

Interoperable IoT Devices and Systems for Smart Homes: A Data Analytics Approach to Enhance User Experience and Energy Efficiency

Yonis Abdirahman Elmi

City University Malaysia, yoniselmi19@gmail.com

ABSTRACT

The Internet of Things (IoT) has revolutionised the way people live and work, and its increasing popularity has led to the widespread adoption of smart homes. However, the lack of interoperability among IoT devices and systems used in smart homes limits their capacity to enhance the user experience and improve energy efficiency. Therefore, this study focuses on improving interoperability between various IoT systems and devices. It was anticipated that the research would contribute to the creation of a more cohesive and integrated smart home environment by helping to develop a data analytics framework that enables the integration and analysis of data from various devices. The study then produces an intended user design strategy for smart homes that takes into account users' wants, preferences, and behaviours during the design phase. The goal of this project was to create smart houses that are more intelligent, environmentally green, and user-friendly and that will benefit both individuals and the whole society.

Keywords: IoT, Smart home, Data analytics, Energy efficiency, Energy management systems and User experience (UX)

INTRODUCTION

The increasing popularity of "smart homes" may be attributed, in part, to the widespread adoption of systems and technologies that are connected to the Internet of Things (IoT) (Malche, 2017; Saif et al., 2021). However, since these systems and devices cannot communicate with one another, their capacity to improve both the quality of the user experience and the efficiency with which energy is used needs to be improved (Fortino et al., 2018; Fotopoulo et al., 2018). In order to enhance the interoperability of IoT devices and systems used in smart homes, a strategy founded on data analytics has been proposed as a potential solution (Harsha et al., 2017). The plan that has been suggested makes use of algorithms for machine learning in order to carry out an analysis of data that has been gathered from a wide range of different kinds of systems and devices. This study aims to uncover patterns and correlations that may be implemented to minimise the amount of energy consumed and improve the user's

experience. This strategy is evaluated by using data from the actual world as part of a smart home project. Then, the study indicates the possibility of improving not just the user experience but also the system's energy efficiency.

The proliferation of IoT devices in smart homes has revolutionised the way we interact with our living spaces. These devices provide a wide range of functionalities, from temperature and lighting control to security and entertainment (Anthi et al., 2019). However, despite the vast array of devices available on the market, there is often a lack of interoperability, resulting in siloed systems that cannot communicate with each other. In order to address these challenges, a data analytics approach can be applied to IoT devices and systems. By leveraging data from different devices, it is possible to create a unified view of the smart home, enabling the development of new services and applications that enhance the user experience and energy efficiency (Huang et al., 2020).

Therefore, the motivation of this academic work is to explore the potential of data analytics in improving interoperability among IoT devices and systems in smart homes. Through this research, we aim to provide a deeper understanding of the challenges and opportunities of interoperability in smart homes as well as propose a data analytics framework for enhancing the user experience and energy efficiency. Ultimately, this work seeks to contribute to the development of more intelligent and sustainable smart homes, creating a more comfortable and eco-friendly living environment for everyone.

I. LITERATURE REVIEW

A. Reseach Gap

While the concept of interoperability and data analytics in smart homes has been extensively studied in the literature, there are still several research gaps that require addressing. Some of the major research gaps in this area include:

- o Lack of standardization: There is currently a lack of standardization in the design and implementation of IoT devices. This has resulted in a proliferation of proprietary solutions that are not interoperable with each other. There is a need to develop standards and protocols that can ensure interoperability among different IoT devices and systems (Al-qaseemi & Almulhim, 2016).
- o Limited studies on user experience: While several studies have explored the technical aspects of interoperability and data analytics in smart homes, there is a lack of research on user experience. There is a need to conduct user studies to understand how users interact with different IoT devices and systems, and how interoperability can enhance their experience (Jabbar et al., 2019).
- o Limited studies on energy efficiency: While energy efficiency is a key motivation for the adoption of smart homes, there is a lack of research on how interoperability and data analytics can enhance energy efficiency. There is a need to develop energy-efficient algorithms and techniques that can optimize the use of different IoT devices and systems in smart homes (Sivaraman et al., 2019; Vishwakarma, 2019).

