Chapter 11
5G and Internet of Things—Integration Trends, Opportunities, and Future Research Avenues

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Abstract The Fifth Generation Communication System (5G) has revolutionized data (voice, text, and hybrid) transmission and communication. Advanced communication protocol and sophisticated technology open up the opportunity to integrate 5G with other state-of-the-art technologies. Similarly, the Internet of Things combines sensors, actuators, and other devices that network together to collect contextual and environmental data for application-specific purposes. Nowadays, the applications of IoT need a fast data transfer to ensure smooth service. 5G has the potential to achieve this function for IoT. However, the energy-efficient architecture and easy-to-manage 5G-enabled IoT are still developing. Hence, the potential vulnerability issues of 5G-enabled IoT architecture need to be studied. In this paper, firstly, we have comprehensively discussed the fundamental architecture and characteristics of the 5G ecosystem. Later, the paper comprehensively outlined the characteristics and layered architecture of the internet of things. Then, this chapter also explores the requirements of 5G-enabled IoT, Blockchain-based 5G IoT, and 5G with artificial intelligence. Followed by this discussion, the chapter investigates the opportunities of 5G IoT in different domains. Finally, this paper investigates and analyzes the research gaps, challenges, and probable solutions comprehensively in a tabular format.

Keywords 5G · IoT · Opportunities · Challenges · Architecture

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Introduction

New technologies, such as Big data, Blockchain, Communication systems, the Internet of Things, Virtual Reality, etc., have revolutionized the world (Li et al. 2018a). The Internet of Things (IoT) facilitates information collection using various devices, exchanges data with the help of communication protocols, and transmits data from real-life situations for different IoT applications. By 2030, IoT modules will have connected more than 80 billion people. It creates a massive volume of data generated from different system nodes. 5G network enables IoT to transfer this data with higher speed and data quality irrespective of the data structure differences.

The IoT systems for future applications will require enormous capabilities regarding the data receiving and processing mechanism. 5G can provide the platform to achieve these capabilities. Implementing a 5G network in IoT infrastructure will pose a new challenge and open many research windows. At the same time, it will provide unrivaled potential in modern times. 5G network aims to improve drawbacks of prior communication networks including 2G/3G/4G. It will also add new capabilities to the mentioned network system forming an architecture for heterogenic use. 5G IoT applications support a variety of QoS criteria, wide spectrum of wireless connections, and large quantities of data traffic. There are various benefits and drawbacks due to the gap in convergent technologies. The installation value as well as the growth of accomplishments for these drawbacks restrains this advancement. 5G is configured to improve the speed and security of our connections. So, 5G will enable modern enterprises and applications due to security, high speed, adaptation of new technologies and applications with a low-cost deployment.

5G is envisioned as a future cellular network technology with a 99.99999 percent dependability and a 100Mbps data transfer rate. It can ensure a consistent high-speed experience for users projecting an estimated one millisecond of round-trip delay. The three primary sorts of applications that make up 5G are Ultra-Reliable Low Latency Communication (URLLC), Massive Machine Type Communication (mMTC), and Enhanced Mobile Broadband (eMBB). Haptic communication and automation integration are made possible using fixed access bands of sub-GHZ mm-Wave embedded with tiny Base Stations (BTS) and mm-Wave local nodes. Furthermore, 5G cellular networks can interface with UAVs in various ways. Blockchain technology, according to recent research, increases the security, privacy, and transparency spectrums of 5G (llah et al. 2019). In compliance with blockchain and AI, 5G can change the world of communication (Haque and Rahman 2020).

The Internet of Objects (IoT) is based on the concept of intercommunication amongst heterogeneous things that use a variety of communication standards, stations, sensors, nodes, data centers, and artificial intelligence (AI) capable devices. As a result, the next generation 5G network will be connected to billions of devices, resulting in a super IoT infrastructure.

5G integrated IoT is an idea to develop the communication and transmission process of data in the IoT environment (Arora et al. 2020). Implementation of 5G in IoT architecture will change tour lifestyle bringing a vast amount of IoT devices in one place within a second. It will provide the applications that we believe to be backdated due to response time as the fastest ones. The 5th generation wireless system is a driver for modern-day IoT applications. Shortly, the 5G will become inevitable for the advanced devices used in IoT systems. Even there is a chance of needing advanced 5G for more advanced applications of IoT like satellite research or worldwide wireless data transmission (Popovski et al. 2018). Nevertheless, along with these, there come some issues regarding the architecture. It is still a new concept and consistently evolving. Getting a low latency in a wide range is not an easy task. 5G itself is developing and has not yet been implemented worldwide. Hence, there remains a vast domain of security and structural challenges.

This chapter explains the opportunities and challenges of the 5G integrated IoT ecosystem. The domain can be extended to blockchain and artificial intelligence perspectives. The outline of the contribution of this work can be briefed as follows:

- The fundamental concept, architecture, and characteristics of the 5G ecosystem and its evolution are comprehensively discussed.
- Discussed an overview of IoT, along with its characteristics.
- The three-layered architecture for IoT systems has been speculated.
- Requirements to build a 5G integrated IoT ecosystem are outlined.
- Presents a holistic description of 5G-enabled IoT application scope in different domains.
- Finally, delves deep into analyzing the research gaps, challenges, and tentative solutions of 5G IoT.

