Chapter 12

Emerging Internet of Things (IoTs) Scenarios using Machine Learning for 6G over 5G based Communications

Raghav Dangey, School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, 600127 Tamilnadu, India,

raghav.dangey2019@vitstudent.ac.in,

Arjun Tandon

School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, 600127 Tamilnadu, India,

arjun.tandon2019@vitstudent.ac.in

*Amit Kumar Tyagi[0000-0003-2657-8700]

Department of Fashion Technology, National Institute of Fashion Technology, New Delhi Delhi India, amitkrtyagi025@gmail.com

*Corresponding author

12.1 Introduction

Technology has become one of the fastest growing areas in communication, and the largest digital carrier of data worldwide. It is clear that device mixing has become increasingly advanced through diverse multimedia competencies with at least 3rd generation connectivity. as a result, this has seen the demand for the increased production of smart devices with better network connectivity and computing capabilities. It has also led to the share of smart connections and devices percentage growing significantly from 45% in 2015 to 86% in 2022, an increment of more than two folds during the figure time frames; it is projected that more than 74 billion devices are to be connected by the year 2026. The rollout of the 5G networks around the globe by the service providers is growing significantly due to ensuring that the end consumers demand higher safety, great bandwidth, and fast connectivity.

Significant advances in wireless sensing devices, communications, and informatics have enabled ubiquitous intelligence, predicting the future Internet of Things (IoT). People are increasingly looking forward to the IoT on a personal and business level. Viahealt h, smart homes, and smart learning, the Internet of Things greatly raises a person's quality of l ife. Note that for a professional approach, the Internet of Things has applications in logistics, smart supply chains, smart transportation, and remote monitoring.

In addition, the various developments in wireless network informatics and telecommunications have paved the realization of universal intelligence and the ideology of global computing in which the objectives were geared to embedding technology in day-to-day life. Smart homes, smart learning, and e-health are just a few examples of how internet of things (IoT) is significantly improving living standards at the individual level. For professionals, the Internet of Things uses a smart supply chain, logistics, transportation, automation, and remote monitoring. Recent trends show the blend of diverse technologies such as embedded systems and integration of sensors with the device to device, cyber-physical systems, and 5th generation communications with IoT as the center. Since new business models have been put in place due to technological advancements, many have been set for IoT implementations that require high privacy, complete security coverage, ultra-low latency, and massive data connectivity.

The involvement in the diversified environments and devices brings a vast variety of expectations and requirements, thus focusing more on the Internet of Things due to its vast range of applicability from human-centric to industry 5.0/4.0. Since IoT introduces significant protection measures for significant protection challenges and due to the wide variety of demanding situations and functionality, there is always a significant dependency of the IoT on the cellular network coverages since the long-term evolutions of LTE were introduced. [1].

12.2. Background work

The 5G-based IoT was created due to anticipated changes in consumer preferences and user demand for a new IoT experience. To ensure they overcame current IoT effects like communication issues and slow data transmission, the developers had to put in significantly more effort. This improved effective data sharing. The 5G-based IoT has been shown to have high data rates, highly scalable and fine-grained networks, extremely low latency, stability, resilience, and security. It also has a high connection density and is mobile. IoT apps will therefore be able to offer improved services thanks to 5G by capturing more data through a faster and more secure connection. Since the qualities of the 5G network are related to the communication requirements, they may be resolved under 5G. As long as the trend is maintained, the communication requirements will be easy to meet. As a result of reducing latency and increasing data transmission speed, the 5G network was created. Between devices, the 5G networks also use communication technology to increase spectral efficiency and enable users to connect nearby without interruptions or destructions. The 5G network developed the integration of edge computing enhanced IoT to improve the quality of user experience.

12.3 Problem Statement and Motivation

The advancements in machine learning have led to a new approach to solving this issue. In this review article, we will study the trends, prospects, and challenges in the world of 5G IoT using Machine Learning (ML) techniques to deliver effective IoT connections.

12.3.1 Motivation

The secret to managing all that data without hiccups and with less power use is machine learning. The 5G network can evaluate data trends and employ learned models to transfer data more effectively thanks to Machine Learning (ML). Due to the discussion's application to the bulk of modern inventions, readers may be inspired to devote time to IoT research and development.

IoT as a key player in smart cities The Internet of Things (IoT) can rightfully be considered to as the foundation for building a realistic smart city because it unites trillions of nodes in a single network that allows remote monitoring and management [3]. IoT may aid in diagnosing and monitoring distributed processes with the added potential of predicting future events by using learning technologies like ML and DL. Additionally, thanks to reduction and optimization, controlling complex systems becomes realistically feasible because of the cheap cost of IoT. The implementation of IoT can go beyond problems with modern cities including a lack of fresh water, monitoring of rubbish dumps, traffic jams, and air pollution. Traffic management, city air management tools, Smart infrastructure, smart parking, and smart waste management are examples of facilities.

