

Smart Home Automation: Taxonomy, Composition, Challenges and Future Direction

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Abstract. Smart home is an evolving technological innovation that originates from the numerous application areas of the Internet of Things (IoT). As the world is driving more and more closer to adopting smart cities based infrastructural environments, in which most activities involve innovative technological connectivity, smart home automation is one of the focused areas which has grown exponentially in the last few decades. The main objective of smart home automation is to make life easier and convenient for homeowners and users. The role of smart home automation is essential to healthcare and the social and economic well-being of all users through the provision of a convenient and conducive place of living. With the spontaneous evolution of new trends in smart home automation design, the various elements and functions of devices used in building smart home systems need to be explained as these technologies have significant benefits. They can assist traditional methods of controlling and monitoring home appliances, improve healthcare for the elderly and disabled, alert homeowners in case of potential risk and enable homes to be controlled even while the owner is far from home. Most importantly, smart home systems have great potential for reduction in energy loss. Furthermore, to provide valuable insights into these technological environments, we must clearly understand some of the available options and gaps in the area of smart home automation systems. This paper presents a taxonomy of IoT smart home automation systems with elaborate discussions on the technologies, trends and challenges in smart home automation system design. A constructive and detailed review of existing literature based on application areas of smart home automation is presented. Lastly, highlights of the approaches, technologies, and strength and weaknesses associated with the smart home automation systems are discussed.

Keywords: Internet of Things · Smart home automation · Home network · Smart home hardware platforms

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1 Introduction

With the emergence and swift growth of Internet of Things and smart home automation systems, people are interested in using convenient mechanisms through the internet to control and monitor appliances [1] remotely. A dynamic interaction and rapid response of smart devices to the needs of homeowners and environmental conditions makes a home smart and intelligent to operate. Some features and technologies are embedded into some of the essential devices we use at homes, namely, lighting, air conditioning, audio and video gadgets, heating control systems, security, and so on to make them intelligent [2]. Computing and connectivity are going beyond the desktop and other forms of traditional computing and moving towards wireless networking of environment and surrounding objects with the aid of Radio Frequency Identification (RFID), smart sensors and network technologies [3]. Transformation of things into appliances, data, connected by application of internet, create services usable in smart home automation [4]. Smart home automation has its background in the application of Internet of Things (IoT) technologies. The IoT technologies led to having smart appliances such as smart lighting control, smoke detectors, fire detectors, temperature monitoring, smart televisions, and so on deployed in smart homes. Some of these smart appliances have embedded sensors for monitoring conditions such as temperature and humidity. These chipped devices can capture, store and send information to the home controller, which enables the homeowner or user to control and monitor their homes remotely [5].

Smart home automation is a significant aspect of IoT, it is growing exponentially and is incorporated into our daily activities, business, health, education and other aspects of our day-to-day lifestyles. Smart home automation aims at five major characteristics, namely: Convenience, Comfort, Consciousness, Care and Control. The ability to control your home remotely from any location gives you convenience, making your house warm before opening the door during winter gives you comfort, and switching ON/OFF of sockets, lights and appliances from a location outside your home gives you convenience. Smart home, in other words, is the foundation for remotely accessible environments (that is, environments in which each appliance can be accessed from a distance and controlled using software such as android and web applications as an interface). As smart home acceptance, application and incorporation are on the rise globally, there are many areas of smart home application benefits that are yet to be discovered and implemented. For example, the smart home health system, which aims at providing basic care for the elderly, disabled and outpatients is one of the areas that is yet to be thoroughly considered.

Another perspective of the smart home shows that it enables homeowners and residents to incorporate communication networks that connect the major appliances and services utilized and allows these to be remotely controlled, monitored or accessed from both within and outside the residence [6]. In smart home, communication network link sensors, appliances and other devices work together to allow for remote monitoring and control by occupants and other verified users in order to provide them with the frequent and regular essential services they require. Smart home does not only benefit home users but also has an impact on the economy and lifestyle of communities

in which it is being used. It reduces stress, saves time and money and avoids wastage of resources and basic amenities. However, to effectively utilize smart home, it has to be automated. Smart home automation system connects controlled devices in the home to a central hub that controls lighting, climate, entertainment systems and allows users to remotely control their home appliances and gadgets through the assistance of ambient intelligent mechanisms [7].

