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Research on the Development Status and the Trend of Smart Home

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ABSTRACT

The emergence of the Internet of Things (IoT) technology provides new directions and contents for the development of smart homes, breaks the time and space barriers between people and home systems, and the application of IoT technology realizes the integration and management of information between smart home devices, prompting people's home life to be safe, comfortable and intelligent, exploring the life needs of contemporary users, and building a harmonious relationship between people and smart home systems. At present, smart home is developing rapidly and has a greater impact on people's home life. This paper will elaborate on the development status of smart homes in the context of the Internet of Things and explore and study the significance and development trend of Internet of Things technology in the field of the smart home.

Keywords: Internet of Things, smart home, development status, trend.

INTRODUCTION

The Internet of Things (IoT) is an extension of the Internet that enables connection, interaction, and Internet functionality between different devices or physical objects. With the rapid growth of IoT devices and applications in recent years, the IoT has played an important role in reducing human workload. In the IoT environment, all devices in our daily lives can be associated with the Internet through their computing and communication capabilities. While the debate continues about the depth of impact and adoption of IoT technologies in the coming decade, it is clear that the penetration of IoT in many areas is rapid and subversive. One emerging area examined in this paper is the application of IoT in the smart home.

The smart home is one of the key components and applications of the Internet of Things (IoT). It is an advanced technology which is helpful in people's daily life. A smart home uses IoT technology to connect various IoT-based household devices, security devices, and communication devices with the home intelligence management system, and the collected data information is processed through cloud computing, digital information recognition, and other technologies, and finally transmitted to the user's mobile terminal. The system provides personalized and diversified services for people, making the inside and outside of the house effectively connected. Users can easily monitor and control all home devices/appliances through the Internet, and these home devices are connected to the Internet using the appropriate network architecture and standard protocols. The advantage of this technology is that it will reduce the workload of people and provide users with security, comfortable living, and energy management. Through IoT-based smart home technology, all smart home devices can communicate with each other whenever and wherever, so as to realize the information interaction between people and things, things and things, to meet people's different needs. At this stage, IoT technology has been deeply used in smart homes, with increasingly stable performance and more efficient control. IoT technology is used to put forward innovative concepts and exponential development for smart homes, breaking the limitations of space and time, which can bring more convenience of life while satisfying users' needs and becoming the mainstream direction of current home development.

In recent years, people's interest in smart home systems has been increasing day by day. Smart home automation systems describe and record the status of connected home devices with an intuitive and user-friendly interface so that users can communicate, monitor, and remotely control different devices with simple operation. Bluetooth, Wi-MAX, Wireless LAN (Wi-Fi), ZigBee, and global system for mobile communications (GSM) are the main communication technologies used in today's smart home systems.

THE INTERNET OF THINGS AND SMART HOME

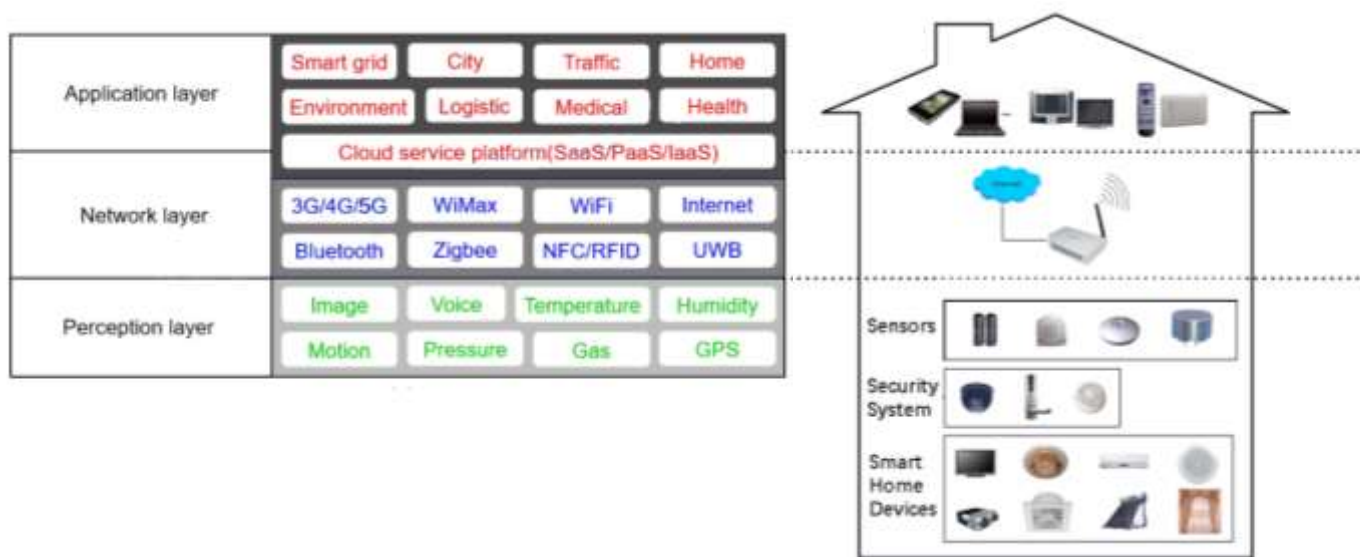
Technically, the realization of IoT functionality requires the integration of multiple technologies in terms of perception, network, and application. Therefore, the basic architecture framework of IoT can be divided into three major levels: perception layer, network layer, and application layer (Figure 1).