The rest of the paper is structured as follows: section "Overview of 5G" provides an overview of 5G and its evolution and general architectural requirements. Section "An Insight into IoT" details the IoT characteristics and the layered architecture. Section "Requirements for 5G Integrated IoT Architecture" illustrates the basics of the 5G integrated IoT ecosystem in different domains. Section "portunities of 5G Integrated IoT" illustrates the opportunities of 5G IoT in various domains. Finally, section "Challenges of 5G Integrated IoT" speculates the challenges of the 5G IoT ecosystem for future research, followed by the conclusion in section "Conclusion".

Overview of 5G

5G enables the next generation of mobile networks to make a quantum leap forward in wireless communication. Day by day, the demands of many applications are increasing. The rapidly changing wireless technology is constantly trying to keep up with this evolution. Applications that are dependent on big data and other networks of multiple things like quick money transfer, detecting critical diseases, inventory management etc. use the characteristics of 5G to enhance the system increasing efficacy (Ficzere et al. 2021). 4G and prior generations cannot support the latest apps that require high data processing ability with high quality of service (QoS) and quality of experience (QoE). The transmission rates are likewise in Gbps, and the typical transmission rate is 100+ (Mbps). The tests show that 5G can give a transmission rate up to 20 Gbps, which is 100 times faster than 4G. So, introducing 5G in the network system can change the communication process entirely.

Evolution of 5G

In the 1950s, the first rudimentary portable communications were introduced in the United States. The first (1G) portable was introduced after three decades. The second generation of radio communication (2G) was spurred by digital technologies that used one's SMS efficiency with the invention of the microprocessor. After a few years, the GPRS combined with 2G network provides the benefits of sharing voice calls, MMS, pictures, etc. more smoothly. For improved systems, the third era (3G) was adopted in the sound and notifying equipment like live TV and fast internet in the twenty-first century. The Fourth Generation (4G) was developed in response to the excessively high momentum of online connection in 4G-enabled gadgets. Modern-day communication exceeds the barrier of mobile phones including iceboxes, computers, automobiles, and other modern gadgets to the architecture. A fast site and data transfer feature is necessary to understand ongoing device engagement and access additional devices. This fact also inspires the innovation of fifth era (5G) of communication. We can simply put it, 5G is a 5th generation mobile network. Here, we will discuss three types of 5G in general (Waring 2018).

Low Band 5G

Low-band 5G uses frequencies less than 2 GHz. These are the radio and television frequencies that have been around the longest. They can cover vast distances, but there are no particularly large channels. The Low Band 5G indicates the lowest possible data rate. As a result, 5G with limited bandwidth is sluggish. These channels vary from 5 to 15 MHz for different cellular networks like AT&T, T-Mobile, and Verizon. It is considered to be the worst case of 5G, which is somewhat faster than 4G.

Medium Band 5G

Mid-band 5G uses 2.5 GHz and 3.5–3.7 GHz frequencies in most countries. It is faster than Low-band 5G using less than 6 GHz frequency. It can cover the majority of frequencies used by the mobile and networks connected to Wi-Fi, as well as several frequencies slightly above them. Because these networks can cover a radius of several miles from towers built-in not more than half a mile across, they are the functioning networks with the highest 5G traffic in most nations.

High Band 5G

Compared to the 5G mentioned above, short-distance tower-enabled millimeter wave spectrum brings high-band 5G. The airwaves have mostly been in the 20–100 GHz band till now. These frequencies have never been used for consumer purposes previously. They're only used across short distances. Therefore, running the tests on several platforms suggests roughly 800 feet away in a dense urban environment from the towers. However, there are many unoccupied signals, allowing for extremely high speeds of hopefully up to 800 MHz at a time.

Characteristics and Requirements of 5G Ecosystem

5G can increase its speed up to 20 times than 4G. It is expected to offer 20 GB per second speed whereas 4G is only promised 1 GB per second. Varying to the network infrastructure and service operator, the speed can vary. According to Qualcomm, 5G has shown a speed of 4.5 GB per second in its tests and an average of 1.4 GB per second (Qualcomm 2020). This is at least 20 times improved speed than the fastest 4G network. Enabling 5G to reach that speed will change the form of HD streaming, making the 'download' button a 'play' button. For the high latency, delay time will be significantly reduced and browsing will faster than ever before. Some of the significant characteristics of the 5G network are:

- Very low latency (around 1 ms).
- Speed up to 100 Gbps (10–100× than 4G and 4.5G).
- Availability of 99.99% over the world.
- Cover 100% of the places.
- Reduction of energy up to 90%.
- Increase battery life for IoT devices with low power up to 10 year.

To have a 5G network with these characteristics in association with IoT, there should be some specific capabilities provided to the architecture (Kozma et al. 2019). Such as:

- Efficient resource management for IoT and bulk operations.
- Prioritize the quality of service and standard control.
- Network slicing and exposure.
- Energy efficacy.
- Application in cyber-physical domain.
- Positioning availability.

High dependability is a fundamental differentiator as compared to non-licensed radio spectrum designs or traditional, evolutionary-engineered heterogeneous networks (Bose et al. 2011). So, it is especially critical for 5G.

