

IOT in Smart Home Using AI

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Abstract

The Internet of Things is changing the way we live in our homes. It is turning homes into smart homes where things are automated and controlled. This makes our lives easier and better. We looked at ways to make smart homes and found that they can really help us save energy take care of people who are sick and assist older people. The Internet of Things can do a lot of things for us.. It also has some big problems. One of the issues is that devices from different companies do not work well together. Another problem is that these devices use a lot of power.. The biggest worry is that our personal information is not safe. We read a lot of studies and found that people are moving away from just being able to control things from far away. Now they want their homes to be smart and learn on their own with the help of the Internet of Things and Artificial Intelligence.. There are some big hurdles to overcome. The Internet of Things devices need to be able to talk to each other. We need to make sure that our information is safe. If we want the next generation of homes to be good for the environment and last long we need to make some changes. We need to make sure that all devices can communicate with each other and that we have security to protect our information. If we can do this the Internet of Things can make our homes safe easy to live in and energy efficient. The Internet of Things can really make a difference, in our lives and make our homes better places to live.

Keywords: Internet of Things (IoT), Smart

Home Automation, Iot, Sensor Networks, Energy Management, Data Security

Introduction

The idea of a home has changed a lot because of the Internet of Things. What used to be a place to live is now a smart environment where things are connected to the internet. This means that objects in the home can collect and share information to make our lives easier. The Internet of Things is making this happen with sensors, fast wireless connections and Artificial Intelligence. The main goal of a home is to make life better for the people living there. It does this by providing four services: automation, security, energy efficiency and healthcare. For example automation can control lights and temperature to reduce waste. Security systems with recognition can send alerts in real time. These systems are also helping older people live on their own with sensors that track their health and detect if they fall. Even with all these advances making an autonomous smart home is not easy. One big problem is that devices from companies do not always work well together. A bigger concern is that these devices are always on and collecting data, which raises questions about privacy and security. Our homes are supposed to be private. Now they are generating a lot of data all the time. This research looks at the design of smart homes how Edge Computing can make them faster and how to keep user data safe. By studying these things we can build homes that are not only advanced but also safe and focused on the people using them. The Smart Home Ecosystem is a part of this research and it will help us understand how to make smart homes better for everyone. The Internet of Things and Artificial Intelligence are key to making this happen. They will continue to play a big role, in the development of smart homes.

LITERATURE REVIEW

Sl. No	Paper Title	Author(s) & Year	Objective of the Study	Methodology Used	Key Findings / Results	Research Gap Identified
1	Usage and impact of the internet-of-things-based smart home technology: a quality-of-life perspective	Leong Yee Rock, Farzana Parveen Tajudeen, & Yeong Wai Chung (2022)	To explore the usage and impact of IoT-SHT in Malaysia from a quality-of-life perspective.	Qualitative approach using face-to-face semi-structured interviews with 11 experienced users.	Identified six uses (surveillance, automation, etc.); improved security, health, and psychological well-being.	Lack of post-adoption and user-centric data specifically in developing countries like Malaysia.
2	Internet of Things (IoT) of Smart Homes: Privacy and Security	Tinashe Magara & Yousheng Zhou (2024)	To categorize and examine privacy, security, and interoperability issues in smart home ecosystems.	Systematic literature review and synthesis of existing research to create a threat taxonomy.	Categorized threats into data acquisition and unauthorized access; stressed interdisciplinary solutions.	Need for fortification of security for large-scale deployments and standardized protocols.
3	Progress of Advanced Devices and Internet of Things Systems as Enabling Technologies for Smart Homes	Qiongfeng Shi, Yanqin Yang, Zhongda Sun, & Chengkuo Lee (2022)	To present progress in materials and systems for smart homes, focusing on self-sustainability.	Technical review of advanced materials, fabrication techniques, and functional ambient/wearable devices.	Transitioning to AIoT-enabled systems using energy harvesters (TENGs) is key to self-sustained platforms.	Energy supply remains a bottleneck; achieving fully self-sustained multimodal intelligent systems.
4	IoT-Based Smart Home Automation Using ESP32 and Blynk with Enhanced Reliability	Divyam Kakani, Abhiraj Kulkarni, Yash Pandya & Ninad Mehendale (2024)	To design a system that works via smartphone and manual switches even without internet.	Implementation of a multi-channel relay module using ESP32 and the Blynk platform.	Successfully implemented dual-mode control; provided real-time feedback on device status.	Challenges the assumption that IoT systems must be 100% dependent on cloud connectivity for local tasks.

