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The Impact of 5G Wireless Technology on Smart Home Automation Systems: A Review of Recent Trends and Applications

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Abstract

Smart Home Automation Systems (SHAS) have become increasingly popular in recent years, offering homeowners convenience, security, and energy efficiency. However, the current generation of wireless technology, such as 4G LTE, has speed, latency, and connectivity limitations, which can hinder the performance of smart home devices. With the introduction of 5G technology, there is a potential for significant improvements in the functionality and reliability of SHAS. However, some challenges must be addressed to realize the benefits of 5G in smart homes fully. To investigate the impact of 5G on SHAS, a comprehensive literature review was conducted to gather information on the current state of the art in smart home technology and the potential benefits of 5G. Additionally, interactive sessions were held with industry experts and stakeholders to gather insights on the challenges and opportunities presented by integrating 5G in smart homes. The data collected was analyzed to identify key trends and issues related to the impact of 5G on SHAS. The findings of this study indicate that 5G technology has the potential to revolutionize SHAS by providing faster speeds, lower latency, and improved connectivity. This can enable more seamless integration of smart devices, enhance the user experience, and enable new applications and services in smart homes. However, some challenges must be addressed, such as security concerns, interoperability issues, and the need for infrastructure upgrades to support 5G technology in smart homes. Hence, manufacturers should prioritize the development of 5G-compatible smart devices to ensure seamless integration with 5G networks. Also, service providers should invest in infrastructure upgrades to support 5G technology in smart homes.

Keywords: Smart devices, Sensors, Actuator, Smart home automation, 5G, Microcontroller.

1 | Introduction

Smart Home Automation Systems (SHAS) is a unique strategy, approach, or framework for using electronic equipment to operate or regulate a process while minimizing the need for human intervention. The idea of

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developing an automation system for a house or business is becoming more and more popular due to its many advantages. Researchers and industrialists are attempting to create cost-effective and efficient automatic systems that can monitor and regulate various machinery, such as air conditioners, lighting, and fans, according to needs. Automation minimizes waste and uses water and power more efficiently while reducing waste. The development of automation technology has made life for humans easier, cosier, and less taxing in every area. With a smart home automation system, you can monitor and operate your household appliances from anywhere globally using a smart laptop or mobile device. These days, automated systems are favoured over manual ones [1–4].

The Internet of Things (IoT) enables connections between people and things at any time, location, and with anybody, ideally over any network and service. Another significant use of IoT technologies is automation. It is the process of monitoring energy usage and managing the environment in workplaces, educational institutions, and museums using various sensors and actuators that regulate humidity, temperature, and lighting. SHAS has garnered significant attention due to the advancements in communications technology. Home automation systems use the IoT to link and control household gadgets through SHAS. IoT technology-connected sensors and household appliances can communicate independently with little to no human input. With the help of a smart home automation system, we may simplify duties in and around our living spaces, such as monitoring lights, fans, doors, heat, humidity, and airflow [5–7]. Attaran and Attaran [8] and Sarraf [9] observed that since the first 1G system was released in 1981, cellular wireless networks have advanced significantly. A new mobile generation emerges roughly every ten years. Through four or five generations of technological revolution and evolution over the past thirty years—namely, the development of 1G, 2G, 3G, and 4G networking technologies—the mobile sector has revolutionized society.

We now have mass-market mobile phones thanks to 1G. Global interoperability, dependable mobile phone service, and the ability to send SMS texts were all made feasible by 2G. 3G enabled high-speed data transfer, enabling us to download content from the Internet. The general public now has widespread access to online platforms and high-speed mobile internet services because of 4G's notable data capacity and speed improvements. Attaran [10] also reported that 5G technology will be the most potent cellular wireless network with incredible data capacities, unlimited call volumes, and boundless data broadcasts. 1G-Cellular Networks in Analog NTT introduced Japan's first commercially automated 1G cellular network in 1979, and Bell Labs followed suit in the US in 1984. 1G networks were solely intended for voice communication and were built on analog protocols with a speed of only 2.4 Kbps (1 kilobit = 1000 bits). Using several cell sites and transferring calls across sites while the user moved between cells during a conversation were made possible by 1G. However, 5G offers an innovative design for diverse services beyond the existing 4G Long Term Evolution (LTE). The fifth-generation (5G) network represents the next major phase of mobile telecommunications standards, with a speed of 1–10 Gbps (1 Gbit = 1000 Mbit). It is anticipated that 5G systems will be available by the end of 2019. Amazing data capacities and limitless data transmission are provided by 5G technology in the newest mobile operating systems. Additional characteristics of 5G networks include improved mobile broadband, dynamic low latency, increased bandwidths, mobility focused on devices, simultaneous redundancy, and dependable links between devices [11–13].

2 | Home Automation System

The advent of digital information technology has brought about swift transformations in human lives. Users' interest in using smart home technologies has grown recently. Using the 5G capabilities, the technology connects numerous devices and enables home automation, monitoring, and many other features. 5G-based technology and IoT make it possible to integrate different systems and gadgets in the house so they may function as a cohesive unit. This facilitates users' ability to manage and keep an eye on several systems and devices from a single platform, such as an app for a smartphone [14–16]. With only a few clicks, the user may interact and operate a variety of devices while it displays and reports the status of the connected devices. These technologies entirely enable domestic appliances' automation, preserving and cutting down on energy use and enhancing user comfort. Early examples of intelligent home systems included Bluetooth technology.

