Smart Home Technologies: A Preliminary Review

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ABSTRACT
In recent years, smart homes have become increasingly popular with the deployment of Internet of Things (IoT). Rapid diffusion of sensing technology also enabled advancement in smart homes. The advancements in these technologies surroundings smart homes have produced many convenient products and services for the smart home consumers. Contradicting to the term convenience, there are still areas to improve to achieve an effective and simple smart home environment. In this paper, a literature survey on the smart home definition, purpose, benefit, and technology are discussed. Furthermore, there is an emphasis on the challenges faced to make smart home an ideal and simple environment to live. There are also proposed solution for some of its challenges.

CCS Concepts
• **General and reference~Surveys and overviews**

Keywords
Smart Home; Home Automation; Sensors Technology.

1. INTRODUCTION
Market research by Zion's Market Research shows that the value of smart home in 2016 was USD 24.10 billion and in 2022 it is expected to grow to USD 53.45 [1]. A smart home is linking together computer innovation, pervasive technology, image processing, advanced communication technology and finally a network of connected devices to deliver services to home users [2].

The conventional digital home is connected based on wired technology which imposes constraint such as setting up the cabling, costly installation, and poor system scalability. Whereas today smart home is designed in a wireless sensor network, absorb less installation cost and support great system versatility [3]. The important aspects of users adopting smart home are because of energy efficient, home security, convenience, entertainment, remote health monitoring and connectivity [2]. Tremendous development of Internet and communication technologies has lead smart home for a better home facilities. In the smart home environment, internet of things (IoT) is one of the technologies that play a crucial role in connecting various devices to IoT application to track user's activities and acquire data generated in the home [5].

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An immense amount of resources are being invested by the government bodies and industries in providing the public with technologies related to IoT and smart home. [4]. IoT is an evolving technology that embeds physical devices, vehicle, appliances, sensors, intermediate devices which helps to communicate between these devices to make our lives smarter. Most smart home devices are supported by both wired and wireless communications.

In smart homes, different home appliances for example, lighting, AC, CCTV cameras, smart TV, washing machines and other items are controlled by using a remote, smartphone or a tablet [1]. Integrated homes display a dynamic way of viewing and controlling the devices [4].

The aims of this research paper is numerous. Firstly, this paper discusses the definition and purpose of smart home with the objective to understand the concept and realization of automation in a typical home. Secondly, a wide collection of literature studies on benefit of smart home to users, which deliberately lead us to find the living importance and credibility in a smart home. Thirdly, a systematic review on technologies revolving in smart home was discussed further to synthesize the role of smart city, IoT and cloud computing. Fourthly, the prime contribution of this paper is to discover challenges revolving in smart home and recommend some potential solutions to improve the issues in smart home. Lastly, a conclusion is drawn with future work in the final section.

The authors performed rigorous, independent and literature wide reading on different areas of smart home implementation. The researcher initiate the research by conducting preliminary research, which provide the authors to formulate problem statement and scope down the literature review to identify research findings in the area of smart home.

The preliminary research and discussion among the authors lead to challenges and issues in the smart home implementation. Firstly, numerous smart home related research papers were retrieved from Springer Link, Science Direct, IEEE, ACM, Google Scholar, Research Gate and other databases. Phrases or keyword such as 'smart home', 'challenges in smart home', 'smart home technologies', 'benefit of smart home' and smart home implementation'', were used in retrieving the research articles, proceeding paper, book chapters, journal and academic thesis from the databases.

The retrieved research materials were considered by reading abstract, introduction and conclusion, this process resulted in a sample of 61 articles. Thirdly, the researchers performed a content

analysis of the selected papers in meeting the research findings of purpose, challenges, benefit, and technology in smart home implementation. As a result, the content analysis compiled 50 papers published in international journals, proceeding, web article and research studies as acknowledged in the reference section

2. SMART HOME

2.1 Definition of Smart Home

A smart home is a place with heterogeneous systems to many front devices with the support of embedded information and communication architectures [6]. Meanwhile, [7] describe the smart home as a home with an integration of digital sensing and communication devices to produce services through seamless communications. The technology of a home which makes the housework or household activity to be automated is named home automation [8][58].

The types of home automation are technology in controlling lights, air conditioner and heating appliances, high-security gates and locks [9][10][15]. Researcher [11], mentions that a smart home is a home with reduced or no human intervention, produce services and information from a composite of other information. Moreover, the smart home is a standard home with a few home automation systems that basically extract the data representing the environment and information gathered at home reliably supports the home services [10].