5G Architecture

The network layer, controller layer, management, and service layer are the four levels of the 5G architecture paradigm. The 5G protocol stack has two sublayers: Radio Link Control (RLC) and Pocket Data Convergence Protocol (PDCP). Instead of base stations (BS), 5G's network architecture uses adaptive, virtual, and flexible radio access network (RAN) points and a sophisticated dispersed design. To establish various data access points, these virtual RANs incorporate additional interfaces, components, and compositions (Ngo 2021). A generic architecture for 5G ecosystem must have the following function:

- Radio Access Network (RAN): 5G uses RAN to connect many technologies providing FDD frequency.
- Data Network: It provides operator services third-party services for internet access.
- Access and Mobility Management: This function ensures integrity protection, authorizes access, manages mobility, links among devices, connect ability, etc.
- Network Slice Selection: This function decides instances for user equipment and information for the assistance function.
- Server Authentication Function: It does the work of authentication for trusted and untrusted 3GPP access.
- Control Policy: This function initiates policy frameworks to control network behavior.
- Network Exposure: It exposes the network application and manages external and internal communication securing information.

There are many more functions of 5G architecture varying from application to application. However, the basic scenario of every function tends to achieve more speed, low latency, proper management, and security (Haque and Bhushan 2021a).

An Insight into IoT

IoT or the Internet of Things is a networked digital system of various electronic devices like sensors, activators, receivers, nodes that compute data, etc. By eliminating human involvement, IoT devices have transformed the data collecting and processing system. From top to bottom, IoT devices enhance the development of concepts like smart home, smart vehicle, smart agriculture (Pranto et al. 2021), smart health care, communication, cybersecurity and many more systems (Haque et al. 2021a). They have been used to conduct, monitor, and produce reactions based on the information gathered. People have been thinking of connecting devices to the Internet for a long time. The Internet of Things, on the other hand, enhances and extends network technology based on existing internet technology, allowing computing and smart objects to connect and communicate with one another. The IoT can be broadly defined as any object that communicates, produces, and interchanges data with other objects via the Internet to perform orientation tracing, tracking, intelligent recognition, and management. This process is conducted by various sensors or peripherals such as GPS, thermal sensors, RFID, etc. (Yang et al. 2011).

Characteristics of IoT

There are many functional and non-functional IoT needs for creating the infrastructure. We will discuss some of the most valuable characteristics of IoT here.

Availability

To provide customers with facilities wherever and whenever they need them, IoT availability must be implemented at the hardware and software levels. The capacity of IoT systems to give functionality to anybody in any location is referred to as software availability (Mistry et al. 2020a). The nature of computers that are always compatible with IoT features and protocols is referred to as hardware availability. To allow IoT capabilities, protocols like IPv6, 6LoWPAN, RPL, CoAP, and others need to be implemented inside the restricted devices of the single board resource. One technique for achieving high IoT service availability is to ensure the availability of critical hardware and facilities (Bahalul Haque 2019).

Mobility

Although most utilities are designed to be delivered via Smartphone devices, IoT implementation is hampered by accessibility. A key IoT premise is to keep customers connected to their preferred resources when moving. When mobile devices are relocated from one gateway to another, service interruptions may occur. Caching and tunneling for service continuity allow apps to access IoT data even if the internet is down for a short time. The vast number of smart devices available in IoT systems is usually included in any solid framework for mobility control.

Scalability

Scalability in the Internet of Things refers to the ability to accept new client equipment, software, and capabilities without compromising the efficiency of existing systems. It is not straightforward to add new processes and manage extra devices, especially when there are several hardware platforms and communication protocols to contend with. IoT applications must be built from the ground up to enable extendable services and operations.

Security and Privacy

On diverse networks, such as the Internet of Things, ensuring user security and privacy is strict. The fundamental functioning of the Internet of Things is built on data transmission between billions, if not trillions, of Internet-connected items. One great problem in IoT security left out of the standards is the key distribution between devices. The growing number of intelligent objects around us with sensitive data necessitates transparent and simple access control management, such as enabling one vendor to view the data. In contrast, another controls the device (Bahalul Haque et al. 2022).

Performance

The performance of IoT services is difficult to evaluate since it is based on the performance of many components and the underlying technology. The Internet of Things, like other programs, must constantly develop and expand its offerings in order to meet user expectations. To give the most value at the lowest cost to customers, IoT solutions must be monitored and validated. IoT performance may be measured using various criteria, including processing speed, connection speed, system form factor, and cost.

IoT also needs to manage the larger amount of information or data created in the ecosystem, ensuring the interoperability and quality of service.

Layered Architecture of IoT

Various designs have been suggested for IoT worlds. In general, such structures are divided into three categories. There are three types of architecture: three-layer architecture, four-layer architecture, and five-layer architecture. In this chapter, we will look at the three-layered architecture. It is organized keeping mid some specific tasks to accomplish by the system like executing service functions, transmitting data, and connection among service devices. It results in three layers, Application layer, Network/Transmission layer, and Perception/Edge layer.

Application Layer

In different implementations, this layer may include various services. Smart grids, healthcare, and autonomous automobiles are examples of IoT deployment in smart cities and homes. Because the application layer might serve as a service support middleware, a networking standard, or a cloud computing platform, security considerations vary depending on the application's environment and industry. The application layer provides customers with the services they require. The application layer, for example, should give temperature and relative humidity values to the client who has requested the information. This layer is critical for the IoT because it allows for creating high-quality smart services that fulfill user demands.