However, there was a restricted region in which the technology could be accessed and operated. By bypassing this limitation, the 5G offers users a fantastic method to use their phones from anywhere globally to manage any equipment in their home. The many communication technologies utilized in today's home automation systems are WiMAX, ZigBee, Wireless LAN (Wi-Fi), and the Global System for Mobile Communication (GSM). GSM technology is a cellular technology frequently employed because of its broad coverage and growing customer base. 5G-based SHAS has been implemented widely to enable intelligent communication between objects and humans without requiring physical interaction. The problem of forgetting to turn off electrical equipment or gadgets has become widespread. Appliances may be turned on when the owner is at work or away from home and finds it difficult to get home [17–19].

3 | System Design

The ATMEGA328P microcontroller, smartphone, flame sensor, PIR sensor, relay module, gas sensor, and GSM modem make up the hardware architecture of the created smart home automation system. *Fig. 1* illustrates a typical smart home using a suggested system (SHS). The intended system sends incoming text messages over the cellular network from the phone user to the 5G modem. The Arduino Uno board, built around an ATMEGA328P microprocessor configured to operate household appliances and provide security through an alarm, receives the orders from the 5G modem in text format. Additional inputs to the system's design come from sensors and system messages that are sent to mobile phones via 5G modems and contain information about the state of household appliances [20–22]. The design of the key parts of the smart home automation system is illustrated in *Fig. 1*.

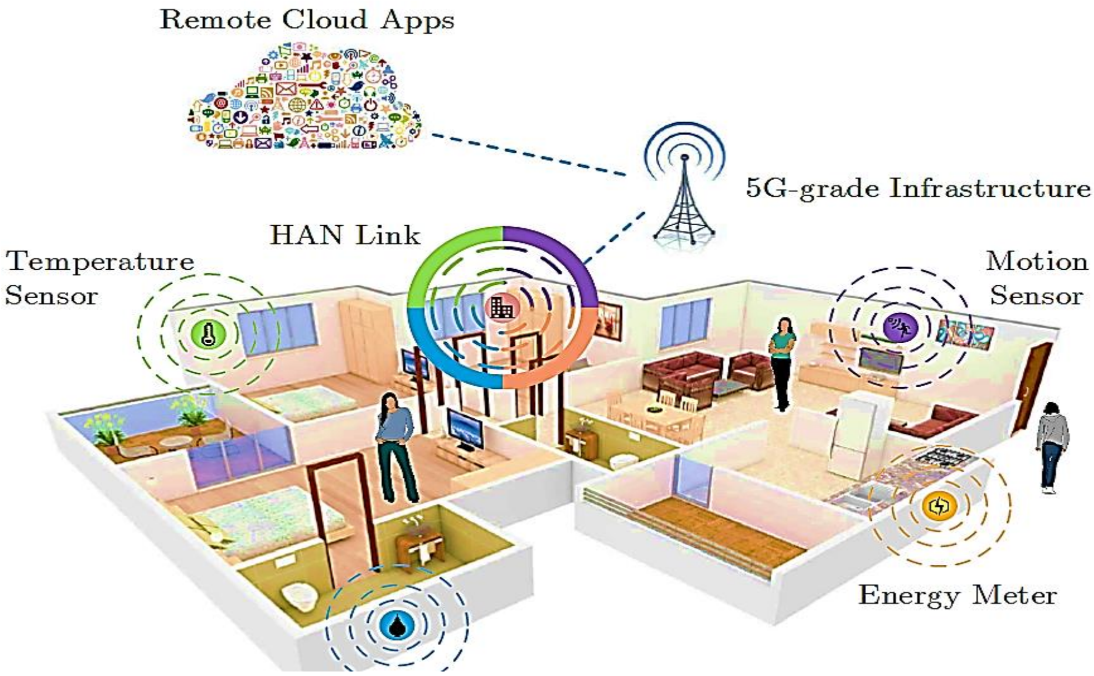

Fig. 1. In-house deployment of smart meters/sensors.

4 | Key Components of Smart Home Automation Systems

Majeed et al. [23], Jacobsson et al. [24], and Singh et al. [25], in the investigative report, observed that SHAS has become increasingly popular in recent years, offering homeowners the convenience and efficiency of controlling various aspects of their homes with just a few taps on a smartphone or voice commands (see *Fig. 2*). These systems consist of several key components that work together to create a seamless and integrated smart home experience. These components include the following:

I. The central hub or controller: this device serves as the brain of the system, connecting all the different smart devices in the home and allowing them to communicate. The hub is typically connected to the home's Wi-Fi network and can be controlled through a mobile app or voice assistant.

II. Smart devices: this includes smart thermostats, lighting, security cameras, and door locks. These devices are equipped with sensors and connectivity features that allow them to be controlled remotely and automated based on preset schedules or triggers. For example, a smart thermostat can adjust the temperature in the home based on the homeowner's preferences or occupancy sensors, while smart lighting can be programmed to turn on and off at specific times or in response to motion.