Despite the wide interest in smart home automation and its relevance to the design and implementation of our future smart cities, studies and researches in this area are very limited and scattered, as only a handful of research papers are available for referencing. Therefore, this paper provides a comprehensive explanation of the concept of smart home, its elements, application areas and services, review of related works, challenges and future direction. In summary, the technical contributions of this paper are as follows:

- Provides an extensive survey of methods and application areas in smart home automation from existing literature.
- Highlights some of the essential elements and technologies for smart home automation system based on the Internet of Things environment.
- Highlights key challenges that mitigate the design and implementation of smart home automation in the Internet of Things environment.
- Suggests future research directions aimed at facilitating the effective implementation of smart home automation.

The paper is organized as follows: Sect. 2 contains an extensive review of related literature pertaining to researches in the area of Internet of Things in smart home automation systems. Section 3 provides the elements for building smart home automation systems in Internet of Things. Application areas services of smart home automation i n Internet of Things are presented and discussed in Sect. 4; Sect. 5 explains the research trends, challenges and future research direction in smart home automation. Lastly, Sect. 6 concludes the paper.

2 Related Work

In application areas of smart home automation, several systems have been proposed, designed and developed through research projects with a focus on making life more convenient for homeowners and home users. The developed systems mostly aim at making home ubiquitous. In this Section, we review some literature related to smart home automation. The reviewed literatures are between 2010 and 2019 and are reviewed based on technologies used, application areas, and strength and weakness of the works. Figure 1 depicts a chart of existing studies carried out in smart home domain from 2010 to 2019 with the focus on application areas. The sources of all the publications identified in this paper were from Google scholar search engine and IEEE Explore databases with focus on ISI and Scopus indexed journals.

Several researches have been made to integrate IoT with Smart Home automation in different area of services. For instance, Muhammad and Ali [8] proposed an automation and control method for lighting, ventilation, air conditioning, heating and

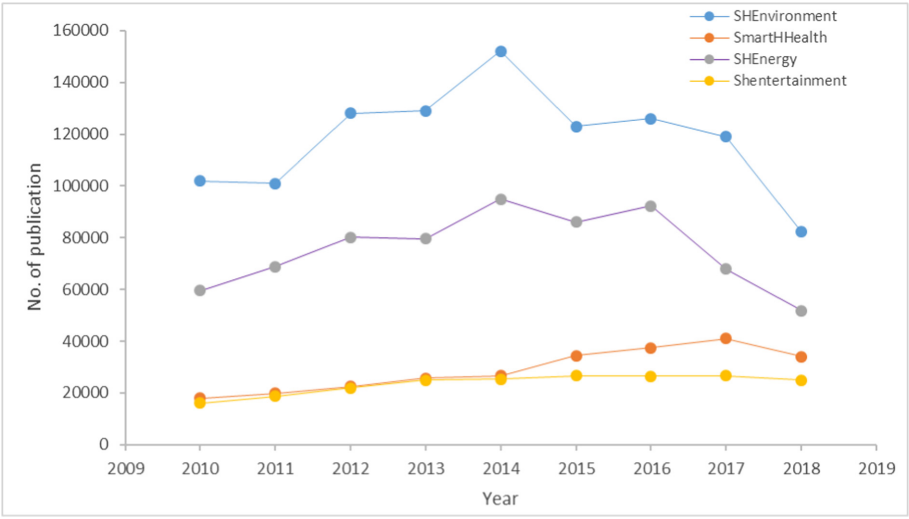

Fig. 1. Academic search trends of research in smart home automation application areas

security appliances in a smart building. The technologies used are Arduino UNO board, LEDs, and sensors which are controlled through a laptop in the building and an Android device when outside the building. The proposed method is implemented and evaluated using LEDs of different colors. The method should be verified using home appliances such as bulbs, fans and so on.

Majid, et al. [9], presented an IoT based sensing and monitoring system for energy efficiency in smart home appliances and monitoring to achieve maintenance of parameters within a certain range. The designed system uses EmonCMS platform for remote control of home appliances and devices. The platform is also used for collection and visualizing of monitored data. Technologies involved are Zigbee, Bluetooth, sensors, Arduino single board and ESP8266 microcontroller board.