12.3.1.1 IoT as a catalyst for 5G

IoT and 5G might change how we communicate in the future. Today, every business wants to gain access to the related client base that these two technologies may enable. With its abundant bandwidth, 5G supports IoT and, shortly, may improve virtual and augmented reality experiences. Although 5G networks have the ability to serve a wide range of IoT-based services, they are unable to fully satisfy the needs of the newest smart applications. As a result, there is a growing need to imagine 6G wireless communication technologies to get beyond the primary drawbacks of the current 5G networks. Additionally, the use of AI in 6G will offer answers for extremely difficult issues pertaining to network efficiency. Future 6G wireless communications has to accommodate large amounts of data-driven applications as well as a growing number of users. In contrast to other studies, this one focuses on recent developments and trends in 6G technology, network requirements, key enabling technologies for 6G networks, and a thorough comparison of 5G and 6G use cases.

12.3.1.2 IoT in the future with Blockchain

Blockchain provides a modern, safe data format. Information is organized into chronologically-ordered blocks. When a data block's capacity is achieved and it is connected to the previous filled block, a chain of data blocks, or "blockchain," is generated. Since there is a record of each transaction in a dispersed environment, the records are resistant to manipulation and hacking, offering a high level of security. Recent years have seen a rise in IoT research. However, this study has mostly been domain-specific because its discussion was narrowed to particular subtopics. The forces behind this, however, are constrained in that they can only talk generally about their areas of specialization without delving deeper into other related topics. With its vast capacity, 5G supports the Internet of Things and may soon improve virtual and augmented reality experiences.

12.3.1.3 Vision of IoT

IoT has been described by Atzori et al. in terms of three visions. The three visions are Things Oriented, which focuses on general things, Knowledge Oriented, which focuses on how to represent, store, and organize knowledge, and Internet Oriented, which focuses on connectivity between the objects [2].

These ideas opened the way for the Internet of Things (IoT) as it is defined by the International Telecommunication Union (ITU) as "from anytime, anyplace connectivity for anyone; we will now have the connectivity for anything" The main aim is to "plug and play smart items," to put it briefly.

12.3.2 Foundation of IoT Architecture:

The foundation of IoT architecture consists of three elements:

- **Hardware:** The sensor nodes, embedded communication, and interface circuitry are included.
- **Middleware:** This consists of tools for processing, analyzing, and storing data.
- **Presentation layer**: It is made of powerful visualisation tools that provide user-facing data in an understandable style across a range of platforms and applications.

The IoT architecture is influenced by a variety of factors. Therefore, efforts are being made in current research to provide the most optimum design that addresses network challenges including scalability, security, addressability, and effective energy consumption. Every time a node joins the network or when the software operating on those nodes has to be installed or updated, An IoT network's security and privacy are also put to the test. The remote wireless reprogramming methodology is suggested in this situation. This protocol enables the node to check each piece of code and scan the installation process for any malicious intrusions.

The information is subsequently translated into a human-readable format by the information converter that relies on the application and stored on the storage medium. The AL provides services to customers using visualization technology. So, by using eGNs and BS at the sensing and control layers to control the SNs' sleep time interval, energy efficiency is accomplished. It can be done by properly allocating hardware resources utilizing the IPL's robust and methodical (with respect to energy) resource allocator. The hierarchal architecture is contrasted with the index tree which is efficient in energy, self-organized things (SoT), hierarchical clustering index tree which consumes optimum amounts of energy, and the object group localization designs (OGL). After careful evaluation, it is determined that the suggested architecture has a functional advantage over rivals. There should be room for adjusting to changes during the initial deployment period. IoT hardware- and open-source software-based solutions should be suggested for this. In this context, using cell phones as IoT nodes is one method of cost-cutting serving as IoT nodes.

12.4 Existing Solutions – IoT Opportunities and Prospects

Due to the great interest in the IoT field, many countries including those of UAE, Brazil, China, and Canada have supplied different models for intelligent cities, smart cranes and urban devices, innovative warning systems against floods, and the smart-grid. 33 IoT projects are now being funded by the European Research Cluster, which is an institution of the European Union. The organization's main goal is to create IoT architectures that are interoperable in terms of technology and knowledge while maintaining security, dependability, and scalability. As a result, the benefits listed were favorable for the nation's economy, growth, urbanization, infrastructure, employment rate, and inhabitants' access to health care and other services. Enterprises were also able to achieve their business demands thanks to IoT implementations. The cloud gateway uses the data obtained from the nodes for analysis in a Microsoft cloud-based architecture. Additionally enabling security and marketing effectiveness is the intended solution. Daimler launched Car2go, using IoT architecture and IBM services.