2.2 Purpose of Smart Home

Smart Home has a purpose of providing services such as control of energy, better security, and home entertainment, dependent and independent lifestyle planning [7]. Its objective is also to reduce human intervention to operate manual homes and help users to get services and information gathered from the smart home. [2]. A smart home is recognized to give convenience, tranquility and centralizing access to control automation [12]. The purpose of smart is to provide home users support in decision making and informed choices through equipping them with important information about their household context [13].

3. BENEFITS OF SMART HOME TECHNOLOGIES

3.1 Enabling better Opportunity

Smart homes provides endless opportunity to introduce smart devices and to network these devices together and control them remotely [7]. Such as healthcare devices for elderly that can be easily adoptable in these environment. These network provides a conducive environment for new devices to be tested and implemented.

3.2 Quality of Life

On a bigger picture, the benefit of smart home is the improved quality of life through the convenience, comfort and also the independence, it gives the special need community [9]. In support of this mentions [6][15][42] that the reason for the popularity of smart home is due to the smart home occupants improved quality of life. In addition, [12] summarized that peace of mind and being able to control from anywhere, has been the top aspects of a smart home.

3.3 Energy Efficient and Eco-Friendly

Home energy saving mechanisms are generating a considerable amount of interest in terms of smart energy systems which monitors the energy wastage levels. Consequently, management of energy consumptions for domestic technologies has been attracting numerous projects and commercial offers [2][47]. Many efforts have been taken to save the environment and one such effort is the implementation of an eco-friendly environment. Other researches, [14] have focused on green energy source in smart homes which reduces the energy wastage and makes the environment as eco- friendly as possible through natural heating and cooling system. Other than that, grid-connected rooftop system has helped smart home to reduce meter reading and support the solar-powered cooker, water heater. In addition water conservation also can be implemented through smart homes [32].

3.4 Remote Accessibility

One of the attractive features of the smart home is accessibility from the remote especially for security surveillance for the residence. Most of these features are very useful especially when residents are away for vacation, for example, being able to control the lights to make their house appear occupied, turning on the heater before arrival, verifying the status of appliances and checking the door have been locked [12].

3.5 Monitoring Through Sensors Network

An embedded sensor network is used for monitoring activities of elderly to address possibility of chronic condition and conduct a health assessment. [50][51]. These service providing system that deploys gas sensors, smoke sensors, remote monitoring, smart locks, smart irrigation and many other sensors at home for automatic predictive systems [52] which provides numerous benefits to the lifestyle of the elderly. Systems such as AmIS collaborates multiple home systems with IoT Gateways and also with the support of environment monitoring component [53].

3.6 Aging in Place and Ambient Assisted Living (AIP & AAL)

Many have invested half their saving on to their homes and planned to stay there permanently. Imagine if this is short-lived by mere ageing issues or some other physically impaired conditions. Smart living conditions are automated and less dependable on other people [51]. A smart home is an enabler for this kind of automation that supports the elderly to age gracefully in their own homes and contribute to their wellness in a long run.. Ambient Assisted Living (AAL) and Aging in Place (AIP) are two areas that have focused on home users who are dependable or particularly dependable. Both of these are well-known for technically supporting the ageing population and people with special needs to foster the needs of people and giving importance to their safety in their own environment. [16], the article argues that ageing in place can mean a person living in his own space and home or relocated to another home where they can use to serve. On the other hand, research by [17], shows the importance of a home automation with multi-sensors playing a role as an ambient for assisted living for the elderly. This research analyzes the combination of a windowing technique and essential service for the elderly lifestyle to recognize their real time activity through a set of statistical spatio-temporal features. During this process the smart homes have to be equipped with many devices to support services such as fall detection. [18], list devices such as “cameras, infrared sensors, accelerometers, microphones, pressure and floor sensors” to be fixed in the homes to ensure data repositories is getting sufficient data. [19].

In addition, the safety of living ambiance can be improved by remote monitoring technology which can be connected to smart home network and the system is linked to the camera or sensors to understand the situation in the home environment. By using the

cloud of intelligent alarm to identify if there is any issues in the home and to provide immediate assistance to elderly people or notify their family [20].

Table 1. Smart Home Benefits.

