

Internet of Things in Home Automation

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ABSTRACT

This paper presents a systematic literature review (SLR) of IoT applications in home automation, examining technological advancements, user adoption, and associated challenges. The study synthesizes current research to outline the benefits, security concerns, and future directions of smart home technologies.

1. Systematic literature review (SLR)

2. Introduction

The advent of the Internet of Things (IoT) has ushered in an era where everyday objects are transformed into a network of interconnected smart devices, capable of generating, exchanging, and processing data with minimal human intervention. In the realm of domestic environments, this has given rise to the concept of 'smart homes,' where IoT technology promises to revolutionize the way we interact with our living spaces. By embedding intelligence into home appliances and systems, IoT has the potential to enhance comfort, increase energy efficiency, and improve home security.

This paper conducts a systematic literature review (SLR) to explore the application of IoT in home automation. Following the methodology outlined by Kitchenham and Charters (2007), this SLR aims to provide a comprehensive overview of the current state of IoT in smart homes. A systematic literature review is a structured form of secondary study that employs a clearly defined protocol to collect, evaluate, and synthesize all available evidence pertaining to a particular research question. The objective is to conduct the review in an unbiased and reproducible manner. The primary studies included in an SLR are considered the building blocks of the research, each contributing valuable insights into the phenomenon under investigation.

The paper seeks to understand not only the technological advancements that facilitate smarter homes but also the real-world application, user adoption, and challenges associated with these technologies. As IoT continues to evolve, its application in home automation remains a dynamic and critical area of research, one that offers substantial benefits and poses unique challenges.

3. Study design

3.1. Review need identification

The main goal of this SLR is to look closely at the research that has been done on using IoT in home automation. As more IoT devices are used in homes, making them 'smart homes,' it's important to understand what's new in this field, what problems exist, and where things are headed. The reason for this study is the increasing role of IoT in making homes smarter. These devices are making our homes

more comfortable, safe, and energy-efficient. But, they also bring challenges like security risks and privacy concerns. So, we need to review what has been researched so far to highlight the good points and the areas that need more work. This SLR will focus on how IoT is used in home automation. This includes a variety of devices and systems. We'll look at studies about how these technologies are made and used, and also studies about what people think about them - like how easy they are to use and how people feel about them. We'll also look at important issues like privacy and security in smart homes.

3.2. Research questions definition

The goal is to address the elements of this quickly developing topic in identifying the research questions for this systematic literature review on the Internet of Things (IoT) in home automation. The primary research question that drives the study is: "How is IoT technology being applied in home automation, and what are the key benefits and challenges associated with these applications?". To dig deeper into this subject, several sub-questions have been formulated. These include: "What are the latest technological advancements in IoT for home automation?" and "How do users adopt and interact with IoT technologies in home automation settings, and what are their experiences and concerns?" The paper also seeks to answer: "What are the main benefits of using IoT in home automation?" and "What are the challenges and limitations, particularly in terms of security and privacy, associated with IoT in home automation?" Additionally, the review considers the question: "What future directions and potential areas for further research are identified by experts in the field?". With these questions in mind, it was the beginning of the process of identifying suitable databases to source relevant papers that can provide insights and answers to these inquiries.

3.3. Protocol definition

In defining the protocol for the systematic literature review on the Internet of Things (IoT) in Home Automation, the researcher adopts a structured and methodical approach. The IoT, in this context, refers to physical objects or systems in home environments equipped with sensors, processing capabilities, software, and other technologies that enable them to connect and exchange data over the Internet or other communication networks. The study deliberately excludes

IoT applications in other fields to maintain a focused exploration of home automation. The protocol involves selecting appropriate databases for sourcing literature, establishing clear inclusion and exclusion criteria tailored to the study's specific focus on home automation, and detailing a strategy for systematically extracting and analyzing data from selected studies.

4. Conducting the SLR

The review conducted by the researcher adheres to the methodology established by Kitchenham and Charters (2007). Accordingly, a series of research questions, which stem from the review's previously stated objectives, have been identified. The researcher will also detail the process followed for selecting the primary papers for the study. This structured approach ensures a thorough and systematic examination of the relevant literature.

4.1. Search and selection process

4.1.1. Database search

The search for relevant literature commenced with the utilization of predefined keywords pertinent to IoT and Home Automation. The academic databases selected for this search included IEEE Xplore, Research Gate, ACM Digital Library, and Google Scholar. This stage was essential for amassing a broad collection of literature within the field. Initially, 30 relevant papers were identified. The automated search was executed by applying the search string to the titles and abstracts of studies in these digital libraries. Among the initially identified 30 papers, a more detailed review revealed numerous irrelevant studies due to the automated nature of the search. As a consequence, further steps in the selection process were necessary to refine and narrow down these results to the most pertinent and relevant studies.