12.4.1 Implementation of AI-Cases For 5G-IoT Networks

One of the key reasons for the installation of numerically demanding and empowering AI based algorithms is the extremely high data rates. Because of the network's high data transmission capacity, efficient algorithms using deep learning for wireless 5G-IoT nodes, such as simulated speech recognition and video classification, are possible [6]. Adding and incorporating the intelligence factor on IoT nodes or a fog-based node towards the edge locations would help reduce time latency, increases link capacity, and boosts the security of the network. 5G-IoT networks might potentially leverage AI-based methodologies to more effectively manage their efficiency at the physical, application and network levels in order to increase data rates by anticipating network traffic patterns, making it simpler to offer users AI-based apps [13]. To make the network self-organized, configurable and adaptive, AI techniques might be used to study network traffic and capacity trend analysis, for example. AI-based optimization techniques might help with dynamic spectrum management, organizing massive data, IoT node interoperability, integrating incorporating various gadgets devices, ultra-densifying devices, even an extended battery life at the physical and network levels.[7]. The following is a list of some present-day and potential future AI-based applications that might be enabled by 5G-IoT:

A. BIG DATA PROCESSING ENHANCEMENT

Massive data processing and crowded communication channels may be addressed by 5G Intelligent IoT. The purpose of the 5G Intelligent IoT, which blends AI algorithms with 5G technology, is to intelligently analyze massive volumes of data while enhancing channel use and optimizing communication channels [4]. The most up-to-date IoT practices and the 5G network's dependable and quick speed foster an environment for developing big data applications with the highest potential, such as facial recognition and natural language processing. The constant connectivity offered by 5G generates a massive volume of data. In 5G IoT-based networks, this data collection may also be used as a channel for communication and decision-making. Additionally, it will support the integration of massive IoT devices and the management of the large volume of data, which is probably measured in TBs.[5]

B. EXPANDING THE HORIZON OF HEALTHCARE

The utilization of AI and 5G in the medical sector can be upgraded to save lives of millions of people by bringing about modifications to the existing system. A tailored, emotion-aware healthcare system with a focus on emotional care has been developed by Chen et al. utilizing 5G, notably for children, the mentally ill, and the elderly [1]. A genetic algorithm was used to trace the apt point for 5G based drone stations within the constraints of energy, cost and coverage. From 2030 onward, the whole health business will be dominated by the promised 6G communication technology. It will rule a variety of industries in addition to the health industry. The future of healthcare may be entirely AI-driven and reliant on 6G connectivity technologies, which will alter how we see lifestyle. In light of this, we imagine a healthcare system for the 6G future of communication technologies. Aspects of quality of life (QoL), intelligent wearable devices (IWD), the intelligent internet of medical things (IIoMT), hospital-to-home (H2H) services, and new business models are also addressed in this perspective as necessary innovations to improve our way of life. We also discuss how 6G communication technology is used in telesurgery, epidemics, and pandemics.

C. INTELLIGENT NETWORKING

One major use case of AI is its application in 5G networks including those of the design descriptions in automated networks which make use of machine learning based techniques for decision making. The goal of implementing a more adaptive regulating mechanism alongside the core NFV functions is to lower system costs while maintaining a competitively high level of QoS. By the time 6G networks are implemented, edge and core computing will be considerably more smoothly linked as a part of a combined communications/computation infrastructure framework. As 6G technology is put into use, this might result in a number of benefits, including easier access to artificial intelligence (AI) capabilities.

D. SMART TRANSPORTATION SYSTEMS

One of the biggest innovations that seems to be taking a foreground in real time world is consistent connectivity through combination of 5G and IoT. Because of this integration, it is now able to access the internet more rapidly. Automakers are looking at additional ways to introduce this technology into the realm of transportation systems now that their interest has risen. An internet connection was used in the investigation of self-driving cars. A smart transportation system allows passengers' cellphones and the automobile itself to connect. A smart transportation system, like other IoT devices, can provide extra possibilities for improved control.The placement of sensors at traffic signals offers the information needed to decide on effective traffic routes and decrease vehicle propagation times. The total traffic system has been enhanced by the combination of IoT and 5G. IoT has assisted in eliminating human labor in sectors like traffic management, which can help to lower expenses.

E. UTILIZING ABUNDANT DATA OF INTER-CONNECTED IoT DEVICES

By correlating the massive amounts of data already available, it is possible to predict accidents and criminal activity using the massive amounts of data created by IoT-based devices connected continuously to 5G. As a result, it aids in the generation of enormous amounts of data (massive data sets may then be utilized to uncover parallels, correlations, and patterns), the development of novel ideas that can become projects for large corporations, and the provision of numerous communication channels. With the use of IoT, real-time data extraction is feasible. The new infrastructure for handling everyday traffic has been made possible by IoT devices. Environment detection has been made possible via wireless network technologies. Additionally, it shows that IoT has been adopted as a surveillance method. Creating large data from IoT devices has helped plan and enhance urban environments. IoT big data analytics have also demonstrated their benefit to society. The highly demanding IoT application often tend to have their interaction needs satisfied by increased data rates. Reduced time delays, upgraded coverage, and backing for several devices. The idea of a genuinely global IoT is made possible by its support for a huge number of devices. 5G may serve as a single interconnection framework, enabling seamless communication of "things" with the Internet, due to its concentration on the integration of diverse access methods [8]. Curating predictions with the data available and making decisions for updating technology to enhance life of quality

The combination of 5G along with AI and IoT seems to improve and empower businesses by forecasting with the help of data available and curating suitable control decisions [9].