Benefit	Reason for Benefit	Author
Enabling better Opportunity	Easily can introduce new smart devices and networking them together and control them remotely.	[7]
Quality of Life	It provides convenience, independence and comfort for ordinary people and special needs, this leading to a quality life.	[6],[15], [42],[9] &[12]
Energy Efficient and Eco Friendly Environment	Smart energy keeps the wastage of energy to a minimum and in addition green energy source supports to keep it eco-friendly.	[2],[14] &[49]
Remote Accessibility	Safety and security, for remotely monitoring and controlling the house	[12]
Monitoring through sensors network	Recognizing activities and cognitive ability to predict the need of people through smart predictive systems	[15]
AIP and AAL	Automation that supports the aged and special needs to age gracefully in their own homes and giving them importance to their safety in their own environment.	[16],[17] [18].[19] &[20]

4. TECHNOLOGIES IN SMART HOME

4.1 Smart Home in Smart City

Smart home is one of the successor system under the smart city development. The concept of smart city is introduced to handle the rapid global urbanization [21]. The United Nations (UN) has conducted a survey in which stated that 66% of the world populations will be living in urban areas by 2050[54]. This denotes almost 6 billion citizens will be occupying urban areas by 2050. Hence, the process of urbanization incur the demand for land, food, sanitation, safety, waste management system and mobility [55]. So, urban cities are under pressure to provide sustainable living standard to the citizens. According to [22], smart city must provide measurable solution to reduce pollution, uncontrolled urban development and cater sustainable living environment. This is because cities incorporate creativity, innovation, multifaceted ecologies, which consist of various stakeholder's with different interest collaborate together to idealize resilient environment to cater quality of life to the citizens [23].

Apart from that, smart city is implemented based on user centric approach, in order to learn and collect data on individuals perception, the smart home will be the appropriate system to get the user data with proper privacy protection [24]. This is also supported by [4], that the emerging technologies are transforming a real implementation in the area of smart city and smart home.

4.2 Smart Home and IoT

Technology that is widely used in smart home is IoT, it is connected with digital devices, detectors, sensors and switches [5]. These IoT devices share resources and information among the devices intelligently. This devices act as a gateway, from where the home user is alerted on the situation in the house and also can control all the devices by using a laptop, smartphone or tablet [9]. The advances in the IoT technology integrate with intelligence systems in the smart home appliances which is to offer the home user a flexible manner to quantify home status conditions and monitor home devices.

The existing home systems with many types of information are being digitally enabled. This virtualized systems and information are correlated into function which are used to do mapping, encapsulation, aggregation, and composition mechanism permitting home appliances to interoperate to perform joint task of household operations [30]. According to [25], smart city and smart home enabled by many technology such as IoT which was revealed in one of the market analysis. The fundamental architecture of IoT provide transparent and seamless connection to system and devices to work on a complex task. The smart home environment consist of many complex task working with heterogeneous end system and sensors which require conspicuous IoT application [26].

In an IoT environment such as smart home, 'things' refers to variety of sensors and actuators. There will be a predefined goal or a default setting to achieve the service desired. This operation is computed from the data collected by the sensors and then decision making or automatic predictive systems provides the service required[15]. Technically, IoT enabled object has the computer competencies of a microcontroller, communication interfaces, protocols to enable devices to interact with each other, interfacing users and provide integral support in the internet. Generally, variety of home appliances and devices built by multiple vendors have the capability to connect to internet.

Smart home provide futuristic quality of life to home users by automating house works. By then, IoT connect the home appliances with the internet which is connecting the things or object in the real world environment. IoT includes objects, home appliances, devices, vehicles, sensors and so on. This is further stated by [27] that IoT can be classified into three paradigms such as middleware in the internet oriented, sensors which is things oriented and knowledge in the semantic oriented. According to [5] research experts are emplacing in developing algorithms for IoT in smart home. Some of the concern in developing the algorithms is to provide solution to security and privacy issues in IoT enabled smart home objects. In the smart home environment the user's detail should be secured and access to the home devices should be protected. . Data communicating in these smart home network are normally supported by the wireless communication which is a highly mobile network with high speed and a non- infrastructure dependent technology. In addition, powerline communication

(PLC) is a wired high speed communication channel with ease of network adaptability with suitable bandwidth, sufficient energy requirement and data exchange rate for varies services although static and noise prone due to thermal agitation in the wires [60]. There is an increase of adoption of wireless sensor network in diverse IoT applications because it is low in cost, easy deployment, and flexibility in dynamically adding devices, integration, and scalability [57].