III. Sensors and actuators: sensors detect changes in the environment, such as motion, temperature, or humidity, and send this information to the central hub for processing. These sensors can also monitor various aspects of the home, such as temperature, lighting, and security, and send this information to the central hub for processing. With 5G wireless technology, these sensors can communicate with each other and the central hub at much faster speeds, allowing quicker response times and more efficient operation. On the other hand, actuators can physically control other devices, such as opening and closing doors or adjusting blinds [26], [27].

IV. Software: the SHAS also incorporates Artificial Intelligence (AI) and Machine Learning (ML) algorithms. These algorithms can analyze the data collected by the home's sensors and devices and make decisions and adjustments based on this data. With 5G wireless technology, these algorithms can process and analyze data in real time, allowing for more accurate and timely responses to changes in the home environment.

V. Voice control technology allows homeowners to control various aspects of their homes simply by speaking commands. With 5G wireless technology, this voice control technology can be even more responsive and accurate, as the faster speeds and lower latency of 5G networks allow for quicker processing of voice commands.

SHAS consists of several key components that create a seamless and integrated smart home experience. From the central hub and smart devices to sensors and actuators, each component plays a crucial role in making the home smarter, more efficient, and more convenient for the homeowner. With the ability to customize and expand the system as needed, SHAS offers a flexible and scalable solution for modern homeowners looking to embrace the benefits of smart technology [25], [28], [29].

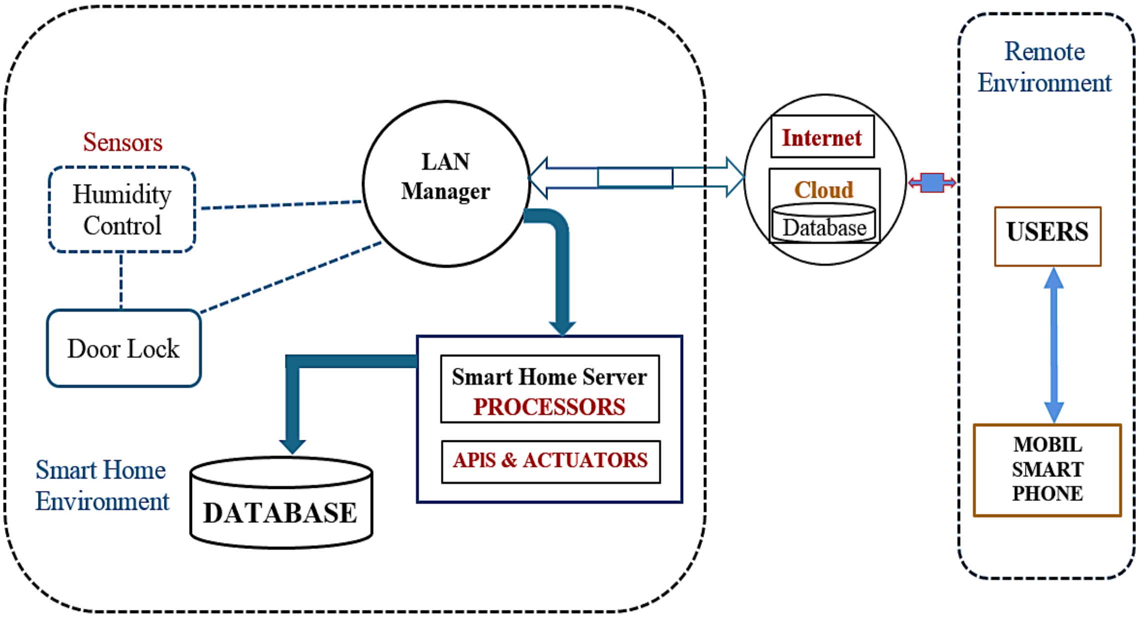

Fig. 2. Smart home paradigm with optional cloud connectivity.

5 | Methodologies of SHAS

SHAS employs various methodologies to ensure smart, efficient, and seamless control of various aspects of the home. This methodology provides convenience, energy efficiency, and enhanced security while ensuring scalability, flexibility, and ease of use. Some of these methodologies include:

GSM-based home automation system

The system uses a PIC16F887 microcontroller to operate household appliances. It utilizes GSM to manage the appliances. This method is based on SMS. GSM is utilized because of its excellent security, coverage, and availability. SMS codes are the primary means of controlling household appliances. The GSM network allows for transmitting AT instructions, which manage household electronics. The gadget may also send messages to the user via SMS. However, this approach may result in extra expenses for the SMS. The gadget cannot be controlled by the user using any UI. An M2M system is what is described as the system. To communicate, it uses GSM. General Packet Radio Service (GPRS), SMS, and Dual Tone Multi-Frequency (DTMF) are among the M2M possibilities that GSM provides. This system decides to employ AT (attention) instructions in addition to SMS messages. Its central command hub is a PC. The PC has an inbuilt GSM dial-up and communication system. The implementation is done in Visual C++. The PC executes the necessary commands after decoding the SMS messages it receives. It's a system that can be configured to meet the needs of the specific application [30–32].

Bluetooth based home automation

Bluetooth technology can be used to control home appliances. The PC client is linked to the Bluetooth module, sensor circuit, and pulse width modulation circuit via USB.

