

Smart Homes Technologies, Connectivity Standards and Challenges.

Timanshi Bhardwaj, Aastha Jain, Vaibhav Tembhekar and Monika Garg
Manav Rachna International Institute of Research and Studies, Faridabad, India

ABSTRACT

Smart Home is an integrated home environment where devices and appliances can be distantly operated from every Internet-connected location globally via a smartphone or any other connected system. The smart home system needs a programme interface or a web server to communicate with an integrated machine. Smart home technology helps improve health and wellness by serving individuals with special needs particularly the elderly. It enables users to access and track their connected home appliances from smart home applications, smartphones, or other networking systems. This makes for more efficient power usage and energy, and also assuring that your premises are safe. They are developed by various organisations with different requirements and technology. These devices are designed by different companies with different standards and technologies. Growth in the smart home industry is driven predominantly by aspects such as progressively growing internet usage, expanded usage of mobile technology, perception of active and balanced lifestyles, and a increasing sense of home security and safety.

The contribution of this study is to compare widely used wired and wireless communication technologies for smart home applications in the personal area network in terms of their standard / protocol, data rate(mbps), coverage range, frequency band, transmission medium and relevant network topologies. These networking technologies include both wired solutions (e.g., Ethernet, Power Line Communication (PLC), HomePNA, MoCA(Multimedia over coax)) and wireless solutions (e.g., WiFi, ZigBee, ZWave, Bluetooth low energy, thread, UWB(ultra wide band). The challenges and market revenue of smart homes is also covered.

Keywords: Communication; Smart homes; IoT; Network

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I. INTRODUCTION

In different fields, the term 'smart' has been seen and is generally understood to mean intellect. In the IoT age, smart home technology, one of the leading new innovations, has turned home appliances into smarter, push button-controllable and integrated units. [1]

The term "Smart Home" was coined in 1984 by the American Association of Home Builders, when things like Motion – sensing lights, programmable thermostats, and security systems were widely available and use. Today we have come a long way from that, now a lot this technology can be controlled by just out voice. In the near future, we won't even require that.

A smart home system, incorporates extremely smart highlights and features to make life simple. In a smart home system, we can control home appliances utilizing our smartphones. The Principle Objective behind Smart Home System is to lessen human endeavours and efforts, power utilization, and to support old matured individuals

and kids. As wireless communication develops, it permits us to access or handle home appliances distantly. At the security perspective if any intruder attempt to enter, there is an anti-theft framework which raise the alert and tells the client with the goal that the client can take the necessary actions right away. Another significant hazardous issue is gas spillage in home. LPG gas is a combustible gas. So, for this situation again the system will raise a caution and tell client.

Today, IoT gadgets are more ample than any time in recent memory, and the cost of Smart home Systems continues dropping, making them an alluring choice for property holders. In any case, the home computerization industry has endured some developing agonies because of restrictive programming and frameworks. Frequently, customers need to make compromises between having the different gadgets they really want and the capacity of those gadgets to function well in a seamless installation.

“Connectivity and interactivity are driving the way families live and manage their homes. So, while we are expected to be in more places due to business travel, children’s school schedules and social activities, these new smart systems provide cutting edge connectivity to your household, even when you’re far away. And when the house is occupied, the high level of automation enables more convenience, control and safety from any part of your property. It all adds up to fewer worries and increased enjoyment of life, which is something we would all welcome. [2]

In this paper we go through numerous technologies both wired and wireless that are used in smart home systems, buildings, and grids discussed in detail in section 5.

II. LITERATURE REVIEW

The increase of IoT based smart home devices, there are many limitations also which occur and remain unaddressed [3]. There are many challenges and benefits of using smart home devices but the users must take care of the energy consumption so that they can control devices safe and secure and with reliable management.

That smart cities have supplied different devices which are based on IOT with increasing development of technologies [4]. As implementation of IoT infrastructure enables a lot of opportunities. But there are challenges occurred in implementation which are explained.

The recent trends and growth in the IoT based smart cities paradigm. Many issues are also discussed like interoperability, low cost, power consumption, security which are very important to discuss for the improvement in technologies [5].

In which for future investigation, issues are discussed based on IoT technologies including telemedicine environment. Studies related to the issues are analyzed and discussed with the users by the taxonomy of research literature on the IOT. Security of the system is also a limitation which led to another taxonomy which is explained for protecting the system [6]. It is also discussed that the security issues can be overcome by industrial work and collaborative academics in the rapid growth of technologies.

