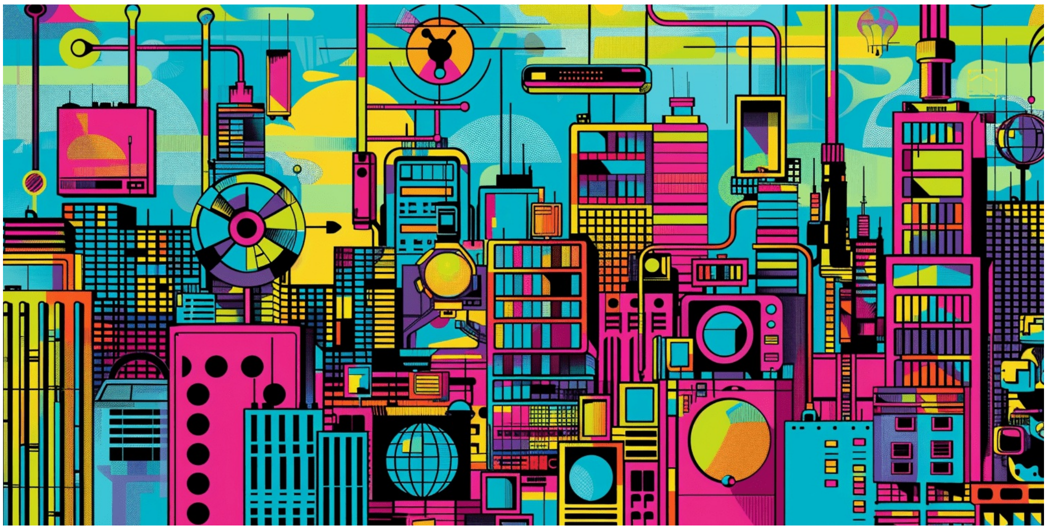

Internet of Things in Smart Grid: A Comprehensive Review of Opportunities, Trends, and Challenges

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Abstract

The rapid advancement and implementation of Internet of Things (IoT)-based technologies has permitted numerous opportunities for technical innovations in diverse aspects of life. IoT technology has enabled the streamlining of processes in numerous fields, ensuring better efficiency of systems to improve the quality of life. This review paper emphasizes the significant research works that concentrate on the application of IoT to smart grids and summarizes the current work done. The paper also discusses the various challenges and opportunities in smart grids while implementing the IoT, addressing the pioneering methods used in IoT along with their relevant application in different fields. The main outcomes of this paper are to provide 1) identify feasible solutions to overcome the implementation challenges; 2) a clearer understanding of the existing technological advancement in IoT application areas; and 3) spread awareness among researchers and professionals in the ground of smart grids and IoT.

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1. Introduction

The number of online capable devices surpassed 22 billion worldwide in 2018, and it is forecasted that it will be increased by approx. 38.6 billion by 2025, and 50 billion by 2030 [1]. These devices comprise vehicles, home appliances, and other electronics items connected with software, sensors, and categorized by their connectivity to the cyber world. New possibilities came up with growing technological advancements in the world that could improve our day-to-day life and offer effective services or production methods. Digitalization has allowed ‘‘smart’’ [2] to become the epicenter of the current technological developments. A smart system is a system or group of systems that incorporates roles of sensing, actuation [3], and monitoring to describe or analyze a condition, make judgments based on the existing data, and make smart actions [4]. A smart energy system expects to have better control and use of energy consumption by aligning consumption with energy generation and combining various energy sectors [5].

The Internet of Things (IoT) is a collection of technologies and applications that offer devices and settings to produce distinct information and link them for rapid data evaluation or “quick” action. Nowadays, the internet has become pervasive and is influencing social life in unbelievable ways [6]. IoT is primarily a digital world that meets up with a glut of sensors and actuators [7], or it can be said that it is a concept in which computing and networking skills are entrenched in some sort of imaginable idea. [8]

The research in IoT is in the beginning phase, so there are multiple definitions for IoT defined by researchers. Theoretically, the term IoT comprises everything connected to the internet, but over time it is increasingly being used to define items that "talk" to each other [6][9]. There are numerous benefits of having things linked with each other, such as 1) more information leads to informed choices, 2) the opportunity to keep track of and record events, 3) automating tasks to reduce workload, and 4) lowering the running costs.

The industries and enterprises are implementing IoT to automate and streamline their regular activities. Connected devices are being integrated into current and developing business processes. It is being used not just to reduce operating costs but to enhance productivity, improve customer experience, and create extra revenue streams.

2. The Need for Smart Technologies

The world is rapidly shifting to technology and expanding in a high-tech sense driven by the current economic system all over the world. Albeit every technological development has a price. In this scenario, the price is extensive utilization of restricted fossil-based resources that create adverse effects on the environment. With the constantly rising population, a substantial infrastructure burden [10] is projected in cities because of the increased developments[11]. The difficult and challenging circumstances drive innovative scientific solutions to ensure the normal operation of cities.

The IoT technologies are crucial for the ongoing high-tech developments and digitalization where a range of various electronic innovations need to be linked conveniently. Figure 1 shows the number of connected devices worldwide in billions [12], which clearly states that the number of IoT devices is increasing rapidly. There is a requirement for more economical services and agile processes in broad, which could be achieved with the appropriate execution of IoT technologies.