Perception layer - sensing information. The perception layer is the underlying and foundation of IoT, mainly addressing the core capability of comprehensive perception of IoT. It is composed of various sensors, security systems, smart home devices, etc. The role of the perception layer is equivalent to nerve endings such as human eyes, ears, nose, throat, and skin, etc. Its task is to identify objects and collect information so as to realize the awareness and perception of " objects. " For example: in the modern smart home, temperature and humidity sensors are widely used to intelligently measure indoor and outdoor temperature, so that people can know the temperature value, so as to facilitate travel and home.

Network layer. It is a converged network based on the existing communication network and the Internet. The network layer is connected with the mobile communication network and the Internet through various access devices, moving the collected data to the applications. It is equivalent to the human nerve center and brain, which is responsible for transmitting and processing the information obtained by the perception layer. In a smart home, each device operates independently of the other and communicates using a local network, with the home gateway acting as the access point, so that smart home users can remotely monitor, control, and manage household appliances or sensors.

The application layer is the interface between the IoT and users (including people, organizations, and other systems), based on collection and interconnection, which provide rich and specific services to users using analyzed and processed sensory data. In the smart home, a wide range of application solutions can be implemented through mobile phones, computers, and other terminals, specifically in the form of interactive behaviors between products and users. The application layer is the purpose of IoT development.

The application of IoT technology connects various smart home products together to achieve rapid integration and management of information, and through different combinations, different smart home systems can be built, such as elderly monitoring systems, child companion systems, home theater systems, etc.



Source: This study.

Figure 1: Smart home system structure.

DEVELOPMENT STATUS OF SMART HOME

In the age of intelligence, with the continuous development and progress of society, people pay more and more attention to the quality of personal home life, and the market of smart home products has a broad prospect. A smart home is the use of modern science and technology and integrates life-related equipment in order to achieve the purpose of systematic and efficient management of family affairs. The safety, convenience, comfort, and artistry of the home can be greatly enhanced, and the requirements of energy-saving and environmental protection can be achieved. Smart homes not only require a high degree of intelligence of each individual facility but, more importantly, integrate individual devices into system control to create the effect of $1 + 1 > 2$. With the development of IoT technology and the improvement of product intelligence, the smart home system will provide more appropriate and considerate services for users.

Smart Home Devices

After the application of Internet of Things technology in smart homes, a range of new smart home devices has emerged. At present, there are many smart home products in the market, such as Xiaomi's Yeelight smart light bulb and bedside lamp (Figure 2), iHealth smart blood pressure meter, smart bracelet (Figure 3), smart weight scale, smart air purifier, and some smart door lock, smart switch, smart curtain, etc. Most of them are controlled by mobile phones through IoT technology, and most of them are independent single, smart products. Voice system, as one of the most basic interaction functions, has been implanted in most of the smart products in the market, such as smart speakers, smartphones, smart voice control systems for cars, floor-sweeping robots, etc. In 2019 smart speakers were introduced for use as one of the smart home devices in most residents' homes. The elderly at home are able to communicate with people who are not around through a smart speaker with a screen, which can meet the spiritual needs of some elderly people living alone. When the smart speaker is connected with other home appliances, the elderly are able to control them by voice. Moreover, this kind of smart speaker also has the functions of checking the weather, playing music on-demand, and consulting. With the introduction of IoT technology, data can be stored and managed among multiple products. The development of this technology builds a harmonious bridge between people and products and truly achieves "contactless interaction." For example, the Xiaomi speaker, which allows users to control the work of the sweeping

robot by giving voice commands to it (Figure 4). Stryker IBed (Figure 5) with embedded alarm systems and other technical communication features can help patients interact with their caregivers. It is compatible with many third-party systems, iBed Wireless currently works with leading suppliers of EHR, Nurse Call, Middleware, Alert Management, and handheld devices (Figure 6).