As in the rapid increase of technologies, the current scenarios are influencing people to adapt the quality life cycle. Different standards are available in the market in which it builds a connection between home devices and innovation [7]. But the challenges also occur which are discussed but the main issue arises in the connectivity. There are low degree of standardisation between the protocols. In the future the standard infrastructure with wireless protocols

that support interoperability are the solution for smart functioning of the devices.

The study offers a description of IoT technology and home automation implementations. Communication solutions for IoT in the home setting are also clarified. As a result of latest advances in Internet and smart solutions, IoT has become a big attraction as a powerful platform for digital services in a wide spectrum of applications such as smart homes, medicine, manufacturing, transportation and a lot more [8].

The paper describes about CPN (customer premises network) and how in general, smart grid implementations in a CPN are driven by the need for Home and Building Energy Control Systems (HEM / BEM) [9]. The construction of an efficient energy management system involves the collection of suitable communication technologies. Further the paper aims to do comparative study of different types of communication networks.

The key aim of the smart home system is to make life easier for elderly and disabled people and to conserve energy. Home automation system eliminates the burden by assuring that you have home protection even though you are not there [10]. A comparison analysis of the smart home device based on innovations such as GSM, Bluetooth, IOT and PIC Microcontrollers with ZigBee modulation is addressed here.

The projected architecture uses the EmonCMS software to capture and simulate controlled data and navigation system of home devices and equipment. The chosen framework is very versatile and easy in application [11]. The study describes a simple and flexible design for solar house monitoring and computerization. The preferred framework is the EmonCMS that requires a cloud service to gather information from sensors using the IoT concept. Data gathered may be viewed, stored or analysed and used for home control systems.

In an attempt to settle the problems of the over-automation and architecture comprehensibility, the study first explores the context of home automation and addresses that communitarian attachment and the assigning of individual character traits to systems / appliances / objects in smart homes is not a recent phenomenon and has been in existence, both traditionally by native cultures and in modern life [12].

Owing to the limited power of sensor devices, numerous Internet access for powerful applications (use of cloud computing and big data technology), and also the complexity of home networks, which enable novice consumers to customise appliances and micro-systems, smart

homes have raised control and safety issues in present days [13].

III. FEATURES OF SMART HOMES

In this advanced technology dependent time, there has never been a faster way of communication, be it between human to human or human to machine. While moving towards a future, where we human don't have to do the repetitive work, or the work that can be optimized for automation, to make our lives even better and explore and experiment on newer things, we feel that smart homes are one of the first steps towards that goal.

The term "Smart Home" was coined in 1984 by the American Association of Home Builders, when things like Motion – sensing lights, programmable thermostats, and Security systems

were widely available and use. Today we have come a long way from that, now a lot this technology can be controlled by just out voice. In the near future, we won't even require that

The most important feature of smart Energy management systems is convenience and faster communication between humans and machine. A smart home provides solutions like energy management, improving home comfort, and security. Furthermore, it can be used for elder people and differently abled, providing them with safe and secure surrounding.

The omnipresent home network has increased broad considerations because of its consistent incorporation into regular day to day existence. This innovative framework straightforwardly brings together different home appliances, smart sensors and energy technology.