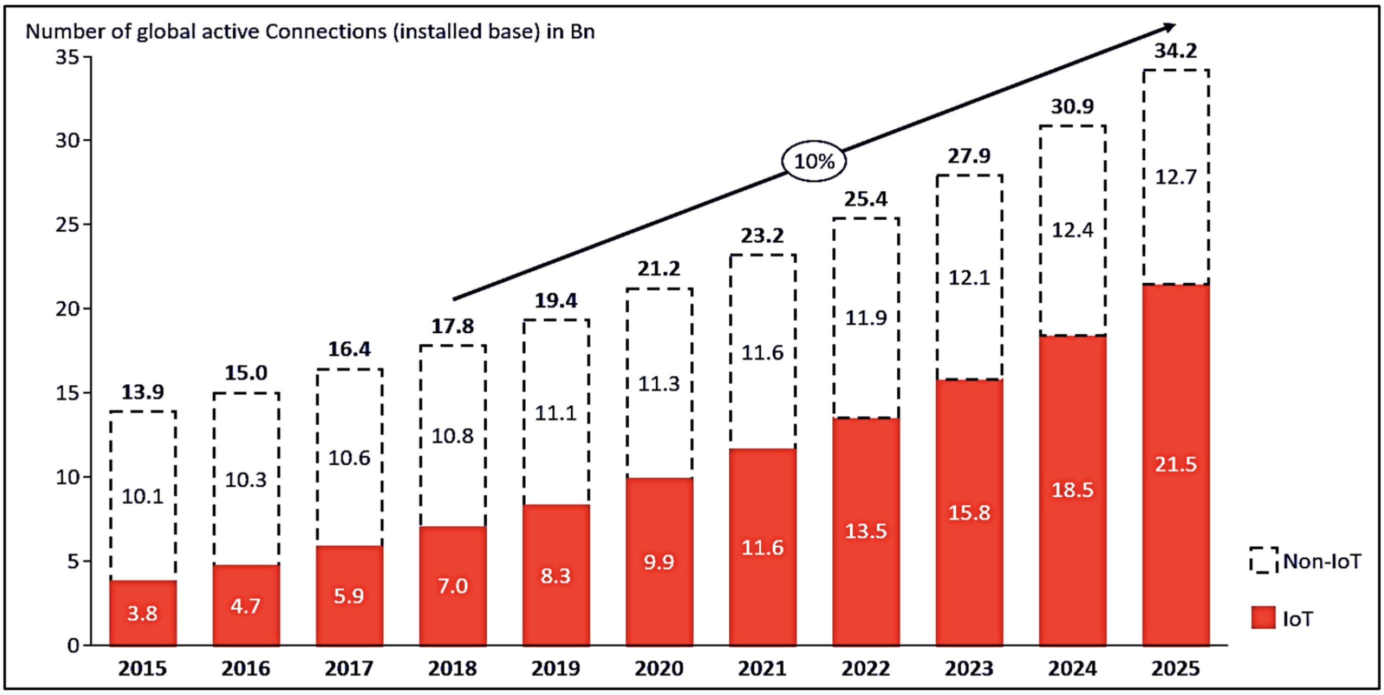

Figure 1. Current Status and Future Prospects of IoT [12]

This paper thus presents a comprehensive, latest evaluation of IoT studies with emphasis on 1) recapping the present concept and application of IoT, (2) presenting the benefits and drawbacks of this technology, and (3) recognizing the challenges for upcoming researchers.

3. Real-World Applications of IoT

Currently, IoT technologies are the crucial pillars of the fourth industrial revolution because of their huge potential in inventions and practical benefits for the community. IoT-based technologies bring a whole new outlook on the evolution of different fields. The growth of certain IoT application areas varies based on factors like:

- Availability of user-friendly software solutions
- Solutions related to data acquisition and sensors
- Connectivity and infrastructure of the network
- Available advancement in electronic components

- Uninterrupted power supply for IoT devices

Some key application areas of IoT are briefly discussed with the developments and challenges. Figure 2 shows IoT application areas that include agriculture, healthcare, transportation, and smart grid.

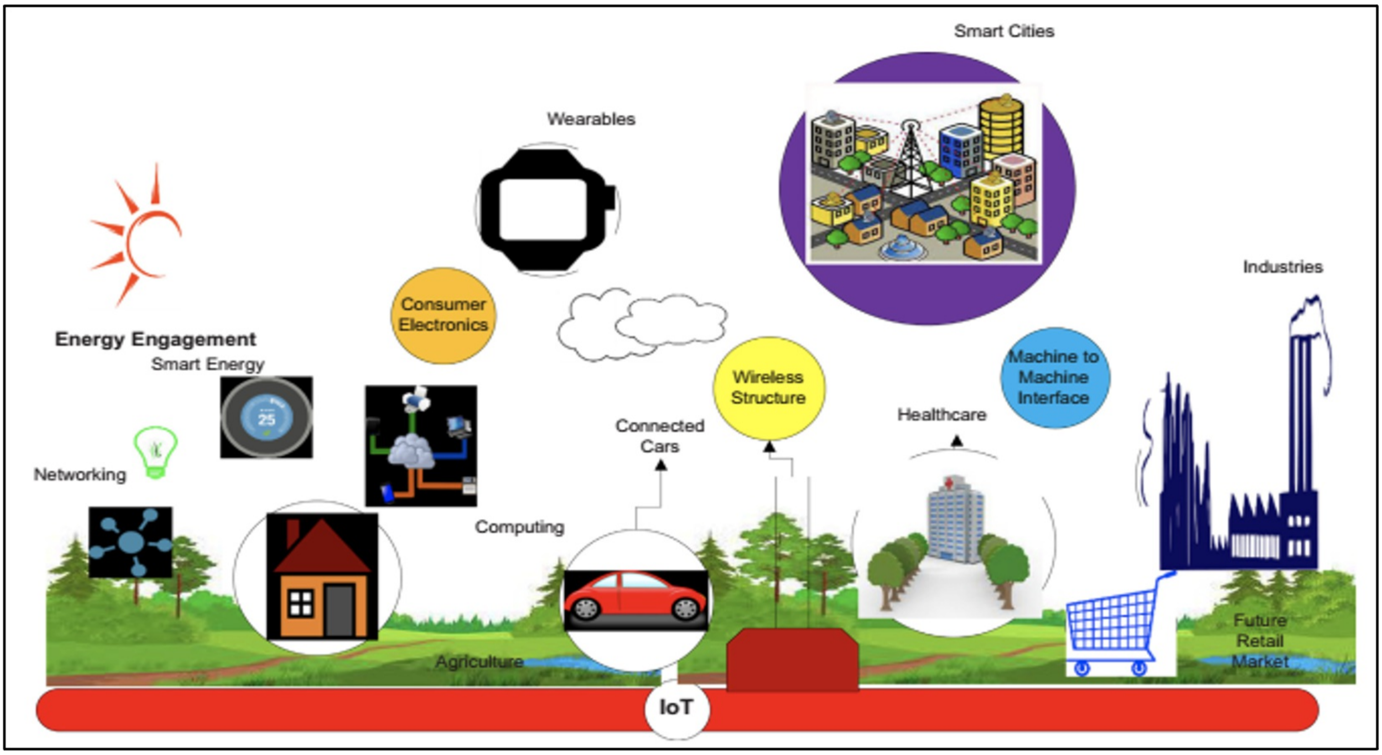

Figure 2. IoT Application Areas [13]

3.1. *IoT in Smart Cities/Devices*

IoT's role is critical in the smart city idea to connect the existing global challenges related to infrastructure. IoT technologies in smart cities would facilitate the use of various devices that lead to a rise in the standard of living in cities and also the lifestyle of the people.

Smart buildings are unique buildings that employ smart automation to create an effective, convenient, and safe atmosphere for their consumers [14]. Automation in buildings with IoT is a leading innovative technology that is competent to deliver solutions for higher security and safety, monitoring users, and enhancing visual and thermal comfort [6] [15]. The main advantage of IoT-enabled smart cities is the identification or early detection of various problems or defects [16].

A smart home is one of the essential applications of IoT. It has been an important consideration in the residential market, and smart home forecasts for the future are promising. Sensors and context awareness are commonly used in smart homes to conserve energy [17]. Smart home devices have become recognized household products as digitalization accelerates with the ease of access to the Internet. This will allow users to save time, resources, and, eventually, money [18] [19]. This becomes a vital element for all smart devices to interact digitally to provide people with a cost-effective experience.