Source: Baidu pictures.
Figure 2: Yeelight smart light.



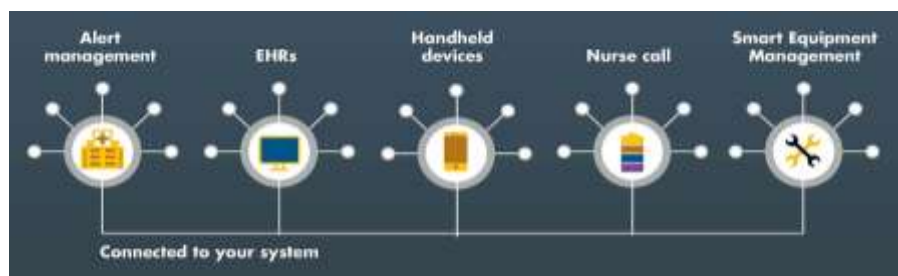
Source: Baidu pictures.
Figure 3: Smart bracelet.



Source: Baidu pictures.
Figure 4: Sweeping robot.



Source: <https://www.stryker.com>.
Figure 5: Stryker IBed.



Source: <https://www.stryker.com>.
Figure 6: Flexible connectivity of Stryker IBed.

Smart Home Security System

The interconnectedness of the Internet means that Internet resources can be attacked from anywhere in the world, which makes network security a key issue. Smart home products take home as the core use scene, and the specificity of the use scenario determines that users have high requirements, high sensitivity, and high concern for product safety issues. Once there are security problems in smart home products, it will threaten the privacy, property, and life safety of users. Many experts have conducted various research on the security system of a smart home (Table 1).

Table 1: Research on the characteristics of a smart home security system.

Characteristics	definition	Author	Security Framework	Security Goals
	Confidentiality refers to keeping data private so that only authorized users	Zegers et al. (2015)	The protocol protects data before it is transferred to the cloud	It improves the flexibility and efficiency of encryption key management.

Confidentiality	(both human and machine) can access that data. Cryptography is the key technology for achieving confidentiality. There is a need to protect original information and sensitive information from being leaked to adjacent networks or even external networks		by separating key encryption from data encryption	
		Park et al. (2014)	For creating virtual activities against bypass attacks in a virtual home environment	Flexibility in controlling the amount of false data transmission to allow for trade-offs between energy efficiency and privacy protection.
Integrity	Integrity is an important security factor in the smart home. An attacker can change the original message by inserting some false information fragment into the transmitted message, or insert malware application, or change the service destination through malicious code. Therefore, integrity mechanisms are important to protect the original data from external attacks	Kang et al. (2017)	An internal security framework of smart home devices is proposed, which uses self-signature and access control technology	Provide security services to ensure device authentication, data integrity and availability, and prevent security threats such as data modification, leakage and code forgery.
Authentication	Authentication is necessary any IoT-based application; it usually deals with simulated threats. In smart home environment, it is essential to implement authentication to prevent illegal use of devices and systems. Authentication is the verification that the data has not been tampered with, and the main purpose is to verify the identity of the device user and prevent illegal users from operating smart home devices.	Kumar et al. (2015)	Lightweight security key establishment scheme	The scheme allows each device to perform lightweight mutual authentication before joining the home network, and uses a short authentication token to establish a security key, which needs to be stored in the home gateway
		Santoso et al. (2015)	Authentication using asymmetric elliptic curve passwords on traditional wifi networks based on the AllJoyn framework	Verify communication between IoT devices and provide users with the means to set up, access and control the system through Android-based mobile devices running appropriate applications
Access	Access refers that only properly authorized users are allowed to access data, communication infrastructure and computing resources, and ensure that these authorized users are not prevented from such access. To protect against potential attackers, each user and each device needs to be identified so that security policies can be implemented. Access to sensitive data should be controlled to avoid illegal access by third parties. Authorization mechanism is used to control the access to network services and sensitive resources by authenticated entities in smart home environment.	Lee et al. (2017)	The system uses Linux to isolate each function of the device, and grants the access to each required function	The access control system based on device function is called FACT, which can achieve more fine-grained access control. Control the access to sensitive information
		Rahmati et al. (2018)	Risk-based access control of permissions	Group device operations according to the risk similarity, and grant corresponding access rights by group The scheme can significantly reduce the security risk.