Sensors and actuators control the circuit. It can receive various orders via Bluetooth thanks to the linked Bluetooth module. Bluetooth devices can quickly identify and scan other devices. It might also be possible to confirm that the devices operate as intended. Additionally, the gadget has a temperature sensor and an illumination sensor that may turn on lights when there is little light outdoors. The fact that Bluetooth has a range of only roughly 10 meters presents another issue with this strategy. One advantage of this system is that it is inexpensive and easy to integrate into an existing system [33–35].

ZigBee based home automation

ZigBee wireless communication technology can be utilized to automate your home. The system uses voice recognition and a PIC microcontroller for this. A microphone is used to record the voice prompts. They're examined and contrasted with a voice storage device. The PIC microcontroller sends commands to the receiver over ZigBee. The receiver device has another PIC microcontroller that can process the command. Relays control the matching appliances. The low-range communication technology of ZigBee is a drawback of this setup. As such, remote access from far-off locations is hindered.

Moreover, the speech recognition feature may become challenging to use. One more characteristic of this system is the inclusion of a smoke detector. When it detects smoke, it sends an alert to the user's integrated mobile phone number [36], [37].

Wireless control systems

According to ElShafee and Hamed [38], Park et al. [39], and Al-Dabbagh & Chen [40], independent devices that are already in the home or office can be connected and combined to form a cooperative network to construct wireless communication systems. Various technologies, such as Arduino and Raspberry Pi, are integrated into the system. *Fig. 3* illustrates how such a system is configured. The universal Plug-and-play capability provides the user with transparent device network access. The system makes use of the Open Service Gateway Interface (OSGi). The appliances are connected via a number of networking technologies. The user application layer uses web browsers, pocket PC programs, and a central console. Speech-based commands can also operate the appliances. Advanced features like device connection and discovery are available. The entire system is implemented using the Linux operating system. The system can also have complex control modules added to it. These control modules are capable of identifying trends and gathering information. The universal plug-and-play system uses several standard protocols to ensure interoperability. The main advantage of the system is its compatibility. Another advantage of the service is its dynamic discovery feature. It can also be applied to service sharing.

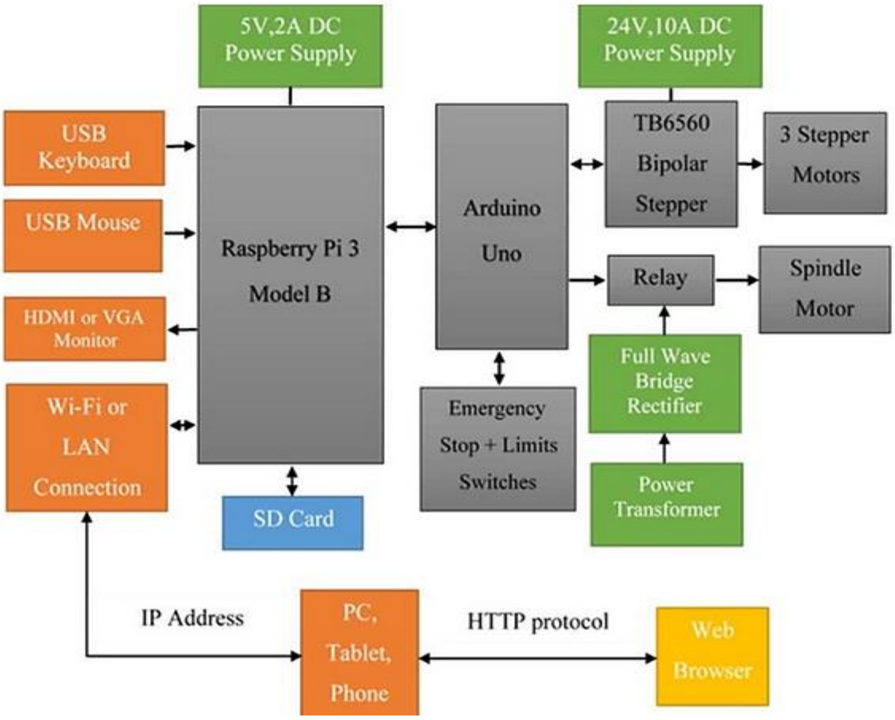

Fig. 3. Block diagram design of a typical wireless controller system.

Z-wave technology

In recent years, home automation has gained popularity as more and more homeowners look to modernize their living areas with smart technologies. Z-Wave wireless communication technology is one of those smart platforms that facilitates easy management and automation of several home appliances. It is one of the major technologies propelling this trend. Z-Wave is a proprietary technology for smart home and office automation services that combines sensors and actuators over radio frequency. More linked devices are being added to people's homes as the popularity of IoT grows. In Z-wave, a wide variety of sensors, lightbulbs, plugs, locks, heating controls, and similar devices communicate with one another. With this technology, every device is managed and controlled by a controller. Low-energy radio waves are used in their operation to transfer data between devices [41], [42]. Z-wave protocol is a radio frequency standard that operates in the industrial, scientific, and medical bands. It is based on the ITU G.9959 definition. It is designed for low-bandwidth data transmission uses, like alarm systems, home automation, and security sensors. Z-wave uses FSK and Gaussian Phase Shift Keying (GPSK) modulations to transmit on frequencies of 868.42 MHz (Europe) and 908.42 MHz (United States). Three layers make up the Z-wave system: radio, network, and application. Together, they build a strong and dependable network that allows multiple nodes and devices to connect simultaneously. The stack covers the Z-wave PHY, MAC, transport, network, and application layers (see *Fig. 4*).