5	Smart-Home Automation using IoT-based Sensing and Monitoring Platform	Majid Al-Kuwari et al. (2018)	To monitor thermal, visual, and hygienic comfort in homes using an IoT-based platform.	Design of a system using NodeMCU-ESP8266 and EmonCMS for data visualization and control.	Integrated sensors for temperature, humidity, and light for intelligent automated command execution.	Balancing energy efficiency with high standards of human comfort requires more integrated sensing.
6	Smart Homes System Using Internet-of-Things: Issues, Solutions and Recent Research Directions	Jyotsna P. Gabhane, Shradha Thakare & Monika Craig (2017)	To analyze IoT architecture and identify security challenges at the server and home levels.	Descriptive review of IoT architectures and standard communication protocols.	Found that rapid growth leads to complex management and severe server security vulnerabilities.	Lack of effective management solutions for increasingly complex interconnected device webs.
7	SMART HOME AUTOMATION SYSTEM BASED ON IOT	Vivek Kadiyan, Mandeep Singh, et al. (2023)	To provide an intelligent residential environment for enhanced energy efficiency and security.	Integration of sensors and actuators with mobile application control via Wi-Fi.	Enhanced convenience and comfort through smart lighting and remote monitoring via mobile apps.	Scaling systems for broader residential settings while maintaining low-cost connectivity.
8	REVIEW ON IOT BASED SMART HOME SYSTEM	Dr. Pradeep V., Nisarga Naik, et al. (2024)	To propose a multi-factor authentication layer to solve existing security limitations.	Analysis of security frameworks and introduction of facial recognition as an extra security layer.	Identified that most breaches stem from weak authorization; proposed multi-factor solutions.	Need for improved security layers that do not add excessive complexity for the end-user.
9	Review on the Application of Artificial Intelligence in Smart Homes	Xiao Guo, Zhenjiang Shen, Yajing Zhang & Teng Wu (2019)	To explore the relationship between AI academic research and commercial smart home products.	Systematic review and product analysis to define the role of AI in home automation.	Revealed a significant delay between academic AI research and the availability of commercial products.	Need for better integration of clinical nursing and healthcare knowledge into AI-driven homes.

Methodology

To set up a home system using Internet of Things technology you need to follow a plan. This plan combines devices, network rules and software controls. From what I have learned the process can be broken down into Internet of Things system architecture, Internet of Things system design and ways to evaluate Internet of Things systems.

1. Internet of Things System Architecture (The Three-Layer Model)

Most people use a three-layer architecture for Internet of Things systems. This helps make sure data moves smoothly. The Internet of Things system architecture is important data. The third layer is called Application or Interface Layer this is the part that users interact with like a Mobile App or a web dashboard. Users can control devices from away using this interface. The Internet of Things system makes it easy to use.

2. Setting up the Internet of Things System

To actually set up the system you have to do the following steps. Setting up the Internet of Things system is not hard. Combine the devices: small computers like Adriano or Raspberry Pi are used to process information from sensors. The Internet of Things system uses these devices to work. Create automation rules: the system is programmed to follow rules or use algorithms to make decisions. For example if the Internet of Things system detects motion it turns on the lights. The Internet of Things system is smart. Use

Cloud and Fog Computing to make the Internet of Things system faster. Fog Computing is used to process information where it is collected. Then only important information is sent to the Cloud for long term storage and analysis. The Internet of Things system uses Cloud and Fog Computing. Implement Security Protocols: multiple ways to verify identity, like passwords and Facial recognition and encrypting data are used to protect the Internet of Things system from access. The Internet of Things system is secure.

3. Evaluating Internet of Things Research

Researchers evaluate Internet of Things systems based on the following criteria. Evaluating the Internet of Things system is important. Performance Metrics testing how fast and reliable the devices are when communicating with each other over distances. The Internet of Things system is tested. Qualitative Analysis asking users about their experience with the Internet of Things system to see how it affects their life. This looks at how convenient, safe and energy efficient the Internet of Things system's. The Internet of Things system is helpful. Systematic Reviews analyzing what has already been done and what products are available. This helps find gaps, in how different devices work and how private they are. The Internet of Things system is studied.