- o Security and privacy concerns: Interoperability and data analytics in smart homes raise several security and privacy concerns. There is a need to develop secure and privacy-preserving solutions that can ensure the confidentiality and integrity of user data (Geneiatakis et al., 2017; Sivaraman et al., 2019).
- o Scalability: As the number of IoT devices and systems in smart homes increases, there is a need to develop scalable solutions that can handle the large volume of data generated by these devices. There is a need to explore distributed and parallel computing techniques that can enable real-time data analytics in smart homes (Javed & Malhi, 2020)

B. Problem Statement

Smart home has become popularity of technology in recent years, with many homeowners and renters adopting various devices and systems to automate and control their homes (Anthi et al., 2019). However, a major problem admitting the industry is the lack of interoperability between different smart home devices and systems.

Currently, there are multiple smart home platforms, each with their own proprietary protocols and standards. This means that devices from different manufacturers often cannot communicate with each other or be controlled through a single interface. This creates frustration for consumers, who may have to use different apps or devices to control different aspects of their homes (Jabbar et al., 2019; Malche, 2017).

Furthermore, as the number of smart devices in a home increases, so does the complexity of managing them. Consumers may find it difficult to set up and configure devices from different manufacturers and may experience issues with compatibility or reliability (Smirek et al., 2016).

Based on the major issue in the research gap, it concludes that the lack of interoperability is the main problem in study. It because the lack of interoperability creates challenges for developers and manufacturers, who must invest significant resources to ensure that their devices are compatible with multiple platforms (Al-qaseemi & Almulhim, 2016; Farooq et al., 2019). This can lead to increased costs and delays in bringing new products to market. Users may have to use multiple apps to control different devices, leading to confusion and frustration. Additionally, devices may operate independently of each other, leading to suboptimal energy consumption and wasted resources (Fotopoulou et al., 2017).

Overall, the lack of interoperability is a significant barrier to the widespread adoption of smart home technology. In order to fully realize the potential of the smart home, the industry must address this problem and work towards creating a more seamless and integrated ecosystem for smart devices (Al-qaseemi & Almulhim, 2016; Smirek et al., 2016). Therefore, this study aims to challenge in developing a data analytics strategy for the Internet of Things (IoT) devices and systems in smart homes that can work together. This is expected in this strategy can improve smart homes' user experience and energy efficiency.

C. Smart Home and Internet of Things

Smart homes are modern homes with devices and appliances that can be connected to the internet and controlled from afar (Fensel, 2021). Internet of Things (IoT) technology allows these devices and appliances to talk to each other and the homeowner to automate tasks, save energy, and make the home safer (Mahmud et al., 2019).

IoT is the network of physical devices, vehicles, home appliances, and other things that are equipped with sensors, software, and network connectivity so that they can collect and share data. In the past few years, this technology has grown quickly, and it is expected to change the way we live and work (Sambana, 2017).

IoT technology is used in smart homes to create a home automation system that works well and is easy to use. Some of the most common IoT devices used in Smart Homes include smart thermostats, smart lighting, smart locks, smart cameras, and smart speakers. It can control these devices with an app on your phone, voice commands, or by setting them up to do certain things on their own.

Smart homes and the Internet of Things (IoT) have a lot of benefits, such as using less energy, being safer, making life easier, and saving money. Smart thermostats, for example, can learn how you like to heat and cool your home and adjust the temperature accordingly (Al-Turjman et al., 2019; Lau et al., 2019). This can cut down on energy use and save you money on your utility bills. Smart locks and cameras can make your home safer, and smart appliances can be easier to maintain and last longer.

