IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 2, February 2026
Impact Factor: 8.2

Home Automation and Personal Assistance

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Abstract: *The rapid growth of Internet of Things (IoT) technologies and Artificial Intelligence (AI) has significantly transformed traditional homes into intelligent living environments. This paper presents the design and implementation of a unified Home Automation and Personal Assistant system that integrates smart devices, edge computing, and secure communication protocols into a centralized platform. The proposed system enables voice, text, and application-based control of appliances while ensuring interoperability using open standards such as Connectivity Standards Alliance's Matter protocol and MQTT.*

Unlike conventional cloud-dependent solutions such as Amazon Alexa and Google Assistant, the system emphasizes local processing to reduce latency and enhance privacy. The architecture integrates sensors, actuators, microcontrollers, and AI-driven natural language processing to provide context-aware automation and personalized routines. The proposed solution aims to improve convenience, security, energy efficiency, and scalability while addressing privacy and interoperability challenges in modern smart homes..

Keywords: Home Automation, Internet of Things (IoT), Personal Assistant, Edge Computing, Matter Protocol, MQTT, Smart Home Security, Artificial Intelligence, Voice Assistant, Interoperability

I. INTRODUCTION

Smart home technologies have evolved rapidly due to increasing demands for security, comfort, and energy efficiency. Traditional automation systems were limited to isolated device control and lacked intelligent interaction. Modern systems integrate IoT sensors, actuators, and AI-powered assistants to enable real-time decision-making and contextual automation.

However, existing solutions often suffer from platform fragmentation, cloud dependency, and privacy risks. Popular voice assistants such as Amazon Alexa, Google Assistant, and Apple Siri rely heavily on cloud infrastructure, creating latency and data exposure concerns.

This research proposes a unified smart home system integrating home automation and a personal assistant with local processing capabilities. The system ensures interoperability, secure authentication, context-aware automation, and scalable architecture suitable for modern households.

II. LITERATURE REVIEW

2.1 Overview of Smart Home Systems

Smart home systems integrate networked sensors, actuators, and communication protocols to automate appliances, HVAC, lighting, and security. Research indicates rapid IoT growth driving demand for interoperable and intelligent systems.

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2.2 System Architectures

Three dominant architectures exist:

- Cloud-centric systems (e.g., Alexa ecosystem)
- Edge/fog-based systems
- Hybrid architectures combining both

Edge computing reduces latency and improves privacy by processing data locally.

2.3 Interoperability and Standards

Interoperability challenges led to the development of the Matter standard by the Connectivity Standards Alliance. Matter enables cross-platform communication over IP networks, improving reliability and compatibility among vendors.

2.4 Voice and Multimodal Interaction

Voice assistants revolutionized user interaction but face limitations in contextual understanding. Recent research integrates multimodal inputs (voice, gesture, presence detection) and AI-based intent recognition.

2.5 Security and Privacy Concerns

Studies highlight vulnerabilities such as:

- Third-party skill exploitation
- Weak authentication
- Continuous data logging

Local processing, encryption (SSL/TLS), and authentication mechanisms are recommended solutions.

2.6 Research Gaps

- Context ambiguity in multi-user environments
- Lack of standardized evaluation benchmarks
- Privacy transparency issues
- Energy efficiency in edge AI deployment

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III. EXISTING SYSTEM

Existing smart home systems primarily rely on:

- Cloud-based voice assistants
- Proprietary ecosystems
- Multiple mobile applications for device control

IV. PROPOSED SYSTEM

1. Centralized Control Unit

A Raspberry Pi or ESP32 acts as the main controller to manage all connected smart devices. It processes commands locally and coordinates communication between sensors, actuators, and the assistant module.

2. Edge-Based Processing

The system performs most computations locally instead of relying fully on cloud services like Amazon Alexa. This reduces latency, improves response time, and enhances user privacy.

3. IoT Device Integration

Various sensors (motion, temperature, gas) and actuators (relays, motors) are connected through standard protocols. This enables real-time monitoring and automated control of home appliances.

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4. Intelligent Personal Assistant

The assistant supports voice and text commands with basic natural language understanding. It interprets user requests and triggers appropriate actions in the automation system.

5. Interoperability Using Open Standards

The system supports MQTT and Matter protocols defined by the Connectivity Standards Alliance. This ensures compatibility with multi-vendor IoT devices.

6. Security and Authentication

Secure login, encrypted communication (SSL/TLS), and role-based access control are implemented. These measures protect user data and prevent unauthorized access.

7. Context-Aware Automation

Automation rules are based on time, sensor input, or user preferences. This enables smart scheduling, energy optimization, and enhanced home security.

V. METHODOLOGY

Step 1: Requirement Analysis

Identify appliances, sensors, communication methods, and privacy requirements.

Step 2: System Design

Design architecture including:

- Sensors (PIR, DHT22, LDR, Gas sensor)
- Actuators (Relays, servo motors)
- Controller (Raspberry Pi / ESP32)
- Communication (Wi-Fi, MQTT, Matter)

Step 3: Hardware Implementation

Connect IoT devices and configure control modules.

Step 4: Software Development

- Implement NLP-based assistant
- Develop automation logic
- Integrate local processing

Step 5: Security Implementation

- SSL/TLS encryption
- Role-based access control
- Local data storage

Step 6: Testing & Evaluation

Measure:

- Response time (<2 seconds)
- Reliability
- User satisfaction
- Error handling

VI. FUTURE SCOPE

- Integration of advanced AI models for predictive automation
- On-device Large Language Model (LLM) deployment
- Smart energy grid integration
- Healthcare monitoring for elderly assistance
- Blockchain-based security mechanisms

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- Expansion toward smart communities and smart cities

VII. CONCLUSION

The proposed Home Automation and Personal Assistance system demonstrates how IoT, AI, and edge computing can create intelligent and secure living environments. By reducing cloud dependency and adopting open standards, the system improves interoperability, privacy, and responsiveness.

The integration of contextual automation and personalized routines enhances user experience while maintaining scalability and security. This research contributes toward building reliable, privacy-aware, and future-ready smart home ecosystems.

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