In the context of this technology, reporting devices are called sensors (they report information by sending a digital or analog signal), controlled devices are called actuators (they switch digital or analog signals), and controlling devices are called controllers (they control other Z-wave devices - remote controls, USB sticks, and IP gateways). Thermostat controls, motor control, electrical display, electrical dimmers, and electrical switches [28], [43], [44].

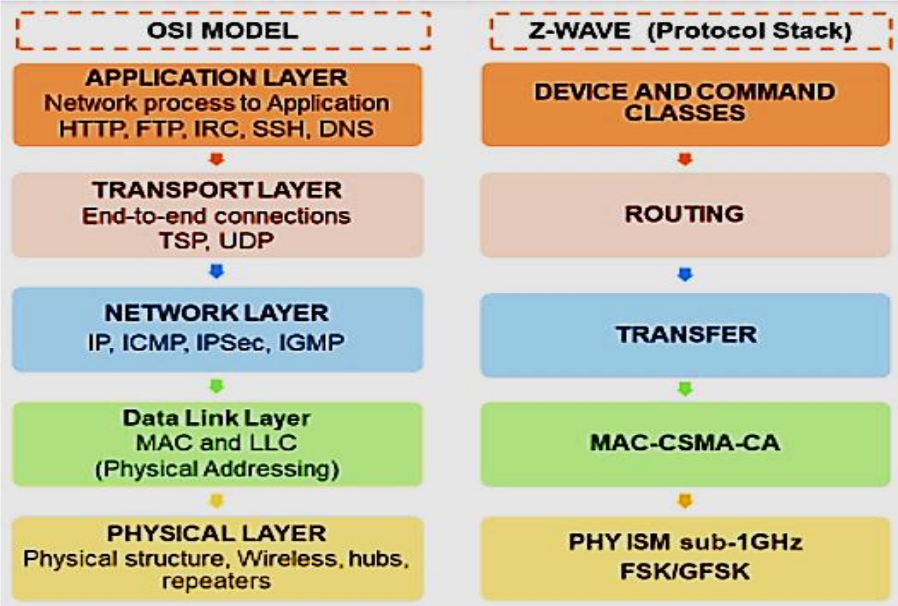

Fig. 4. Diagram of Z-wave protocol stack.

6 | Advantages of 5G Deployment in SHAS

Čaušević & Medić [45], Alam et al. [46], and Arjmandi [47] reported that the advent of 5G wireless technology has brought about significant advancements in various industries, including SHAS. This next-generation technology offers the following advantages that have the potential to revolutionize the way we interact with our homes:

I. One of the key advantages of 5G technology in SHAS is its ability to provide faster and more reliable connectivity. With speeds up to 100 times faster than 4G, 5G enables seamless communication between devices in the home, allowing for real-time monitoring and control. This increased speed and reliability ensure that smart home devices function efficiently and respond quickly to user commands.

II. 5G technology offers lower latency (as seen in *Table 1*), which is crucial for SHAS. Low latency ensures that devices can communicate with each other instantaneously, reducing delays in response times. This is particularly important for applications such as security cameras and smart thermostats, where real-time monitoring and control are essential.

III. The increased bandwidth of 5G technology allows more devices to be connected simultaneously without compromising performance. This means homeowners can add more smart devices to their automation systems without experiencing network congestion or slowdowns. This scalability is essential for accommodating the growing number of connected devices in modern homes.

IV. 5G technology in SHAS enhances security features. Security and privacy concerns have become increasingly important with the rise of IoT devices in the home. 5G offers improved encryption and authentication protocols, making it more difficult for hackers to access sensitive information or control smart devices remotely.

V. Hence, the impact of 5G wireless technology on SHAS is undeniable. From faster and more reliable connectivity to lower latency and enhanced security features, 5G offers many benefits that can significantly improve the functionality and efficiency of smart homes. As this technology continues to evolve, we can expect to see even more innovative applications and advancements in the field of home automation.

Table 1. Comparison of 1G to 5G wireless communication [48].

S.No	Parameter	1G	2G	3G	4G	5G
1	Deployment year	1970	1993	2001	2009	2018
2	Technology	AMPS	GSM	WCDMA	LTE, WiMAX	MIMO, mm-waves
3	Access framework	FDMA	TDMA CDMA	CDMA	CDMA	OFDM
4	Switching type	Circuit switching	Switching type	Packet switching expect for air interface	Packet switching	Packet switching
5	Internet service	No	Narrowband	Broadband	Ultra-broadband	Wireless World Wide Web
6	Bandwidth	2.4KHz	25 MHz	25GHz	100 MHz	30 GHz
7	Data rates	2 kbps	64 kbps	2Mbps	1Gbps	>1Gbps
8	Advantages	Voice calls	Multimedia features	High security, international roaming	High-speed handoffs, global mobility	Extremely high speeds and low latency

7 | Drawbacks of 5G Deployment on SHAS

Pons et al. [49], Gures et al. [50], Alsharif and Nordin [51], and Tezergil and Onur [52] opined that the rapid advancement of technology has led to the development of 5G wireless technology, which promises faster speeds and lower latency for SHAS. While this new technology provides many benefits, it also has the following disadvantages and drawbacks that need to be addressed:

I. One of the main drawbacks of 5G wireless technology on SHAS is the potential for increased security risks. With the increased speed and connectivity of 5G networks, there is a higher risk of cyber-attacks and hacking. Hackers could potentially gain access to sensitive information or control over smart home devices, putting the privacy and security of homeowners at risk.