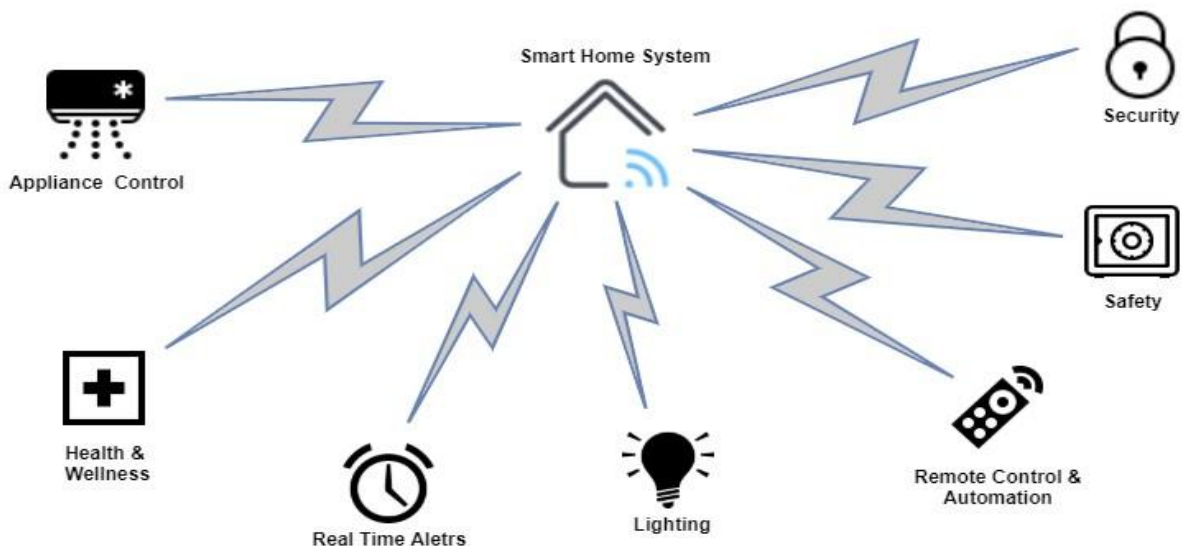


Fig.1 Example of a Smart Home System

Energy Efficiency

Smart home frameworks and gadgets help conserve energy by permitting the client to screen and control energy use in new ways.

Energy through warming, cooling, conditioned air and lighting perhaps be given when there is a demand on the customer side. Customers should oversee when and how much energy must be consumed. Smart Home allows users to take control of their homes, with voice or with their smartphones, Smart-Home hubs can turn off appliances completely when not in use, thus removing the chance of energy drainage due to machines that are idle, and therefore energy efficiency is increased. For example: A smart thermostat is a fundamental part of any energy management system because a home's heating and cooling system is one of the biggest energy

consumers in the house. Smart home systems make many heaters programmable. If home owners are not present at certain times during the day, their radiators will automatically shut down. If they arrive home sooner than planned, they can access their smart home via an app on the go. For example it is not necessary to run the heating when nobody is at home during the day. But even when airing the heater does not have to be on [14].

Security

The notion of providing security in Smart Home environments relies on the maintenance of six essential properties; Confidentiality, Integrity,

Authentication, Authorization, Non-repudiation and Availability. Confidentiality, Integrity, Authorization, Non-repudiation and Availability play very important roles in ensuring of

Smart Home internal network security. However, Authentication can be considered as the first step in the pyramid of a security mechanism [15,16].

A security system connected with a Smart Home Hub, a system like this might comprise of smart doorbells, smart locks, smart cameras, smart thermostats, smart lights, and smart smoke alarms, etc. Smart doorbells let you know who is at the door by activating the camera and sending you a clear picture of the person, despite your location. Smart Locks are also a great security device in a smart home as they use the smartphone to handle the locking and unlocking duties. Smart Cameras are essential for a smart home with their smart motion sensing and pattern recognition algorithms they can help monitor a door entry and trigger and alarm or alert the user.

Comfort

Smart Home Systems offer advantages in numerous territories including restricting natural effect, saving money on energy costs and improving structure security and wellbeing. The frameworks not just control building capacities, they change information to assist clients with deciding approaches to additionally diminish expenses and increment the effectiveness and solace of their structures. Smart Home Systems educate clients about their condition, yet in addition give a level of control over it where suitable. Smart controls empower building inhabitants to regulate their energy use. Using home automation systems, makes smart homes more a comfortable living space. For example: Smart thermostats, can be pre-programmed to a comfortable temperature before you enter your home. Smart Lights could be automatically turned on when you walk into a room or have a variable brightness based on the time of the day. Smart fire detectors, can alert you anywhere, despite your location. Researchers showed that rapid feedback to inform occupants are improving comfort conditions but a correct system functioning is crucial for perceived comfort and satisfaction with systems [17].

IV. COMMUNICATION TECHNOLOGIES FOR SMART HOMES

The subsequent segment of paper describes the innumerable wired and wireless technologies which can be used in smart homes/buildings/grids.