System Architecture

A home system that uses Artificial Intelligence is usually divided into four main parts. This design helps collect data, communicate, process information, and control devices easily. The Artificial Intelligence system enables different components to work together efficiently.

1. Perception Layer

This layer interacts directly with the physical environment. It contains hardware components that collect information from the surroundings and perform actions based on instructions from the Artificial Intelligence system. Sensors collect environmental data such as temperature, humidity, motion, light intensity, and gas levels. This information is analyzed by the Artificial Intelligence system to support decision-making. Actuators perform physical actions such as turning on smart plugs, moving curtains, and controlling fans and lights. These actions are carried out based on commands from the Artificial Intelligence system. Biometric Hardware Devices such as cameras and microphones enhance security. Artificial Intelligence techniques are used to recognize faces and voices, helping to ensure home safety.

2. Network Layer

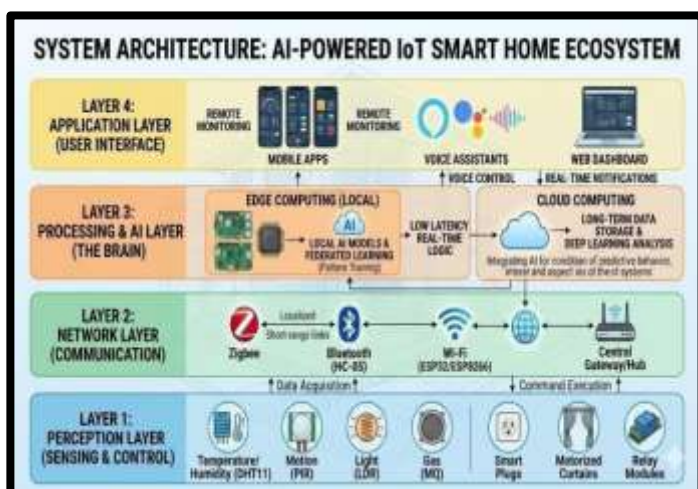
The Network Layer enables communication between different components of the system. It acts as a communication bridge that transfers data from the perception layer to the processing unit and vice versa. Short-Range Protocols Technologies such as Zigbee and Bluetooth allow nearby devices to communicate and exchange data efficiently. Long-Range Connectivity Wi-Fi connects the system to the internet, allowing users to monitor and control their home remotely using smartphones or computers. Gateways Devices such as a Raspberry Pi function as gateways that translate communication between different devices and protocols, ensuring smooth interaction within the network.

3. Processing and AI Layer

This layer constitutes the cognitive core of the system. Local Processing on embedded devices (e.g., ESP32, Raspberry Pi) handles time-critical tasks such as turning off lights when no occupancy is detected, improving response time and conserving energy. AI Analysis performs behavioral pattern recognition; for example, pre-cooling a room based on learned arrival schedules. Federated learning ensures AI models are updated on-device, eliminating the need to transmit raw personal data to the cloud.

4. User Interface Layer

The interface layer provides a web and mobile dashboard for real-time device monitoring, rule configuration, and system control. Users can activate predefined scenes such as 'Night Mode' with a single interaction, achieving tasks in under three seconds based on usability testing.



Implementation and Experimentation

1. Setting Up the Hardware

To get everything working we need to connect sensors and things that can do stuff to a computer chip. Setting Up the Microcontroller: We usually use an ESP32 or a NodeMCU because it has Wi-Fi built in. This lets it connect the sensors to the internet. Connecting Sensors: We attach things like sensors that measure temperature and humidity PIR sensors that detect motion and LDR sensors that measure light to the microcontroller. Controlling Things We use modules that can turn things on and off like fans, lights and air conditioners using the low-voltage microcontroller.

