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# The Role of ML, AI and 5G Technology in Smart Energy and Smart Building Management

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**Abstract:** With the help of machine learning, many tasks can be automated. The use of computers and mobile devices in "intelligent" buildings may make tasks such as controlling the indoor climate, monitoring security, and performing routine maintenance much easier. Intelligent buildings employ the Internet of Things to establish connections among the many components that make up the structure. As the notion of the Internet of Things (IoT) gains attraction, smart grids are being integrated into larger networks. The IoT is an integral part of smart grids since it enables beneficial services that improve the experience for everyone inside and individuals are protected because of tried-and-true life support systems. The reason for installing Internet of Things gadgets in smart structures is the primary focus of this investigation. In this context, the infrastructure behind IoT devices and their component units is of the highest concern.

**Keywords:** 5G technology; sustainability; smart building facilities; machine learning; management building environment

## 1. Introduction

When compared to 4G, 5G is expected to increase data transfer speeds by a factor of 20, from 1 Gbps to 20 Gbps. Users will be able to access data and information considerably more rapidly as a result of this innovation. This is a significant advancement, particularly for the military, emergency services, and urgent response teams. However, better battery solutions will be required since 5G-enabled devices will experience significant battery life loss due to the use of high-powered signal boosters.

This increase in speed comes with several significant drawbacks. The use of higher frequency bands was one of several changes made to the 5G radio. This aided in increasing speed and decreasing latency. These higher frequency bands are only useful for very short distances because they are quickly blocked by objects such as buildings. They are excellent for industrial automation, but operators will need many more 5G radios in urban areas to cover the same area, and the technology is still insufficient for rural areas.

Cyber-attacks will undoubtedly increase in probability due to 5G connections' greater speeds. As a result, hackers will find it simpler to target more gadgets that are linked to the internet through the frail linkages among them. Although 5G will increase the availability of IoT devices, this danger is anticipated to increase as well. The security risks associated with the Internet of Things multiply as their quantity increases, making it more difficult to manage them. Hackers may be able to obtain and extract data, including personal information, considerably faster than in the past if a device is linked to a 5G network.

Individuals' communication skills have significantly changed due to the rapid advancement of technology. This will likely soon change many cities' appearance. Due to the increasing convergence of new data streams, improvements in sensor technology, and novel findings in building materials research, buildings will be substantially more intelligent in the future. Several cities' most famous buildings have been destroyed to make room for new construction. Shortly, scientists expect that cities will experience considerable changes as technology and social necessities change; it is this continual change that puts pressure on urban architects and designers to adapt. By 2050, it is projected that between 66 and 70 percent of people on Earth will live in cities [1]. The impact of urbanization on towns, neighborhoods, infrastructure, and the environment has been the subject of several studies [2] regarding the maintenance of dependable, energy-efficient services without compromising the ease and enjoyment of their users. Although other academics have looked at this subject of study from various angles [3], it remains a popular subject. An implementation plan is being created, and it will need a wide range of resources and expertise. In the past, individuals were responsible for developing smart homes, neighborhoods, and communities. This is mainly because of the Internet's present constraints and the fact that the sensor networks established in infrastructure, cities, and buildings are not seamlessly integrated [4]. Fifth-generation (5G) wireless networks are now being implemented worldwide. By connecting devices and equipment from various manufacturers, 5G technologies seek to improve service quality, network capacity, and systems throughput for a range of vertical applications [5]. In addition, 5G mobile communication has improved the data rates to 1Gbps as compared to 10–100 Kbps of 2G GSM technology [6–10].

Over the past two years, 5G technology has seen considerable use in the construction industry as researchers in academia and business have examined the possible advantages of 5G technology. Several companies, such as IBM and Intel, have already created and marketed smart buildings as an example of 5G's competitive advantage and bright future [11]. Understanding how 5G technology might be applied to produce smart buildings is essential. Although a few brief studies on 5G-based smart buildings have been conducted, the implementation of 5G technology in building design has not yet, to the best of our knowledge, been the subject of a thorough investigation [12]. Given the increased interest in researching this subject, a critical first step for academics studying civil, building, and architectural engineering might be an analytical examination. It is crucial to understand the technological needs of the construction industry because the 5G sector is primarily focused on technology and employs a top-down method in which consumers are not the most significant stakeholders. This will improve a building's intelligence and accelerate the advancement of 5G technology. In addition, the development of 5G technology has been greatly helped by the spread of intelligent mobile devices and the rise of communication technologies. Therefore, it might be a technical facilitator for a wide range of fresh economic opportunities and industrial uses.

The development of 5G technology might also make it possible for various devices to speak with one another. Global businesses and consumers should prepare for significant changes once 5G wireless networks are accessible. The Internet of Things (IoT), which produces vast amounts of data, is the foundation for the applications for smart cities [13]. The potential 5G and AI applications in smart buildings are presented in Figure 1.

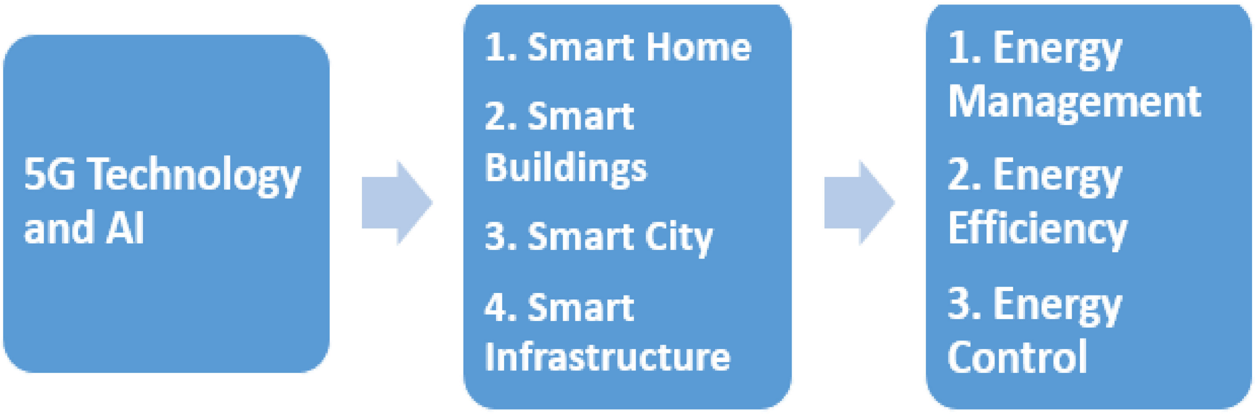


**Figure 1.** The 5G and AI applications in smart buildings [14].

Finding the best way to proceed may be challenging, given the volume and complexity of this data. The most modern techniques for analyzing massive datasets include deep reinforcement learning (RL), machine learning (ML), and artificial intelligence (AI). Analyzing these datasets might make it easier for organizations to follow their long-term goals [15] and make the best decisions [16] feasible. Such methods' accuracy can also be improved by adding more training data. As a result, people may learn more and make better decisions [17]. According to [18], there has been a notable rise in the use of cutting-edge methods for big data analysis to build smart cities. In the meantime, technology makes several strategies for improving commercial buildings' energy efficiency possible and people already use their cell phones to control their kitchens, lights, washer, and dryer. Businesses will succeed as the economy shifts from conventional industry silos to integrated digital ecosystems by utilizing the Services 4.0 (IMDA, 2020) principles which call for services to be end-to-end, efficient, empathetic, and predictive of customer demands. The built environment value chain will change for developers, architects, planners, builders, equipment and technology suppliers, property managers and their security partners, and cleaning and maintenance as IoT devices, interactive media (AR/VR), and cloud-based technologies become more widespread. The next major advancement in the development of international communications will be fifth-generation (5G) technology, also referred to as "beyond 2020 communication", which has been used successfully in many places throughout the world. Faster mobile broadband, reliable low-latency communication services, and extensive machine-to-machine connectivity are the three main concerns for 5G networks [19].