3.2. *IoT in the Cultivation Sector*

Efficient agricultural production is needed for our society to escape a possible shortage of food supplies in the future due to several factors [20] [21]. The use of IoT technology in agriculture will undoubtedly be beneficial to secure the food demands and enhance the agricultural production processes' efficiency [22] [23]. The food waste issue can be solved by implementing the IoT to keep track and secure food demand and increase the productivity of agricultural production [24]. Along with the help of IoT, data-related to crops can be gathered and used to monitor the yield to detect potential diseases at an earlier stage, which can reduce the yields of a particular type of crop [25]. Further, the monitoring of soil properties such as humidity, temperature, and moisture would improve agricultural production methods and save water through an automatic irrigation system. The irrigation action can be supervised remotely and the cultivation activities can be monitored more effectively in the future than other traditional techniques [26] [27]. Currently, the use of unmanned aerial systems (UAS) in agriculture is developing to assist cultivation with monitoring and decision support on the farm [28] [29]. In the food and farming industries, the IoT is projected to be a game changer. However, an important task for large-scale acceptance of IoT is to deal with the enormous heterogeneity of the area [30].

3.3. *IoT in Transportation Sector*

The transportation sector is significantly changing and will continue to change in upcoming years, particularly because of the growing application of electric cars in the market [31] [32]. Automotive technology is aspiring to develop optimal solutions to enable vehicles (cars, etc.) to function more effectively. Currently, the IoT has emerged in the 'Internet of Vehicles' concept, which demonstrates its potential in this important area [33]. Smart transportation systems can automate the roadways, railways, and could transform the passenger experience in the coming days [34]. IoT qualifies as an apt solution to cater to the automotive digital market where automobiles are more economical and reliable in terms of performance. Cars having IoT technology work with inputs based on sensors and handle vehicle operations more autonomously [35] [36]. Automotive solutions with IoT bring in a connection between large, well-known companies in the information technology (IT) sector and the automotive market [37]. IoT systems have the potential to fully transform the driving environment and enhance the efficiency of the transportation infrastructure in many ways [38]. As the number of vehicles is gradually increasing, the pollution is also increasing, and due to improper maintenance, the performance of the vehicle degrades over time. An IoT-based system can monitor different types of vehicle parameters and control pollution [39]. The challenging aspect of IoT application in transportation is the prevention and evasion of crash vehicle collisions [40], which could be unraveled with a targeted utilization of IoT devices[41].

3.4. *IoT in Healthcare*

Another important area for IoT solutions is healthcare, which aims to provide quality and necessary treatment to patients at the right time. An improvement in the quality of healthcare services could be achieved via IoT support, and finally, with the increase in patient care, as the regular interaction of doctors with patients can be implemented with the use of IoT [42] [43]. Treatment of diseases such as cancer and diabetes can be made more efficient and comprehensive through upcoming IoT-based solutions like closed-loop insulin delivery, ingestible sensors, coagulation testing, etc. IoT devices and products can facilitate remote health monitoring, thus helping avoid frequent hospital visits [44]. Substantial growth in the software development in hospitals is anticipated so that different devices with advanced software could be linked together with laboratory data to produce an advanced level hospital management system [45] [46] [47]. The development of smart solutions could be very helpful with the global pandemic, like in the recent COVID situation, to keep track of medical triage, staff availability, etc. The present COVID-19 pandemic allows for the evaluation of several IoT applications or devices that may aid in the effective monitoring and management of the pandemic, demonstrating the increased value of IoT solutions.

3.5. *IoT in Industrial Sector*

Industrial IoT can drive the industrial ecosystem with the advancement of improved sensors, big data[48] analytics, and developing software resources [49]. IoT provides consistent solutions by facilitating active communication with industrial data and explains several industrial challenges, including all types of industries [50]. This enables industries to efficiently identify inadequacies and facilitates fault detection at an early stage, which leads to profits and productivity [51]. However, focused research is needed for the efficient deployment of IoT technologies in the market to realize how IoT technologies can be executed in industries where benefits could be realized [52].

3.6. *IoT in Social Life*

Wearables such as fitness tracking bands, tracking belts, smart wear, and smartwatches are the fastest-growing applications of IoT [53]. These IoT devices are being upgraded occasionally to create small and energy-saving devices. According to a Forbes survey, top-labeled companies planned to trade about 411 million wearables in the digital market in 2020 [54]. There is an application ‘Circle Sense’ which identifies social interactions of a user with various sensors and recognizes the social circle of that user by evaluating the sequence of events and individuals engaged in those events [55]. Further, the emotion of any person can be studied using IoT based on facial expressions, hand activities, body actions, and sleep patterns. [56]

3.7. *IoT in Waste Management*

Waste disposal is becoming a global challenge these days. Every year, the planet produces 2.1 billion tons of urban solid waste, with at least 33% of it not being handled in an environmentally sustainable way [57]. Waste management in the sense of a circular economy is a major concern today, where IoT is required to provide more efficiency in waste management and recycling of various materials [58] [59]. There are different solutions developed with the help of IoT and available in the market that are in the direction of smart waste monitoring. IoT systems may also be used in waste truck coordination [60]. IoT technology may also be used to minimize food waste by using smart appliances[61].

3.8. IoT in Smart Grid and Energy Management

Energy transition has become an essential requirement because of the limitations of fossil fuel reserves and pollution reduction [62]. Large-scale adoption of renewable energy and advanced energy management of electric grids has turned out to be a critical aspect. A major part of IoT technologies in the smart grid is to save electricity, which can be possible only by enabling smart power management in the smart grid. The biggest challenges for service providers and users in conventional power grids are reliability and power quality [63]. Useful benefits, including economic aspects, efficiency improvements, and analysis of the collected data through IoT devices, could improve grid reliability [64]. Demand-side management in homes is a critical application area of IoT. Current advancements in the IoT era offer solutions to enrich the management of the challenges and implement the methods of a Smart Grid [65]. The vital role of IoT technologies pertaining to smart grids is to conserve electricity while providing cost-effective distribution of electrical energy [66]. The economics of electricity can also be modernized with IoT, and they can ensure benefits for both customers and service providers.

IoT technologies' growth in smart energy management is anticipated to precisely enable the load estimation and management strategies of renewable generation [67]. IoT precedes associating and remotely controlling anything in every domain. Similarly, the smart grid structure attracted the interest of the worldwide research group, and the concept of IoT integration with the smart grid shows immense growth possibility.