Moreover, Shahram, et al. [10] presented a smart home automation tele-care system in conjunction with MEDeTIC. The system is designed to monitor and detect abnormalities in health situations of senior citizens, support medical consultations for the elderly from home and analyze activity patterns for unusual behavior in the system through Fuzzy Logic. Techniques of telemedicine and home automation were combined in the system. Technologies involved are sensors, Bluetooth and Zigbee. The system provides video conferencing and tele-consulting support between patient and doctor.

Waheb, et al. [11] presented a design and implementation of smart home automation system for controlling all electrical home appliances via WiFi with the use of an android-based smartphone, tablet or laptop. The system also monitors environmental conditions such as temperature and humidity with the use of sensors and has the ability to control or monitor voltage. The technologies used in the system are Arduino, ESP8266 WiFi module, temperature, humidity, and smoke and motion sensors. Remote control of electrical appliances in the designed system aims at reduction of energy

consumption levels. The security of the home is also ensured with the ability of the system to send alerts to a user's phone in case of intrusion or breakage into the house.

Also, in [12], a smart home automation and energy management system for managing and power flow scheduling was presented. Home devices are controlled by mobile devices or systems through the internet for energy management in the system. The system was evaluated and tested with a prototype design using a controlled load bank to stimulate a scaled random real house consumption behavior. The technologies involved are Arduino Board, sensors (fire, gas, temperature, smoke, temperature and humidity), RFID and ESP8266 module.

Moreover, Abdulrahman, et al. [13] presented a design and model implementation of home automation system by application of Internet of Things. Seamless communication between individual applications and systems with a high level of security with use of robust web service protocol was ensured in the system through the deployment of Web Application Messaging Protocol (WAMP). Hardware development of the system was based on modular design for better functionality and reliability. Energy efficiency was ensured by the use of power actuators for control of home appliances. The system monitors ambient meteorological conditions and quantities such as temperature and light intensity. Environment and system interact and thus conditions are controlled based on the quantities measured.

Mohamed, et al. [14], in their approach, presented a smart home automation system based on Arduino microcontroller kit and LabView platform. The major functions of the system are to control light, manage temperature and monitor home security through an ultrasonic security camera. Temperature is measured by sensor, and Microcontroller in the system is capable of automatically turning on a fan once the temperature exceeds the set limit. Monitoring, access and control of the system are based on the signals received from the installed sensors in the system. The system was evaluated based on object distance, and range sensor is able to detect and automatically adjust the rate of temperature. Technologies involved are Arduino, temperature sensors and motion detectors.

A home healthcare system for recovery process, monitoring rehabilitation, studying daily activities and behavioral changes in patients was presented in [15]. The system is a Cloud-Based Smart Home Environment for home healthcare. Physiological data and body activity information are collected through non-invasive wearable sensors. Environmental sensors are deployed for collection of motion and activity information of humans. Data are stored in the cloud using a hybrid data storage model. The system proffers a solution to the provision of information about a patient at home to health caretakers. The limitation is the high level of energy consumption due to sensors and data transmission. Technologies used are environmental sensors and Zigbee protocol. Evaluation and experimental results showed that the system is effective in healthcare monitoring and assistance.

Himanshu, et al., in [16], proposed a smart home automation system for detection of presence or absence of a human or object in the house. The system aims at also providing information about levels of consumption of energy by sending a message to the homeowner, checking the status of gas cylinders to notify the homeowner if lower than a set threshold, and control of home appliances such as lights, fans and doors. The

system uses technologies such as sensors for detection, MCU ESP8266 microcontroller and Arduino.

Smart home automation system for monitoring and control of different aspects of home through Android Application was designed by Hamzah, et al. [17]. The system controls and monitors temperature, humidity, gas, flame, light, measures water and humidity level in the soil, and detects motion. Temperature in the room is adjusted when it exceeds the set value. The kitchen is installed with a flame sensor and gas leakage sensor to forestall fire accidents. The designed system is also capable of garden irrigation. Security of homeowners is protected through an alert in the system to notify users of an intruder in the home/building. Technologies used are Arduino, PIR motion sensor, ESP8266 Microcontroller and Bluetooth. The designed system controls and monitors the home remotely and automatically, but exchange of data is limited to short range due to Bluetooth deployed in the system.