4.1 wire technologies

Ethernet

Ethernet is a means for a local area network or LAN to link computers together. Since the 1990s, it has been the most commonly used way of

connecting LAN computers together. The fundamental concept of the architecture is that it is available to many devices and can transmit data at any time. Ethernet was at 10 Mbps per second at the beginning. It was relinquished under IEEE 802.3u in 1995. Today's most widely used Ethernet is at 100 MB per second. Expeditious Ethernet was capable to provide data at a rate of 100 Mbps which was a major progress over the 10 Mbps Ethernet systems. It was relinquished under IEEE 802.3u in 1995. Owing to the short Ethernet patch cables with their RJ45 connectors, which are used to link most desktop computers to data network routers, Ethernet is perhaps the most generally recognised. Coaxial cable for Ethernet is costly and arduous to install. As they restrict stray pickup further, the shielded twisted pair is safer and thus data losses are minimised. Fiber optic cable is progressively used as it offers very high tolerance to pick up and contamination and enables very high data rates to be transmitted. Speed, reliability, security are some benefits of Ethernet over Wi-Fi.

MoCA

MoCA is brought as Multimedia over coax. MoCA innovation is utilized as an in-home spine to ensure wireless communication. MoCA technology reduces the cost of operating the whole network, or overall cost of ownership, as a result of its high

Efficiency and reliability and the support it offers for cellular networks. It began in 2004 with MoCA 1.0 accomplishing network paces of up to 100 Mbps. Since MoCA utilizes coaxial link, it isn't profoundly susceptible to the electrical impedance that different networks can have issues with.

PLC

The process of transmitting power and data for communication from one end to the opposite end via the similar existing network of wires is called Power Line Communication. It offers broadband data communication through a modular signal to conductors already in use for the transmission of electric power. Today, this can be achieved by the wiring of the house or premises and can also be accomplished by the current delivery grid of electric power. In addition to transmitting the contact signals, PLC also helps the customer to control and track all the attached equipment on the power line since it is incorporated in the same cable system. PLC would not involve any additional wires to be mounted, which will greatly decrease the expense of implementation and it likewise has a huge reach.

HomePNA

HomePNA 3.1 utilizes frequencies over those utilized for digital subscriber line and analog

voice calls over telephone wires and underneath those utilized for broadcast and direct transmission satellite TV over coax, so it can coincide with those accommodations on similar wires. With rise of HPNA 3.0 data speed can reach up to 240 mbps which has made HPNA contender of Ethernet and different advances. If a Home Phone line Networking Alliance (HomePNA) networking framework is introduced on phone circuits that are as yet being used for voice communications, issues with line commotion on the circuit can significantly influence the performance of both the data network and the telephone framework.

4.2 Wireless technologies

z wave

The Z-Wave convention is an interoperable, remote, RF-based transmission technology planned explicitly for control, observing and status perusing applications in private and light business conditions. Developed, demonstrated and comprehensively sent. It is designed explicitly for control and status applications, fortifies data rate of up to 100kbps. It is a mesh network utilizing low-vitality radio waves to connect from device to device, taking into consideration remote control of home devices and different gadgets, for example, lighting control, security frameworks, indoor regulators, windows, locks, pools and garage entryway openers. The longer wavelength and lower frequency of the Z-Wave sanction it to facilely perforate articles and walls, along these lines setting up a more solid and quicker communication geography between the associated Z-Wave gadgets. It has Low power utilization for remote transmission when contrasted with Wi-Fi. Because of lower power utilization, the battery life of Z-Wave gadgets expands up to long periods of use.

Wi-Fi

Wi-Fi is a group of wireless network protocols, in light of the IEEE 802.11 group of standards, which are usually utilized for LAN gadgets and Internet access. Wi-Fi innovation might be utilized to give local network and Internet admittance to gadgets that are inside Wi-Fi range of more than one or one router that is associated with the Internet. The present wireless networking system standard we as a whole use today is alluded to as IEEE 802.11ac. Present home wireless routers are likely 802.11ac agreeable, and operate in the 5 GHz frequency space. With Multiple Input, Multiple Output (MIMO) – numerous antennas on sending and accepting gadgets to truncate flaws and lift speed – this standard reinforces data rates up to 3.46Gbps. The inclusion of one or more interconnected access points (hotspots) can stretch

out from a zone as little as a couple of rooms to as extensive the same number of square kilometres. Inclusion in the bigger region may require a set of access points with protruding coverage. Convenience, mobility, expandability, cost are a few advantages yet on the opposite side security and range are the down factors.