The previous generation of technology, 4G, has a slower data transfer rate, i.e., the maximum download speed is 100 M bit/s. However, as 5G develops, it will be possible to use more intelligent, sophisticated equipment. A 5G network's main job is to make it easier for users to communicate with one another. To guarantee that the proper control is applied for each case, 5G may also be changed in real-time. Fifth-generation technology can be used in many industries to deliver data quickly [20]. The assured latency of less than 1 millisecond with 5G makes it perfect for time-sensitive programs. Additionally, it has less strict latency constraints for applications that do not need a quick response.

In summary, 5G could be used in a range of contexts that demand strict process controls and, thus, the durable network and network reliability can be reduced for applications that do not rely on this process. In addition, massive amounts of data can be processed instantly with 5G technology but the system can still manage a small quantity of data if that is all that is necessary. One of the most significant 5G applications nowadays is the IoT. Many industries and businesses use it and it has recently been very well-received. By December 2020, there may have been up to 24 billion devices with Internet of Things capabilities.

## 2. Literature Review

In recent years, smart grids, smart homes, and energy efficiency have all gained popularity. The author of [14] emphasized that SBs (Smart Buildings) are aware of both themselves and the grid. The foundation of SB's communication with SG is real-time demand response. The authors of [15] drew attention to the fact that the three main qualities that distinguish an SB from structures from prior generations are responsiveness, adaptation, and flexibility. In [16], the authors made clear the need for SBs to have enough knowledge and comprehension of the local populace as well as the surrounding environment to function effectively; this will help to improve the inhabitants' experience in an SB that has been tailored to their environment. Additionally, an SB is a complete system in and of itself rather than a collection of several discrete settings. As a result, an SB's interior spaces may interact with one another and provide a more stable environment. According to [17], the primary focus of the SB concept is integration, which refers to the integration of the building's system as well as the method by which the building is built and put into operation. The author also emphasized the need of integrating information both vertically and horizontally so that both those who manage the amenities and those who reside in the building may access it. According to [18], "buildings that integrate and account for intelligence, enterprise, control, and materials and construction as an entire building system, with adaptability, not reactivity, at the core, to meet the drivers for building progression: energy and efficiency, longevity, and comfort and satisfaction." Additionally, an SB is not concerned with how the structure is designed; rather, it is concerned with how the facility will work after it is finished. A structure must be able to fulfill the purpose for which it was intended as well as be adaptable enough to change its design and make improvements in response to the demands of its users in order to be deemed sustainable. Effective facilities management (FM) is critical to achieving SB goals since O&M costs make up roughly 60% of the total expenses spent by owners [21]. The SB's goals are based on adopting effective facilities management practices (SFM). The management of smart facilities uses the most advanced and cutting-edge information technology and machinery to achieve the goals of smart buildings. With increased visibility, practical insights, and cost savings, SFM is empowering owners and tenants [16–18]. Building information modeling (BIM), the Internet of things (IoT), artificial intelligence (AI), digital twins (DT), augmented reality (AR), virtual reality (VR), mixed reality (MR), Construction Operations Building Information Exchange (COBie), and data analytics are some of the technologies that enable this management. Most of these technologies rely on cloud computing, high bandwidth connections, and low latency connections to provide improved outcomes. However, before these cutting-edge technologies can be deployed on a larger scale, several challenges presented by the current wireless networks (such as Wi-Fi, 4G, and 3G) that allow these features need to be resolved [22].

According to [23], buildings in Pakistan waste 40% of all energy supplied due to inefficient control and management, so a lot of work has been focused in the academic world on the development of energy-efficient building designs. However, the convenience and ease of the people using the building should not have to be compromised in the name of a smart building. Therefore, a solution that uses less energy while maintaining the residents' ease must be developed. This has led to the creation of building energy management systems for commercial buildings to track and improve energy efficiency.

The statistical relationship between heating and cooling energy use, external factors, and occupancy levels was initially studied by [24]. They concluded that energy is wasted significantly in even "green" buildings. To solve this problem, they developed a technique for autonomously controlling power using mobile phones with GPS and several other services. Without wireless Internet, the model could not have been made. The technology keeps track of the phone's location and uses that information to determine how far away the building is. An energy strategy will be initiated if the distance exceeds a given range, i.e., the air conditioner might be set up to shut off automatically to save electricity. To determine how well the IoT-based model worked, the results were measured using an electrical meter and then analyzed in several different ways.

A system for only one home was created by [25]. This system included elements from the Internet of Things and novel software architectures. In addition to the corresponding software systems, we developed a technique for installing IoT devices in residential buildings. Each product was tested using a variety of sensors, smart plugs, actuators, intelligent meters, and a universal home gateway (UHG).

According to [23], energy-efficient construction is increasingly required in developing countries. The United States Environmental Protection Agency (USEPC) wants to cut the energy use in commercial buildings by 20% between 2020 and 2030. Additionally, the government has set a target of reducing pollution by 33% by 2025. Industries can save a lot of resources and improve the state of the environment by attaining these goals with the use of the Internet of Things (IoT). Because they can easily share information, smart meters are necessary for smart grids. It is a brand-new energy meter that continuously tracks energy use and reports on crucial data, including frequency, voltage, and phase angle. Additionally, they have wireless communication capabilities to exchange diagnostic data [26].

Authors reported analyses of some of the most effective strategies and procedures that have been used or created to handle the issue of energy management. They said that customers' continued reluctance to see the advantages of EMS and make investments in it, owing to a lack of technical expertise and financial concerns, is one of the most important factors limiting energy management systems. As a result, a significant amount of research is still required in order to make the EMS trustworthy and helpful for the intended client group. Much more study is necessary, and concerns concerning the system's reliability should also be thoroughly studied for modes of operation that are independent of the grid [27].

A new strategy for optimal grid frequency regulation (FR) in an interconnected power system where regional ac grids and an offshore wind farm are linked via a multi-terminal high voltage direct-current (MTDC) network. In a linked power system, this innovative approach seeks to provide optimum grid frequency management. As part of the suggested technique, decentralized H controllers are created in order to synchronize the functioning of synchronous generators and MTDC converters. As a consequence, optimum power distribution across linked ac grids is realized, and frequency variations within each grid are minimized [28].

An optimum framework for the aggregation of residential needs was provided. RLAs serve as LSE agents within the framework of this paradigm. Their job is to distribute DRRs quickly and effectively across home appliances without compromising residents' comfort levels. They also strategically compensate people for their involvement, which may boost participation in incentive-based DR programs [29].

### *2.1. Smart Building System and 5G Communication Technology*

In 2020, a significant portion of the population will have access to 5G services which confirms the need to create national-scale 5G smart cities. One of the essential elements of developing smart cities is a smart edge system based on 5G and other technologies for collaborative intelligence. This is because these networks have distinct qualities that enable them to meet the wide range of needs of smart cities. Intelligent building requires the use of both attempted methods and trying to cut technology to achieve its objectives. Intelligent buildings are created employing the latest communication and control technologies to give people a healthy and comfortable atmosphere.

Chinese academics define "smart buildings" as those that employ government communication and technological systems, successfully manage their data, and make money for their owners. These structures benefit the environment and the safety, efficiency, and utility costs of individuals who live or work there [30]. The following trends have been identified through smart building research during the last 32 years:

1. An increase in uniformity and transparency across the control network. Industrial Ethernet systems are used in various industries due to their adaptability. In the future, Fieldbus systems will operate similarly to Ethernet networks.
2. Increasingly, intelligent buildings in the future will use wireless connection technology. Rapid developments in wireless LAN technology in recent years suggest that wireless communication technologies may soon be widely integrated into intelligent buildings.
3. Video transmission technologies over internet networks will be used more frequently in intelligent buildings.
4. Because intelligent buildings can use multiple networks, system integration, and data aggregation technologies are set to become essential research priorities to ensure the network structure is perfect, functions are not duplicated, investment expenses are kept to a minimum, resources are consolidated, and information is transmitted effectively.