Zhuang, et al. [18] proposed an energy management system for smart home, based on optimal power scheduling method. The proposed system is for the home area network, based on smart grid and scheduling method for usage of power in the home. A genetic algorithm was adopted to optimize Operation Start Time of appliances, and Real Time Electricity Pricing was used for power scheduling in the home with the assistance of preference of residents. The system aims at optimizing power consumption for users and the pricing scheme also benefits utility companies.

A security system for smart home automation system was presented by Ajao, et al. [19]. The smart home automation system is for security of doors in order to safeguard access into the home. Entries into the home premises are authorized and authenticated before access is granted. A message is sent to the home user for security notification upon access or denial of access. Sensors are also embedded in the system for motion detection. Control of the home security system is through wireless IoT communication and Android mobile application. The presented system is easy and flexible to use but capturing of images of intruders is not included for surveillance.

Energy management in the home through distributed framework algorithm of appliance scheduling was proposed by Phani, et al. [20]. The proposed framework is demand response based on cost minimization. Scheduling of appliances in the system is based on knowledge of the price of electricity for the period. Greedy algorithm was proposed for cost minimization at the user's end, and to schedule appliances, a user needs to find an optimal start time and operating mode. Simulations and optimization methods show the proposed framework tends to yield lower costs for users, lower generation costs for utility companies and lower load fluctuations. The system was evaluated based on performance of the proposed algorithm.

Al-Ali, et al. [21] proposed a smart home Energy Management System that utilizes off-the-shelf Business Intelligence and Big data analytics software packages to manage energy consumption level and meet a consumer's demand. Home appliances are interfaced with IoT object (Data Acquisition module) with unique IP address leading to a large mesh network of devices in the system. Energy consumption data from each device in the system is collected by data acquisition system on chip module and then transmitted to a centralized server for processing and analysis. The system was tested and validated using a prototype built in laboratory to mimic heating, ventilation and air conditioning (HVAC) systems in a residential area.

Moreover, Jinsoo, et al. [22] proposed a smart home energy management system that generates energy based on wireless and wired networks. Power and energy from home appliances are transferred and measured through a low-power Zigbee communication network. Energy is generated through renewable energy sources (solar power and wind power) and home energy usage is optimized based on Power Line Communication. Light was installed as a means of energy and power measurement in a prototype system and was used for implementation with the home server of the proposed system. Results showed that the home server can achieve energy conservation and save energy costs.

An accident prevention subsystem for smart home automation was presented by Vasyl, et al. [23]. The system aims at sending signals to home users in case of potential danger/accident that may arise from fire outbreak in the home. Fire, gas and smoke sensors were used for detection of possible fire outbreak and a water leak detector for prevention of water leakage. In the proposed system, a neuro-controller interfaces the sensors with the appliances and alarms, and built models are based on Arduino microcontroller and programming model based on Artificial Neural network to test reliability and functionality. However, there is no implementation to show the installed home appliances and functionality.

Smart home control and monitoring system based on database replication method was proposed by Wibowo, et al. [24]. The user accesses the smart home through a single online master database through login (username and password). The system can control and monitor multiple systems online; however, implementation was not stated and system functionality depends solely on an online database, which implies that if there is problem with the online database, the system cannot function. A home mobile healthcare system for wheelchair users was developed by Lin, et al. [25]. The developed system and architecture are based on Wireless Body Sensor Networks (WSBN) and the system is used for measuring heart rate, ECG, and body pressure through nodes of the WSBN and ECG sensors. Apart from healthcare, this system is also capable of sensing a home environment and efficient monitoring of human activities in the home.

Also, Paul, et al. [26] proposed a smart home automation system based on voice control and Natural Language Processing (NLP). In the system, the user sends commands through speech to the mobile device, the message is interpreted and an appropriate command is then sent to a specific home appliance. NLP is used to interpret voice command in the mobile device. Home appliances are interfaced with Arduino board and programmed to interact with mobile devices. Better connection between user and devices is enhanced with NLP.