Bluetooth LE

The BLE technology offers a clear and secure interface that is highly valued by Manufacturers of consumer electronics, developers of mobile applications, and engineers. It has become more and more relevant with all Internet of Things problems. Bluetooth Low Energy's key attribute is certainly its very low consumption of energy. The BLE technology is simple to deploy and is designed to regularly move small amounts of short range data. Finally, with a significant battery lifespan, it remains cost-effective. The rate is fixed at 1 Mbps for Bluetooth 4.2 and earlier. However, for Bluetooth 5 and later, depending on the mode and PHY used, the rate varies. As with earlier versions, the rate can be 1 Mbps or 2 Mbps when using the high-speed feature. BLE operates in the 2.4 GHz ISM spectrum, which is significantly affected by obstacles such as metal objects, walls, and water (especially human bodies) that exist all around us.

ZigBee

ZigBee is an IEEE 802.15.4-based standard for a set of high-level networking protocols used to construct close proximity networks for lightweight, low-power digital radios, like domotics, data processing of medical equipment, as well as other low-power low-bandwidth products, built for micro enterprises requiring wireless communications. ZigBee is providing low-latency connectivity. ZigBee chips are usually coordinated with radios and microcontrollers. ZigBee works in the industrial, science and medical (ISM) radio bands: 2.4 GHz in most of the parts around the world; while some systems still use 784 MHz in China, 868 MHz in Europe and 915 MHz in the US and Australia. Though in these areas too, they use 2.4 GHz for most merchandised ZigBee products for personal use. Data rates range from 20 kbps (868 MHz band) to 250 kbps (2.4 GHz band).

Thread

Thread has been built for user applications and appliances in and around the premises, and to allow this to be done, Thread has been developed to provide fast and safe communications between hundreds of gadgets and ultimately to the cloud through real-time Internet Protocols via a low-power, wireless mesh network. It has been

optimised to fit low power operation-a feature that is becoming extremely critical for IoT systems. Thread has been developed to facilitate the transmission of IPv6 data, a capability that most related networking systems cannot actually handle. Thread is built on validated wireless protocols, consisting IEEE 802.15.4 as well as 6LoWPAN.

UWB

Ultra-wideband is a radio automation that can use a lesser energy intensity for low range, high-bandwidth networking over a significant part of the radio spectrum. UWB has conventional uses for non-collaborative radar imaging. The most recent applications aim data gathering, precise locating and surveillance systems. UWB sends data by producing rf signals at unique time frames and consuming a broad bandwidth, thereby allowing pulse time modulation.

Wire Technologies For Home IoT Network

Technology	Standard/protocol	Coverage area	Data rate (Mbps)	Frequency Band	Transmission medium	Network topology
Z-wave	Z-Wave	LAN	0.097	900 MHz	Radio	Mesh
Wi-Fi	IEEE 802.11	LAN	1000	2.4 GHz, 5 GHz	Radio	Star, Mesh
Bluetooth LE	IEEE 802.15.1	PAN	1	2.4 GHz	Radio	Star-bus
ZigBee	IEEE 802.15.4	PAN	0.244	2.4 GHz	Radio	Star, tree, Cluster, Mesh
Thread	IEEE 802.15.4	PAN	0.244	2.4 GHz	Radio	Mesh
UWB	IEEE 802.15.4a	PAN	>100	3 GHz	Radio	Star

Wireless Technologies For Home IoT Network

Technology	Standard/protocol	Coverage area	Data rate (Mbps)	Frequency Band	Transmission medium	Network topology
Ethernet	IEEE 802.3u	LAN	100	500 MHz	Twister pair, Fiber optic cable	Star, coaxial Bus, point to point
MoCA	MoCA 1.0	LAN	1000	1500 MHz	Coaxial Cable	Tree, Bus
PLC	IEEE P1901	LAN	200	<100 MHz	Power Line	Bus
Home PNA	HOME PNA 3.0	LAN	240	36 MHz	Phone Line	Star

V. CHALLENGES IN DESIGNING SMART HOMES

Connectivity of home appliances

Connectivity of smart home appliances are the problem faced by the users. As there are many appliances connected to the web so a lot of IPs are required. Some external factor affects by increasing the complexity of homes network as there is a variety of networks, communications and materials are present. The devices can use any network like wifi, Bluetooth etc. to communicate. Traditional protocols are based on IP networks access so they face difficulties in connecting to wireless and non IP environment. In such a multitasking environment, some of the data communicated in the network get lost. High packet error rates and connectivity loss can be resulted because of the usage of wireless

technologies as they have high interference in multiple environment.