D. Benefits of Smart Home Technologies

- The possibilities for adding smart devices, networking and controlling them remotely are unlimited in homes that are equipped with such devices. such as easily adoptable healthcare equipment for the elderly in this setting. New device testing and implementation can take place in this network's hospitable environment (Ang et al., 2019; Huang et al., 2019).
- On a larger scale, the advantage of a smart home is an enhanced quality of life thanks to the comfort, convenience, and freedom it provides the special needs population. In support of this, it is stated that the increased quality of life for smart home residents is the cause for the appeal of these homes. Also, the two main advantages of a smart home have been summed up as being in charge from anywhere and having peace of mind. (Lau et al., 2019).
- In terms of smart energy systems, home energy-saving techniques are garnering a lot of interest. Home energy-saving strategies are catching the attention of smart energy systems, which monitor energy waste. To regulate energy usage for home technology, a number of initiatives and business offerings have been developed (Tomic et al., 2010). One of several steps done to protect the environment is the implementation of an eco-friendly environment. Additional research centred on renewable energy sources in smart homes that reduce energy waste and maintain the most environmentally friendly climate possible by using natural heating and cooling systems. In addition, the grid-connected rooftop system has enabled smart homes to accommodate solar-powered

appliances like the oven and water heater and reduce metre readings. Moreover, smart homes can be used to achieve water conservation (Saif et al., 2021; Smirek et al., 2016). Table 2.1 show some benefit of smart home.

The Internet of Things (IoT) is a kind of linked technology that may be found in many modern homes. It can communicate with digital devices such as detectors, sensors, and switches. These IoT devices are able to intelligently exchange information and resources with one another (Farooq et al., 2019.; Xu et al., 2019). These devices serve as a gateway, through which the home user may get notifications about the state of the home and also operate all of the devices by using a desktop computer, a mobile phone, or a tablet computer. The advancements in Internet of Things technology combine with intelligence systems in smart home appliances. The purpose of this integration is to provide the home user with a flexible method to quantify the current conditions of the house and monitor the gadgets in the home (Sambana, 2017; Sundas & Panda, 2020).

The currently installed home systems, which contain a wide variety of information, are being converted into digital formats. These virtualized systems and information are coupled into functions, which are then utilized to conduct mapping, encapsulation, aggregation, and composition mechanism, which enables home appliances to interoperate with one another to carry out joint tasks of household operations (Dorothy et al., 2017; Farias et al., 2016). According to the findings of one of the market analyses, smart cities and smart homes may be enabled by a variety of technologies, including the (IoT). The underlying architecture of the (IoT) provides a link to systems and devices that is both transparent and smooth so that users may carry out complicated tasks. The environment of a smart home is comprised of numerous difficult tasks that include dealing with a variety of end systems and sensors, all of which need for prominent IoT application (Alaa et al., 2017).

The term "things" refers to a wide array of sensors and actuators in an Internet of Things environment like a smart home (N. Mani et al., 2020). To accomplish the intended level of service, a predetermined objective or a default configuration will be used. This operation is calculated using the data that was gathered by the sensors, and then either decision making or automated predictive systems are used to offer the service that is needed. Strictly speaking, an Internet of Things enabled item has the computing capabilities of a microcontroller, communication interfaces, and protocols that allow devices to connect with one other, as well as interfacing users and providing fundamental support in the internet. In general, a wide range of household appliances and equipment that were manufactured by a number of different manufacturers have the potential to connect to the internet (Anthi et al., 2019).

By automating household tasks, smart homes give their owners a futuristic quality of life. When that happened, IoT connected household appliances to the internet, linking items or objects in the real world. IoT encompasses things like furniture, household appliances, gadgets, cars, sensors, and more (Dubey et al., 2020). IoT can be categorized into three paradigms, such as middleware that is internet-

oriented, sensors that are things-oriented, and knowledge that is semantic-oriented, which further supports this claim. Experts are reportedly working on creating algorithms for IoT in smart homes. Algorithm development is partially motivated by the need to address security and privacy concerns with IoT-enabled smart home products. The user's information should be protected in the context of a smart home, as should access to the devices (Huang et al., 2019). Wireless communication, a highly mobile network with high speed and a technology that is independent of infrastructure, is typically used to provide data communication in these smart home networks. power line communication methods are also used. Technology user friendliness must protect the notions of acceptability and usefulness from the viewpoint of the users who actually use the technology(Sharma et al., 2020). The study demonstrates how concerns about ergonomics, security, privacy, and trust are all related to how well-liked a technology and it also highlights the need for users to critically assess the designs of smart home devices (Solanke, 2017).