The major cases of 5G applications in smart buildings and infrastructures are presented in Table 1.

**Table 1.** The major cases of 5G applications in smart buildings and infrastructures.

| References | Building Type | Major Use Case | Related Building System |
|---|---|---|---|
| [11] | Business | IOT | End-user applications for building maintenance. |
| [6] | Hospital | ML | Occupational localization to choose the most efficient path for healthcare departments. |
| [25] | Residential | 5G | Smart grids for homes. |
| [31] | Hospital | AI. | Using AI for drug discovery applications. |
| [32] | Hospital | Machine learning | All connected devices' health and welfare are continuously compared and monitored by the health-Guard system. |
| [33] | Smart Factory | ML | Faster data transmission and exchange process while minimizing data loss, drops in system performance, delays in real-time processing, and difficulty managing several machines and items from a single protocol. |
| [34] | Smart Industry | AI. | Predictive maintenance and extensive data management. |
| [35] | Smart Factory | ML | Business participants can distribute network functionalities among several network domains. |

### *2.2. Advantages of 5G*

#### 2.2.1. Smarter Network Operations

Users will have access to the 5G networks' breakneck transfer speeds, extremely low latency, highly dependable experiences, extremely high connection densities, high traffic densities, and extremely high mobility. Networks will become more spectrum- and energy-efficient as a result, as well as more cost- and energy-effective to operate and maintain.

#### 2.2.2. Intelligent Prediction and Usage Control

With the availability of big data and higher processing abilities, the control over users' lives is expected to increase. We can predict a significant increase in the intelligence of our sensing and judgment systems with the emergence of 5G technology. The new capabilities of 5G technology, such as real-time perception and the ability to analyze user characteristics (such as preferences, geographic location, network context, and terminal status), will be very beneficial to businesses in creating technological solutions that guarantee the effective deployment of data-driven network functions and resources.

#### 2.2.3. Flexible Network Operations

The development of 5G technologies depends on customer feedback. As a result, it has been created to meet the needs of both mobile internet users and IoT organizations. Access networks can be connectors or identities using base-station networks due to 5G technology.

A lightweight access network topology can be developed to make the system easy to install and maintain. The development of new network services and simplifications will be permitted on data networks to ensure that system and forwarding operations run smoothly and that network control is adaptable.

#### 2.2.4. Decreased Operational Cost

The highly adaptable data packets in 5G communication networks make them simple to modify and customize. In addition, complex wiring, bridges, or underground pipes are not required throughout the construction process. This lowers the long-term costs of building and maintaining the network's infrastructure. Owing to the flexibility of 5G technologies, the cost of operation is expected to decrease if we ignore the establishment cost. The system is flexible enough to handle changes in demand or difficulties brought on by the collaboration of several users. The technique is easy to use and adapt and speeds up tasks while cutting expenses.

#### 2.2.5. Higher Reliability of Operations

Data transmission technology utilized by industrial automatic control systems is very reliable. Examples of well-established and reliable wired communication technology include Ethernet, hubs, and switches. The method used by 5G networks for data verification is channel coding. Additionally, 5G technology can determine whether data was correctly transmitted or not at all; in this case, the issue will resolve on its own.

### *2.3. Features of a 5G-Enabled Smart City*

A smart building comprises various interconnected systems, controllers, sensors, and devices. A network of remote-controllable communications exists in the intelligent building [36]. A sensor must confirm that all windows are closed for the air conditioner to work. If there is a considerable temperature change, this sensor would be trigged and as a result, the air conditioner and windows will communicate after the sensor turns on the air conditioner. Even if they can work together, air conditioning and window control systems are often made by different companies. A mechanism for integration must be devised to enable independent management and operation of the building.

### *2.4. Challenges of Achieving 5G-Based Smartness in Pre-Existing Buildings*

The 5G network has been developed to support a population that is becoming more mobile and connected. Additionally, it will make it easier for creative business models to flourish. However, the major challenge is enabling 5G-based operations in pre-existing building architecture as the architecture is not modifiable once it has been developed. Hence, transformation is a huge challenge when developing a smart city and embedding an already-developed building with it. The amount of data that must be transported and mobile broadband traffic will considerably expand in the upcoming years as mobile broadband is used in a variety of contexts and settings. New, scalable services will be developed with the help of 5G and it will support the growth of current mobile broadband services. This means that a wide range of use, from those that require a small amount of data to those that need a vast amount of data quickly, will be supported by 5G [37]. To give residents of smart buildings a comfortable and easy life, a variety of networked devices, systems, controllers, and sensors are needed. Therefore, a network of remote-controllable communications exists in intelligent buildings [36]. The major goals of intelligent buildings are presented in Table 2.

**Table 2.** The major goals of intelligent buildings.

| References | Goals | Requirements | Descriptions |
|---|---|---|---|
| [38] | Location-based services | Check up on the precise location of the targets. | The location of personnel and other building resources is tracked to increase the effectiveness of service delivery. |
| [21] | Energy efficiency | Communicate with the environment (building-to-building or building-to-infrastructure). | Without compromising on safety or quality of life, the building's energy use should be optimized to become a Net Zero Building. |
| [39] | Facility management | Ensure that the devices and equipment in the building can communicate. | Maintenance work and the coordinated use and management of building resources can reduce operating and maintenance expenses and time. |
| [11] | Indoor occupant ease | Recognize the members' behavior patterns. | Optimizing climatic conditions based on user preferences may increase health and productivity. |

### *2.5. Possible Solution for Embedding Pre-Existing Buildings' Architecture with Smart Cities*

As was already mentioned, smart buildings have a lot of benefits, but they are hard to use and embrace widely due to their drawbacks. The authors of [40] described a smart system with a central system that connects to building subsystems and communicates with them using open protocols in real-time. This method can reduce the energy used compared to a traditional BMS system that uses many communication protocols. The possibility of smart cities and smart buildings cooperating is covered in another study [3]. The study hypothesized a smart building in a smart city and looked at how artificial intelligence might be used in the future to control both smart cities and smart buildings. Privacy issues were discussed in [41] because smart technology in facilities puts people's safety and privacy at risk. Because of this, they suggested using digital rights management to safeguard intellectual property online. Customers give the utility information about their monthly consumption in exchange for discounts or other benefits, but they must agree to the utility's closer examination of their data. The authors of [4] examined many variables, including the fact that this technology is still relatively new, that have contributed to the poor utilization of BMS; BMS and its applications are only poorly known.

There is not enough energy for everyone; most infrastructure parts need to be maintained often and the economy is in bad condition. Many people learn about BMS by looking at the financial and energy efficiency benefits of integrating it into business buildings. This would encourage commercial and public developers to use this technology. The authors of [16] developed a model for an energy-saving smart building that is enabled by the Internet of Things (IoT). Applying the simulation with the suggested smart building model and management system was challenging for several reasons, including a lack of suitable tools and funding. They suggested testing an energy-saving technology and a management system to operate and monitor the proposed smart building concept. The authors of [42] investigated the difficulties presented by the requirement for sustainable solutions because there are not enough resources and the population is growing, leading to increased utilization of the assets already available. They devised a strategy for linking all intelligent systems in smart homes to the Internet and the cloud of things. The authors of [43] reviewed the research and talked to experts to find the most critical problems with smart buildings. They highlighted issues in technology, society, politics, and economics. Here are a few suggested solutions:

- Once the framework is in place, new technical courses can start immediately.
- Plan for how to split the expense of building infrastructure.
- Use techniques of producing energy that are economical.