In addition, Radjeep, et al. [27] proposed a location detection system for smart home environment. The proposed system is intended to detect the location of a person in a home and to assist the medical caregiver to locate the patient in the home, provide healthcare, and keep track of the patient's daily living and medical condition from home. Technologies involved are Raspberry Pi, Arduino, and sensors. Voice recognition was embedded in the system to make the search for location easier and reduce the stress of the learning curve of new technologies for caregivers and family. The system is in progress and needs improvement for large scale implementation and reliability.

3 Elements of IoT Smart Home Automation

This Section presents a taxonomy of IoT Smart Home automation based on methods, technologies, application areas and other components involved in smart home automation systems. Furthermore, this Section also presents the taxonomy that will aid in defining the components required for the smart home automation from a high-level perspective as shown in Fig. 2.

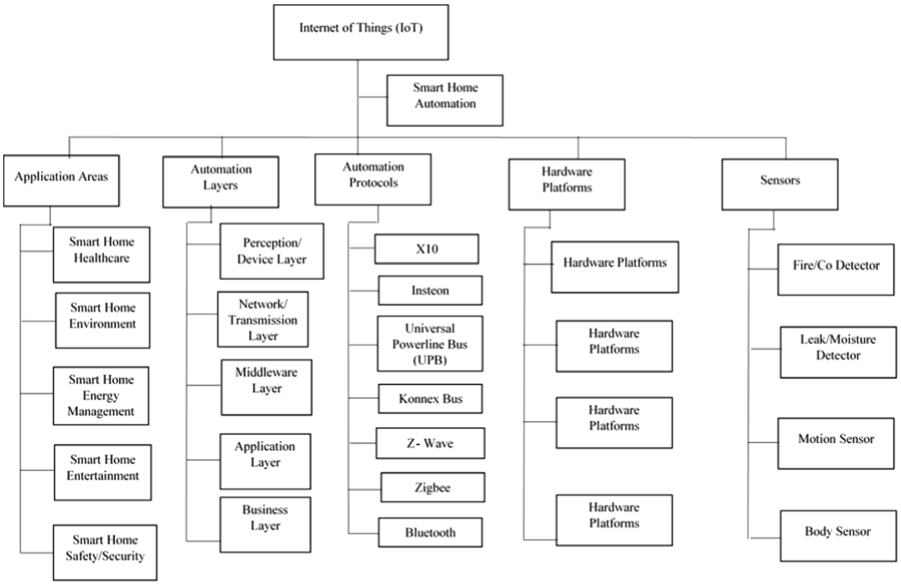

Fig. 2. Taxonomy of smart home automation system

Internet of things smart home automation involves a wide range of smart devices, appliances and sensors which are all interconnected and communicate with each other at anytime, anywhere and the communication is often wireless [28]. Elements of smart home are things and devices needed to make it smart and effectively communicate/interact with one another. These include mainly the home network, hardware platforms and home automation.

3.1 Internet of Things - Smart Home Automation Layers

IoT-Smart home can be divided into five layers namely: Perception, Network, Middleware, Application and Business layers. Higher-level layers are the Application and Business layers while lower level layers are Perception and Network layers and Middleware is the intermediate layer [29].

3.1.1 Perception Layer

The perception layer entails physical objects for collection of information from the smart home environment and is also referred to as the device layer. The overall management of devices such as identification and collection of specification information (location, humidity level, temperature level, etc.) by each type of sensor in the system are part of the responsibility of this layer. This layer consists of different types of sensors and environmental elements [28, 30].

3.1.2 Network Layer

The Network layer is responsible for secure transmission of information from sensor devices to the information processing system. This layer keeps sensitive information confidential from sensor devices to the central information processing system via RFID, WiFi and other transmission technologies [28]. Network layer is also referred to as transmission layer.

3.1.3 Middleware

Collection, transmission and processing of data in smart home automation are coordinated through a medium referred to as Middleware. The middleware layer is in charge of managing services in smart home and also acts as an intermediate layer to create an interface between lower level layers and higher level layers [30]. In smart home automation, communication passes through the middleware to other components involved in the system [31]. Middleware functions as a mechanism or software for hiding distribution of a home automation system from the user, and unification of different technologies through a single standardized API to the developer [32]. With middleware, products from different manufacturers but with the same technology can be used.