E. Overview of IoT and its Applications in Smart Homes

The Internet of Things (IoT) is a network of physical objects such as cars, appliances, and other household items that are connected to the internet and have sensors, software, and network connectivity built in the system (Sambana, 2017). One of the most popular applications of IoT technology is in smart homes. Smart homes are homes that are equipped with IoT devices and sensors that can be controlled remotely. These devices and sensors are integrated into the home's systems to automate tasks, save energy, and improve home security (Janeiro, 2019).

Some common IoT devices used in smart homes include smart thermostats, smart lighting, smart locks, smart cameras, and smart speakers. These devices can be controlled using a smartphone app, voice commands, or programmed to perform specific tasks automatically (Lau et al., 2019).

Smart thermostats, for example, can learn your heating and cooling preferences and adjust the temperature accordingly. Smart lighting can be programmed to turn on and off automatically or change color depending on the time of day or your mood. Smart locks can be unlocked remotely or using biometric authentication, and smart cameras can be used to monitor the home while you are away (Lu et al., 2010).

IoT technology is also used in smart appliances, such as refrigerators, ovens, and washing machines. These appliances can communicate with each other to coordinate their activities, optimize energy usage, and provide notifications to the homeowner when maintenance is required (Motlagh & Mohammadrezaei, 2020).

The benefits of IoT technology in smart homes are numerous. They include improved energy efficiency, enhanced security, greater convenience, and cost savings. For example, smart thermostats can reduce energy usage by up to 15%, while smart lighting can reduce energy consumption by up to 60%. Smart locks and cameras can improve home security, and smart appliances can reduce maintenance costs and improve their lifespan (Kapourani et al., 2015).

IoT technology is transforming the way of live and smart homes are just one example of how it can be applied. As more devices and sensors are integrated into our homes, the potential for IoT technology to improve our lives will only continue to grow.

F. Identify the Headings Interoperability in Smart Homes

The interoperability challenge in smart homes arises because different devices and systems are often manufactured by different vendors, using different protocols and standards (Daniele et al., 2016). This lack of standardization can lead to compatibility issues, resulting in user frustration, dissatisfaction, and inefficient energy consumption. For example, suppose the smart thermostat is incompatible with the smart lighting system. In that case, the user may have to manually adjust the lighting every time the temperature changes, which defeats the purpose of automation (Al-qaseemi & Almulhim, 2016).

Several standards and protocols, like Zigbee, Z-Wave, and Wi-Fi, have been made so that smart home devices can work together. These standards aim to provide a common language for different devices and systems to communicate and work together seamlessly. However, even though these standards are in place, it is still hard for devices to work together because not all vendors follow the same standards, and different devices may need different standards (Danbatta, 2019).

Another approach to addressing the interoperability challenge in smart homes is using Middleware. Middleware refers to software that acts as a bridge between different devices and systems, enabling them to communicate and work together seamlessly. In addition, Middleware can translate between different protocols and standards, allowing devices and systems to work together, even if it not originally designed (Chaqfeh et al., 2012).

In addition to standards and Middleware, data analytics can also be used to enhance interoperability in smart homes. By analysing data from different devices and systems, data analytics can identify patterns and trends that can be used to optimize the performance of the home automation ecosystem.(D. Bansal & Chhikara, 2014). For example, data analytics can be used to optimize energy consumption by turning off appliances and systems when they are not in use or by adjusting the temperature based on the user's habits and preferences (Chaqfeh et al., 2012).

Interoperability is a critical challenge facing the adoption of smart homes. Even though many standards and protocols have been made to deal with this problem, interoperability still needs to be improved (Lee et al., 2021). Not all vendors adhere to the same standards, and different devices may require different operating standards. Middleware and data analytics can also be used to enhance interoperability in smart homes by providing a bridge between different devices and systems and by optimizing the performance of the home automation ecosystem through data analysis(Bansal & Kumar, 2020; Taj et al., 2018).