4. Recent Trends in IoT

The comprehensive solutions with IoT technology bring about numerous shifts in different sectors of the economy, starting from agriculture to healthcare. Different IoT-based smart products can be used for customer satisfaction in the world market, which leads to cost-effectiveness, safety, security, and luxury. The growth of IoT technologies is booming, and the projected investments in IoT technologies are over $120 billion by 2022, with a compound annual growth rate of nearly 7.3%, which is higher than expectations [68]. Smart cities are at the top of the list of smart improvements because of the initiatives provided by the government [69]. Figure 3 signifies the overall present-day market structure of IoT technologies, which shows that the major market share of IoT is distributed among smart cities, smart homes, industrial IoT, and healthcare industries [70].

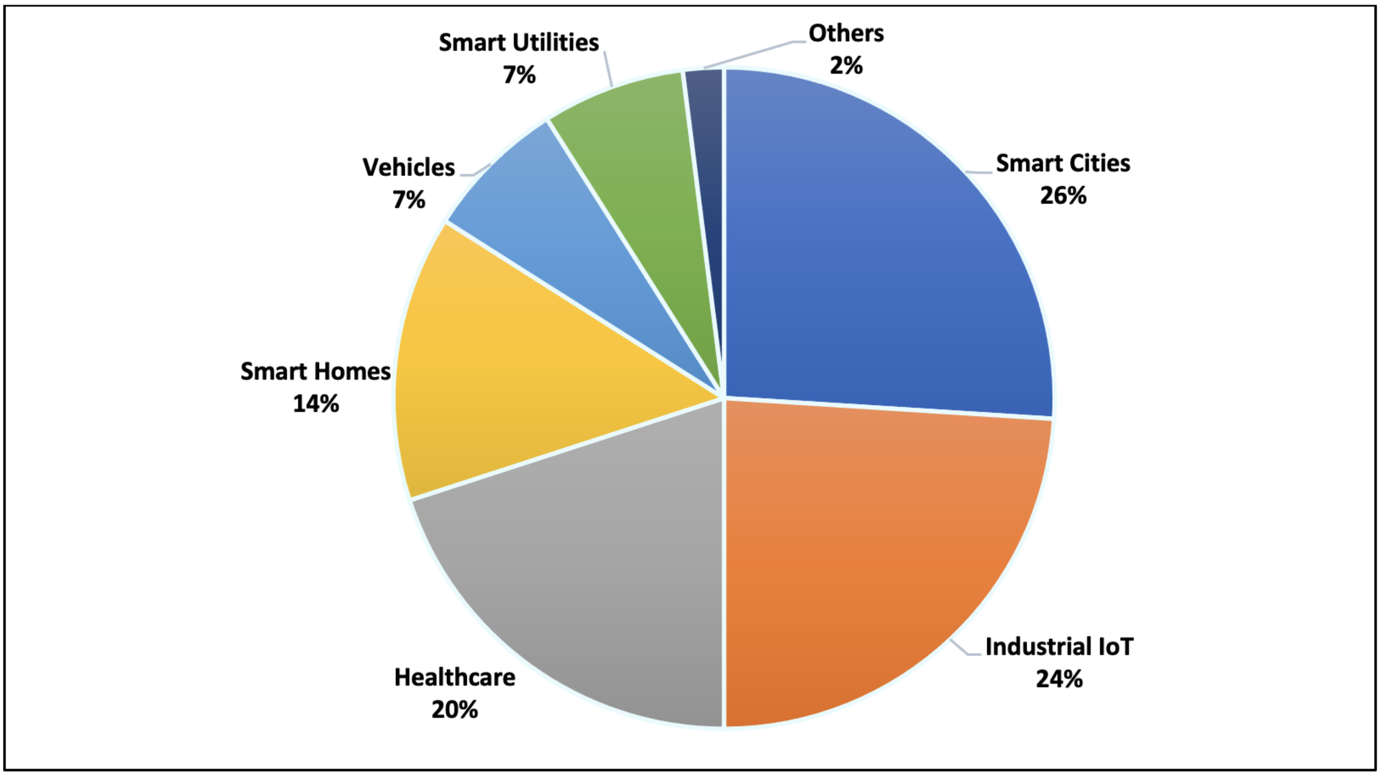

Figure 3. General market structure of IoT Technologies [71]

The smart grid can be viewed as one of the leading applications of IoT because the intelligent smart grid would not be possible without it [72]. Therefore, considering IoT technology as a universal benchmark for communication in the smart grid, new doors will be opened in order to boost the possibilities for potential developments [73].

5. Combination of IoT and Smart Grid

The smart grid is described as the transformation of an electricity system specified by the flow of communication or data and electricity to build a programmed smart energy supply network by incorporating its consumers [74]. It is intended to solve the concerns of the electricity grid such as low consistency, excessive outages, GHG emissions, and energy security.

The Smart Grid is steadily drawing the attention of policymakers, the business community, and the academic world. It is a futuristic power system that depends on two-way interaction between its components, being extra consistent, extra effective, and self-healing, with computerized meter reading and dynamic pricing [75]. The steering force behind the idea of the smart grid is to improve planning, maintenance, and operations, confirming that every element of the grid can 'listen' and 'talk', and to allow automation in the smart grid [76]. IoT offers collaborative real-time network connections to consumers and devices through different communication methods, powering equipment across smart devices, and high-speed data sharing across different applications that enhance the overall effectiveness of a smart grid [77].

In smart grid language, IoT is defined as an expressive idea that communicates the capacity of any device to link to other objects, as well as the development of embedded intelligence in communicational grids [78]. This intelligence can contain assessments, identification, security, grid procedures, and control. The role of IoT in the smart grid can be classified into the following three sub-layers [79]:

1. Information resources layer – Installation of IoT smart instruments and devices for the purpose of data collection, processing, and sharing
2. Communications layer – collects data from smart devices by IoT communications protocols for transmitting
3. Information processing layer – The ability of big data analytics to realize, expand, and anticipate with the use of algorithms

The smart instruments in the electricity grid encompass a wide range of equipment used in consumption, distribution, transmission, and production. Perhaps not all power grid components have enough intelligence to be termed IoT parts. Thus, the installation of IoT smart devices for the aim of collecting data from non-intelligent equipment is the initial stage in this progression. IoT smart devices include wireless sensors, RFIDs, M2M devices, GPS, and every kind of data collection device [79][66][13].