3.1.4 Application Layer

Based on processed information in middleware layer, application layer is responsible for general applications management. For instance, if there is an alert from the middleware layer, actions for control are taken in the application layer. Application layer is responsible for proper operation deployed application [30].

3.1.5 Business Layer

Management of the overall system, including application, sensors and other devices are the responsibility of business layer. The business layer is capable of creating practical graphs, business models, reports, and so on, based on the amount of accurate data received from the lower layer. Analysis of a report generated from this layer assists the functional manager in making more accurate predictions and decisions about business strategies [28].

3.2 Home Network

A network is a group of two or more devices that can communicate. Smart home involves integration of various devices to form a system. In a smart home, network makes use of a range of techniques such as computers, network communication

protocols to communicate with objects and devices in the home. The two major levels of communication in smart home are connection between devices, objects and appliances in the home (internal network) and communication between the home and the internet world (external network).

Internal network is the network that makes appliances, devices, products and services inside the home communicate with themselves. Internal home network can be based on wire, cable or wireless connection, protocols and controllers. Local Area Network (LAN), Personal Area Network (PAN) and Body Area Network (BAN) are mostly used in indoor environments, into which home automation can be categorized. Local Area Network is the connection of several devices over a network in the same location and limited area, typically within a single building or home [33]. PAN is a communication between devices near a person. Examples include wireless keyboards, mouse, and barcode scanners. BANs are based on smart objects localized on the body of the user. They are a continuity of PAN but on a smaller scale [34]. Network communication in smart home involves protocols and controllers.

3.3 Hardware Platforms

Hardware platforms are an integral part of home automation technology in building a smart home. Platform in this context refers mainly to microcontrollers used in the development of home automation systems. ESP8266 Board, Intel Edison, Raspberry Pi and Arduino board are some of the major boards used in configuring IoT smart home systems. A sensor is an hardware device that detects certain external stimuli and responds in a distinctive manner. It is used to measure/monitor properties such as pressure, position, temperature or acceleration. With the development of Internet of Things, smart home sensors can help in the prevention of property damage. There are many types of sensors that are applicable in smart home automation [35]. These are environmental sensors (gas, water, smoke, lighting, movement, rain, wind, humidity, wind, temperature, and so on), multimedia sensors (microphones, cameras, and so on), physiological sensors (for measuring blood pressure, pulse rate, body temperature, respiration, and so on) and wearable sensors (sensors that are worn by the users by embedding in shoes, eye-glasses, ear-rings, clothes or directly placed on the body).

4 Smart Home Application Areas and Services

Smart home system was developed to make life convenient and reduce wastage of resources. To achieve these and many other aims, its applications are diverse but can still be monitored and controlled from any location for safety, care, and convenience. Smart home automation system renders services in areas such as healthcare for the elderly or aging, security, control and monitoring of home appliances and environmental conditions, improved energy efficiency and entertainment. Figure 3 presents an illustration of automation areas and services for smart home systems.