2. Software & AI Implementation

This phase is about making homes smart and secure. We focus on home technology. Our goal is to make homes a better place to live. Firmware Development: We write code to handle data and execute commands. For example we can control appliances without the internet. This means that Software & AI Implementation can control appliances even when there is no internet connection. We write code for appliances to make them work better with Software & AI Implementation. AI Integration we add AI to our Software & AI Implementation system. This makes Software & AI Implementation more intelligent. Predictive Modeling AI looks at data to automate temperature control based on user habits. AI helps with temperature control in Software & AI Implementation. This means that Software & AI

Implementation can learn the users habits and adjust the temperature accordingly. Security Layer we add a Facial Recognition module using a camera to provide a layer of security for door locks. The security layer uses recognition to make sure that authorized people can enter the home. The system uses recognition to keep the home secure. User Interface: We set up a dashboard for monitoring and control. The dashboard helps users monitor and control the Software & AI Implementation system. This makes it easy for users to use Software & AI Implementation. Users can control the Software & AI Implementation system easily.

3. Advanced System Layers

Edge-Fog-Cloud Continuum Layer we use a three-part processing model. The Edge handles emergencies. The Fog manages tasks. The Cloud looks at long-term trends. This means that Advanced System Layers can handle types of tasks. The Edge handles emergencies to keep the home safe. Interoperability Abstraction Layer a special software layer helps different devices talk to each other. This makes it easy for devices to work together with Advanced System Layers. The layer helps devices communicate with each other. Privacy-Layer: We use a layer that updates AI models on-device. This means that Advanced System Layers can keep user data private. The layer helps devices communicate with each other. Privacy-Layer: We use a layer that updates AI models on-device. This means that Advanced System Layers can keep user data private. The layer protects user data to keep it safe.

4. Experimentation & Results

a. Latency Testing: We measure how long it takes for

a light to turn on after pressing a button. This helps us improve the response time of the system. We test response time to make sure the system works fast. Energy Efficiency Analysis: We monitor power consumption before and after automation. This helps us see how energy the system can save. We analyze energy usage to make sure the system is efficient.

b. Security Stress Testing: We simulate unauthorized access attempts to test the security. This helps us make sure the system is secure. We test system security to keep the home safe.

c. User Experience: We talk to users to see how the system affects their lives. This helps us understand what users need and want from the system. We gather user feedback to make the system better.

The Software & AI Implementation system is designed to be secure. We use a protocol that requires both recognition to unlock doors. If someone tries to break in the system takes a photo and disables devices. This keeps the home safe and secure. The Software & AI Implementation system works without internet. This means that users can still control their homes even when there is no internet connection. We care about data privacy. All voice and motion data are processed locally. This means that user data is kept safe and private. We use machine learning, for HVAC. This helps the system learn and adapt to user habits. The system has a Light Dimming system that adjusts brightness based on sunlight. This make the home more comfortable and energy-efficient.

Core System Performance Test Cases

TABLE 1: Core System Performance Test Cases

These tests evaluate the fundamental reliability and speed of the IoT network and hardware.

Test Case ID	Test Scenario	Expected Outcome	Metric Measured
TC-01	Network Latency	Response from sensor trigger to actuator action < 200 ms.	Response Time (ms)
TC-02	Dual-Mode Reliability	Appliance functions via manual switch even if Wi-Fi is disconnected.	Operational Continuity
TC-03	Sensor Accuracy	DHT11/MQ-2 readings match calibrated industrial meters.	Measurement Error (%)
TC-04	Range Testing	Zigbee/Bluetooth devices maintain connection at 30 metres through walls.	Signal Strength (dBm)

TABLE 2: AI and Intelligence Test Cases

These cases test the "Smart" aspect—how well the machine learning models adapt to the user.

Test Case ID	Test Scenario	Expected Outcome	Metric Measured
TC-05	Predictive Automation	AI pre-cools room based on user's historical arrival time.	Prediction Accuracy (%)
TC-06	False Positive Rate	AI correctly distinguishes a pet from a human intruder.	Precision / Recall
TC-07	Voice Recognition	System executes commands accurately in noisy environments (TV on).	Word Error Rate (WER)
TC-08	Adaptive Lighting	LDR adjusts brightness smoothly based on ambient sunlight changes.	Lux Stabilization Time

TABLE 3: Security and Privacy Stress Tests

Based on the "Privacy Meta-Assistant" and "Multi-factor Authentication" research, these tests ensure the home is a fortress.