Source: This study.

Smart Home Whole-house System

The smart home whole-house system (Figure 7) mainly consists of a lighting control system, electrical control system, environmental control system, and central control management system. Each system can operate independently, realizing the intelligence of living scenes and making corresponding feedback according to the changes of the environment and user behavior habits.



Source: Baidu pictures.

Figure 7: Smart home whole-house system.

The German company OTB has installed a collection of smart assistive devices for the elderly in a nursing home apartment, providing the home facilities needed for independent living elderly, as well as monitoring the physical condition of the elderly in the nursing home through smart device data and responding to emergencies in real-time. For example, remote control of bed lifting, pre-alarm sensor mattresses, under-bed sensor blankets, and automatic meal feeders, etc., can help the elderly live independently and have a certain degree of safety. The German company OTB is at the forefront of smart product innovation in the design of the whole-house smart home.

In recent years, there have been new breakthroughs in smart home design in China. For example, in an apartment for the elderly, intelligent home systems such as emergency call, intelligent environment, intelligent nanny, intelligent night, sleep monitoring, intelligent curtain, intelligent window, intelligent air conditioner, IoT door lock, etc. are installed in the rooms to connect basic home devices and electrical appliances, and build an interconnected home network through IoT, cloud computing, voice recognition, and artificial intelligence technologies, freeing the hands of the elderly and allowing the elderly with mobility or visual impairment to operate various home appliances easily. Among them, the emergency call and intelligent positioning system can locate various actions and conditions of the elderly, and give an emergency alarm, which can quickly give feedback on the occurrence of emergencies and improve processing efficiency; The intelligent environment control system senses the environment through sensors, monitors the formaldehyde, dust, temperature and humidity of the home environment in real time, uses the device controller to respond, automatically opens the windows or fresh air or air purifiers, and adjusts the indoor temperature and humidity value according to the changes of the environment, so as to create a suitable environment for users to live in; Intelligent nursing mode can detect various physical values of the elderly, as well as help the elderly to adjust a reasonable diet, remind meal precautions, and ensure all-round safety and health; The intelligent lighting system can turn on or off the lights through voice operation, which reduces the complexity of switching operation, and can automatically turn off the lights at home when there is sufficient daylight, in addition, when it detects that the elderly get up at night, it can automatically turn on the lights in bathroom and corridor through voice command or human body sensor to avoid bumping and falling due to dim light, which reflects the ability of identifying and judging information of smart home, aiming to maximizing the comfort of the residents and hopefully providing some service support for the elderly with limited mobility.

DEVELOPMENT TREND OF SMART HOME

At present, there are still various problems in smart home products, which cannot meet people's higher demand for smart products. In the process of future development, the smart home will evolve gradually with the continuous collection and analysis of big data and the continuous progress of science and technology so as to continuously improve the intelligence level. With the rapid development of IoT technology, many families have started to use the smart home system. Applying IoT technology to a smart home can make people have a better life experience and feel the convenience and speed provided by a smart home.

Improve Security

Security is the basic premise and guarantees to improve the quality of life and future development and progress (Figure 8). As a resource-sharing technology, IoT technology can be connected with multiple users, which provides people with a good living experience, but at the same time, there are also various problems, such as exposing their privacy and providing opportunities for illegal personnel. In the process of designing the smart home, designers need to comprehensively consider user privacy and smart home security and need to deal with various risk factors, such as smoke detectors to prevent residential fire, infrared detectors at the main entrances and exits to prevent burglaries, and smart cameras to help users keep track of their home and family members' activities. These smart security devices (Figure 8) cooperate with each other to quickly provide users with information about their homes, improving the quality of life for people while providing a more comprehensive approach to home security. The

introduction of smart products greatly enhances the emergency risk-avoidance mechanism required by users to understand and solve problems as soon as possible. Many experts have carried out a variety of research (Table 2).



Source: Baidu pictures.
Figure 8: Smart home security system.

Table 2: Research on smart home safety.