In response to the emergence of IoT, smart grid solutions are being created to meet the expectations for long-term sustainability, offer information on the energy sources utilized, and warn users when demand is high [69]. Various characteristics are directly linked with the smart grids and IoT, indicated under [80]:

- Advancement and incorporation of demand response and energy efficiency resources [81]
- Implementation of smart skills for metering, grid functions, and smart grid allocation
- Incorporation of smart appliances into the smart grid
- Incorporation of advanced energy storage and peak-shaving techniques
- Providing timely updates and control options to customers

The smart grid is a transmission network built on top of the energy grid that collects and analyses data from various electrical grid components to forecast power supply/demand for use in electricity management. Figure 4 depicts the IoT architecture in conjunction with the smart grid, with the goal of building an open platform that includes secure smart metering, responsive monitoring, and intelligent demand-side response. As a result, the IoT gateway becomes an essential building piece for communication between smart sensors and the cloud, allowing metering to be monitored remotely over the internet. [82]

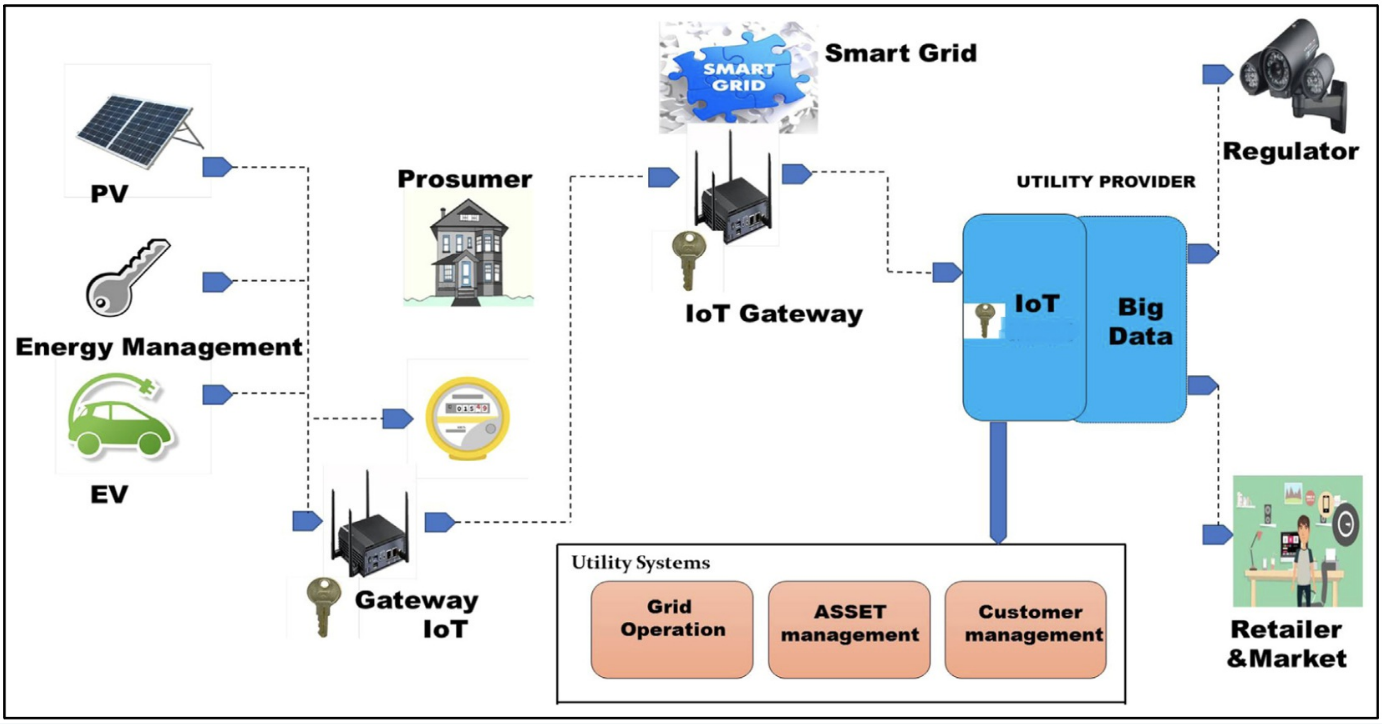

Figure 4. Universal Planning of IoT-aided Smart Grid [13]

5.1. *Application of IoT-based Smart Grid System*

IoT applications in the smart grid can be categorized into 3 categories based on the three-layered IoT design[83] [84]. (1) IoT is applied for utilizing numerous IoT smart devices for monitoring; (2) IoT is applied for data assortment from equipment using smart equipment by different communication technologies; and (3) IoT is applied for managing the smart grid by various application interfaces. [72]

A smart grid comprises 3 main sub-systems consisting of 1) power generation, 2) power transmission and distribution, and 3) power deployment. IoT can be extended to all these sub-systems and promises to be a potential approach for improving them, creating IoT a crucial aspect of the smart grid. Figure 5 represents the current and prospective applications of IoT-based smart grid systems.

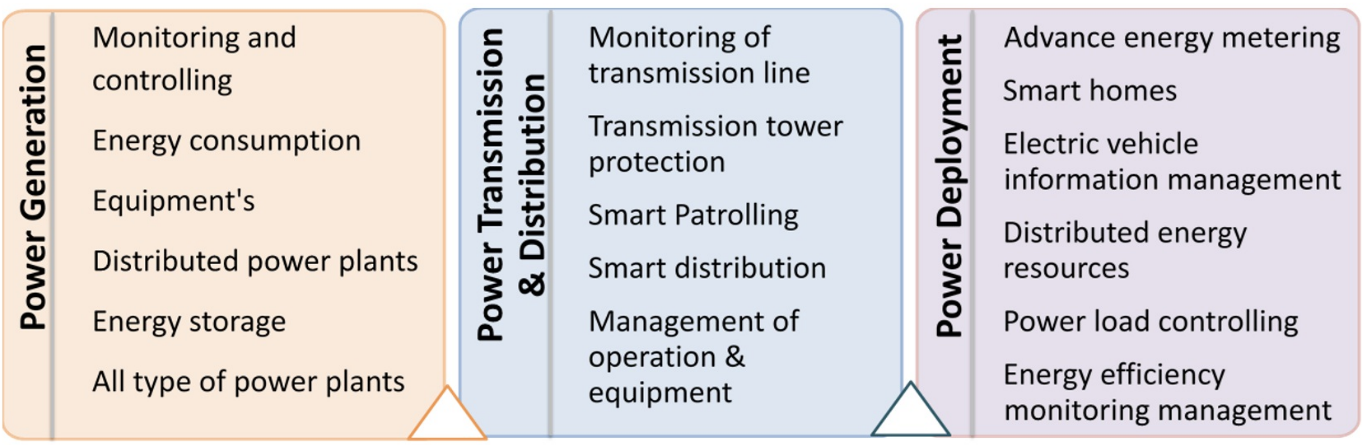

Figure 5. Current and Prospective Applications of IoT-Aided Smart Grid

5.2. *Advantages of Monitoring the Smart Grid with IoT*

Smart grids enable monitoring of energy flows and adjustment to variations in power requirements and supply in real time. These systems can take advantage of technologies such as machine learning [85] and artificial intelligence to analyze and configure the devices [86]. Using IoT in a smart grid generates immense advantages for monitoring distinct areas in the grid. Figure 6 shows the benefits of the IoT-aided smart grid with different controls. For example, the monitoring control leads to asset optimization, and feeder & voltage monitoring leads to the fault management of the grid [87]. Nevertheless, all the benefits depend upon the security and connectivity of the internet connection.