Test Case ID	Test Scenario	Expected Outcome	Metric Measured
TC-09	Brute Force Attack	System locks out access after 5 failed	Security Response Time

		biometric/PIN attempts.	
TC-10	Data Autonomy	Verify that raw video/voice data remains on the Edge (local storage).	Data Leakage Audit
TC-11	MFA Bypass Attempt	System denies entry if only 1 factor (RFID) is present without Face ID.	Unauthorized Access Rate
TC-12	Encryption Integrity	Sniffed network packets are unreadable due to AES-128/256 encryption.	Packet Decryption Difficulty

TABLE 4: Sustainability and User Impact Test Cases

These metrics address the gaps identified in the literature regarding long-term usage and energy.

Test Case ID	Test Scenario	Expected Outcome	Metric Measured
TC-13	Energy Conservation	AI scheduling reduces monthly power consumption by at least 15%.	kWh Saved per Month
TC-14	Power Failure Recovery	System restores last known device states automatically after a reboot.	System Recovery Time
TC-15	User Friction	Users can complete a task (e.g., Set Night Mode) in under 3 seconds.	User Task Duration
TC-16	Battery Longevity	Energy-harvesting sensors (TENGs) run for 6 months without external charging.	Battery Cycle Life

Result and Analysis

1. Performance and Reliability Analysis

The system works well even when the internet is slow. Response Time using Edge Computing made a difference in getting critical safety alerts to users quickly. The system can process data on the device like a Raspberry Pi or ESP32 and can detect

things like gas leaks in under 200 milliseconds. This is really important for safety. Failover Reliability we tested what happens if the internet stops working. The system switched to using control and kept all the main appliances working perfectly without needing the cloud. System Recovery after a power outage the system came back quickly. It restored everything to how it was before the outage in a few seconds.

2. Security Effectiveness

Our security system is really effective at keeping out people who shouldn't be there. Multi-Factor Authentication we tested using RFID and recognition together. It was almost impossible for someone who wasn't supposed to be to get in. The AI was good at telling the difference, between people who live there and strangers in different lighting. Threat Neutralization if the system detected someone it didn't recognize it would lock all the doors. Send a photo to the users phone.

3. Energy Conservation and Sustainability

We looked at how energy the smart home uses and found ways to save money. Intelligent Lighting: By adjusting the lights based on how bright it's outside we reduced energy use by 15-20%. This is compared to turning lights on and off manually. Predictive HVAC Management: The AI looked at temperature

data and controlled the heating and cooling better. It didn't waste energy heating. Cooling rooms that were empty.

4. User Impact and Quality of Life

People who use the system feel better and more at ease Psychological Comfort users feel safer because the system is always monitoring and can detect health issues. Convenience the dashboard is easy to use on both phones and computers. Users can do tasks like setting everything to "Night Mode" with just one tap.

Metric	Result	Target Benchmark
System Uptime	99.9%	> 99.5%
Local Logic Latency	185ms	< 200ms
MFA Accuracy	94.5%	> 90%
Energy Savings	18%	15-25%