- The “Adoption of Intelligent Building Technology in Social Housing Projects” to the grid’s electrical infrastructure has seen more and better investments.
- Affordable smart metros for people on fixed incomes.

In summary, even if there are many problems with intelligent building management, smart buildings can use technological advancements and cost-effective solutions to ensure a sustainable future.

Computer networks called wireless sensor networks (WSNs) are made up of sensor nodes that are linked together and use sensors to monitor their surroundings. A few big, wired sensors made up the earliest sensor networks, but by the late 1990s, this had begun to change [44]. Around the turn of the century, wireless sensor networks became more common as CPUs and radio modules, and sensors all became smaller. These networks cannot securely acquire and send data without a network backbone linking sensor nodes to final devices (gateway). The popularity of self-configuring wireless ad hoc networks has led to the development of wireless sensor networks in the business world. In ad hoc networks, which resemble mesh networks, sensor nodes and endpoints can communicate with one or more of their neighbors and exchange information or instructions without regard to predetermined structures. As a result, multi-hop communication is also made possible in which data is passed from node to node until it reaches its destination. However, this demonstrates how these networks operate unpredictably and dynamically.

The network architecture is different from always-on computer networks since the network infrastructure is not standardized. As a result, nodes can be added to an already functioning system without advance notification. Multi-hop ad hoc networks provide benefits such as being easier to set up, improving the reliability of the connection, and having the capacity to self-heal [45].

A network of connected computers known as the Internet of Things (IoT) can collect, process, and turn real-world data into information that people, organizations, and governments can use. The Internet of Things (IoT) is the network of all connected computers. The most valuable data is generated by combining data from massive pieces of technology with analytics using the Internet of Things platform, which connects devices and things with sensors. Applications for IoT technologies include, but are not limited to, location technologies, communication technologies, cloud technologies, and detection systems. A graphical representation of a WSN is presented in Figure 2.

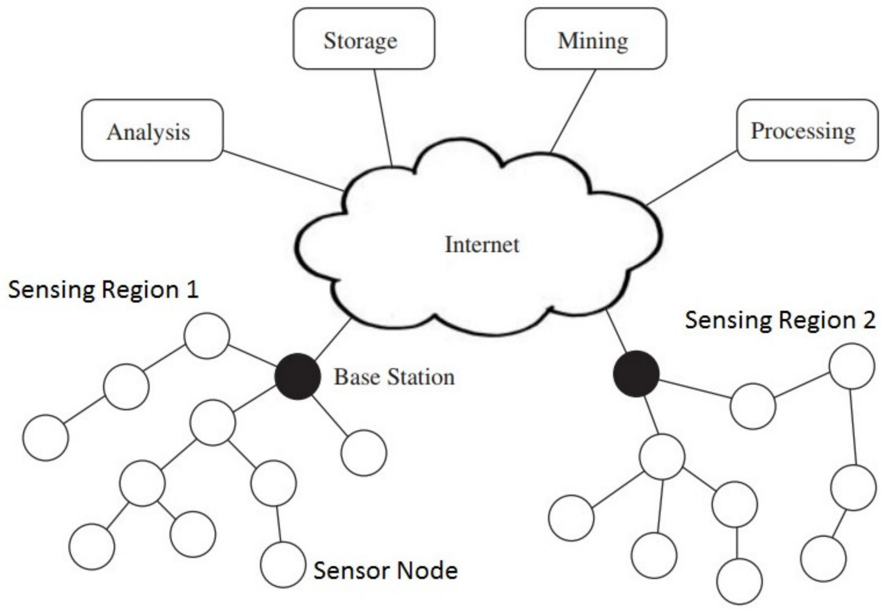


**Figure 2.** Fifth-generation-based WSN architecture [46].

One or more sensor nodes can communicate with one another to form complex network topologies that track various events over the radio. High-frequency, better measurements can be taken without affecting or interfering with the processes being studied. Wireless communication is used to control network architecture and collect sensor data. Every type of data is routed through the network to the command center via a central control point (query system or server). Ad-hoc and multi-hop operation, the flexibility to join sensors, two-way communication, cost-effectiveness, low energy consumption, and self-repair are all features of many current wireless sensor networks [47]. Any measurement can be communicated over wireless sensor networks without revealing the data's context. WSN sensing modules are modular and have numerous open connectors for plugging in digital and analog sensors. This makes it easier to install and communicate with different kinds of sensors. Thermometers, hygrometers, high-precision vibration sensors, and GPS modules are a few of the many types of sensors that can be used. Due to developments in manufacturing, standardization, and the field of micro sensors, microelectromechanical systems (MEMS) can now be used in these systems as small, affordable, and accurate measuring sensors (MST). The architectural requirement for smart buildings is graphically represented in Figure 3.

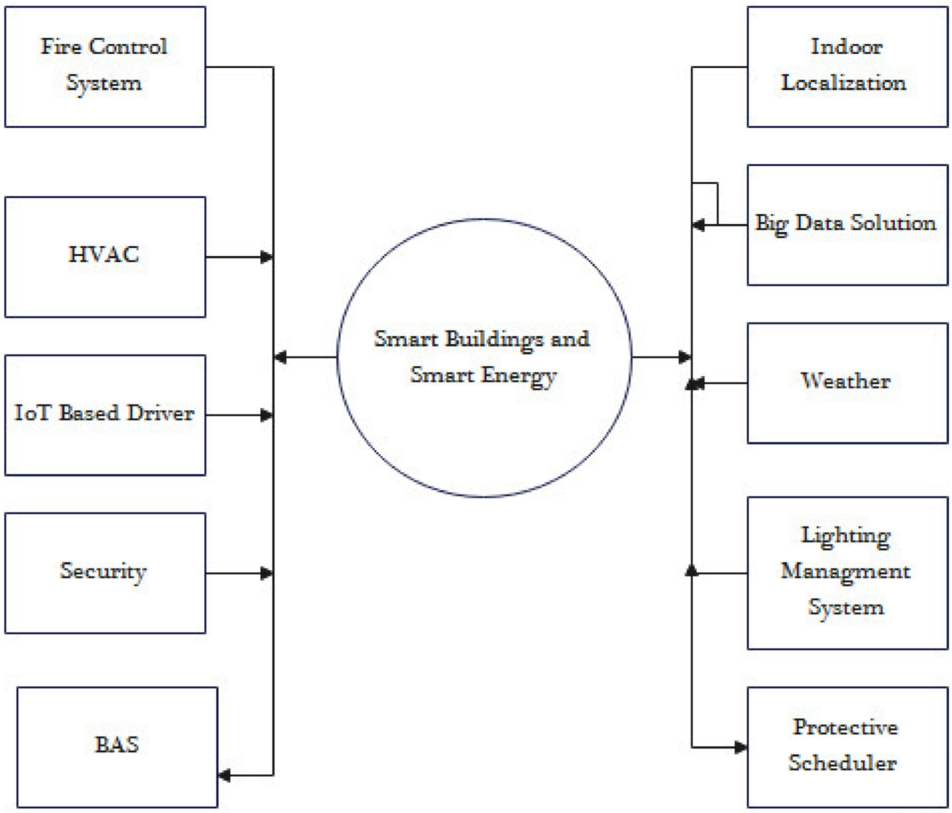


**Figure 3.** Architectural requirements to integrate pre-existing buildings with a smart city.

Due to their requirements, sensor networks are different from other networks. Unique communication protocols and algorithm management that prevents takeover are necessary to meet these objectives. As a result, the effectiveness of a network structure is greatly influenced by each node's capacity for self-organization. Nodes can disappear, and new ones can appear without affecting communication; this keeps the network from breaking down. Client-server architectures, for instance, do not work well in this situation. With event-based solutions, these sensors operate more effectively. An alarm is sent when a sensor goes over a set threshold. Unique cooperation algorithms are needed to communicate these events to the network's self-organizing routing nodes. In other cases, the node's data has been analyzed and used to infer something about the architecture of the network.