12.4.2 How IoT has enabled a smart environment?

The idea of a "smart environment" has gained enormous popularity in the last ten years. The concept is vast, encompassing home/office, utilities, healthcare, transportation/logistics, and many other areas. Augmented reality maps, self-driving cars, smartphone ticketing, and passenger counts have all been effectively deployed in the transportation and logistics industry. Additionally, these technologies are presently being continually enhanced. IoT-enabled robot taxis are being developed for prospective use. Similar benefits accrued to society through telemedicine, wearable technology, smart biosensors, smart ambulances, and remote patient monitoring in the IoT-enabled healthcare arena [10], As depicted in **Figure 01.**

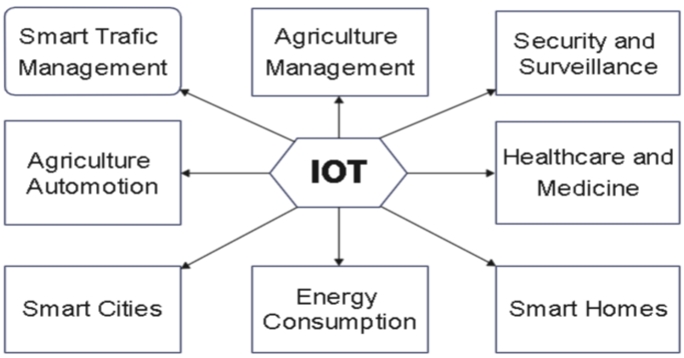

Figure 1: Domains Representing IoT

Table 1: How IoT has enabled a smart environment?

Applications	**Communication Enablers**	**Network Types**	**Modules**

Smart Cities	Wi-Fi, 3G, 4G, Satellite	MAN, WRANs	Urban IoT architectures, protocols, and supporting technologies. Information hub for the smart city that is integrated.
Smart Homes	Wi-Fi	WLAN	Software-defined networks are used in a cloud-based home solution for location identification of defective locations (SDNs)
Smart-Grid	3G, 4G, Satellite	WLAN, WANs	A method for monitoring transmission lines in real-time to prevent disasters.
Smart-Schools	Wi-Fi	WLAN	Controls Student reports, assignments, and information.
Smart Buildings	Wi-Fi	WLAN	Controlling access to services within a typical smart building
Smart Transport	Wi-Fi, Satellite	WAN, WLANs, MANs	Smart passenger counting and smart ticketing
Smart Health	Wi-Fi, 3G, 4G, Satellite	WLAN, WPANs, WANs	Distant medical care
Smart Industry	Wi-Fi, Satellite	WLAN, WPANs, WANs	Remote monitoring uses less energy, and improved decision-making.

The idea of practical, cost-effective smart homes and cities has improved not just the infrastructure and framework of the country but also the lives of the end users. Smart health care successfully manages consumer health. To keep a track of the training routines and to verify them, the smart gym concept is highly beneficial to end users. Because modern humans are increasingly socially involved, there is a need for time to automatically update one's social occurrences immediately on social media. As a consequence, while dealing with privacy and security concerns, the benefits of IoT were also apparent at the end user level [11]. In a summary, **Table 1** summarizes the technological specifications that are currently being included in published literature on IoT enabling smart environments.

12.5 DISCUSSION ON 5G-ENABLED IoT FROM 5G CELLULAR TECHNOLOGIES

A. 5G EMPOWERED IoT – GLOBAL INGENUITIES

Around the world, several activities are being conducted to implement and standardize 5 G-enabled IoT. Beyond 4G, many European initiatives are also available [1]. The research and technological practices were also started by International Mobile Telecommunications (IMT) in 2013 and the standardization was completed in 2016. It was determined in 2015 that the group and committee in charge of technical specifications, which would be in charge of creating 5G RAN, will be formed by the Third Generation Partnership Project (3GPP). [12]. The International Telecommunication Union-Radio Communication (ITU-R) has been tasked with designing and defining 5G technology by 2020 throughout the same period.

B. SPECTRUM NECESSITIES OF 5G-IoT

To suffice the growing needs and requirements of consistently rising traffic, new generation concepts and innovations, wireless domain innovation, and the development of 5G enable IoT to require cutting-edge services and solutions. According to 5G Americas, a mixture of low, mid, and high band spectrums is preferable in order to acknowledge the utilizations of 5G that enable IoT. Some use cases are better served by mixing many bands than others. Each band is compared under different usage scenarios. [12] In addition to conventional spectrum requirements, the 3GPP has designed a new 5G air interface known as New Radio (NR) [1][14].