Network Layer

Acting as a bridge, the network layer controls data transfer to subsequent layers. This layer connects to the visual layer. Different smart devices are connected to the network layer following control function protocol (IEEE 802.x) and authentication standards (GPS, and Near-Field Connectivity (NFC)). A server backend architecture, smart devices, and the Internet protocol contribute to this tier. In addition, the network layer can be handled according to the peculiarities of the deployed environment. The transmission of data is highly prone to cyber-attacks. Intelligent intrusion detection key encryption with secured management-based IoT security framework is the most popular along with the latest adoption of blockchain technology.

Edge Layer

Edge layer manages the IoT devices or sensors like RFID, different actuators, cameras, intensity detectors, moisture and pressure sensors, etc., using gateways in a coordinating function to connect with the client or their working domains. Its main task is to collect data from the environment and transfer them forward for further processing. IPs like IPv6 or gateways can transmit this to follow protocol translation and traffic management. The sensors and actuators prohibit a common and standard security mechanism from protecting these devices. Hence, the interoperability among devices and physical accessibility expose a handful of security threats. Researchers have proposed security solutions for this layer based on machine learning, multi-stepped authorization, secure channeling through anti-malware, etc.

Requirements for 5G Integrated IoT Architecture

5G-enabled IoT needs special attention for its heterogeneity, advancement, and application. However, there are some requirements that all the architecture should follow (Li et al. 2018b):

- 5G IoT must ensure a low latency of 1 ms considering the sensitive internet system and medical perspective.
- The architecture must ensure low energy consumption for low-battery life IoT devices but enough for 5G to transfer data.
- An advanced application like Virtual Reality or Augmented Reality needs a high speed of 25 Mbps, so the architecture must follow with the future needs.

- Security must be top-notch, considering massive data transmission at a very high speed.
- The devices with mobility factors will get priority for the 5G IoT infrastructure.

The fundamental 5G IoT architecture consists of five steps in general: sensors, IoT Gateway, 5G-based station, cloud storage, and application (Arsh et al. 2021). These steps can be comprised in IoT layers to bring up a general 5G IoT architecture.

Edge Layer of 5G IoT

The sensors and gateway of IoT can be comprised of 5G in this layer. For example, sensors for wearable ECG, temperature, smart manufacturing etc. will use this layer to transmit and process information using 5G technology (Shdefat et al. 2021).

Network Layer of 5G IoT

The network layer will hold the 5G base station and cloud storage to process data using IoT devices.

Application Layer of 5G IoT

The application layer will provide all the support for the end system like smart home, smart supply chain, etc. (Haque et al. 2021b).

Following the above-mentioned general architecture, 5G IoT can support millimeter-wave (Rahimi et al. 2018), D2D communication, nano-chip, wireless software (Huang et al. 2020), mobile edge computing, data analytics cloud computing (Mudigonda et al. 2020), and many more technologies and application. In Fig. 11.1, we have shown a generalized architecture for the 5G integrated IoT ecosystem.

Blockchain-Based 5G IoT

Blockchain (Haque and Bhushan 2021b) can bring trust and improved security to 5G IoT. It can accelerate data exchange at a lower cost by implementing a cryptographic encryption system to the architecture. The immutability and accountability that blockchain can ensure for the system are marvelous (Hewa et al. 2020). Blockchain integrated 5G IoT can bring revolution to industrial IoT, Unmanned Autonomous Vehicle (UAV), and so on (Haque et al. 2020). Blockchain and 5G IoT can also be

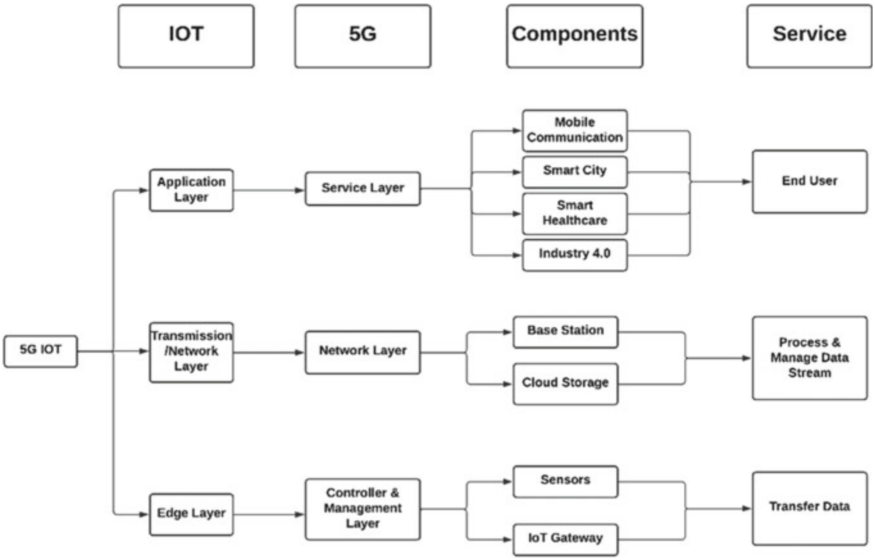

Fig. 11.1 A general 5G IoT-layered architecture

integrated with deep learning (Kaur and Shalu 2021). The architecture consists of the device layer, blockchain network, 5G mobile network and cloud network (Satpathy et al. 2021). It provides a data transmission using a smart contract with a 5G speed. Again, 5G IoT can be embedded with 5G mm-wave technology to build its processing center, object processor, sensing regions and application layer (Haque et al. 2021c). These layers work together using cloud storage and a 5G network to provide services like education, fire station, transportation, factories, etc.