	Author	Significant Aims
Monitor	Jabbar et al. (2018)	<ol style="list-style-type: none"> 1. Smart home (SH) automation system uses Arduino Mega microcontroller to build robot system. 2. Sensors are used to show humidity, temperature, and movement in the house.
	Zandamela (2017)	<ol style="list-style-type: none"> 1. Send real-time video information, detect fire, movement, and intrusion, monitor humidity, and temperature. 2. The system has an excellent interconnection, low power consumption, low price, high precision, real-time monitoring, and strong anti-interference performance.
Remote monitor and instant control of household devices	Adiono et al. (2017)	<ol style="list-style-type: none"> 1. Both the RSA and EAS algorithm is utilized for encoding the entire data communication. 2. Control the home devices dynamically and intelligently according to activities and instructions. 3. All data presented by the smart home platform related to the condition of the building.
	Joshi et al. (2017)	Manage many home devices. Users can watch and access it from anywhere.
Monitoring and safety warnings	Madupu and Karthikeyan (2018)	<ol style="list-style-type: none"> 1. Collect data from different sensors such as smoke, passive infrared, vibration, and humidity, check the home environment, and monitor the condition of the house. 2. Identify intruders or fire alarms, send information to users when abnormal.
	Tanwar et al. (2017)	<ol style="list-style-type: none"> 1. Use cameras and sensors to monitor the room. 2. When the system detects an intruder or any threat, the owner will receive advanced security warning messages such as images and e-mails captured by the system.

Source: This study.

Enhance Interactivity

With the progress and development of society, the interaction should not only be reflected in the functions but also focus on the interactive experience of emotions. In the design process of a smart home, the designer should not just solve the basic problems of using the function but also consider the human-computer interaction in the process of using, and regard it as a kind of partner to promote emotional interaction. The cold command language and single operation process can hardly give people a sense of intimacy, while the rich and flexible interactive performance can be more pleasant to the body and mind. Through smart home control systems and various sensors (Figure 9), residents can break through the limitation of space distance, carry out the multiple smart devices interaction, space and human interaction, psychological and physical interaction, indoor space, and external environment interaction. Carry out real-time information transfer between the space and people, especially the physiological emotions, expression characteristics, body temperature, movement rhythm, heartbeat, and other physiological signals of people are matched with the smart space, to establish the interactive relationship between the user and the space, so as to realize the interactive mode of the smart home and enhance the sense of space experience. For example, intelligent curtains can be controlled to adjust the intensity of light in the room, and intelligent tables and chairs can be controlled to free up space and create a sports



field for the user's fitness needs.

Source: Baidu pictures.

Figure 9: Interaction system of a smart home.

Achieve Technology Integration

Nowadays, the concept of "intelligence" has been rooted in people's hearts, and after enjoying the convenience brought by smart homes, people pay more and more attention to the application of new technology in the home. As an intelligent product, smart home is constantly adapting to the development of society, integrating new technologies into the development of smart homes, and combining with the usage environment of smart homes to make smart homes develop in the direction of more convenience, safety, and comfort. The single and traditional technology can no longer meet the diversified needs of people for smart homes at this stage. Therefore, the realization of a smart home needs the integration and development of several technologies. In the background of big data, artificial intelligence technology (AI), cloud services, cloud computing, Internet of Things technology (IoT), combined with 5G technology, are all important technical contents that need to be introduced and used in smart homes, and are integrated with the development process of smart home, so as to unite more devices and transfer and process information, and realize the effective transformation process of information, which brings new possibilities for the development of smart home, makes the services of smart home more intelligent and humanized. According to user behavior, user habits, environmental scenes, and other kinds of information, it can provide actionable intelligence with self-learning, self-adapting, and self-judging, ask users in advance when running. In the face of complex automated operations and scenes, it can remember and learn, and has the ability to judge the identity of users after system authentication, and provide customized services for users with specific identities, fully forming a user-centered smart home model and realizing a truly smart home life. For example, smart homes can accurately predict users' next behavior and implement it in advance through large-scale data collection and processing. The smart kitchen system will start cooking automatically when the user is off work, and the user can eat when he arrives home, eliminating the process of cooking by himself.

Practical and Easy to Operate

The principle of practicality is not only the key of design but also the foundation of design. At present, the smart home has the trend of functional integration, and there are more and more functions, but some of them are the wishful thinking of designers, the practicality is not high. Redundant functions increase the difficulty of product operation, which leads to a worse user experience. The complicated use process is easy to make people exclude or even reject, then these functions become a decoration and meaningless. Therefore, practicality and ease of operation are the key factors for users to psychologically accept smart homes. In order to bring users a good user experience, the product must be functional, simple, have clear control, and meet the user's habits.