Energy consumption

Energy consumption can cause home network traffic in transmission of data. As there are various devices and all updates it required, the CNN face problem like robustness, synchronization, energy consumption and many more. Smart home power system face problems in the management of the energy consumption. The sensors connected which records issue like data interruption and low battery face problems like low battery supply and physical damage. An efficient network require less power consumption and low battery drainage for communication. Advancement in wireless communication and micro-electronics can be solve the issue for low power consumption in low cost as

the devices contain a group of sensors which requires continuous source of energy.

Control and Management of the Systems

In rapid growth of technologies and improvement of architecture many problems occur in control and management of the systems. Number of appliances increasing face difficulty in managing and controlling which cannot provide user comfortable and secure space. There is a disadvantage in the smart home systems for independent management of the subsystems which is difficult to integrate. The control and remote access of the smart home system is also a challenge due to the increase in IoT technologies. The control devices of home appliances also have several drawbacks like poor scalability, inability to expand to other devices and device interface. Only few studies solve the issues in IoT management in smart home field. The problem also occur in the branding of various tools and technologies which provide similar medium in communication. When users are outside the home, they face problems in controlling and managing the appliances from long distance.

Security and protection of Home Networks

Security is the main concern for every IoT devices. Most security issues occurs with Smart Home system. Hackers can reach the network infrastructure, for example. All intelligent devices, particularly security equipments, can be regulated by them [18]. Private data and HVAC appliances are the most important factors of home security that usually cause hijacking or data get leak. Security and privacy are the stakeholders which encourage users to buy IoT based smart home appliances. Strong privacy measures should be provided so that user can ensure and easily trust on the systems.

Multiple access points of the device can be a privacy problem.

Sensor network

It is the most important technology which can shape up the world by the measuring ability and understanding the environmental indicators. Recently improvement in the technologies provided low cost and high efficiency devices which employ remote sensing devices in largescale. The most challenging thing in sensor is to process large scale data accordingly in order to consume less energy and networks. Sensor nodes are the devices which limits the energy consumption and storage capability.

Interoperability

The capability of two or more different devices and networks to communicate the data with each other together. It is the main concern because the user demand devices which are easy to use and connect. Wi-Fi alliance has proven interoperability and it is one of the most trusted certified regimes. The Bluetooth SIG has comprehensive certification that covers the whole protocol stack and application profile that helps to achieve interoperability.

Data Analysis

Huge quantities of data will be generated using IoT sensors. Processing such a vast volume of data is a big undertaking. Effective algorithms are important to infer from those enormous results [19].

Smart Home Market Revenue in recent years

The following section describes the global market size of smart homes (2016-2022) which is expected to rise to US\$ 53.45 billion by 2022.

global smart home market from 2016 to 2022 (in billion U.S. dollars)

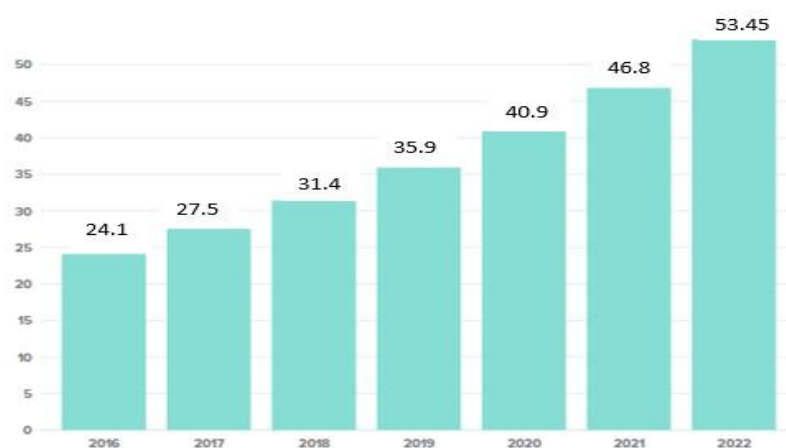


Figure 2

VI. CONCLUSION

At the moment, smart home networks are shaping users with a standard of living. IoT will shortly link even the smallest gadgets in the house to the web. The paper outlines the existing industry standards that are the foundations of the local network and technology. The problems in the smart home network are also tackled on the basis of its connectivity. As wireless communications have reduced operational costs, quicker implementation, greater flexibility and reliability than their wired technologies, wireless networks are preferred in most consumer layouts for network implementations in the smart home system. The projected sales of appliances and software used in smart homes are estimated to expand more and more. In the near future, a common architecture that promotes interoperability of various wireless protocols will provide the key for smart home service.

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