5G IoT with Artificial Intelligence

Adversarial artificial intelligence can provide great security support towards 5G IoT (Bohara et al. 2021). It can enable technologies like massive MIMO, cloud RAN, multi-RAT to prevent security threats like fast gradient sign method, one-pixel attack, DeepFool etc. The architecture accepts machine learning methodology like logistic regression, naïve Bayes, Q learning, K-means, Markov decision model etc. (Haque et al. 2021d).

Opportunities of 5G Integrated IoT

5G, is a booming technology that has opened many windows of opportunities. High-speed and large-bandwidth capabilities will support more than 60,000 connections. Furthermore, 5G brings all networks together on a single platform. It also gives subscribers the ability to monitor their accounts and take swift action. 5G is backward compatible with earlier generations of networks. Moreover, 5G is designed to deliver the globally uninterrupted and constant connection. Enabling 5G with IoT will accelerate the development in many other sectors including technology, business, industry, etc.

Technological Advancement

IoT includes many aspects of technology that 5G can make the best use of. 5G can make these technologies overcome their shortcomings providing remarkable achievements. Here, we will discuss some technologies that 5G will change forever.

Network Function Virtualization (NFV)

NFV is used to develop network service resiliency and lessen the time it takes to adopt new systems and technologies. It separates the hardware and software requirements for complicated operations (Han et al. 2015). The NFV performs the role of a virtualization enabler and facilitates the dissemination of 5G-IoT. Virtualized load balancers, intrusion detection systems, and firewalls are all instances of NFV. Integrating 5G with IoT will allow NFV to detect threats more accurately and provide network services with flexibility and developed scalability.

Mobile Cloud Computing (MCC)

Cloud computing is a service that allows one to outsource his or her processing resources (Failed 2020). End-users can get authorized access to databases, datasets, and information over the Internet, including the ability to analyze and transfer with the power of 5G networks. Cloud computing is a new fundamental technology in IT architecture that allows users to compute or store data without building up an extensive infrastructure. The MCC combined cloud computing with mobile computing to give consumers elasticity and on-demand services. Many services now allow users to connect their mobile devices to the cloud. Data transmission using edge computing with 5G decreases the transfer time. Moreover, the inclusion of these technologies guarantees that context information has reduced latency and is more accessible.

Device-To-Device Communications (D2D)

5G network enables smooth D2D communication implementing direct communication without any intermediary (Goyal et al. 2021). There are four types of this D2D communication, including transmission among devices using the operator-controlled link, transmission among devices with the device-controlled link, direct D2D communication with an operator-controlled link and direct D2D communication with a device-controlled link (Mani Sekhar et al. 2021).

Software-Defined Network (SDN)

SDN opens up new network administration and design (Abdelwahab et al. 2016). It is emerging as the most promising answer for the Internet's future. It has two distinguishing features: data plane separation and advanced application development programming. This allows for more effective configuration, efficiency, and flexibility when creating network architectures (Xia 2014). The SDN prototype was used to create 5G networks in order to retain a flexible and quicker 5G-IoT topology (Xie et al. 2019).

Millimeter Wave Communication

Mobile networks continuously need increased retention to improve frequency. 5G mm wave can pave the way for newly developed radio wave frequency. It will enable IoT to work more efficiently providing high speed (up to 20Gbps) and high availability accompanied by a mobile network than 4G network. Moreover, the enhanced broadband in mobile networks due to this 5G evolution will initiate applications like VR and augmented video, live streaming, UHD video, etc.

Mobile Edge Computing (MEC)

A significant portion of cloud services has been possible because of the development of several advanced computer applications such as artificial intelligence and smart environments. Cloud computing has various needs, including low latency, location awareness, and mobility support. The MEC (Ahmed and Rehmani 2017) can bring the mentioned operations and resources nearer to the network edge. Because of MEC in 5G IoT, applications such as VR and AR will grow.

In addition to these technologies, many more are constantly being added to our day-to-day life all over the world. The network capability and coverage must be developed to mitigate this global traffic. 5G has the ability to evolve with these new innovations as well as enhance its ability (Nguyen et al. 2020).

Smart Cities

From supply chain management of all the necessary goods and needs of daily life to home automation system to improved communication, 5G will have a broader use in smart city programs. Smart Cities will benefit from 5G network with developed sensors advancing the urban infrastructure. 5G will be able to manage massive amounts of data and combine a variety of intelligent technologies that are continuously connecting with one another to bring a genuinely linked city even closer together (Minoli and Occhiogrosso 2019).

Smart Healthcare

Because 5G will have an impact on IoT, it will also have an impact on the areas touched by IoT. The Internet of Medical Things, or IoMT, is the most important of them. Rural and other comparable isolated places that lack proper health services can tremendously benefit from the Internet of Things connectivity. After a long crave of world-class health services to be remotely achievable like distant operations are becoming a possibility (Ahad et al. 2020).

Smart Vehicles

Automated cars collect various data on temperature, weather, traffic, GPS position, and other factors using modern sensors, resulting in a significant volume of data. A lot of energy is expended in the generation and processing of so much data. To deliver best services, these vehicles depend largely on real-time data transmission. The system that is built-in these vehicles can be initiated to collect every kind of data that are required including the crucial ones with high-speed connectivity and minimal latency. Eventually, it will enable the vehicles to autonomously monitor its operation and enhance future models including the system algorithm (Mistry et al. 2020b).