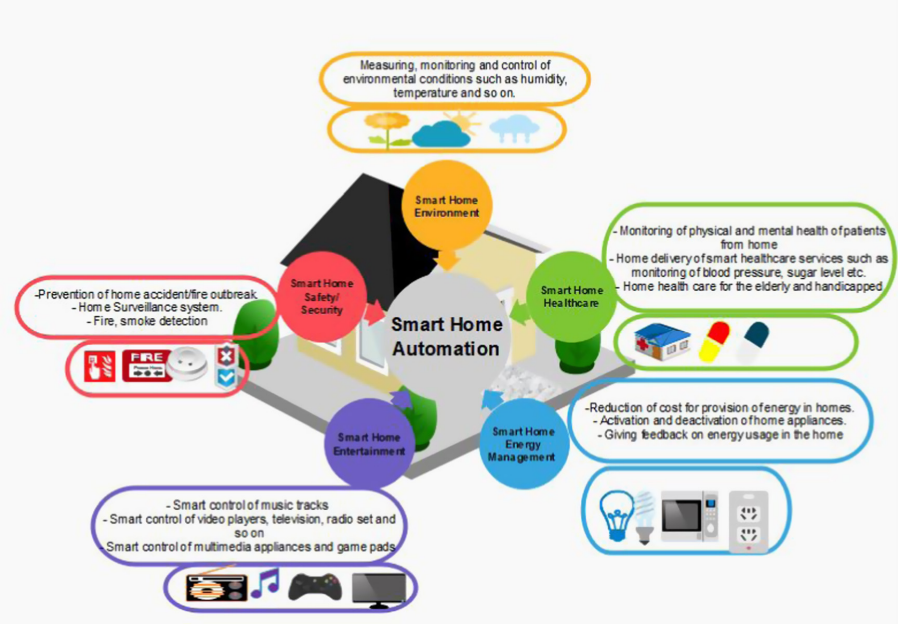

Fig. 3. Smart home application areas

4.1 Smart Home Healthcare

Health care is the prevention, treatment and management of illness or the preservation of mental and physical well-being through services offered by medical personnel. Smart home technology enables a better life quality with an independent and comfortable life for the elderly [36]. Automating a home will make it possible for doctors to monitor patients while at home and give patients the pleasure of having company at home. Also, smart home healthcare aims at catering for the needs of the disabled by making controlling appliances from devices such as phones, which are easily accessible to them. Other means of control and monitoring in home healthcare are the use of technologies such as sensors, wrist-straps and actuators. Some application areas of smart home healthcare include tracking of patients, data gathering, object sensing, monitoring and delivery of medical supplies online, administering drugs to patients while at home, and so on [4].

4.2 Smart Home Energy Efficiency

With technologies used in smart homes, there is reduction in energy. Heating, cooling, lights, water pumps and other electrical appliances in the home can be controlled by homeowners/users from any location through smart home technologies. Energy reduction is achieved with technologies such as automatic timers and motion detectors that automatically turn off lights when not in use and light dimmers to reduce wattage

and output, thus saving energy [35]. Other areas are control of home appliances through smartphones as an automation system is also mobile application based.

4.3 Smart Home Entertainment

Social and lively environments are achieved in the home with convenience through IoT. Volume of music and changing tracks can be controlled without pressing buttons on the player. Smart home entertainment eliminates unnecessary remotes and makes life more convenient with control of different entertainment appliances from a smart phone. Interoperable communication in smart homes is obtainable through technologies such as WiFi, Bluetooth, Zigbee, for Plug-and Play services, Audio/Video remote control, Video Distribution Technology and High-Definition Television [37] for entertainment in the home thus making control of entertainment appliances possible.

4.4 Smart Home Safety

Quick detection and prevention of abnormal occurrences such as fires, flood, electricity leakage or unauthorized access in the home can be achieved with smart home technologies. For detection of unauthorized access and security violation signals can be sent from home to a user through smartphone application and there will be rapid response to control such situation. Smart homes are equipped with sub-systems for video surveillance, alarms, remote monitoring and emergency response [38].

5 Research Trends, Challenges and Future Direction

Smart home trends are increasing as deployment and application areas of smart home automation are opening up. In the previous sections, literature works have been reviewed and technologies in smart homes have been discussed and explained. In order to understand the direction of research in smart home automation, this Section aims at discussing research trends, challenges and possible solutions for future direction.

5.1 Research Trends

5.1.1 Energy Efficiency and Reduction in Consumption Level

Home energy management systems are for conservation of electricity costs, improvement of energy utilization through monitoring and scheduling of home appliances based on preferences of home users [39]; they tend to lower consumption rate of energy, increase the availability of energy to consumers and reduce or eliminate wastage. Current research trends favor demand-side management more than the supplier. But on the side of the supplier, research should be channeled towards developing energy efficient algorithms and systems that will deploy smart homes to balance efficiency, profitability and utility at both consumer and supplier's ends.

5.1.2 Privacy, Security and Trust in Smart Home

Security of data is currently under research for information generated in smart homes. Automation of various devices, users in the home and technologies generate lots of data, but preservation and integrity of these data needs to be worked on. Under security, authentication and authorization of users still needs to be considered in smart home system design and development. Current research shows proposed and prototype designs to address these issues.