II. Another disadvantage of 5G technology is the potential for increased electromagnetic radiation exposure. The higher frequency bands used in 5G networks have raised concerns about the health effects of prolonged exposure to electromagnetic radiation. This is particularly concerning for SHAS, which relies on wireless communication.

III. Implementing 5G technology in SHAS may also increase homeowners' costs. The infrastructure required for 5G networks, such as new antennas and equipment, can be expensive to install and maintain. This could result in higher costs for homeowners looking to upgrade their smart home systems to take advantage of 5G technology.

IV. Deploying 5G networks may also lead to compatibility issues with existing smart home devices. Many current smart home devices are designed to work with Wi-Fi or Bluetooth technology and may not be compatible with 5G networks. This could result in homeowners needing to replace or upgrade their existing devices to fully utilize the benefits of 5G technology.

While 5G wireless technology offers many advantages for SHAS, several disadvantages and drawbacks must be considered. From security risks and health concerns to increased costs and compatibility issues, homeowners should carefully weigh the pros and cons of implementing 5G technology in their smart home systems. It is essential to address these drawbacks and find solutions to mitigate the potential risks associated with 5G technology to realize the full benefits of SHAS.

8|Key Functions of SHAS

Pirbhulal et al. [53], Stolojescu-Crisan et al. [27], and Khan et al. [54], in their investigative studies, observed that SHAS has become increasingly popular in recent years, offering homeowners the ability to control various aspects of their homes with just a few taps on a smartphone or voice commands to a virtual assistant. These systems are designed to make life easier, more convenient, and more efficient for users, with the following key functions that set them apart from traditional home automation systems:

I. One of the key functions of SHAS is its ability to connect and control multiple devices and systems within the home. This includes everything from lights and thermostats to security cameras and door locks. By integrating these devices into a single, cohesive system, users can easily monitor and control them from a central hub, such as a smartphone app or a smart speaker.

II. Another important function of SHAS is its ability to learn and adapt to the user's preferences and habits. Using AI and ML algorithms, these systems can analyze data from sensors and devices to anticipate the user's needs and adjust settings accordingly. For example, a smart thermostat can learn when the user is typically home and adjust the temperature accordingly, saving energy and increasing comfort.

III. SHAS also offers the ability to create custom routines and scenes. This allows users to automate multiple devices with a single command, such as setting the lights to dim, the thermostat to adjust, and the music to play when it's time for bed. These routines can be triggered manually or scheduled to run at specific times, making creating a personalized and efficient home environment easy.

IV. Security is another key function of SHAS, with many systems offering advanced encryption and authentication protocols to protect user data and privacy. In addition, these systems often include features such as remote monitoring and alerts, allowing users to keep an eye on their homes even when they're away. Some systems even offer integration with third-party security services, such as monitoring companies or emergency responders, to provide an extra layer of protection.

Hence, SHAS incorporates a wide range of functions that can enhance a home's convenience, comfort, and security. By connecting and controlling multiple devices, learning and adapting to user preferences, and offering customizable routines and scenes, these systems provide a seamless and efficient way to manage the modern home. With advanced security features and the ability to integrate with third-party services, SHAS offer a comprehensive solution for homeowners looking to make their lives easier and more connected [27], [54].

9|Applications/Uses of 5G Network in SHAS

Minango et al. [55], Lopes et al. [56], and Sindhushree and Naik [57] observed that the advent of 5G technology has revolutionized the way we interact with our surroundings, particularly in the realm of SHAS. With its lightning-fast speeds and low latency, the application of the 5G network has opened up a plethora of possibilities for enhancing the efficiency and convenience of smart home devices. These applications include the following:

I. One of the primary applications of the 5G network in SHAS is in the realm of security. With the high bandwidth and low latency of 5G, smart home security cameras can stream high-definition video in real-time, allowing homeowners to monitor their property remotely with unparalleled clarity and responsiveness. Additionally, the low latency of 5G enables faster response times for security alerts, ensuring that homeowners can take immediate action during a security breach.

II. Another critical application of the 5G network in SHAS is in the realm of energy management. With the ability to connect a multitude of smart devices to the network simultaneously, 5G enables homeowners to monitor and control their energy usage in real-time. This allows for more efficient energy consumption, saving costs and reducing environmental impact.

III. The application of the 5G network in SHAS enables seamless connectivity between various smart home devices. With its high bandwidth and low latency, 5G ensures that smart devices can communicate with each other quickly and efficiently, leading to a more cohesive and integrated smart home ecosystem. This allows for greater automation and customization of smart home systems, enhancing the overall user experience.