Smart homes have various sensors, devices, and systems that enable automation, energy efficiency, and security. However, these systems often use different protocols, technologies, and standards, leading to

interoperability issues. Interoperability refers to the ability of different devices and systems to work together seamlessly, regardless of their underlying technology (Tomic et al., 2017). Achieving interoperability in smart homes ensures that different devices and systems can communicate and work together effectively (Taj et al., 2018).

Interoperability is essential for successfully implementing and adopting smart homes. Without interoperability, smart home systems would be limited in functionality, usability, and compatibility. In addition, interoperability offers several benefits, including:

1. **Improved User Experience:** Interoperability enables different devices and systems to work together seamlessly, resulting in a better user experience. For example, interoperability can enable users to control different devices and systems using a single interface rather than multiple interfaces.
2. **Increased Energy Efficiency:** Interoperability can enable different devices and systems to communicate and share data, resulting in increased energy efficiency. For example, interoperability can enable a smart thermostat to communicate with a smart lighting system, allowing the lighting system to adjust its settings based on the temperature and occupancy of the room.
3. **Enhanced Security:** Interoperability can enable different security systems to work together, resulting in enhanced security. For example, interoperability can enable a smart lock to communicate with a security camera, allowing the camera to start recording when the lock is unlocked.
4. **Reduced Costs:** Interoperability can reduce the costs associated with implementing and maintaining smart home systems. For example, interoperability can reduce the need for custom integrations and the complexity of system maintenance.

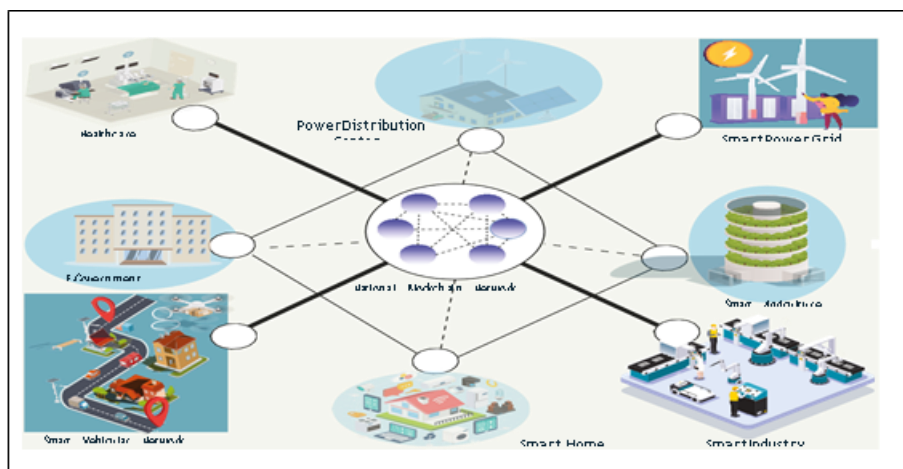


Figure 2.1 Importance of Interoperability in Smart Homes

II. METHODOLOGY

Achieving interoperability in smart homes is critical for ensuring that different devices and systems can work together seamlessly. However, as we discussed in the previous section, there are several challenges associated with achieving interoperability. In this section, we will explore some of the approaches that can be taken to address these challenges and achieve interoperability in smart homes. Approaches to Achieving Interoperability in Smart Homes:

1. **Standardization:** One of the most important approaches to achieving interoperability is standardization. By establishing common standards and protocols, manufacturers can ensure that their devices are compatible with other devices on the market. This can help to reduce complexity and increase consumer choice.
2. **Middleware:** Middleware is a software layer that sits between different devices and systems, allowing them to communicate with each other. Middleware can help to bridge the gap between devices that use different protocols or standards, enabling them to work together effectively.
3. **Cloud-based solutions:** Cloud-based solutions can provide a centralized platform for managing smart home devices and systems. By storing data and applications in the cloud, manufacturers can ensure that devices can communicate with each other, regardless of their location or the protocols they use.
4. **Open APIs:** Open APIs (Application Programming Interfaces) can provide a standardized way for different devices and systems to communicate with each other. By making APIs available to developers, manufacturers can encourage the development of third-party applications that can work with their devices.
5. **Partnerships and collaborations:** Partnerships and collaborations between different manufacturers can help to promote interoperability. By working together, manufacturers can ensure that their devices are compatible with each other, providing consumers with a wider range of options and a better user experience.