Smart Logistics

Advanced IoT tracking devices that can execute logistical activities will be able to use 5G connectivity. The real-time data transmission will be faster than ever before with the efficacy of high speed and low latency of 5G. Moreover, it will be energy efficient in case of long supply chain that takes time. For example, a consumer may learn where the fruit is grown, at what temperature it is kept during transit, and when it is delivered to a retailer (Wang et al. 2020).

Smart Grid

In day-to-day operations, the need for power is rapidly growing. Demand management can be aided by smart grids and virtual power plants. 5G technology is appropriate for real-time management in the energy and utility industry providing solutions that would ensure optimal operations and maintenance by quickly recognizing and responding to grid faults (Shahinzadeh et al. 2020). 5G can renovate the smart grid replacing wired technology establishing better deployment flexibility and cheaper expenditure.

Business

5G-enabled IoT is predicted to deliver more than just technical advancement; it is also estimated to support 22 million employments globally. The modernization of transportation, industry, agriculture, and other physical industries is likely to drive this rise. Areas like construction of oil miners, freight fleets, and railway that need faster transmission due to the nature of the product will be affected positively (Rong et al. 2020). 5G has the ability to advance smart manufacturing and intelligent equipment. In near future, 5G will enable IoT to do near-instantaneous network traffic management, resolution, increase security and public safety, and operate remotely.

Aerial and Satellite Research

The advancement of 5G network also opens the window of vast aerial and satellite communication and research. High Altitude Performance system (HAPs) is being investigated in accomplice with satellite. Modifying the 5G network with Narrowband-IoT (NB-IoT) makes it a seamless integration (Gineste et al. 2017). It can enable moderately structured satellites to communicate at low bitrate. It is also possible to enhance the 5G mobile network with combined satellite-terrestrial networks (Fang et al. 2020).

Mitigating Pandemic Situation

5G can renovate the technologies to mitigate issues in pandemic situation. The integration of 5G and IoT improves the telehealth service to check patients remotely through massive Machine Type Communication (mMTC). Moreover, 5G-supported Bluetooth Low Energy (BLE)-based IoT devices can manage COVID-19 patient detection and monitoring (Haque et al. 2021e). The massive connectivity of data does not need any gateway and provides long-time battery support for low-power IoT devices (Siriwardhana et al. 2020).

Industrial Usage with Other Technologies

5G-enabled IoT can revamp many industries by developing specific technologies as well as mitigate some of their core issues. Some of the technologies that will enable industrial IoT significantly are discussed here.

Blockchain Integrated 5G IoT

5G IoT can be integrated with decentralized blockchain technology to ensure better privacy and security of data in industrial IoT (IIoT) (Haque et al. 2022). Supply chain industries that store data on blockchain require real-time data tracking like timestamp, origin, shipment, amount, etc. (Haque and Bhushan 2021c). 5G-enabled IoT can ease the traceability ensuring public verifiability for stakeholders. In addition to this, combined with deep reinforcement learning (DRL), blockchain integrated with 5G IoT can provide a secure sharing scheme for IIoT (Liu et al. 2019).

Big Data Processing with Machine Learning (ML)

Various machine and deep learning approaches used for big data analysis like viz, Convolutional Neural Network, Recurrent Neural Network, Deep Neural Network, etc. need higher optimization and processing time. Along with them, complex mathematical models are used that take higher execution time. 5G-enabled IoT can reduce this time greatly and save energy ensuring efficient industrial resource management (Dai et al. 2019).

Artificial Intelligence (AI)

To build an AI-based industry, a lot of data are needed to train and test AI algorithm model. 5G-enabled IoT has the ability to provide the developed infrastructure to collect this huge amount of data (Kumari et al. 2020). Using this data, AI can generate valuable insights for the industry as well as give clear context of the network to further develop it.

Optimization System

5G-enabled IoT addresses network-related issues in IoT using many procedures of optimization. These optimization procedures include stochastic, heuristic, and computational approach along with genetic and evolutionary algorithms, etc. This aids in the effective monitoring and minimization of IoT device-generated network traffic.

Video Surveillance

Video surveillance is another application that is projected to operate well in the 5G ecosystem. Many industries as well as private sectors throughout the world are using surveillance systems. Wired connection is still used by many video surveillance systems today. Wireless communications like Wi-Fi and cellular are gaining popularity due to their ease, speed, and low cost of implementation. In near future, it is expected to increase at a higher rate to ensure better security. The utilization of 5G will support the necessary peed boost required for real-time video data analytics and the propagation of a large number of surveillance (Kumhar and Bhatia 2021).

Challenges of 5G Integrated IoT

5G integrated with IoT has provided us with extraordinary features ubiquitously. State-of-the-art research has shown that more applications and advancements are achievable through extensive connectivity ensuring reliable Quality of Service (QoS). With these advancements, come a lot more challenges that need to be taken care of. Here, we will discuss some of the crucial challenges of 5G integrated IoT.

General Challenges

5G IoT can be molded with other technologies but posed similar type of challenges irrespective of their applications.