Additionally, each sensor in a sensor network has a finite amount of energy, as if these varying requirements were not enough. Therefore, the nodes must work properly and make use of the fewest number of control packages possible. For instance, the node can sleep if there is no activity in the monitored region and only wake up when communication is needed [48].

This intelligent building combines tried-and-true methods with state-of-the-art tools. Modern communication and control technologies are used in constructing intelligent buildings to create enjoyable, easy-to-use, energy-efficient, and environmentally friendly spaces for people to work and live [49]. Chinese academics define "smart buildings" as those that use cutting-edge communication and technology (such as self-monitoring apparatuses), efficiently handle their data, and make money. In the realm of smart buildings, which are all eco-friendly, cost, effective, and energy-saving, the following growth patterns have been observed:

## 3. Architectural Requirements for Integrating Pre-Existing Buildings with a Smart City

The goal of smart cities is to create a more intelligent urban environment by putting together a lot of different kinds of urban infrastructures and making them work together. In this instance, smart cities depend heavily on smart buildings and would not be conceivable without them. People in smart buildings can be assured that AI and the Internet of Things are ensuring their safety. IoT smart buildings use sensor data to minimize energy consumption and increase operational efficiency. Adding Internet of Things devices to smart buildings helps regulate energy use [50]. The Internet of Things (IoT) collects and analyses environmental parameters such as humidity, temperature, and pressure to conserve energy in smart buildings. In smart buildings, Internet of Things sensors monitor and regulate the illumination by turning lights on and off as needed. IoT technologies can improve emergency management and response, improving outcomes in these hazardous situations. The Internet of Things has altered how we think about safety systems by connecting sensors and providing managers, rescuers, and people at risk with real-time data. Utilizing these technologies and taking advantage of recent advancements in smart building projects provides evident benefits, as demonstrated in Figure 4. If structured smart systems had these kinds of applications, they might be more user-friendly and convenient. Smart building and smart energy diagrams are presented in Figure 3.

### *3.1. Automation Systems*

Intelligent building automation systems are required to create to automate and improve resource management in buildings. Scalability issues include managing the existing number of devices and keeping them linked [51]. The time needed to install all sensors directly relates to the overall cost of an Internet of Things system. The BAS keeps track of how each service is doing and alerts the building management to any possible issues.

### *3.2. IoT Based on Indoor Localization*

To locate goods, a hybrid IoT indoor localization technique is needed. A hybrid algorithm is a technique for problem-solving that combines the best features of many algorithms. IoT applications are increasingly requiring sensor-based monitoring and deployment inside and understanding the characteristics of the inside environment significantly improves efficiency [52,53].

### *3.3. Lighting Management System*

IoT-based lighting control is necessary for efficient building lighting management, and businesses have implemented it using various techniques. The development of the Internet of Things (IoT) will be aided by the introduction of visible light communication (VLC) technologies [54]. Many different types of technology have used infrared communication. Because LEDs create visible light, there is a common misunderstanding that they do not emit VLC [51].


**Figure 4.** Big data generators in smart buildings.

### 3.4. Protective Schedulers

Smart plug load controllers in outlets and power outlets may notice and react appropriately when a big load, such as a computer, is drawing electricity from the grid. Plug load schedules can be included in lighting and building management systems (BMS) to simplify operations [55].

### 3.5. Big Data Handling System

Many organizations face considerable challenges when transferring and integrating vast volumes of data. Extensive data databases and conventional databases work together to produce the required results. However, significant data exchange between customers is viewed as a serious issue [56]; big data has raised significant problems concerning the security and privacy of personal information. IoT integration into distributed energy systems boosts energy efficiency while reducing waste. Thus, environmental issues are reduced [14]. Figure 5 shows the sources of big data in smart building infrastructure that need to be stored and handled efficiently.

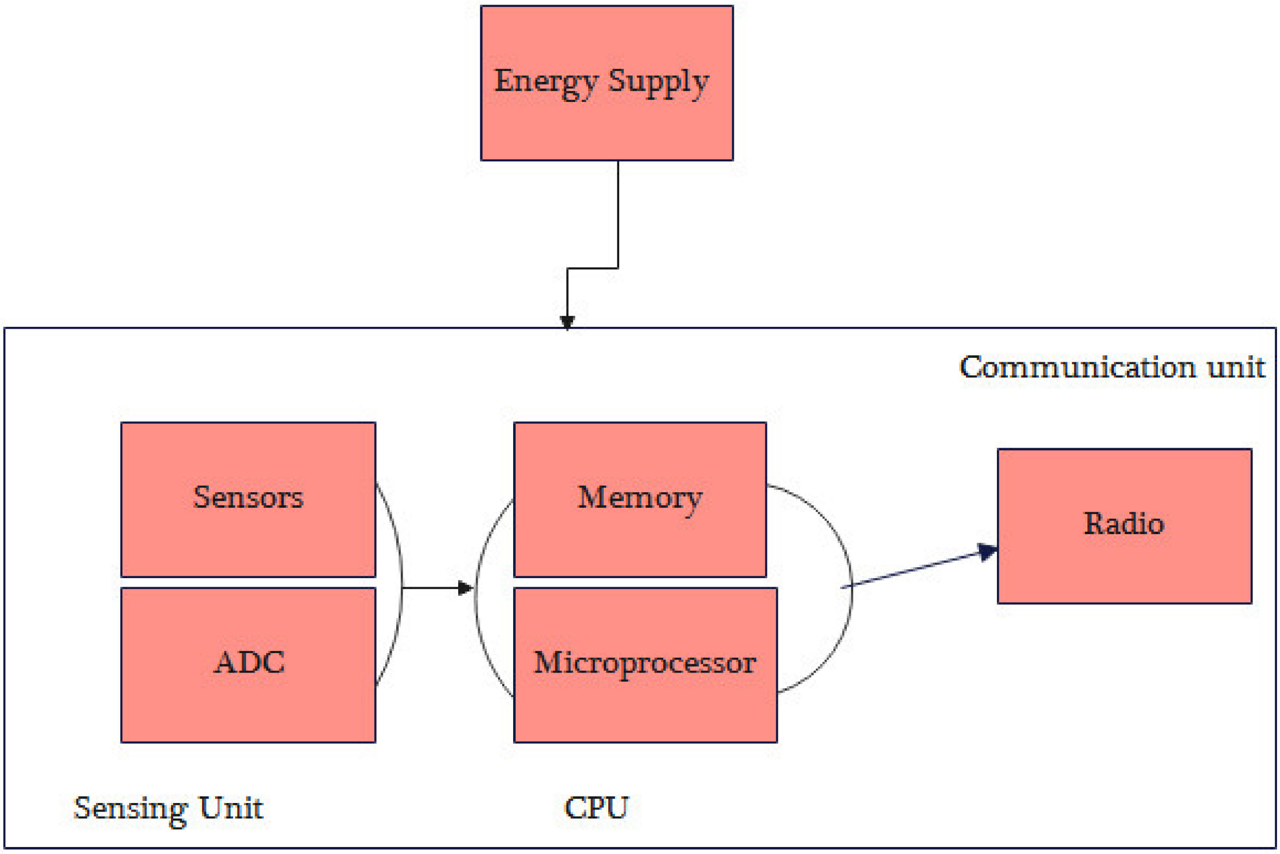


**Figure 5.** The architecture of a sensing unit for smart buildings [57].

### *3.6. Fire Control System*

Only the most advanced fire control systems can provide fire alarms that precisely identify the fire's starting place. In a smart building, apps, the cloud, and wirelessly connectable devices can help avoid fires. Temperature sensors that can recognize smoke alarms and activate them automatically in an emergency can significantly improve fire safety in a smart building. The operation of modern fire protection and alarm systems is handled by highly complex computer networks that include fire detection and emergency communication systems [58,59].