Achieving interoperability in smart homes is essential for unlocking the full potential of smart home technology. Standardization, middleware, cloud-based solutions, open APIs, partnerships, and collaborations are just a few of the approaches that can be taken to address the challenges associated with achieving interoperability. By working together, manufacturers, policymakers, and other stakeholders can help to create a more interoperable smart home ecosystem, providing consumers with greater convenience, security, and energy efficiency.

Smart homes are equipped with various sensors and devices that generate data, such as temperature, humidity, energy consumption, and more. Analyzing this data can provide valuable insights into how smart homes are being used and how their performance can be optimized. Data analytics has emerged as a critical approach to extracting insights from this data (Shang & You, 2019).

Data analytics refers to examining raw data to draw insights and conclusions. In the context of smart homes, data analytics can be used to optimize energy usage, enhance security, and improve the user experience. For

example, data analytics can be used to predict user behavior, detect security threats, and optimize energy consumption. There are several use cases of data analytics in smart homes.

Smart homes have become increasingly popular, and their growth has created a need for better user experience (UX) in smart home systems. However, creating smart homes that are both usable and enjoyable presents challenges and opportunities for designers and researchers.

One of the main challenges for improving UX in smart homes is the complexity of these systems. Smart homes typically involve multiple devices and technologies, and users may struggle to understand how different devices work together. This complexity can also make it difficult for users to customize smart home systems to their individual needs and preferences.

Another challenge for improving UX in smart homes is privacy and security concerns. Smart homes collect a vast amount of personal data, including information about user behavior and routines. This data can be vulnerable to security breaches and misuse, which can lead to serious privacy violations and other negative consequences for users.

Then, a challenge for improving UX in smart homes is the lack of standardization in the industry. Different smart home systems use different interfaces, protocols, and technologies, which can make it difficult for users to switch between systems or for designers to create compatible systems.

Despite these challenges, there are several opportunities for improving UX in smart homes. One opportunity is the development of artificial intelligence (AI) and machine learning (ML) technologies. These technologies can be used to create smart home systems that learn and adapt to users' behavior, preferences, and needs, which can enhance the UX and make smart homes more intuitive and personalized.

Another opportunity for improving UX in smart homes is the development of standardized interfaces and protocols. By creating common standards for smart home systems, designers can make it easier for users to understand and customize these systems, and for designers to create compatible and interoperable systems.

Finally, an opportunity for improving UX in smart homes is the integration of smart home systems with other technologies and services, such as health monitoring, transportation, and entertainment. By integrating smart home systems with other technologies, designers can create comprehensive and seamless user experiences that extend beyond the home environment.

In short, improving UX in smart homes presents challenges and opportunities for designers and researchers. By addressing the challenges of complexity, privacy and security, and lack of standardization, and by leveraging the opportunities of AI and ML, standardized interfaces and protocols, and integration with other technologies, designers and researchers can create smart homes that are both usable and enjoyable for users.

Smart homes are an increasingly important part of modern life, providing users with increased energy efficiency, convenience, and security. However, to provide these benefits, smart home systems must be designed with the needs and preferences of users in mind. User feedback and evaluation methods are crucial tools for

achieving this goal, allowing designers and researchers to understand user needs and preferences and identify areas for improvement.