4.3 Smart Home and Cloud Computing

The cloud computing is an extended version of distributed computing, based on converged frameworks, boundless scaling, a versatile and shared administration which provide a quick reply for a highly unique nature, flexibility, processing requirements and storage capacity for a smart home [28]. With this technology, a compact device such as a smartphone can become a user interface to a huge data center which can be connected to a home automation system. The storage capabilities it has is significant to the smart home for processing and storing data that are gathered from multiple sensors [30]. It also includes data that can be gathered by a modern service such surrounding monitoring system, energy management, CCTV, smart light system and others.

A newly refined solution can be created by integrating legacy home networks, numerous sensors, built-in component in home appliance and cloud computing for building smart clouds for a home automation system. Enabling cloud computing in the home automation is technologically viable, thus provides positive impact for the home users and community [29].

5. CHALLENGES

Although since the 1980's there have been many research strongly supporting the growth of smart home. Smart home is still a new concept at certain part of the world, although with the presence of digitalization and automated appliances has been around for a long time [56]. This is due to inherited constraint with the smart home expectations, the role of user's involvement and capability of the systems. This concept has not been popular among home users because of many issues such as technophobia. Figure 1 shows the smart home challenges, which is the highlight of this paper. The current applications, protocols, devices, network protocols, and other necessary technology are still ineffective to fully commercialize smart home around the world. There are many challenges in making communication efficient among the devices manufactured for smart home environments.

5.1. User Acceptability

Studies show that there is a lack of user acceptance test done on innovative technologies [50]. According to [37], a well designed user interface should still have an iterative improvement process so it does no effect the services provided to the specific users [33], has emphasized the importance of usability and accessibility suitable for specific situations. Research also focuses on improving more on the sensing, actuation and network services instead of considering user acceptance of the services itself[2]. Designing a user centered and intuitive device interface is an issue because as normally they are dealing with large scale complex system interfaces that prevent them from concentrating on the actual task [52].

The research also highlights that there is also a social barrier and domestication which is a growing consensus to this challenge. Future proofing has been an inevitable term when reliability, debugging and interoperability is explored because it determines compatibility between successive generations of smart home technologies. Technology user friendliness which has to safeguard the concept of acceptability and usability of the technology in the perspective of the users who uses the technology itself [51]. Their studies show that issues such as security, privacy, trust, ergonomics concerns are jointly related to acceptability of the technology which also shows the concern for a critical evaluation of designs of smart home technologies with the users.

5.2. Limited Mobility Range in Ad hoc Network

Residents in rural area can enjoy smart home area network even though they have limitations to access to broadband services such as WiFi which operates at a 100m range with Star topology. Nevertheless with technology such as Zigbee and Bluetooth, residence can create an ad hoc network that connect multiple smart device and control devices. This made the possibility of remote area homes to adopt smart home but the only limitation is that network mobility range that ZigBee operate at 1-20m and requires Mesh topology, whereas Bluetooth operate at 100m but on point to point topology which caters to short range communication [61][31].

5.3. Universal Platform

Research shows that smart home systems assist a lot in aging-in-place services however many of these well designed robot systems have issues in connecting to other systems because they do not have a standard platform and application programmable interface [33].

5.4. Interoperability

In home automation system, connectivity is considered the most vital element to keep the home network seamless and it basically depends on the standards and communication protocols [34][35]. Many research has been conducted to achieve effective interoperability as well as other autonomous behaviors of smart homes. The result of integrating new devices or sensors to the current settings in the home automation could be difficult to be customized. It can be favorable to the user or maybe not [36]. Some of these protocols can even fade away. When comes to wired sensors such as environment sensors, there are some disadvantages with wired sensors such as environment-dependent and limited heterogeneous functionalities.

5.5. Relevancy of Extracted Data

The data driven approaches using data mining techniques or other machine learning techniques to collect a good dataset requires experts to interpret the raw data [10]. One of the major problems identified was the repetition of the data collected from sensors, It will only be relevant after filtering the data .Thus, there are research showing that categorizing the extracted data into low-level data and other smaller set of high level knowledge will then significantly give the data higher relevancy [36]. Context information collected through sensors will corresponds to various aspects of the pervasive interaction services [41]. Data extracted for context awareness becomes irrelevant if it is not used within the time, majority of it are belonging to a dynamic category. Majority of the context is attributed to the dynamic category for example real lite location for moving devices or person [13].