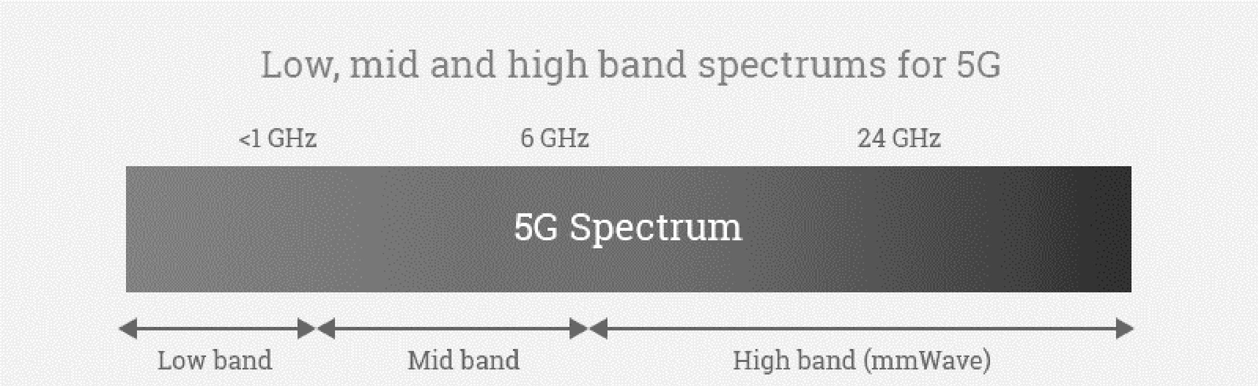

Figure 2: Spectrum Types Graphic

There is still a disconnect between the assurances and guarantees put forth by 5G network and it's actual deployment of 5G technology when examining the abovementioned frequency features and needs in **Table 2 and figure 2**. Therefore, the establishment of 5G requires the use of certain technology. For instance, mmWave transmission and reception have a high route loss and a high rate of absorption from atmospheric factors like rain and vegetation. To increase coverage and reduce path-loss at mmWaves, there's a high chance that it is a micro version cellular design. This created the foundation for the novel idea of a compact, low-power cellular base station (BS).

Table 02: Spectrum Types, their characteristics, and uses

Spectrum Type	Characteristics	Use Cases
Low-frequency band (below 1GHz)	- Higher Coverage and Mobility - Wider channels availability	1. Massive Machine-Type Communications 2. Indoor applications
Higher frequency millimeter waves (mmWave) bands	- Short-range with low latency - High capacity due to wider channelization	1. Enhanced mobile broadband Communications 2. Urban and sub-urban applications
Mid-frequency bands	- Short-range with low latency and high capacity transmission for a few macro-based stations	1. 5G implementation in uncrowded/open areas 2. Urban deployment

Currently, a 4G BS uses hundreds of antenna ports to effectively manage its traffic. M-MIMO technology, which aims to integrate several antennas on a single BS, is used to resolve this. The installation of the Internet of Things was the goal of the 5G technology, which attempted to integrate numerous heterogeneous access methods. Beam division multiple access (BDMA), a cutting-edge technology utilized by the 5G network, splits the beam based on the location of the mobile devices, whereas BS allows each device to receive an orthogonal beam. This allows for repeated access to the devices, greatly boosting capacity with little disturbance. To maximize spectrum efficiency, mmWaves, M-MIMO, and beamforming are also used in 5G technology, which likewise needs high throughput and low latency. By incorporating the full-duplex technology, which focuses on the transceiving mechanism of antennas, this need is addressed [12]. A 5G transceiver must be able to operate in both Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) modes to be able to transmit and receive data at the same time and on the same frequency. This is acquired by using transistors made from silicon which take up the role of switches and ensure transmission at the same frequency [1]. Even though the above-mentioned techniques are in the infant stages, research is carried out to acknowledge the inadequacies and curate an efficient 5G system.

C. STRUCTURES ACTIVE IN 5G PHY LAYER TO SUPPORT 5G-IoT

Some of the elements that have been normalized for the LTE or Advanced LTE concepts are MIMO, CoMP, and HetNets [1]. These technologies provide huge connections and fast data rates, which is exciting. Therefore, these ideas are used in 5G technology. These ideas are first explored to provide context for the next subsections. [12].

- **CARRIER AGGREGATION / ACCUMULATION:** Carrier aggregation is a method that improves network performance in the uplink, downlink, or both by increasing data capacity, throughput, and rates. It improves spectrum use by merging two or more carriers from the same or different frequency bands into a single aggregated channel. Based on 3GPP Release 10, carrier aggregation was implemented in 4G LTE-A. It combines up to five LTE-A component carriers (CCs), each with 20 MHz of capacity, bringing the total available bandwidth to 100 MHz. There are high chances of mobile devices getting multiple CC when utilizing carrier aggregation [12]. One CC is chosen as a major component carrier (PCC) in uplink and downlink while the others must be chosen as subsidiary component carriers (SCC). Different 3GPP versions now contain a much larger number of CCs [15]. Even though carrier aggregation is an extremely strong and powerful, the product of intermodulation may Hinder with the signal due to the inter and intra band carrier aggregation [1].