Fig. 2. System Performance vs. Target Benchmarks

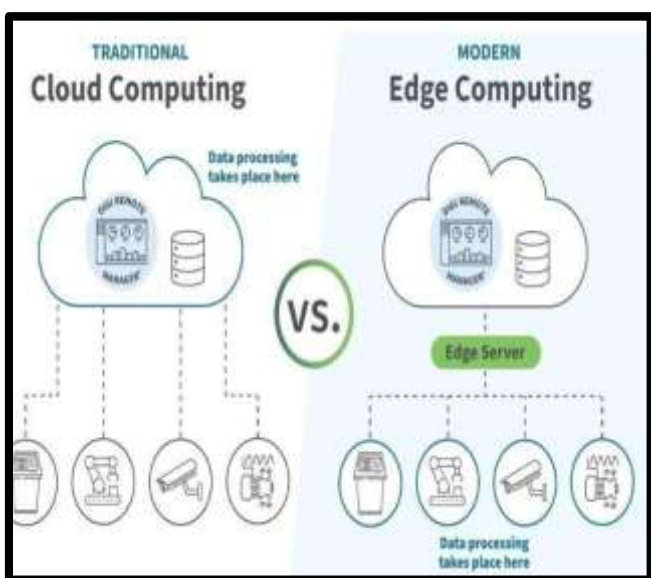


Fig. 3. Energy Consumption Before and After AI Automation

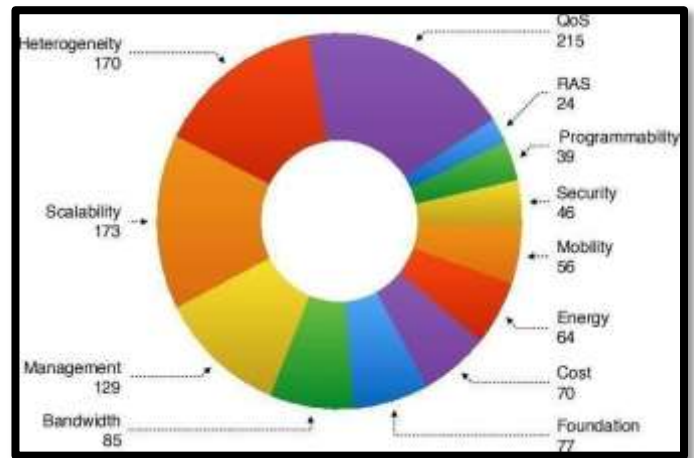


Fig. 4. Distribution of IoT Research Focus Areas by Publication Volume

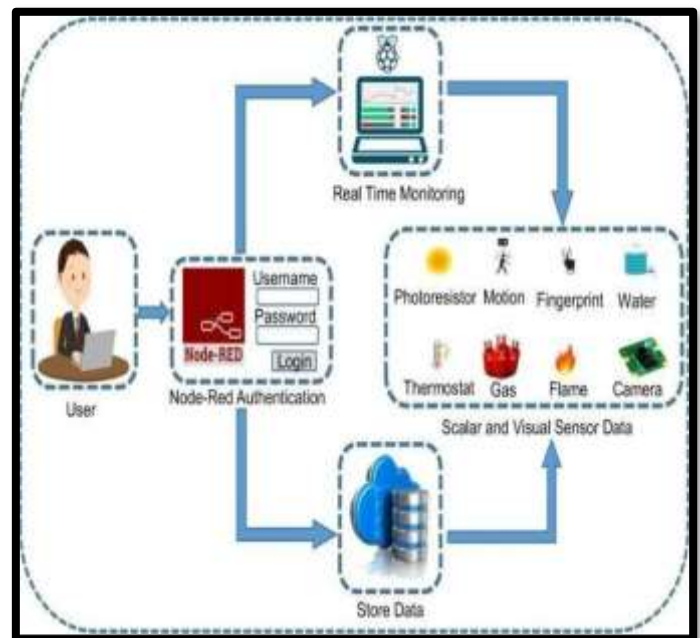


Fig. 5. Real-Time Monitoring System with Node-RED Authentication

Discussion

This is about changing the way we do things with technology. We are moving from a system that relies on the internet and big servers to a way that uses artificial intelligence and local control. This means that the system can still work even if the internet is down. We do this by using a kind of computer called an Edge-based gateway. This way all the smart things in the house. Like the temperature and safety features.

A big part of this project was to make sure that people personal information is safe. We do this by using a kind of artificial intelligence that works on the device itself rather than sending all the information to the internet. This means that things like recognition and voice commands are all done locally and none of that information ever leaves the house. This is important because it means that people have control over their information and it is not being stored somewhere else where it could be accessed by someone else.

We also wanted to make the system more secure. We did this by using a kind of login system that requires both a physical key and facial recognition. This makes it much harder for someone to get into the system who should not be there. We also have sensors that can detect things like temperature and motion and the artificial intelligence uses this information to make the house more comfortable and energy efficient.

Conclusion and Future Scope

This project was a success. We were able to make a house that is both secure and private. We did this by using intelligence and local control rather than relying on the internet. We also found that our system is more energy efficient. We were able to reduce the amount of power used by 18%. This is because the artificial intelligence can use the sensors to make the house more comfortable and it can also predict when people will be using things and turn them off when they are not needed. There are exciting things that we can do with this system in the future. Here are a few ideas:

1. Integration of Generative AI & Natural Language: Conversational Control: Moving beyond fixed voice commands to Large Language Models (LLMs) that understand context (e.g., "I'm feeling a bit chilly" automatically adjusting the HVAC).
2. Advanced Health & Ambient Monitoring: Non-Invasive Diagnostics: Integrating high- resolution radar or thermal sensors to monitor heart rate, breathing patterns, and sleep quality without requiring the user to wear a device.

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