Low Control on Data Usage and Storage

A massive quantity of data are created in a 5G IoT network. It is created through devices that are unique to numerous businesses. As a result, these data are frequently out of the control of all the stakeholders or users concerned (Sinha et al. 2017). The data can be subject to all suppliers whose equipment creates a network node, all service providers who use a common 5G network architecture, or all users who share a single cloud platform when used by all parties (Jaitly et al. 2017). As a result, it is a complex task to track which data come from whom, who is the creator and the processing system.

Scalability

Cloud-based architecture enables 5G IoT to control and manage the overall network. To put it another way, the nodes in the network create data for processing to a common cloud. Then, the network nodes send back the control signals to carry out tasks like storage reallocation, traffic management, fault management, routing, and so on. However, as the number of connected devices grows, so does the volume of data they generate, making scaling up the capacity and computational power of centralized cloud servers an approaching problem. Furthermore, devices connect to the cloud nodes via a gateway or an edge node in 5G and IoT ecosystem (Mehbodniya et al. 2022). Due to the large number of devices attempting to connect to the cloud, the fronthaul, midhaul, and backhaul networks directly close to gateway nodes frequently become narrowed reducing the scalability of the overall network.

Complicated Interaction Among Devices

The technological standards embedded in the devices that are used in 5G IoT ecosystem have varied signaling wave, different data bits, different PHY and MAC protocols, coding structure, user interfaces, etc. The operation of these devices is also backed by different operating systems. So, it is a very complicated task to initiate a mutual communication standard that will be followed throughout the 5G IoT infrastructure. Again, a common program or operating system that can keep up to different communication protocol for multiple devices is also very difficult to introduce. Hence, it can prohibit the extension of certain application and even restrict some devices to use in 5G IoT environment (Singla et al. 2021).

Data Auditability

Data created in 5G IoT networks have several owners and are extremely noncompliance, making it difficult to trace and audit. There are also situations when there are no common standards or protocols in place for data as discussed before to be shared across devices owned by various businesses (Bhushan and Sahoo 2017). Furthermore, data may be non-processable or not transmittable across various divisions of an organization due to differing communication protocols and also because of trust difficulties (Bhushan and Sahoo 2019). Similar sorts of data like meteorological and environmental data are sometimes not being impart or inter-operated by multiple entities in order to arrive at an agreed reasoning.

Heterogeneity of 5G and IoT Data

Both 5G and IoT ecosystem has a varied nature causing several compatibility concerns while implementing distinct applications. Because the data created in IoT networks and 5G cellular networks are diverse and multidimensional, it is almost impossible to forecast exact characteristics and outcome. As a result, early operations like as cleaning, ordering, and preprocessing are required to train this type of data since the integration of such a diverse set of data leads to incorrect calculation. Hence, test of datasets in diverse situations needs to give more attention to this aspect for dataset training and feature selection. Sensors and humans, for example, create data for IoT networks in smart homes. However, a common or central server must contain all the data utilized in this application (Palanisamy and Bhatia 2022). This server will be responsible to pool and train data from many sources so that it can cope with data variety and achieve higher prediction accuracy.

Blockchain Integrating 5G IoT Issues

Blockchain, integrating with 5G IoT, opens opportunities for many applications. But many of them come up with different challenges too. Some big challenges for blockchain integrated 5G IoT ecosystem are discussed here.

Processing Time

A few self-executing tasks like transaction and block verification are required to build the chain in the blockchain ecosystem. These computations follow some specific cryptographic procedures to maintain the authenticity of the blocks in blockchain that takes a lot of time. It can be a solution to lessen the amount of training data but there are specific computing restrictions in the IoT context that could lead to security problems. As a result, a big concern for the implementation of blockchain in the context of IoT is it needs fewer resource-intensive replacements to reduce processing time.

Privacy and Security

IoT alone brings many privacy issues to the blockchain integrated 5G network for its vast number of devices using numerous sensors connected worldwide. Moreover, blockchain prefers to public verification of transaction. Keeping up the encryption procedure of blockchain along with 5G data protection carries a significant challenge. There are some studies to overcome this issue proposing homomorphic computation to cover up the data at the time of access of any user (Zhou et al. 2018). But controlling over 51% of data from 5G IoT ecosystem can lead to reverse transaction or double-spending problem. So, combined solution is still a big challenge.

Storage Scalability

A major need of blockchain technology is the constant storing of transactions and blocks. Each node should theoretically have a copy of the ledger that grows in tandem with the transactions. From a scalability standpoint, the IoT ecosystem's storage effect will have an influence on the overall system's operation. The changing transactions that come with scaling up the system, in particular, need a lot of storage.

Cost

Blockchain has its own scalability issues, but on the other hand, throughput or cost is another big difficulty with this technology. For IoT, it is difficult to keep up with the growing number of transactions and their size. Two more issues that arise often are latency and transaction throughput. Due to the less data generation of private blockchain than public blockchain, it is more preferable to IoT environment. But 5G IoT generates big data and the analysis of this huge throughput by blockchain increases computational cost.

5G mm-Wave Issues

5G mm-wave application has promising significance in increasing robustness of the IoT ecosystem, low latency, and higher capacity allocation for Multiple Input Multiple Output (MIMO) technologies. But it has a range limitation in communication. Moreover, the core of 5G mm-wave is combined with devices that are different in characteristics like LTE and mm-wave band. Again, it is susceptible to blockage restricting its mobility for its rich scattering environment. It also consumes a lot of power due to extensive use of hardware. Hence, disturbance in connection for weather condition makes it challenging to use with IoT infrastructure (Dang 2022).