- **MASSIVE-MIMO (M-MIMO):** A mix of antenna expansion and sophisticated algorithms is needed for MIMO systems. Although it has many facets, MIMO has been utilized in wireless communications for a while now. Both mobile devices and networks frequently include multiple antennas to improve connectivity, provide faster speeds, and improve user experiences. Massive MIMO, a variation of MIMO, increases the number of antennas on the base station to outperform outdated systems. In addition to having additional antennas, the network and mobile devices need more intricate architecture to coordinate MIMO operations. These developments are achieving the performance enhancements required to support the 5G consumer experiences. [12] To increase the capacity of tiny cells, this approach makes it possible to deploy high-order multi-user MIMO (MU MIMO). [16] An omnidirectional antenna is used in the macro cell to supply control-plane communication at lower band frequencies, while a highly directed M-MIMO beam is used to send user-data traffic at mmWave band frequencies. [1] As a result, more MIMO technologies are being used. The benefits of M-MIMO have proven to be advantageous especially since it can boost the radiation up to 100 times [16].
- **COORDINATED MULTIPOINT PROCESSING (CoMP):** CoMP uses distributed MIMO to transmit and receive from various antennas, some of which may not be in the same cell, in order to lessen received spatial interference and improve the quality of the received signal. Along with physical layer security (PLS) development, CoMP has shown to be a fantastic interference mitigation solution. With appropriate base station synchronization, it offers great secrecy coverage probability and interference

performance (BSs). CoMP-based resource allocation methods provide a significant increase in capacity and, thus, less interference [12] [17]. When combined with MU-MIMO, CoMP is a particularly successful strategy for boosting cell edge coverage and lowering outages brought on by blocking and channel issues. The CoMP is a transceiver technology that reduces interference problems. [1] This is accomplished by leveraging channel state information to coordinate transmission and reception among the widely dispersed BSs [17].

- **HETEROGENEOUS NETWORKS (HetNets):**
- The pico base station need to coordinate hinderance for the control and traffic channels with major macro interferers to offer services to the user terminals [18]. Each wireless access network in the HetNet ecosystem has unique properties, including capacity, access technology, security, power consumption, latency, coverage, and access cost. HetNets have the intriguing property that certain wireless access networks are layered over others in a way that naturally creates a multilayer structure or hierarchical cellular mobile network. A mobile user must be equipped with a multi-interface device that can identify and connect with the access network that fits personal expectations and the requirements of apps to fully utilize HetNets and benefit from what these networks have to offer [1,18, 19].
- **D2D COMMUNICATIONS:** It is regarded as a typical way to use the method of transferring data from the base point to each device. As a result, Device-to-Device Communication was selected as a method for data transfer on a 5G network since it is thought to be more advanced and effective. D2D communication also has a lot of benefits because it doesn't rely on a base station to provide data. For instance, improving spectral efficiency and system capacity, lowering latency on the network and energy consumption in the EU, disassembling the 5G mobile network, and extending network

coverage. Device to Device (D2D) is a potential technology for 5G; in addition to enhancing connection in the next networks, D2D offers greater data rates, more capacity, and better QoS. [20] In the context of 5G, "D2D communication" refers to a paradigm in which devices speak with one another directly rather than sending data over the network infrastructure. [1].

- **CENTRALIZED RADIO ACCESS NETWORK (CRAN):** A 5G design called the cloud radio access network (CRAN) makes use of cloud computing to accomplish its goals. The possibilities of CRAN are also diminished by problems with security, fronthaul, and a centralized baseband unit (BBU) pool restriction. For the centralized BBU processing to function properly, fronthaul links in CRAN must have very low latency and large bandwidth. In real-time applications, a link's capacity is typically constrained and time-delayed. decreasing the CRAN's spectrum and energy efficiency as a result [1] [21]. To address the CRAN fronthaul concerns, a heterogeneous CRAN (HCRAN) that isolates the user plane from the control plane was proposed.

D. STRUCTURES ACTIVE IN 5G NETWORKING LAYER TO SUPPORT 5G-IoT

- **SOFTWARE-DEFINED WIRELESS SENSOR NETWORKING (SD-WSN)**

A combination of SDN and WSNs is the SD-WSN. The logical plane for control from the networking device in the decentralized segment is the main aim of using the approach for constructing 5G networks [22]. A centralized software-based paradigm like SDN is required to ensure a constant QoS due to the growing needs of the many linked devices. The deployment of additional connections and nodes, resource allocation, and other network management challenges will all be much simplified by the SDN. [23, 24].

- **VIRTUALIZATION OF NETWORK FUNCTION (NFV):** Network slicing, a feature of virtual network architecture that enables the construction of many virtual networks on top of a single physical infrastructure, will be made possible by NFV in 5G. The demands of applications, services, devices, consumers, or operators may then be accommodated through the customization of virtual networks. [25] These standards serve as the foundation for each element of the architecture, enhancing stability and interoperability. The components of NFV architecture are: Software programs called virtualized network functions (VNFs) provide network services including file sharing, directory services, and IP setup [12, 25].
- **COGNITIVE RADIOS (CRS):** There is a shortage of spectrum due to the existing IoT applications, which range from crucial to huge in terms of connection and network resource overload. Therefore, it is imperative to make effective and wise use of the spectrum to meet the rising demand. In a radio set, the first part relates to recording the spatial and temporal fluctuations with less interference. An optimum spectrum can then be recorded for transmission. Typically, this is a region of the spectrum known as a "spectrum hole" or "white space." [26] Interference is lessened in three different ways if it is being utilized by any authorized user. First, jump over to the other spectrum hole. Second, by limiting its power level, and third, by switching the modulation method that is being employed. Depending on its hardware, a CR can broadcast and receive utilizing a variety of frequencies, modulation techniques, transmission powers, communication techniques, protocol specifications, and transmission access techniques. The RF front end of cognitive radio, contains a wideband antenna, power amplifier, and adaptive filter, to set its conventional counterparts apart. Wideband sensing is made possible by an RF front end with these features. A CR should also be able to pick up weak signals

across a broad range. The cognitive radio cycle is followed by the CR as it attempts to adapt to the requirements of a radio environment. [26, 27]

The cycle has three fundamental steps:

1) Sensing Spectrum

2) Spectrum Evaluation

3) Decision on the spectrum.