Several user feedback and evaluation methods are available in smart homes, include polls, discussions, focus groups, usability tests, and field investigations. Each approach has benefits and drawbacks, and the selection of approach relies on the study issue, the stage of development, and the resources that available The summarize the user feedback in Table 3.1

Table 3.1 Summarization of user feedback and evaluation methods

Method	Type of Data Collected	Level of User Involvement	Cost and Time Required
Surveys	Quantitative	Low	Low
Interviews	Qualitative	High	Low to Moderate
Focus Groups	Qualitative	High	Moderate to High
Usability Testing	Quantitative and Qualitative	High	Moderate to High
Field Studies	Quantitative and Qualitative	High	High

Table 3.1 summarizes key information about each method, including the type of data collected, the level of user involvement required, and the cost and time required. Surveys are a low-cost, low-involvement method for collecting quantitative data about user preferences and satisfaction. Interviews and focus groups are higher involvement methods for collecting qualitative data about user experiences and perceptions. Usability testing involves observing users performing tasks with a smart home system, allowing for both quantitative and qualitative data collections. Field studies involve long-term observation of users in their natural environment, providing rich qualitative and quantitative data but requiring a high level of involvement and resources.

Discussion: Each user feedback and evaluation method has its own strengths and weaknesses, and the choice of method depends on the research question, the stage of development, and the available resources. For example, surveys may be useful for obtaining broad feedback from a large number of users, while usability testing may be more appropriate for evaluating specific design features. Field studies may provide the most detailed and realistic data about user experiences, but may be too resource-intensive for some projects.

User feedback and evaluation methods are crucial for designing and improving smart home systems that meet the needs and preferences of users. Surveys, interviews, focus groups, usability testing, and field studies are all valuable tools for collecting data about user experiences and perceptions. The choice of method depends on the research question, the stage of development, and the available resources. By using appropriate user feedback and evaluation methods, designers and researchers can create smart home systems that are both usable and enjoyable for users (Zeng et al., 2019).

The impact of the study work on "Interoperable IoT Devices and Systems for Smart Homes: A Data Analytics Approach to Enhance User Experience and Energy Efficiency" can be significant in several ways.

Firstly, the research work can contribute to the development of more intelligent and sustainable smart homes by enhancing the interoperability among different IoT devices and systems. By developing a data analytics framework that enables the integration and analysis of data from different devices, the research work can help create a more cohesive and integrated smart home environment. This can enhance the user experience and improve energy efficiency, ultimately leading to a more comfortable and eco-friendly living environment for everyone.

Secondly, the research work can have practical implications for the design and implementation of IoT devices and systems. By identifying the research gaps and proposing solutions to address them, the research work can help guide the development of standardized and interoperable solutions that are more user-friendly, energy-efficient, and secure. This can benefit both manufacturers and consumers of IoT devices and systems, leading to a more efficient and sustainable market for smart home technologies.

Thirdly, the research work can have implications for policy and regulation in the smart home industry. By identifying the challenges and opportunities of interoperability and data analytics in smart homes, the research work can help inform policy decisions and regulatory frameworks that promote innovation, competition, and sustainability in the smart home market. This can benefit society as a whole by promoting the adoption of more intelligent and sustainable technologies that enhance our quality of life and protect the environment.

Overall, the impact of the research work on "Interoperable IoT Devices and Systems for Smart Homes: A Data Analytics Approach to Enhance User Experience and Energy Efficiency" can be significant in promoting the development of more intelligent, sustainable, and user-friendly smart homes that benefit both individuals and society as a whole.

CONCLUSION

This research concerns the detailed methodology that was used to achieve the objective of this study. The identification of challenges and achieving interoperability in smart homes. The data analytics approach suggested in this research is a new way to solve the problem of how IoT devices and systems in smart homes can work together. By using algorithms for machine learning to look at data from different devices and systems, the approach could reduce energy use and improve the user experience. In addition, the approach is scalable and can be applied to different types of smart homes, making it a valuable tool for homeowners and energy companies. Overall, this research shows that data analytics is expected to improve the performance of IoT-based systems in smart homes. Then, it also focuses on one development of the user experience that concerns user-centred design in smart homes. Moreover, the user feedback and evaluation methods will also be used to achieve the results of

the study. It also includes the expected impact that influences the real-life condition and the expected outcomes as the points that have to be achieved.

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