Threat Protection of 5G IoT

Even after mitigating issues of 5G and IoT distinctively, security threats will come again in a 5G integrated IoT infrastructure. There are lots of security threats like DoS attack, signaling storms, slice theft, penetration attacks, Man-in-the-middle attack (MITM), TCP level attack, security key exposure reset and IP spoofing attack, etc. are intended to technologies like SDN, NFV, Cloud server, etc. (Bhushan and Sahoo

2020). These attacks can not only expose the overall 5G IoT application but also make a big impact on privacy of data (Ahmad et al. 2020). There are some solutions to these attacks like usage of low-powered nodes and sensors, cloud and application security for SDN and NFV, etc. But it is still a concern for future prospective 5G IoT ("5G support for Industrial IoT Applications 2020).

Table 11.1 summarizes and provides a short overview of the prominent challenges and their possible solutions of 5G integrated IoT system.

Apart from the stated issues, there will come more shortcomings and challenges in 5G IoT systems and applications. Hence, it will provide future directions for a large number of domains of research and development.

Conclusion

This paper is focused on the opportunities and challenges of 5G IoT integration in several domains of application along with their possible solutions. 5G network has the ability to connect more than 100 billion of devices and exchange data at least 10 times quicker than LTE resulting a game changer in IoT environment. The aim should be the introduction of scalable, affordable, and efficient network architecture for 5G IoT connecting vast amounts of devices. The applications of 5G IoT in several domains to increase efficacy can bring a lot of opportunities along with challenges. The architectural and security aspects are needed much concern. Furthermore, manufacturers must conduct quality and maintenance testing to guarantee the adoption of future software and hardware to perform their functions under a variety of scenarios (Li et al. 2018c). 5G IoT can give huge economic benefits to enterprises eager to embrace this new world when combined with important technologies like cloud security, artificial intelligence, and remote computing. In this chapter, we try to analyze the opportunities of 5G integrated IoT ecosystem for eradicating the shortcomings of IoT describing the features of 5G. The 5G IoT architecture also shows that there are many challenges and forthcoming research direction. We hope these illustrations will provide thorough insights and inspire the development of 5G IoT applications.

Table 11.1 Summary of challenges and state-of-the-art solution of 5G IoT

Domain	Challenges	Description	Solution	References
General challenges	Low control on data usage and storage	Different types of data are used by different entities Difficult to track down source of malicious data	A BICM-ID-based NAND flash memory system optimize with EPEXIT algorithm to manage data storage	Fang et al. (2021)
	Scalability	Ability and computational power to scale up data nodes decreases with the growth of data routes Attempt of numerous data to access cloud results in narrowed gateway	A cost-efficient SDN with data optimization in several sectors of industrial IoT and 5G	Okwuibe et al. (2020)
	Complicated interaction among devices	Lack of common operating system among interacting devices	A protocol named oneM2M using ontology	Jin et al. (2021)
	Data auditability	Lack of compatibility among entities to process, transfer and share data	Kernel bypassing using RDMA and DPDK	Varga et al. (2020)
Heterogeneity	Data disparity	Variation in 5G and IoT technologies poses extra attention to preprocess data Dataset testing and feature selection get compromised	Proposed possible solutions for 5G HetNet mobility management based on paging, registration, and access procedure	Gures et al. (2020)
AI integrated system	Bandwidth demand	Requires high bandwidth to manage complex algorithm	Suggested a B5G framework capable of high-bandwidth functionality	Hossain et al. (2020)
	Cost	Optimization cost tends to be higher due to usage of vast amount of data for training and testing	A VNF-optimized low-cost adaptation for AI operations is proposed	Ibrahimpašić et al. (2021)
Blockchain integrated System	Processing time	Requires fewer resource-intensive 5G IoT structure to reduce overall processing time	Smart contract-based blockchain integration	Mehta and Gupta (2020)

(continued)

Table 11.1 (continued)

Domain	Challenges	Description	Solution	References
	Privacy and security	Encryption process for 5G data is difficult to establish	Combined with deep learning, a blockchain-based four-layered framework is proposed	Rathore et al. (2021)
	Storage scalability	Large chain of blocks reduces storage scalability	Utilizing fog computing and cloud manufacturing equipment, a Hyperledger Fabric framework is introduced	Hewa et al. (2020)
	Throughput	Less data generation is preferable for private blockchain but 5G IoT requires big data increasing computational cost	Blockchain with VNFs following a novel consensus algorithm	Hakiri and Dezfouli (2021)
Spectrum	5G mm-Wave issue	Lack of consistency among LTE and 5G-enabled devices Affected by weather condition	An antenna design is proposed using hybrid beam forming for mobile transmission	Chen (2020)
Device standard	Common protocols	Scarcity of common protocols and standards irrespective of devices and application	A ZigBee-based IoT system is proposed for multi-device operation platform	Wang et al. (2021)
Security threats	Cyber-attacks like TCP level attack, IP spoofing, etc	Threatens privacy of data and exposes overall system	A convolutional neural network-based malware detection system is introduced	Anand et al. (2021)
Infrastructure	Network scalability and interoperability	Limitations of hardware and advanced technology to combine 5G with IoT	Multiple frequency antennas with the power of front-end radio frequency, diplexer, and triplexer are designed	Sharma et al. (2021)

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