Depending on the quality of each use case, several spectrum choice criteria might be explored. [1] All these structures make the CR effective for successful deployment in 5G. [12]

E. ARCHITECTURAL VIEW OF 5G-IoT

For the base of massive IoT data analysis, a 5G framework should be capable of providing a scalable network, virtualization, cloud services, etc. In essence, a 5G-IoT-based architecture needs to offer an independent HetNet that is self-configurable under the application requirement. The primary components of a cellular 5G architecture are the front-haul, mid-haul, and back-haul networks. The remote radio-head (RRH) is connected to the BBU through the front-haul network. Back-haul describes the coaxial cable and/or optical fiber link thfibernnects the BBU to the main wired network. The link between RRH and the next link is referred to as the mid-haul. The radio network and network cloud are the two logical layers included in the 5G cellular network architecture. It may be explained that a high data rate can be attained by employing steerable antennas at the BS and the mobile station with cutting-edge CMOS technology and the mmWave spectrum. [1] Owing to the mmWave spectrum's unsuitability for mobile communications—specifically due to propagation problems such as path losses, blocking, air, and rain absorption, etc. By deploying big antenna arrays, directing up the beam energy, and coherently collecting it, these problems are now mostly handled. [12].

F. QoS IN 5G-IoT

The spectral efficiency and latency of a 5G cellular network may be utilized to understand its QoS. Although the latency requirements for user and control plane data differ, non-orthogonal signals and radio access methods can be employed to improve the spectrum efficiency of a 5G network. [28] In the case of a 5G network, there is a significant improvement in cell spectral efficiency as well as a 50% reduction in control plane latency [29] [30].

G. STANDARDIZATION IN 5G-IoT

There are primarily two types of standards involved in the 5G-IoT standardization process. One set of standards deals with network technology, protocols, standards for wireless communication, and standards for data aggregation. The second is a regulatory requirement that covers data security and privacy. [1]

3. PROPOSED MODEL

The proposed models for researching the threats to emerging trends and prospects on 5G-IoT are summarized below **in Table 3**: [31] Along with references of models, their techniques, and specifications are summarized in **Table 4**.

TABLE 3: PROPOSED MODELS ON THREATS RESEARCH WITH DESCRIPTIONS SUMMARIZED.

S. No	Year	References	Description	Security aspect affected
1	2018	Xin Zhang and Fengtong Wen [21]	The USD and UDS are two algorithmic models proposed for a new user who is anonymous in the IoT segment.	Authentication
2	2018	Mohammad Dahman Alshehri and Farookh Khadeer Hussain [22]	Proposes a secure communications paradigm between IoT nodes utilizing hexadecimal values combined with a cluster-based fuzzy logic implementation approach.	Confidentiality and trust management
3	2019	Priyanka Anurag Urla, Girish Mohan, Sourabh Tyagi, and Smitha N. Pai [23]	The model presented here is a multi-stage security paradigm that uses fully homomorphic encryption (FHE) and elliptical curve cryptography (ECC) to mitigate cryptographic threats.	Integrity
4	2019	Hongsong Chen, Caixia Meng, Zhiguang Shan, Zhongchuan Fu and Bharat K. Bhargava [24]	Proposes a unique method for detecting low-scale DoS attacks that includes trust assessment using the Hilbert-Huang transformation in Zigbee WSN	Availability and trust management

5	2019	Michail Sidorov, Ming Tze Ong, Ravivarma Vikneswaran, Junya Nakamura, Ren Ohmura and Jing Huey Khor [20]	Offers a radical safety and security framework curated for a lightweight and simple RFID protocol that highlights the supply chain management through blockchain.	Authentication
6	2019	Munkenyi Mukhandi, David Portugal, Samuel Pereira, and Micael S. Couceiro [26]	Presents a basic security architecture that includes MQTT and Robot Operating System for robotic communication in Industrial IoT. The two main techniques are data encryption and authentication.	Authentication and integrity
7	2019	Pooja Shree Singh, Vineet Khanna [27]	Provides a speech recognition prog built on Mel-frequency cepstral coefficients (MFCC) for user identification and authentication that may be used in an IoT context to protect the privacy, confidentiality, and integrity of data.	Confidentiality, Integrity, and Privacy

TABLE 4: REFERENCES OF MODELS, THEIR TECHNIQUES, AND SPECIFICATIONS [31]