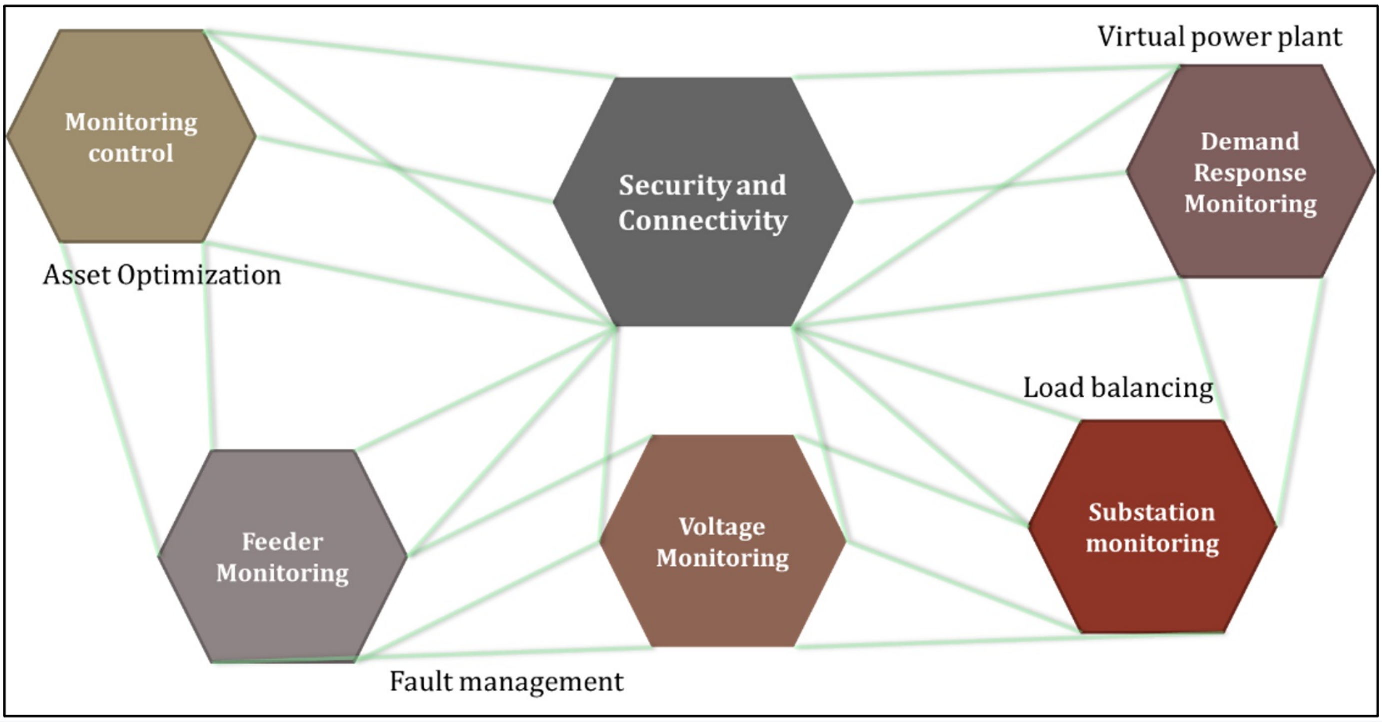

Figure 6. Advantage of monitoring IoT-aided Smart Grid

With the help of IoT, the utility providers receive maximum benefits due to the ability to continuously monitor energy consumption and thus reduce losses [88] [89]. However, adequate measuring instruments must perform this action. Here, smart metering devices might be an effective solution, getting the consumers and suppliers, and supplying the data on utilization on a real-time basis. Consumers can adjust their energy consumption for different times, including peak time, and save their energy bills based on the load pattern with the help of smart meters. Many researchers are focusing on developing advanced IoT-based hardware and software solutions that can provide real-time information about appliance efficiency, data use, and energy flow information because of the possibilities generated by using IoT solutions. [90].

While smart grids are critical elements of energy sustainability, it is limiting to characterize the theory of smart energy solely through them. Smart buildings also play an important role. The energy efficiency of building systems using smart technology provides gradually smart-resources management, excess prevention, taming the people's life quality, and creating buildings more flexible in recent climate changes [70]. Building automation and IoT enable remote control of individual buildings as well as entire neighborhoods in terms of energy use and stability.

6. Challenges and Opportunities in Implementing the IoT in Smart Grid

Integrating IoT in smart grids creates new challenges and opportunities for IT service providers. Certain areas need to be explored and analyzed to comprehend the process. The economy, national security, and healthcare are all heavily reliant on a consistent supply of electricity, and the most difficult feature and critical challenge in smart grids is ensuring their protection [91].

6.1. *The Challenges Facing IoT in Smart Grids*

6.1.1. *Cyber Security*

Cyber-attacks are widespread and may happen at any moment, according to a growing number of security researchers [92]. Furthermore, cyber security issues have rapidly emerged as the most serious threat to smart grid data. In a smart grid, each linked device can be a possible port to IoT infrastructure or personal data, which creates concerns related to privacy and security [93]. As a result, the security of this data is a contentious issue in smart grid big data deployment, and cybersecurity experts must incorporate these risks into big data to ensure privacy.

6.1.2. *Energy Supply*

Since the introduction of IoT technology, integrating IoT in smart grids and providing energy supply for a plethora of network-connected devices has been considered a mammoth problem. Earlier, due to limited resources, the selection of a suitable energy source to serve IoT devices was a difficult task. However, now, the energy supply is no longer considered a major drawback [94]. The IoT-smart grid devices should be capable of maintaining their functionality for a long time without needing battery changes and of repairing hardware malfunctions.

6.1.3. *Data Administration*

Data management is critical in the smart grid, and it necessitates a dynamic server that serves as a hub for data, software, and other products [95]. The complexity of the energy system is caused by hurdles such as the grid's massiveness, the diversity of connected devices, the synchronization of connected devices, the interpretation and data analysis associated with many components and devices, and data storage constraints. Furthermore, the components' communication, reaction, and interaction are considered a sort of difficulty.

6.1.4. *Big Data*

A smart grid with IoT capabilities is a huge network made up of a number of devices that are used in the generation, transmission, and distribution of power. Over time, a considerable amount of data will be created, which will need to be managed. The notion of big data analytics has been presented and is progressively expanding in recent years with many standards. A set of data that can't be obtained, processed, or managed is referred to as "big data" [96].

6.1.5. *Equivalent Standards*

In an IoT-enabled smart grid, the different components of the energy grid employ embedded sensors to generate a variety of data [97]. All generated data must comply with a common standard to accomplish integrated management[98]. Given the variety of operating systems sponsored or integrated by several significant corporations, it appears difficult to develop an agreement on a common standard at this time [99] [100].