4.1.2. Merging, and duplicates and impurity removal

The second phase involved identifying duplicate entries and removing them to ensure a set of unique papers. The following phase focused on excluding studies that did not meet specific criteria: papers whose titles did not align with the topic of IoT in Home Automation and those not written in English. In the fourth phase, the remaining papers were further filtered based on their abstracts, resulting in a refined set of 10 final papers.

4.1.3. Application of the selection criteria

After identifying the initial set of studies from the database search, the next step involved applying specific selection criteria to further refine this list. This process was crucial to ensure that the final studies chosen were directly relevant to the topic of IoT in Home Automation.

The selection criteria included factors such as:

- **Relevance to the Topic:** Ensuring the study specifically addresses aspects of IoT in home automation.
- **Quality of Research:** Assessing the credibility and thoroughness of the research methods used in the study.
- **Publication Date:** Prioritizing recent studies to ensure the information is current.

Once these criteria were applied, a set of primary studies that were most relevant and valuable to the research objectives was obtained. From these selected studies, key data was extracted. This involved gathering important information from each study, such as their findings, methodologies, and conclusions.

The extracted data was then carefully analyzed and organized. This analysis aimed to draw out meaningful insights and patterns that would address the specific research questions about IoT in Home Automation. By summarizing this data in an organized manner, a clear and comprehensive view of the current state of IoT in home automation could be presented, directly addressing the research questions laid out in the study.

4.2. Data extraction

Based on the questions from subchapter 2.2, the main topic of choice, the quantity of citations, and the quality of the authors' and abstracts' work on the subject of IoT in Home Automation, 10 articles were chosen, which are listed in Table 1. This structured approach in the search and selection process ensures that the literature review is comprehensive, focused, and yields the most relevant and high-quality studies in the field of IoT in Home Automation.

4.3. Data synthesis

Stolojescu-Crisan et al. (2021)

The paper "An IoT-Based Smart Home Automation System" proposes a system called qToggle, designed for interconnecting sensors, actuators, and other data sources for home automation. The system uses a flexible Application Programming Interface (API) and is based on ESP8266/ESP8285 chips and Raspberry Pi boards. A key feature of qToggle is its user-friendly smartphone application, which allows users to control various home appliances and sensors. This system is notable for its flexibility and potential for further development with different devices and add-ons.

The research contributes to understanding the latest technological advancements in IoT for home automation, particularly in the context of user-friendly and cost-effective solutions. It addresses the user adoption and interaction with IoT technologies, highlighting the ease of use and the importance of accessible interfaces for controlling home automation systems. The study, while touching upon the benefits of such systems, also raises concerns about their limitations, particularly regarding the number of devices that can be connected and potential security and privacy issues.

Chakraborty et al. (2023)

Id	Cite	Title, Authors	Year
P1	Stolojescu-Crisan, Crisan and Butunoi (2021)	An iot-based smart home automation system, Stolojescu-Crisan, C., Crisan, C., Butunoi, B.P	2021
P2	Chakraborty, Islam, Shahriyar, Islam, Zaman and Hasan (2023)	Smart home system: A comprehensive review, Chakraborty, A., Islam, M., Shahriyar, F., Islam, S., Zaman, H., Hasan, M.	2023
P3	Singh and Khan (2021)	Applications and challenges in iot based smart homes, Singh, B., Khan, M.	2021
P4	Adedoyin, Shoewu, Adenowo, Yussuff and Senapon (2020)	Development of a smart iot-based home automation system, Adedoyin, M., Shoewu, E.D.O., Adenowo, A., Yussuff, A., Senapon, M.	2020
P5	Mahmud, Ahmed and Shikder (2019)	A smart home automation and metering system using internet of things (iot), Mahmud, S., Ahmed, S., Shikder, K.	2019
P6	Sepasgozar, Karimi, Farahzadi, Moezzi, Shirowzhan, Ebrahimzadeh, Hui and Aye (2020)	A systematic content review of artificial intelligence and the internet of things applications in smart home, Sepasgozar, S., Karimi, R., Farahzadi, L., Moezzi, F., Shirowzhan, S., Ebrahimzadeh, S., Hui, F.K.P., Aye, L.	2020
P7	Yar, Imran, Khan, Sajjad and Kastrati (2021)	Towards smart home automation using iot-enabled edge-computing paradigm, Yar, H., Imran, A.S., Khan, Z.A., Sajjad, M., Kastrati, Z.	2021
P8	Orfanos, KAMINARIS, Piromalis and Papageorgas (2020)	Smart home automation in the iot era: A communication technologies review, Orfanos, V., KAMINARIS, S., Piromalis, D., Papageorgas, P	2020
P9	Gill, Yang, Yao and Lu (2009)	A zigbee-based home automation system, Gill, K., Yang, S.H., Yao, F., Lu, X.	2009
P10	Wang, Liu, Sun, Pang, Sun, Lin, Lui and Ren (2022)	A survey on iot-enabled home automation systems: Attacks and defenses, Wang, Z., Liu, D., Sun, Y., Pang, X., Sun, P., Lin, F., Lui, J.C.S., Ren, K.	2022