5.6. Commercialization

Findings from [2], factors such as unavailable technology or delay in commercialization that hinders smart home to be popular. Most of the smart home products are rushed to be commercialized before even being tested well by the users [13]. Studies by [7]

show that technology developers have also missed out the essential concepts of home users such as who the users are and how they will utilize the smart home technologies while in the rush to commercialize the product to the market.

5.7. Failure to Respond to Faulty Systems

It is evident in [11] [49] that adoptive home systems should have a model designed to teach the home users the operation of the system to enable them to respond to faulty systems. Thus, self-healing systems should be made compulsory.

In the research by [46], five component has been proposed as a key component for self-organization, those are neighbor discovery, medium access control, local connectivity, path establishment and service recovery management.

5.8. Security and Privacy

The home automation system often has issues with system hacking and threats [37], mostly on the security of the server side [38]. On top of that, controlling home automation system from remotely is a challenge in terms of secrecy and privacy [39]. Together with this, ecological impact factors are also emphasized [7]. Normally the server side security is less as no specific method for authentication which can provide a space to attack home automation systems [8]. Author [36] addresses these issues happens because of the usage of network connection facilities. Users do not feel in control of their unpredictable environment and home safety [4][36]. Domotic sensor apparently settled the issues of patient's privacy issues on the data extraction from sensors [40].

5.9. Cost

In any adaptation of technology, cost undoubtedly plays a crucial role whether to purchase or maintain that technology. Technology acceptance studies from [37] prove that there were concerns about the costs of purchasing, executing, utilizing and maintenance.

5.10. Societal Changes

Involvement of technology in homes has been argued to have wider and long term societal changes which cause indirect and unintended consequences such as increased dependence on technology and may also cause increase in obesity, and laziness [13]. In the IoT field, there is a need for optimization and service provisioning for example data collected from the entire community of smart homes is used to analyze community-wide trends and behaviors [45].

5.11. Sensor Calibration

Every activity that is recognized by accelerometer recognizes where the signals collected by tri-axial accelerometers, quality control of these sensors has to be monitored. Sensors calibration on a per-user scale would allow a generalizable framework to be ported to other populations such as the elderly. Calibration routines give positive implications for the models developed [44]. In order to deploy the sensors, important information of the sensors guidelines and information on the calibration for the sensors is not provided by manufacturer [59]. Thus controlling the quality of the sensor orientations in real-world systems is challenging.

5.12. Computing and Battery Life

With current advancement in sensors, price drops and other data gathering techniques for the enormous amount of data that is collected, will increase computing burden and a need for longer battery life [43][51].

5.13. Effectiveness of Data Filtering Algorithms

Not surprising, when tremendous amount of data is gathered, context redundancy will be inevitable, therefore there is a need for refinement of context filtering algorithm that is effective. [43]. One of the major problem identified was the data collected from sensor has a lot of repetition and only after file filtering it makes more sense.

Figure 1. Smart Home Challenges

6. POTENTIAL SOLUTIONS

It is suggested that a sandboxed environment can solve the unpredicted problems of inserting a new device or sensor to the existing set of any smart home [35]. Combining the advantages of PLC communication with wireless communication capability producing Power Line Wireless (PLC) system that will have higher speed, non-infrastructure independent, ubiquitous home access, and better bandwidth efficiency for connecting static and mobile devices in a home [60]. In addition, artificial intelligence (AI) algorithms can make it function according to the service required by the users. For a more useful service, AI algorithm is used to extract redundant data using context reasoning and give refined value to the data extracted. Cloud technology also is a revolutionary platform and it is a potential solution to the huge capacity of data [45].

7. CONCLUSION

The growing environment of "smart homes" highlights home appliances in the home to interoperate with each device to provide the home user the power to monitor or control their home task and promote quality of life. The evolving advances in the technology cater many digitally enabled solution for home users. However, technology factor is not the only consideration in designing smart home application but taking into account the actual end user needs have to fully consider to have a successful and sustainable smart home implementation. For the future research in a smart home, the aspects of ethical, cost, adaptability of technology, security, technical aspect, legal, organization impact and constraint need to be explored in detail to provide a better implementation of the smart home. Consequently, this will provide a quality lifestyle for various types of smart home users.

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