### *3.7. Heating, Ventilation, and Air Conditioning (HVAC)*

Intelligently designed heating and air conditioning systems use sensors from the building automation system to gather data about the environment. The users of a building can modify the temperature and humidity in various spaces using climate control and ventilation systems. The dependability of the facility can be increased by predicting and locating HVAC system defects in advance and so lowering the likelihood of expensive tool failures.

### *3.8. Smart Security Solutions*

The rise of so-called "smart buildings" has brought up significant issues that must be handled to conform to regulations and make places much more comfortable, efficient, and secure. These issues include safety and the choice of an alarm verification service. Businesses cannot create smart buildings with the user in mind without technology. If a natural hazard or cyberattack causes the Internet to go down, people must still be safe inside these structures and be able to carry on regularly [26].

### 3.9. Smart Weather Management

A building's temperature is a key control variable. Because modern facilities can control their temperatures, there is a significant chance to save energy and improve people's comfort. One is more likely to experience a cool summer breeze than a warm winter wind. By monitoring the wind speed, the wind sensor's main job is to determine how much air is moving through the ventilation ducts [60].

## 4. The Use of 5G-Powered AI and Drones to Develop a Facade Inspection System

Fifth-generation and AI-powered façade inspection systems are part of the industry 4.0 standard for smart building infrastructure management. An overview of the industry 4.0 framework for embedding smart building infrastructure is given in Figure 6. The goal is to build a prototype for a drone-based facade inspection system that can take high-resolution photos and videos in real-time. After acceptance, pictures or videos will be sent to a remote AI-powered defect detector for review. The embedding scenario for 5G and VR in education is presented in Figure 7.

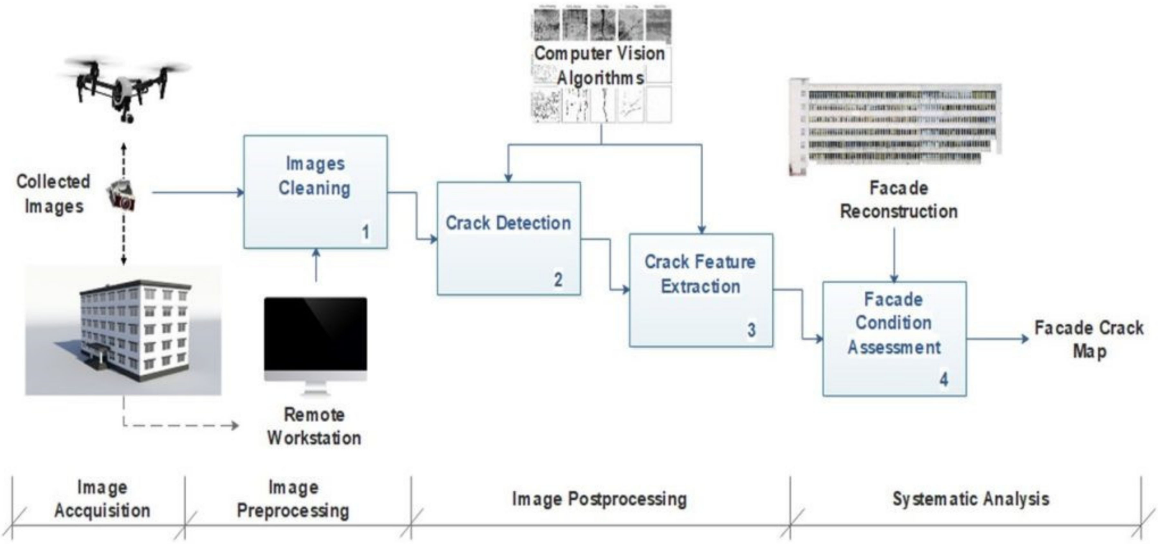


**Figure 6.** Workflow of a 5G-powered façade inspection system using AI and drones [6].

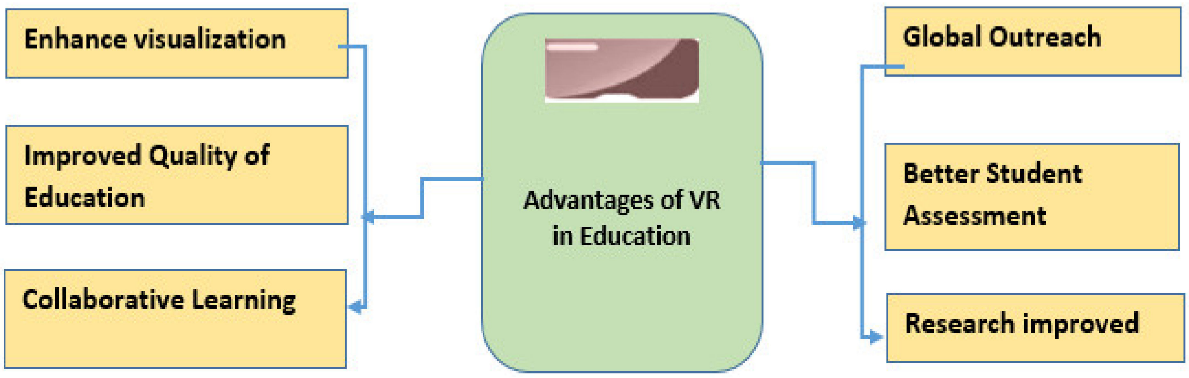


**Figure 7.** Fifth-generation and virtual reality (VR) in smart education [6].

This innovation will completely overhaul conventional manual inspection systems. Not only will this improve the safety of those working at heights, but it will also enable more comprehensive inspections to be carried out. In turn, this will generate significant changes to workflow and operational effectiveness throughout the building inspection industry.

*Industry 4.0 Smart Educational Framework Based on Augmented Reality, Virtual Reality, and BIM Remote Educational Training*

Big data, the Internet of Things, augmented reality (AR), and virtual reality (VR) will become more common in all businesses as the country moves closer to industry. Institutes of higher learning (IHLs) must continue to create the next generation of leaders and a skilled labor force supported by trying to cut technologies to realize its goal of becoming a leading digital economy.

A smooth education platform built with VR and AR technologies, utilizing a 5G network for faster transmission and a remote device to run immersive and engaging classes, could digitally transform and fundamentally alter education, integrating technology into teaching and assisting the country in realizing its vision. The embedding scenario for 5G and virtual reality in education is presented in Figure 7.

Every future project and facility manager need to be able to measure things accurately. The measuring domain is where students apply their understanding of basic building practices, components, and methods. Measurement difficulties significantly negatively impact students' ability to succeed in their final years of school and the workplace [61]. However, the 2D hardcopy drawings used to teach building measures are difficult for students to read and understand. They find it challenging to estimate the amount of construction work that needs to be done because of this and students must understand both 2D and 3D graphics to do the calculation. Students must also be familiar with construction techniques to understand the construction process fully. Most NUS students lack mechanical and construction competence. Using enhanced teaching materials and approaches, NUS can promote more effective ways to educate and learn about measuring and construction technologies. The industry 4.0 framework for digital education technologies is presented in Figure 8.