Table 1
List of selected articles

The authors extensively analyze the current state of smart home systems, focusing on technological advancements like smartphone apps and voice control. They discuss how these technologies have revolutionized user interaction with smart home systems, making them more intuitive and user-friendly. The article also sheds light on significant challenges like system security, highlighting vulnerabilities to cyber threats and stressing the need for improved protective measures. Additionally, it touches on the economic aspect, noting how the high costs of advanced technologies can be a barrier to wider adoption. This comprehensive review offers a detailed look into both the progress and the challenges faced in the realm of smart home automation.

Singh and Khan (2021)

The article presents a detailed analysis of IoT applications in smart homes, focusing on their various implementations, benefits, and associated challenges. The paper reviews numerous IoT-enabled smart home applications, outlining their flexibility, energy efficiency, and security enhancements. It discusses the implementation challenges such as human motion detection, scalability, lack of global standards, interoperability, device connectivity, and affordable cost.

They authors discuss the implementation of IoT for energy-efficient solutions, such as automated lighting systems which adjust brightness based on natural light levels, and climate control systems that optimize heating and cooling for energy savings. The paper also digs deeper into IoT-enabled security enhancements, including smart locks that offer remote access control and surveillance systems with real-time monitoring capabilities. These examples illustrate the practical benefits of IoT in enhancing home automation, efficiency, and security.

The challenges highlighted include interoperability issues between different IoT devices and the need for scalable architectures to support an increasing number of connected devices. The article emphasizes the importance of establishing global standards to address these challenges and enhance the functionality of smart home systems. The researchers suggest that future research should focus on developing new IoT architectures and services to address these challenges and enhance the capabilities of smart home systems.

Adedoyin et al. (2020)

The article focuses on creating a home automation system using Internet of Things (IoT) technology. The system allows for remote monitoring and control of home appliances

via an Android interface or automatic control using sensors and a PIC microcontroller. It aims to improve energy conservation and assist individuals with physical challenges or busy lifestyles. The system includes features like temperature, light, and motion sensors, and operates in both manual and automatic modes. The paper discusses the design, implementation, and testing of the system, emphasizing its practicality, efficiency, and user-friendliness.

Mahmud et al. (2019)

The article focuses on applying IoT for efficient home automation and energy management. It showcases a system that allows users to control and monitor home appliances and energy consumption remotely. The control features in the article's IoT system are facilitated by a microcontroller connected to home appliances and a Wi-Fi module for internet access. This setup enables remote operation and monitoring through a website interface. Users can conveniently manage home devices and monitor energy usage in real-time from any location, enhancing the user experience. The system's integration of automation and energy metering exemplifies improved energy management by allowing users to track and control their consumption, leading to potential energy savings and efficiency. The paper does not write anything about security and privacy, which are critical in IoT systems.

Sepasgozar et al. (2020)

The article provides an in-depth analysis of how AI and IoT technologies are currently used in smart home environments. It conducts a systematic review and content analysis of various scholarly papers to understand the integration and application of these technologies. The focus is on identifying gaps, which highlight the need for more advanced systems that can effectively manage energy consumption and provide comprehensive care solutions for the elderly, using the combined capabilities of AI and IoT. It underscores the importance of developing integrated and efficient smart home systems to address these specific challenges.

It offers specific examples of AI and IoT applications in smart homes. For instance, it discusses energy management systems that use IoT sensors to optimize electricity usage, and AI algorithms that learn and predict the homeowner's preferences for heating and cooling. It also explores elderly care systems where AI assists in monitoring the health and safety of senior residents, utilizing IoT devices like motion sensors and wearable health trackers. These examples illustrate the practical applications and potential benefits of integrating AI and IoT in smart home environments, addressing the identified gaps in energy efficiency and aged care.

The research method involves a thorough examination of existing literature to chart the present landscape and anticipate future developments in smart home technology,

emphasizing the need for more integrated and efficient systems. The article highlights the crucial role of AI and IoT in evolving smart home systems, especially in improving energy management and developing advanced care systems for the elderly.

Yar et al. (2021)

The article proposes a new smart home automation system using Raspberry Pi (RPI) and edge computing. The system in the article uses Raspberry Pi (RPI) as a central control unit for local data processing, which is a key aspect of edge computing. This setup allows the smart home system to process data from IoT devices and sensors directly on the Raspberry Pi, rather than relying on cloud computing. This local processing approach enhances the system's efficiency by reducing the time taken to process data, decreasing bandwidth usage, and lowering overall energy consumption. This method also improves data privacy and security, as sensitive information is processed within the home environment, not transmitted to external servers. The framework is designed to be cost-effective, secure, and energy-efficient, with the potential for easy integration into existing home architectures. The study compares its system with existing solutions, demonstrating improvements in motion detection speed, energy efficiency, and relay switching times.