There is a requirement for a better understanding of the challenges in implementing the full capacity of the smart grid with IoT. Table 1 summarizes various challenges in implementing the IoT in the smart grid based on the literature reviews and the work done till now. It also explains the effects and the opportunities to overcome the challenges.

Table 1. Challenges, Effects and Opportunities of IoT in Smart Grid

Parameter	Challenge	Effects	Opportunities
Data Privacy [101] [102] [103]	Possibility of revealing sensitive data about the consumers. [104]	Usage of HVAC data in the home management system can reveal info about the availability of people, which can lead to theft or unwanted act. [105]	A suitable mechanism should be formed such as trust management [104], authorization of usage of data, and detecting identity spoofing. [106]
Cyber Attacks	• Possibility of damage of IoT-enabled smart grid infrastructure. [107] • Misuse of data transmitted between users and utility.	Make the appliance work erroneously or damage to the instrument may cause a financial meltdown. [13]	Need secure communication by considering resource limitations and establish security measures for the IoT devices [108]
Congestion in Network	Delay and packet loss affects the performance of the smart grid. [66]	IoT gateways have to re-transmit the data packets which contributes to further delay and increases the probability of overcrowding. [109] [72]	Optimize the design by obtaining an optimal number of the gateway to minimize the number of connections. [110]
Reliability of Network	• Real-time scenario between the meter, sensors, and actuators. • An issue in transferring the enormous data in the real-time scenario.	Scheduling and non-scheduling of loads require a rapid connection in energy management analysis. [111]	Utility provider should set up their internet infrastructure for scheduling appliances.
Energy Acquisition [72]	Limited resources and capabilities for battery-operated devices. [112]	Different sensors used to track transmission lines, failing the connection led to a big transmission loss. [113]	• Appropriate energy harvesting methods should be designed. [114] • data fusion process should be used to gather user data [97]
Scalability	Adding new operations and establishing new devices is a challenging job particularly in presence of different hardware platforms	Network lack results in inadequate system performance and need of reengineering the entire system [100]	Must be designed from the ground up to empower extensile services and operations [115]

	hardware platforms		
Interoperability Required	Different gateway and IoT devices with different designs and resources. [66] [104]	Exchanging the information is very critical. [114]	• Should be considered by in cooperation of product developers and IoT device maker [84] • Use IP-based networks. [99] • IoT Devices ought to support various communication procedures and system architectures.
Mobility	Connecting users with their preferred services constantly whilst on the move [116]	Service disruption for portable gadget can happen while shifting from one gateway to other [117]	Should recommend a technique that permits applications to access data in situation of absence of network.
Database Management	Sensors, smart meters collect a huge amount of data	Data processing and management use a lot of energy and generate a bottleneck	Should design smart grid in a manner that stores and process the massive data effectively [118]
Lack of Standard [119] [120]	Many individual standards for IoT devices based on the use, make, country [121]	Cause safety, trustworthiness, and interoperability concerns for IoT devices in the smart grid	The standardization process should be unified.
Adverse Operating Conditions	Many devices work in harsh conditions like extreme weather, underwater, exposure to electromagnetic waves.	Cause harm to the devices and smart grid leads to elevated operational cost	• Should satisfy the requirement of reliability and compatibility. • Should design with signal coverage in each condition. [122]

Many challenges must be addressed in forthcoming research directions to accomplish the technical goals while applying the IoT in the smart grid. As IoT devices work in diverse environments, including harsh conditions like extreme temperatures, underwater conditions, and exposure to electromagnetic waves, the devices should satisfy the requirements of reliability and compatibility.

6.2. *The Answer to the Biggest Challenge – Cyber Security*

The IoT technology is now being debated in research. It is necessary to overcome issues at all levels and improve efficiency to increase the usefulness and practicality of IoT [123] [124]. IoT is being used by smart grids to produce more intelligent, efficient, and sustainable solutions. In the coming years, there can be a serious need for cyber security defense. Thus, the below section discusses potential solutions for mitigating the risks that compromise security.

6.2.1. *Deep Learning Methods*

Deep learning is not a new concept in recent years. Machine learning is growing towards deep learning, which allows machines to imitate humans and have analytical learning skills. It enables computers to emulate human learning processes to obtain new artificial intelligence skills. Deep learning has demonstrated substantial gains across most machine-learning-based systems [125] [126], indicating that intrusion detection created on deep learning has the inherent benefit of identifying encryption assaults and zero-day attacks [127].

Several existing works focused on applying deep learning methods in cyber security research are in use nowadays. Few methods, such as Recurrent Neural Network (RNN) [128] [129], and Convolutional Neural Network (CNN) [130], which assists in the development of innovative approaches for solving cyber security issues with the greatest precision. The models in deep learning may be applied to many parts of cyber security defense depending upon their features. Deep Belief Network (DBN) is a powerful data processing tool that can quickly turn high-dimensional data into low-dimensional data while preserving significant data characteristics. [131] [132]. It is regularly used for feature extraction and selection in cyber security systems [133]. The RNN method is preferable to the CNN method for a security system with high accuracy and analytical capabilities [126].

6.2.2. *Deployment of cloud IoT*

Cloud computing is a computing model that comprises a collection of computer resources (such as servers, storage space, and services). The objective of cloud computing is to enable easy and rapid access to these resources. Cloud computing can be used in IoT-enabled smart grids, which are described as cloud IoT [96] [134]. The idea of cloud IoT still needs to be matured in the future.

7. Impact of IoT and Future Research Directions

7.1. *Long-Term Impacts of IoT*

Private organizations and policymakers are speeding up the implementation and development of smart grid initiatives that can sustain energy systems. IoT offers a wide scope of functions in the power sector, like energy production, renewable energy integration, etc. [135]. Each rapidly evolving technology has certain negative consequences that must be carefully considered. When it comes to IoT technology, there are a few key points to note to grasp the long-term implications of their accelerated growth:

- IoT technologies have expanded the use of scarce resources or raw materials, both of which have been or are becoming scarce (for example, certain precious metals used for the manufacture of electronics).
- Purchasing electronic devices has become affordable, leading to increased demand and hence a rise in production volume, resulting in more resources being used. In that context, a rebound effect is likely.
- The long-term implications of IoT on the environment remain unclear. Considerable energy is needed to sustain IoT system development and operation.
- A rise in electronic waste is anticipated because of the large number of IoT-based devices expected to be deployed in the near future.
- IoT technologies in some sectors can limit direct social contact (an important aspect for individuals) and reduce the requirement for labour.

7.2. *Future Research Directions*

Energy acquisition for IoT-enabled applications is a significant open question. Using blockchain in smart cities can also provide increased protection by allowing strong transactions in a safe, clear, and absolute record. However, both blockchain and smart grids are in their early stages, and substantial exploration is required to assimilate them [136]. As a solution, new energy harvesting technologies in conjunction with IoT devices should be created. The difficulty in creating modern power supply devices is cost, reliability, and efficiency. Implementing IoT poses challenges in the smart grid. Figure 7 explains the open issues and research domains for IoT with the Smart Grid.