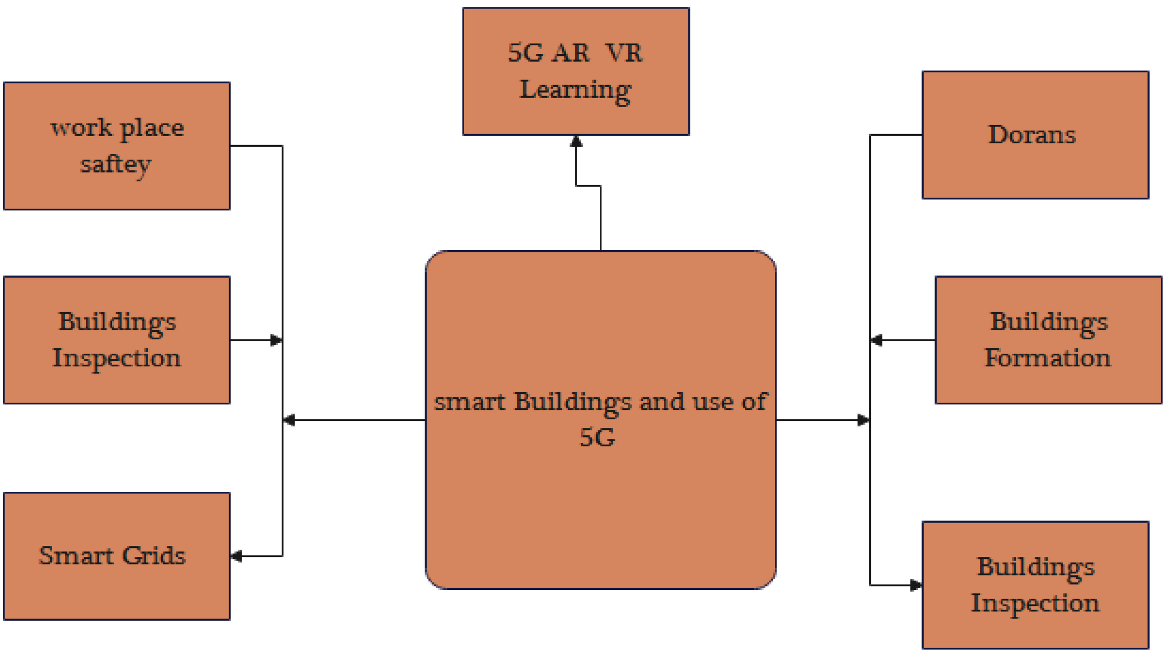


**Figure 8.** Industry 4.0 framework for digital education technologies [15].

Students are better prepared to learn and understand how to measure and build technologies when involved in a 5G, augmented reality, or virtual reality experience. These integrated apps have the potential to react based on the students' movements and interactions with their surroundings, as well as create a virtual building environment that students may use to help them visualize the many portions and shapes of architecture. A graphical representation of the implementation architecture is presented in Figure 9.

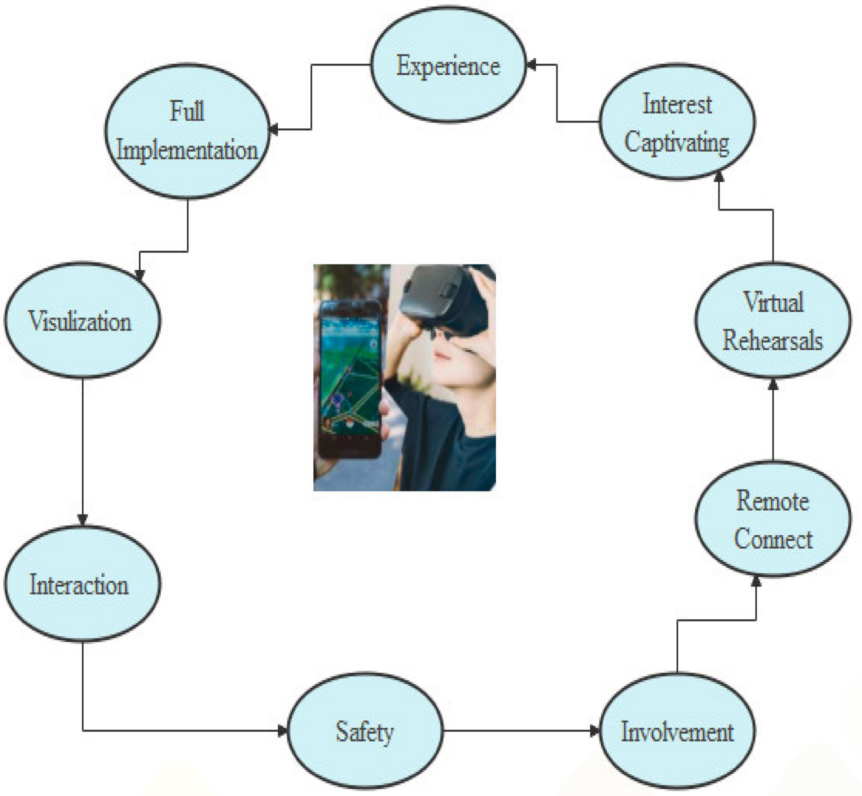


**Figure 9.** Graphical representation of the implementation architecture.

People now have new ways of understanding the various ways that direct user experience has changed reality. Students have benefited from this program because it allowed them to participate in more active learning in a 3D virtual environment; they learned more quickly overall and were better at remembering the material. However, high bandwidth and low latency are essential for correctly operating content and movies that use augmented and virtual reality.

The data needs of augmented and virtual reality now exceed what 4G networks can handle. Augmented reality and virtual reality applications that inspect buildings and teach construction methods need 5G to function. With virtual reality technology, students can work together in a secure, online environment in a classroom or workplace. Students can develop their internal senses by interacting with various virtual objects, messages, and data. Traditional methods of instruction and training, including using static images or two-dimensional (2D) drawings, do not offer as many degrees of freedom as virtual reality (VR) visual representations (DoFs). Apps for virtual reality and augmented reality can now be bought. BIM is used by several virtual reality programs, including Escape, Unity VR, and IRISVR. The workflow of a 5G-powered façade inspection system using AI and drones is presented in Figure 10.

However, these platforms' possibilities are limited because they typically only provide 3D VR representations of BIM models. Although these tools can help visualize architecture, they should not be used in a learning environment. According to several academics, VR-enhanced online learning to cut teaching techniques could be used in future construction engineering education and training. The use of different education methods is presented in Figure 11.