Orfanos et al. (2020)

The article offers an analysis of communication technologies used in IoT-enabled smart home automation systems. It discusses various wired and wireless communication technologies, highlighting their technical characteristics, user interaction, security/quality, and cost aspects. The paper focuses on how these technologies, including popular ones like Zigbee, Z-Wave, and newer IoT standards, contribute to the development of smart home systems. Zigbee, known for its low power consumption and high data security, is suitable for applications requiring frequent data transmission over short distances. Z-Wave, on the other hand, operates at lower frequencies, offering a wider coverage area, making it ideal for larger homes. Both technologies are designed to be user-friendly, allowing for easy integration and interaction in smart home environments. They emphasize efficiency in terms of data rate, range, and energy consumption, balancing performance with energy-saving capabilities.

The study provides guidance for users in selecting appropriate communication technologies for home automation. It considers factors like cost, balancing the initial investment against long-term benefits. Security is a major focus, with an analysis of how different technologies protect against unauthorized access and data breaches. Technical requirements are also examined, including compatibility with existing devices and the technical expertise needed for installation and maintenance.

Article	Approach	Tools	Case study
P1	IoT-based smart home automation system		real-life
P2	Comprehensive review of smart home systems		academic
P3	Challenges in IoT-based smart homes		real-life
P4	IoT-based home automation development		real-life
P5	Home automation and metering using IoT		real-life
P6	Content review of AI and IoT in smart homes		academic
P7	IoT-enabled edge-computing for home automation		academic
P8	Review of communication technologies in IoT		academic
P9	Home automation using Zigbee technology		academic
P10	Survey on IoT-enabled home automation security		academic

Table 2
Approach Comparison Table

Gill et al. (2009)

The article provides a thorough explanation of the ZigBee-based home automation system's architecture. It details how various home devices such as light switches, radiator valves, and safety sensors are integrated into a unified network using ZigBee technology. This integration allows for efficient and secure communication between devices, enabling automated control and monitoring of different aspects of the home environment. The paper highlights the specific functionalities of each type of device within the ZigBee network, demonstrating the comprehensive nature of the home automation system.

Wang et al. (2022)

The article offers a detailed look at an IoT-based smart home system with a strong emphasis on security and computational efficiency. The model presented in the article focuses on enhancing the computational efficiency and data security of a smart home system. The article describes several strategies to balance computational efficiency and data security in a smart home system. These strategies include optimizing data transmission protocols to reduce computational load, implementing robust encryption methods for data security, and designing efficient algorithms for real-time data processing and analysis. Additionally, the model employs advanced authentication mechanisms to ensure data authenticity and integrity within the IoT network. These approaches collectively enhance the performance and security of the smart home automation system.

5. Results

The purpose of this paper's systematic literature review was to learn about the current state of the art in the field of Internet of Things in Home Automation. The goal was to provide an answer to the issue that was posed in Section 2.2. Ten relevant studies were found. The information in these publications is sufficient to provide the answers to the questions. Considering how little research has been done on the subject of the Internet of Things, more has to be done to

improve and develop the technology to make IoT devices in the home automation industry more reliable and secure.

5.1. Application of IoT in Home Automation

In response to the primary research question, "How is IoT technology being applied in home automation, and what are the key benefits and challenges associated with these applications?", the selected studies collectively demonstrate a diverse application of IoT technologies. From the development of user-friendly interfaces, such as the qToggle system (Stoloiescu-Crisan et al. (2021)), to comprehensive reviews of smart home systems that incorporate IoT and machine learning (Chakraborty et al. (2023)), the results show a trend towards increasing automation and ease of use. The use of Raspberry Pi and edge computing (Yar et al. (2021)) illustrates a shift towards local data processing to enhance security and efficiency. The integration of Zigbee in home automation systems (Gill et al. (2009)) indicates a preference for low-power, secure, and efficient communication technologies.

5.2. Technological Advancements in IoT for Home Automation

The latest technological advancements in IoT for home automation, as per the sub-question, are highlighted by the innovations in communication technologies (Orfanos et al. (2020)) and the design of systems that optimize energy usage and provide comprehensive security solutions (Wang et al. (2022)). Examples include smart metering systems that allow for remote energy management (Mahmud et al. (2019)) and the use of AI to predict and adjust to homeowner preferences (Sepasgozar et al. (2020)).

5.3. User Adoption and Interaction with IoT Technologies

The review identified that user adoption and interaction with IoT technologies in home automation settings are generally positive, with studies reporting that systems are becoming more

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