5.1.3 Innovative Technology

As smart home automation systems are evolving and becoming acceptable in homes, new research is coming up with the discovery of innovative technologies that will be compatible in smart home automation systems and eliminate interoperability issues among devices so as to develop and implement systems that will enable efficient interaction and communication among devices in the system. From 2017, the research focus seems to have shifted from prototype and framework to development of real systems that are universal, scalable and have interoperability in smart homes. Trends are moving towards making devices from different manufacturers communicate reciprocally.

5.2 Challenges in Smart Home Automation

Challenges identified in smart home automation are security attacks, privacy concerns, incompatibility of devices and technologies in smart home automation system, and integrity of information sent and received. Smart home automation systems are designed for continuous monitoring of home, health, environment and to also give prompt notification to avert danger or accidents in the deployed area of application. Although a plethora of research appears to be regularly evolving on the subject of making smart home automation systems fully functional without danger or challenges, there are still areas of general challenges associated with smart home automation that need further development to improve performance of the system. These challenges are discussed in this Section.

5.2.1 Authentication, Authorization and Integrity of Users

Authentication and authorization of users in case of stolen control devices, are still a neglected part of smart home automation. Also, security applications to forestall unauthorized access into the home or developed system is another challenge in smart home automation system. Most of the developed systems do not focus on deployment and integration of security measures to check companion users of the system. A possible solution to this challenge is for developers, in conjunction with vendors/manufactures of devices involved in smart home automation of systems, to consider authorization and authentication while developing the system. Research effort should be intensified on possible solutions to authorization and authentication of people and devices involved in smart home automation systems. Moreover, use of authentication codes for access and gateway ensure data integrity and authenticity.

5.2.2 Privacy of Information/Data

Preservation of patients' data, privacy and authentication on the user's side to confirm if communicating with the right medical personnel in smart home healthcare system is another challenge attached to smart home health care area. Developers should ensure that the users' integrity and information are kept private and that they are communicating with the correct personnel at every instance of using the system.

5.2.3 High Cost and Incompatibility of Devices

Most technologies and devices used in smart homes are above average price levels; this makes full implementation and deployment of smart home systems slow. Efforts should be made towards making prices of devices and technologies lower than the current rate. Another challenge is incompatibility of devices; different manufacturers are involved in the supply of home automation devices and most of these devices do not communicate with each other because of differences in manufacturer. Manufacturers should reach high standards of production of smart home automation devices. A possible solution to incompatibility of devices is for developers of systems to design systems that will be built on compatible devices and development of gateways that will support communication of devices from different manufacturers.

5.2.4 Efficient Energy Management

Most smart home systems involve sensing devices for monitoring parameters and alarm systems, actuators and other devices that are electricity dependent for functionality. Connecting all these devices in smart home automation can lead to energy overload. Use of some appliances especially during electricity peak periods can also lead to high consumption of energy. All these contribute to challenges in energy efficiency in smart home automation. The use of solar energy supply or batteries can serve as possible solutions to the challenge of energy efficiency in smart home automation. Development of scheduling process in smart home automation systems can enhance their energy efficiency.

6 Conclusion

In this paper, we presented a review of IoT-smart home automation system. Smart home automation system aims to bring convenience and ease of access to home owners/users. A review of related literature in application areas of smart home automation systems was discussed with a highlight on technologies involved, design methodologies alongside their required implantation technologies, as well as strengths and weaknesses of the existing literatures published to date. Furthermore, the elements of smart home automation systems were discussed in detail, likewise properties of smart home automation technologies, sensors, automation layers, protocols and hardware platforms were also discussed to give prospective IoTs systems designers and developers of smart home automation system the necessary insight to those essential elements. Application areas of smart home automation were also discussed and lastly, trends and challenges were discussed and possible solutions to the identified challenges highlighted. Future opportunities for the smart home automation systems would

involve interfacing them with intelligent enabled smart sensors such as motion sensors for security surveillance and light sensors that will assist in conserving energy wastage by ensuring efficient optimization of usage. Furthermore, the next step for smart home adoption is its extension and integration to smart city design and automation process.

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