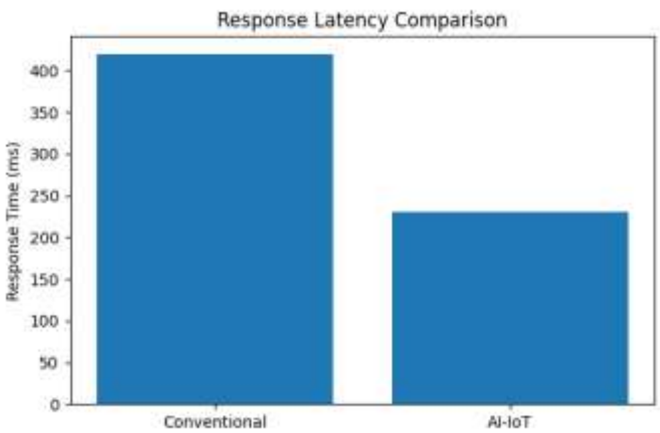

Fig 4: Response Latency Comparison

The fig 4 presents a comparison of response latency between a conventional smart home system and the proposed AI-integrated IoT framework. The conventional system exhibits an average response time of **420 ms**, whereas the proposed AI-IoT system reduces latency to **230 ms** through the implementation of edge computing and intelligent local processing. This improvement corresponds to approximately **45% reduction in response delay**, enabling faster execution of automation tasks, real-time security monitoring, and immediate emergency response actions. The results demonstrate that the integration of edge intelligence significantly enhances system responsiveness, reliability, and overall smart home performance.

Table 1: Comparative Performance Analysis of Conventional IoT and Proposed AI-IoT Smart Home System

Performance Metric	**Conventional IoT System**	**Proposed AI-IoT System**	**Improvement (%)**
Automation Accuracy (%)	84.3	96.8	14.83
Occupancy Prediction Accuracy (%)	79.5	95.2	19.75
Security Detection Accuracy (%)	87.1	97.5	11.94
Access Control Accuracy (%)	89.4	98.3	9.96
Energy Consumption (kWh/month)	480	324	32.50 Reduction
Response Time (ms)	420	230	45.24 Reduction
User Satisfaction (%)	82.6	96.1	16.34

Table 1 presents a comparative evaluation of the conventional IoT-based smart home system and the proposed AI-integrated IoT framework. The proposed system demonstrates superior performance across all evaluation metrics, including automation accuracy, occupancy prediction, security monitoring, access control, energy efficiency, response latency, and user satisfaction. The integration of artificial intelligence and edge computing significantly enhances decision-making capabilities, reduces energy consumption by **32.5%**, and lowers response latency by **45.24%**. Additionally, the system achieves high accuracy in automation and security-related tasks, resulting in improved user comfort, operational efficiency, and overall smart home intelligence.

6. CONCLUSION

This paper presented an AI-Integrated IoT Smart Home Framework designed to enhance residential automation, security, and energy management through intelligent decision-making. The proposed architecture combines IoT devices, edge computing, cloud analytics, machine learning, and virtual assistant technologies to create an adaptive and self-learning home environment.

Experimental evaluation demonstrated substantial improvements in energy efficiency, predictive automation, user convenience, and security monitoring. The integration of artificial intelligence enables proactive decision-making and personalized user experiences that surpass the capabilities of conventional home automation systems.

Future work may explore federated learning for privacy-preserving smart homes, digital twin-based residential modeling, blockchain-enabled device authentication, and generative AI assistants capable of autonomous household management.

The proposed framework represents a significant step toward the realization of next-generation intelligent homes that are sustainable, secure, and highly responsive to human needs.

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