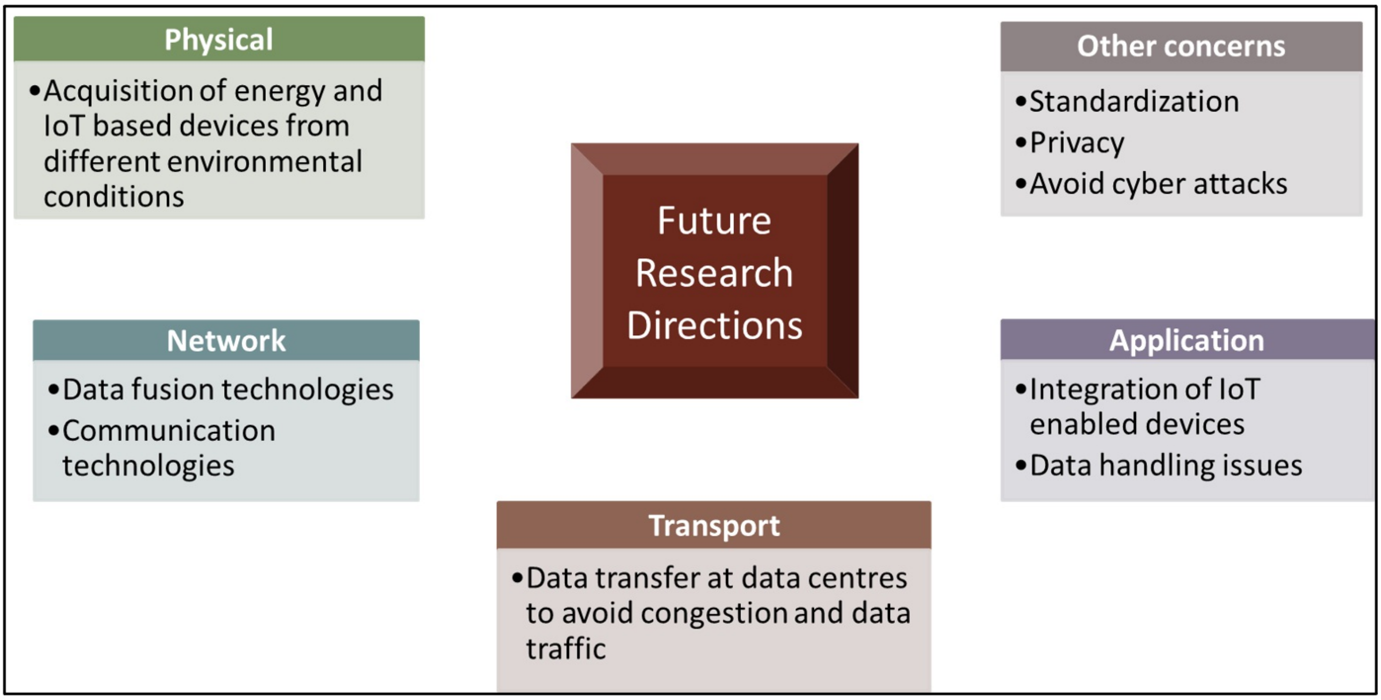

Figure 7. IoT-based Future Directions for the Smart Grid

Machine learning can also assist IoT-based smart grid systems in learning about their previous activities and making better decisions [137]. Electrical load forecasting is a difficult challenge due to unpredictable circumstances, like climate and time. It is a curious area to explore the applications of machine learning to IoT-based smart grids and other systems that can considerably enhance performance.

8. Conclusion

In this digital era, technological possibilities are progressively transforming the economic sector and cultures. Digitalization has facilitated numerous opportunities for technology improvements and effective utilization of limited resources, i.e., Information Technology and the Internet of Things, supporting smart technologies. 'Energy Digitalization' is one of the prominent evolving implementation areas of IoT technologies.

Healthcare systems might benefit from IoT as well, both in terms of efficiency and cost, which is essential for hospitals. The present COVID-19 epidemic prompted the evaluation of several IoT devices that might aid in efficient monitoring and control, demonstrating the increased value of IoT goods. The transportation sector is also leveraging the benefits of IoT devices in vehicles to control and monitor. In the highly demanding area of autonomous vehicles, significant developments are expected in the coming future. The energy industry is currently one of the most advanced application areas of IoT technology. Smart homes, the creation of smart and adaptable microgrids, and developments in effective demand-side management of power networks are among the solutions being developed.

The smart grid is the upcoming grid that explains the challenges of uni-directional data flow, energy waste, rising energy needs, trustworthiness, and safety in the conventional power grid. The IoT helps the smart grid by delivering smart devices (sensors, actuators, and smart meters) for the monitoring, evaluation, and management of the grid, and connectivity, automation, and tracing of such devices. Thus, smart grids are expected to expand rapidly in the energy market. This shows that IoT-aided smart grid networks universally boost multiple network-based operations at higher levels of energy generation and transmission. The convergence of IoT is expected to quickly increase functionality, energy, and economy, amalgamating the complete automation of a smart grid built on the IoT. With the development of IoT-based smart grid systems, a concentrated research effort is needed on addressing the security issues using efficient cybersecurity mechanisms.

This study summarizes the current work in the smart grid from researchers all over and identifies the challenges during the implementation of IoT in the smart grid. When the nation begins its fourth industrial revolution, the study focuses on the issues that smart grid-based IoT systems face and the various opportunities to improve them. The main purpose of this analysis is to suggest feasible and practical solutions to the challenges encountered during the implementation of IoT in the smart grid. This study also offers insights into the evolution of the technology and its application in society.

It is evident from the above-mentioned recent study results that IoT innovations are an opportunity for society and can offer valuable benefits to the community. There is no question that IoT technology would offer multiple benefits to society and an increase in the quality of life. Any technology has vulnerabilities and disadvantages that must be established and carefully inspected promptly. This also refers to IoT, which can transform our lives and behaviours. The intensive ongoing research and development carried out in IoT technology has enabled devices to work together with one another, collect data, and function as required. IoT has added what we now call smartness to devices, processes, and systems. Smartphones, cities, grids, transport, healthcare, and many other systems have achieved this intelligence. This technological transformation is gradually penetrating lives from a privilege to an essential requirement.

Some potential IoT application areas are still unknown or have a lack of strategy for addressing them. This indicates that more intensive research in this difficult area is needed to uncover new and significant societal benefits. The applicability and significance of IoT technologies in forthcoming times are apparent and will play a critical role. This is the time to work towards holistically integrating IoT into our lives to ensure safety, security, and sustainability.

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