IV. 5G network also finds its applications in SHAS in energy management. By automating the control of heating, cooling, and lighting systems, homeowners can reduce their energy consumption and lower their utility bills. For example, SHAS can adjust the temperature settings based on the homeowners' preferences and schedule, ensuring optimal comfort while minimizing energy waste. Additionally, SHASs can integrate with smart meters to provide real-time energy usage data, allowing homeowners to track and analyze their consumption patterns.

The applications and uses of 5G networks in SHAS are vast and varied (as seen in *Fig. 5*). From enhancing security and energy management to enabling seamless connectivity between smart devices, 5G technology has the potential to revolutionize the way we interact with our homes. As the technology continues to evolve and expand, we can expect to see even more innovative applications of 5G in the realm of SHAS [56], [57].

Fig. 5. Applications of 5G wireless communication [48].

10 | Operation Principles of 5G Network in SHAS

With the rapid advancement of technology, SHAS has become increasingly popular among consumers. These systems allow homeowners to control various appliances in their homes through the use of connected devices and sensors. One of the key technologies enabling the seamless operation of SHAS is the fifth-generation (5G) network [58], [59]. The operation principles of 5G networks in SHAS are crucial for ensuring the smooth functioning of these systems. 5G networks are designed to provide high-speed, low-latency connectivity, essential for supporting the large number of devices typically found in a smart home. This high-speed connectivity allows real-time communication between devices, enabling them to work together seamlessly to provide homeowners with a more efficient and convenient living experience.

One of the critical principles of 5G networks in SHAS is network slicing. Network slicing allows for creating of virtual networks within a single physical network, each tailored to the specific needs of different applications. This enables SHAS to have dedicated network resources optimized for their requirements, ensuring reliable and efficient communication between devices. Edge computing is another vital principle of 5G networks in SHAS [60]. Edge computing involves processing data closer to where it is generated rather than sending it back to a centralized data center. This reduces latency and improves the responsiveness of SHASs, allowing for faster decision-making and more efficient operation of connected devices.

Furthermore, the use of advanced technologies such as AI and ML in 5G networks can further enhance the operation of SHASs. These technologies can analyze data from connected devices to identify patterns and trends, enabling predictive maintenance and proactive management of home automation systems. Thus, the operation principles of 5G networks play a crucial role in allowing the seamless operation of SHAS. By providing high-speed, low-latency connectivity, network slicing, edge computing, and advanced technologies such as AI and ML, 5G networks can support the efficient and reliable operation of SHASs, ultimately enhancing the living experience for homeowners [61–63].

11 | Concerns on Electromagnetic Radiation Exposure from the Higher Frequency Bands Used in the 5G Network on SHAS

Korkmaz et al. [64], Rowley [65], and Weller & McCredden [66], in their investigative studies, observed that with the advent of 5G technology, there is a growing concern about the potential for increased electromagnetic radiation exposure from the higher frequency bands used in SHAS. While 5G promises faster speeds and more reliable connections for smart devices in the home, there are concerns about the health implications of increased exposure to electromagnetic radiation. One of the main concerns with 5G technology is the use of higher frequency bands, such as millimeter waves, which have shorter wavelengths and higher energy levels than the lower frequency bands used in previous generations of wireless technology. These higher frequency bands have the potential to penetrate deeper into the body and cause more harm to human health. Studies have shown that exposure to electromagnetic radiation can have a range of negative health effects, including increased risk of cancer, neurological disorders, and reproductive issues. While the scientific community is still divided on the exact health risks associated with electromagnetic radiation, a growing body of evidence suggests that long-term exposure to high levels of electromagnetic radiation can have detrimental effects on human health.

In the context of SHAS, the potential for increased electromagnetic radiation exposure is particularly concerning. SHASs rely on interconnected devices that communicate wirelessly, often using radio frequency signals. With the introduction of 5G technology, these devices will be operating at higher frequencies, potentially increasing the level of electromagnetic radiation in the home environment. Proponents of 5G technology argue that the increased speed and reliability of 5G networks will outweigh any potential health risks associated with higher levels of electromagnetic radiation. They also point to the fact that regulatory bodies such as the Federal Communications Commission (FCC) have set limits on the amount of electromagnetic radiation that devices emit, ensuring that exposure levels remain within safe limits. However, critics of 5G technology argue that these regulatory limits may not be sufficient to protect human health, especially in the long term. They point to studies that have shown adverse health effects from exposure to even low levels of electromagnetic radiation and argue that the cumulative impact of increased exposure from multiple devices in the home could pose a significant risk to human health [67], [68]. While 5G technology holds great promise for the future of SHAS, there are legitimate concerns about the potential for increased electromagnetic radiation exposure from the higher frequency bands used in 5G networks. As technology continues to evolve, it is essential for regulators, manufacturers, and consumers to carefully consider the potential health implications of increased exposure to electromagnetic radiation in the home environment [68], [69].