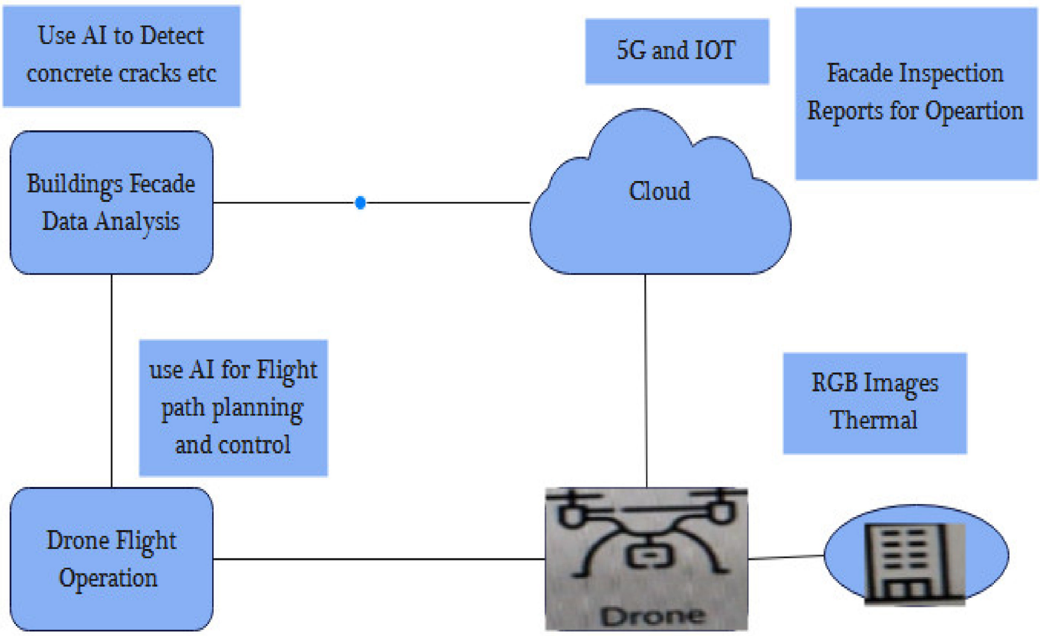


**Figure 10.** Workflow of a 5G-powered façade inspection system using AI and drones [23].

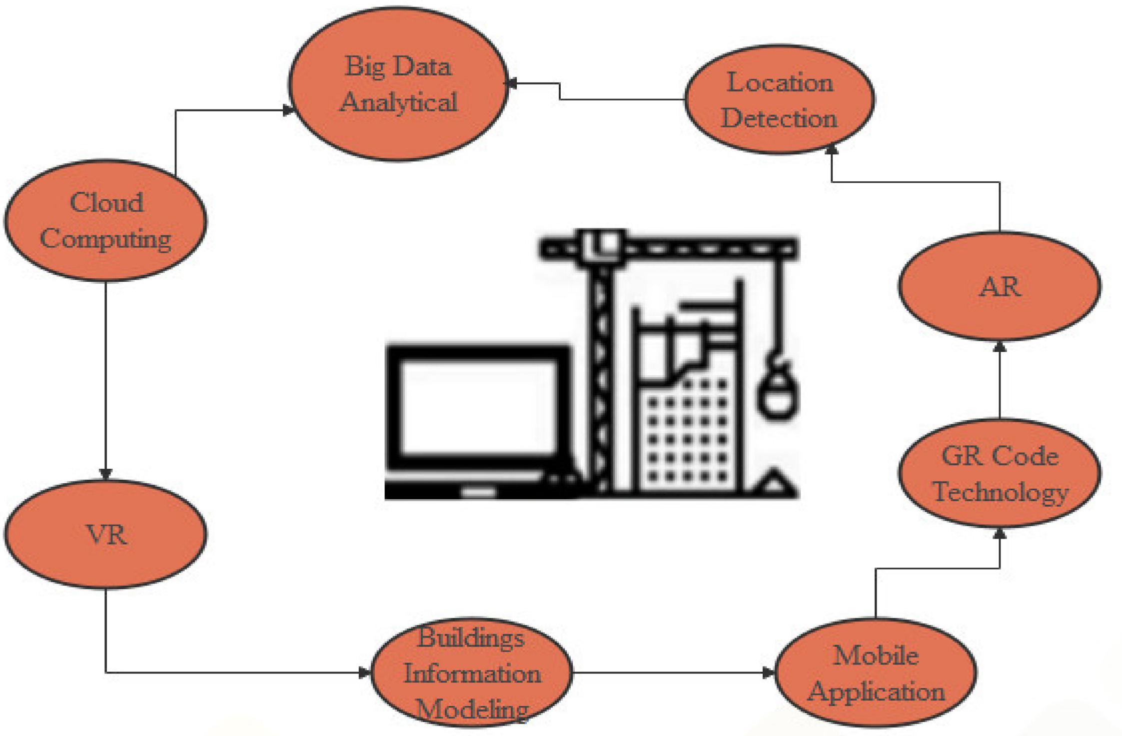


**Figure 11.** The use of different methods in education [19,62].

Structure in education is required. As a result, students will have a better understanding of the current state of the world. MILES is a virtual reality (VR)-based remote education and training system for FM that makes use of 5G networks. Virtual reality, which is now available on 4G networks, has a high latency, which can cause pain, motion sickness, and hazy images. We believe that low-latency options enabled by 5G can solve these issues. In addition, students could participate from any location with an internet connection.

## 5. Conclusions

To the best of our knowledge, this paper is the first report from an ongoing smart building infrastructure management project based on 5G technology which identifies the challenges and the development of solutions to achieve the goal of technology integration. This article discusses the role of AI and 5G technology in smart energy and smart building management, as well as the potential challenges and solutions that may be encountered soon with the adoption of 5G technologies in the field of smart building and infrastructure management. The paper outlines the most formidable challenge that must be addressed as the integration of pre-existing buildings into smart cities and installation requirements for achieving quality experience. Furthermore, various requirements such as safety, security, and privacy, as well as the development of smart protocols and handling architecture for big data storage, necessitate the development of frameworks that aid in the improvement of integration and control systems. The development of such an integration framework would ensure the infrastructure-based operations' speed, security, and supervisory control. One such integration challenge is incorporating smart educational technology based on AR and VR into smart building architecture. Taking these details into account, as well as the research, development, and testing being performed in 5G laboratories, this article examines the current global trends in AI and 5G applications for smart buildings. We assumed eight dimensions of a smart framework, also known as the industry 4.0 standard, that can be integrated with the proposed smart building architecture. We anticipate that by outlining these requirements, challenges, and potential future benefits, this article will serve as a knowledge base for ongoing development in the area of 5G-based smart building management efforts. We also discuss the outcome of 5G technology, potential applications, and long-term goals as well as the potential 5G applications in smart buildings and various approaches to environmental improvement. This study outlines the challenges that 5G smart energy managers will face, as well as the building management issues that will arise as a result of the introduction of 5G. This study could be useful for academics and business professionals interested in developing and improving smart cities in the context of big data and 5G.

## 6. Recommendations and Future Work

This section recommends aspects of future work and states that the advantage of 5G technology could help in achieving smart building control through automated systems.

Both the Internet of Things and 5G wireless technologies are expected to see widespread adoption in the next years. The first 5G deployments will occur in urban areas at the level of practical application. From the perspective of the Internet of Things (IoT), this may prove to be a positive trend since many "mainstream" IoT applications will support smart cities, smart campuses, and smart buildings. The need for bandwidth from a range of smart city applications is the most crucial element in the development of enhanced mobile broadband (eMBB)-based 5G services in general and new-generation 5G Internet of Things (IoT) applications. The development of 5G cellular technology that can handle high data transmission rates thus requires the usage of the millimeter wave spectrum. However, the application of millimeter wave solutions requires the usage of microscopic cells. For the sake of managerial simplicity, an implementer may prefer to use a cellular/5G IoT technology for all nodes, regardless of whether they are located indoors or outdoors, rather than a heterogeneous mix of various IoT technologies that have evolved over time. An implementer will typically try to use only one or a small handful of IoT technologies. In particular, the applications of the Internet of Things based on 5G in smart city settings are covered in this paper. The necessity for tiny cells, transmission problems at millimeter wave frequencies, building penetration problems, the need for distributed antenna systems, and the impending rollout of pre-5G Internet of Things technologies are some of these concerns. However, this article specifically focuses on smart city contexts.

Smart building management activities require the integration of many IoT-based smart devices as a source of big data generation. Therefore, devising a decentralized cloud storage system is required for integration with smart building infrastructures to obtain real-time performance goals.

Fifth-generation technologies have the capacity to make buildings, communities, and cities more functional due to the new technology's creation and widespread use. The principles of use, including the domain-specific language, need to be developed with the integration of artificial intelligence (AI) and machine learning (ML) based approaches so that they can be used in smart cities with 5G technology.

Moreover, there is a need to deploy a wide range of compatible technologies, with support from 5G technology, to meet the public's expectations and act as a control system for architectural features such as thermal comfort, energy efficiency, and environmentally friendly solutions.

Large cities can make use of the significant benefits of innovative city technologies. More research is needed to figure out how to design and build cities cost-effectively because the innovative city concept is gaining attention on a global scale. Renewable energy sources need to be used to regulate the limited supply of non-renewable energy sources and to assure the long-term profitability of local operations. For this purpose, the development of a controlled and automatic system based on AI and 5G is another research area open for future development.

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