Focus on Humanized Design

The concept of humanized design focuses on the diversity of people and the design of smart home products according to their behavioral habits, psychological needs, and physiological structure. At the same time, designers should pay full attention to the needs of users of different ages.

Users of different age groups have different lifestyles and behavioral habits, so the smart home systems are also diverse. For example, children's smart homes should focus on entertainment elements (Figure 10), and smart audio-video systems and VR entertainment systems, etc., can be installed. At the same time, children are in the formative stage of thinking, so the entertainment system should have the correct value guidance, such as smart early education products. Some smart seats should be adjusted according to the growth of children to correct their sitting posture. Young people's smart home is mostly practical and comfortable, and they are accustomed to the automatic cooking and cleaning functions. Smart homes for the elderly are mostly health care, such as wearable smart products that record the blood pressure and heart rate of the elderly from time to time and transmit all kinds of information to various smart home products through Internet of Things technology. In case of abnormalities, the smart home system will take an emergency call service to inform the hospital and children, so that action can be taken the first time. Some elderly people may have visual or hearing impairment or less mobility, so when choosing smart home devices, it is important to consider that these devices should have strong voice recognition capability.



Source: Baidu pictures.
Figure 10: Versa tiles.

Advocate Energy Saving

At present, smart home products are being updated more and more quickly, and people abandon the original ones in order to pursue the latest technology to meet their daily needs. The life cycle of the products will be shorter and shorter, which makes the cost and power consumption of smart homes relatively large. In order to make more people choose a smart home, broaden the market and achieve sustainable development of smart homes, designers should try to extend the life cycle of smart home products. For example, smart home products can automatically download the latest system to achieve independent optimization of the product, at the same time, reduce energy consumption and power consumption while ensuring its performance. Under the current concept of green development, the energy-saving development of smart home products will become a trend in the future because it not only protects the environment but also helps to reduce costs. Through the design of a smart home, precise control of home appliances and other devices can be realized so as to reduce residential energy consumption. For example, smart windows and smart curtains can greatly help to make rational use of natural light and effectively reduce the frequency and duration of artificial light use. According to the indoor thermal environment and other conditions, the ventilation and temperature systems in smart homes provide users with a suitable temperature and humidity while avoiding the waste of heat and providing a feasible solution for home energy saving.

Unify Industry Standards

Currently, the most significant problem of a smart home is the lack of uniform standards in the manufacturing and production process. Each smart home manufacturer has its own manufacturing standard, and the relevant smart systems can only be used in its own products. With the gradual popularization of smart homes and the individual needs of users, this problem limits the choice of smart home products for users and hinders the development of the smart home industry. Therefore, it is necessary to establish basic services for cross-platform interconnection, realize the mutual cooperation between products of different platforms, and achieve the unification of smart home application standards. In this way, users will have a wide range when choosing smart home products, rather than being limited to one. Build a perfect interconnection system and truly realize "whole house intelligence."

There are various different smart home products in the market, and due to different protocols among enterprises, the user's terminal control system can only operate specified types of products. At this stage, some enterprises have started to produce smart home series products, taking Xiaomi Smart Home as an example. It has realized information integration and management among various types of smart home products based on IoT technology. Users can control Xiaomi speakers by voice through the voice interactive control system, and then realize the intelligent control of the rest of the smart home products, and also realize the control of all Xiaomi smart home products through the mobile app, which has initially built a smart home suitable for users to live in. In the future, the development of smart homes is bound to develop towards the standardization of protocols so that only one app can control all kinds of smart homes.

CONCLUSION

With the rapid development of science and technology, the emergence and application of IoT provides technical support for the development of smart home, extending and expanding the home space, integrating the home as one for leisure, entertainment, relaxation, and life, which can make a pleasant and comfortable experience for the mind and senses. The smart home has become one of the needs of home life. And with the application of IoT technology, there will be more home devices connected to IoT. IoT will become a complex system that is both simple and unimaginable, and the possibilities of those devices integrated with IoT will be unlimited. The diversity of smart home products builds all kinds of different types of the smart home that change the original lifestyle of users. With the arrival of the 5G era and the deep development of smart homes, the combination of IoT technology and the smart home system can better enhance the intelligence level of home life, make the smart home system more perfect, provide a more convenient and effective life experience, and build a harmonious development between people and smart home, which is the future development direction of the smart home.

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