12 | Recent Trends with Key Milestones on the Deployment of 5G Wireless Network Technology on SHAS

Recent trends in deploying 5G wireless network technology on SHAS have shown significant advancements and key milestones. Integrating 5G technology into SHAS has revolutionized how smart homes operate, providing faster and more reliable connectivity for a seamless user experience. One of the key milestones in deploying 5G on SHAS is the increased speed and bandwidth capabilities that 5G networks offer. With speeds up to 100 times faster than 4G networks, 5G enables SHAS to process and transmit data more efficiently, leading to quicker response times and improved overall performance. This enhanced speed and bandwidth have allowed for the development of more sophisticated smart home devices and applications, further enhancing the automation and convenience of smart homes. Another milestone in deploying 5G on SHAS is connections' improved reliability and stability [70–72].

5G networks are designed to handle a higher volume of connected devices simultaneously, making them ideal for the interconnected nature of smart homes. This increased reliability ensures that smart home devices can communicate with each other seamlessly, creating a more cohesive and integrated home automation system. Furthermore, the low latency of 5G networks has been a game-changer for SHASs, allowing for real-time communication and control of smart home devices. This low latency enables smart home users to monitor and adjust their devices remotely with minimal delay, enhancing the overall user experience and convenience of smart home automation. Hence, deploying 5G wireless network technology on SHAS has brought significant advancements and key milestones that have transformed how smart homes operate. With faster speeds, increased reliability, and low latency, 5G has paved the way for a more efficient and seamless smart home experience. As the technology continues to evolve, we can expect to see even more innovative developments in the integration of 5G into SHASs, further enhancing the automation and convenience of smart homes [72–74].

13 | Conclusion and Recommendation

The deployment of the 5G network in SHAS has been a topic of interest, with this study exploring the recent trends and applications and the potential benefits and challenges associated with this field of research. Based on the findings from this study, it can be concluded that the integration of the 5G network in SHAS has the potential to revolutionize how we interact with our homes and devices. One of the key findings from this study is that the 5G network offers significantly higher data speeds and lower latency compared to previous generations of wireless technology. This means that SHASs can operate more efficiently and respond to user commands in real time, leading to a more seamless and intuitive user experience. Additionally, the increased bandwidth of the 5G network allows for more devices to be connected simultaneously, enabling a greater level of automation and control within the home.

Furthermore, this study revealed that deploying a 5G network in SHAS can enhance the security and privacy of smart devices [75]. With features such as network slicing and edge computing, the 5G network can provide a more secure and reliable connection for smart devices, reducing the risk of cyber-attacks and unauthorized access. This is crucial in ensuring the safety and confidentiality of personal data collected by smart devices in the home. However, it is essential to note that concerns are also associated with deploying a 5G network in SHAS. One of the main concerns identified in this study is the potential for increased electromagnetic radiation exposure from the higher frequency bands used in the 5G network. While research on the health effects of the 5G network is still ongoing, policymakers and industry stakeholders need to address these concerns and implement appropriate safety measures to protect consumers.

14 | Recommendations

The deployment of 5G networks in SHAS has been a topic of interest in recent years, with many conventional studies exploring this technology's potential benefits and challenges. Based on the findings obtained from this study, the following recommendations are suggested to guide the successful implementation of 5G networks in SHAS. Stakeholders in the SHAS industry need to prioritize security and privacy considerations when deploying 5G networks. One of the findings of this study implies that increased connectivity and data transfer speeds of 5G networks can pose significant security risks if not properly managed. Therefore, SHAS providers must implement robust security measures, such as encryption protocols and authentication mechanisms, to protect sensitive data and ensure system integrity. SHAS providers need to consider the interoperability of devices and systems when deploying 5G networks.

Findings from the literature indicate that the proliferation of IoT devices in smart homes can lead to compatibility issues, which can hinder the seamless operation of SHAS. To address this challenge, SHAS providers should adopt open standards and protocols that enable different devices to communicate and work together effectively within the network. Studies in literature have demonstrated that deploying 5G networks in SHAS can significantly enhance the performance and responsiveness of smart home devices, such as security cameras and thermostats. However, to fully leverage the benefits of 5G technology, SHAS providers must ensure that their infrastructure can handle the increased data traffic and processing demands. Therefore, it is recommended that SHAS providers invest in infrastructure upgrades to support the high bandwidth and low latency requirements of 5G networks.

SHAS providers must engage with regulatory bodies and policymakers to address any legal and regulatory challenges associated with deploying 5G networks. That is, there is a need for SHAS providers to comply with data protection laws and regulations, such as the General Data Protection Regulation (GDPR), to safeguard consumer privacy and ensure the ethical use of data in SHAS. Therefore, by collaborating with regulators and policymakers, SHAS providers can navigate the complex legal landscape and ensure compliance with relevant laws and guidelines. Hence, deploying 5G networks in SHASs presents a promising opportunity to enhance the functionality and efficiency of smart home devices. By following the recommendations outlined in this study, SHAS providers can successfully integrate 5G technology into their systems and deliver a seamless and secure smart home experience for consumers.

Authors' Contributions

Michael Bassey, conceptualization, development, and analysis. Francis Etang, investigation and delivered resources. Aniekan Ikpe, supervision, guidelines, investigation, and delivered resources. All authors have read and approved the manuscript.

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Data Availability

Data can be shared upon request even if it is mentioned that the data is in the article.

Conflicts of Interest

The authors declare that they have no competing interests.

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