References	**Technique used**	**Confidentiality (C)**	**Integrity (I)**	**Availability (A)**	**Trust (T)**	**Authenticity (Ay)**

Xin Zhang and Fengtong Wen [21]	Data encryption method				✓	✓
Mohammad Dahman Alshehri and Farookh Khadeer Hussain [22]	Fuzzy-logic-based ram algorithmic method	✓			✓	
Priyanka Anurag Urla, Girish Mohan, Sourabh Tyagi, and Smitha N. Pai [23]	A multi-level data encryption method	✓	✓			
Hongsong Chen, Caixia Meng, Zhiguang Shan, Zhongchuan Fu and Bharat K. Bhargava [24]	Mathematical evaluation method			✓	✓	

Michail Sidorov, Ming Tze Ong, Ravivarma Vikneswaran, Junya Nakamura, Ren Ohmura and Jing Huey Khor [20]	Block chain-based authentication method					√
Munkenyi Mukhandi, David Portugal, Samuel Pereira, and Micael S. Couceiro [26]	A cryptographic-based data encryption method		√			√
Pooja Shree Singh, Vineet Khanna [27]	Socket programming	√	√			√

12.6. Emergence of 6G

Wireless communication has been more important over the last few decades. The global deployment of fifth-generation (5G) communications, which have many more capabilities than fourth-generation communications, is expected to begin soon. Between 2027 and 2030, the sixth-generation (6G) system, a new wireless communication paradigm with full AI support, is expected to be in operation. Faster system capacity, higher data rate, lower latency, higher security, and enhanced quality of service (QoS) compared to the 5G system are some of the fundamental issues that must be solved after 5G.

Throughput, latency, energy efficiency, rollout costs, reliability, and hardware complexity are all trade-offs in 5G technology. After 2030, 5G is unlikely to be able to keep up with demand. Following that, 6G will bridge the demand gap between the market and 5G. The main goals of 6G systems are (i) massive data rates per device, (ii) huge number of connected devices, (iii) global connectivity, (iv) reduced delays, (v) decreasing consumption of energy by battery free devices and nodes in IoT, (vi) extremely reliable connectivity, and (vii) connected intelligence with machine learning capability. These goals are based on historical trends and predictions of future needs.

The simultaneous wireless connection of the 6G system is predicted to be 1000 times greater than that of the 5G system. In contrast to the enhanced mobile broadband (eMBB) in 5G, it is anticipated that ubiquity services will also be a major part of 6G. A crucial component of 5G, ultra-reliable low-latency communications will be a key driving force in 6G communication, with capabilities including End-to-End (E2E) latencies lower than one millisecond, nearly 99.99% dependability, and 1 Tbps peak data throughput. The 6G communication system will be capable of supporting numerous linked devices. The major use-cases of this revolutionizing technology would be along the lines of a super smart society, connected robotics and autonomous systems, wireless human computer interactions, industrial automation, haptic advancements and communications, IoE, and so on [30].

12.6.1 6G vs 5G: A Comparative Study

The table given below gives a detailed survey highlighting the similarities and contradictories of 5G and 6G technologies respectively.

Table 5: Comparison of 5G and 6G

Features	5G	6G
Frequency Bandwidth	It is allocated for loa and high band frequencies: sub 6 GHz and more than 224.25 GHz	This is mainly allocated for higher band frequencies ranging between 95GHz to 3THz
Data Rate	One of the fastest connections currently available with approximately 20 gigabits being transmitted per second.	Predicted to have almost 5 times the data rate of that of 5G, transmitting around 100 gigabits per second.
E2E Delay	Approximately 1 millisecond	Approximately 0.1 millisecond
Architecture and Framework	Heavy and dense sub 6 GHz with smaller cells of millimeter waves.	Cell free smart surfaces at high frequencies

Device Types	It can be deployed in smartphones, sensors, drones, etc.	It can be used in distributed ledger technologies, smart implants, and so on.
Traffic Capability	Around 10 $Mbps/m^2$	Ranges between 1 to 10 $Gbps/m^2$

12.7. Trending Research Issues and Challenges of 5G-IoT

One may witness a drift from different wireless technologies including 1G, 2G, 2.5G, 3G, 3.5G, and 4G towards 5G. It is acknowledged because 5G technology exceeds its predecessors in addressing the major challenges of cellular networks.

The following issues are annexed:

• Increased bandwidth

• Massive data-rate

• High connectivity

• Reduced end-to-end latency

• Cost-effectiveness

• Accordant Quality of Service

• Device computational capabilities

• Device intelligence services

Some summarized challenges in the 5G-IoT network and their solutions are described in table 05. [1]

Table 6: Challenges in the industry of 5G IoT and their solutions

S.No.	Challenges	Solutions
1	Flexibility in the 5G physical layer radio architecture to meet the various IoT requirements	A random-access channel is used in the design of appropriate radio numerology to enable high connection densities and to handle transceiver flaws and channel degradation.
2	Radio access technologies (RATs) and significant signaling overhead in network control systems for network edge devices.	An extensive overview of client-controlled HetNets for 5G networks is given, along with distributed and hybrid control techniques.
3	It is introduced that several businesses, like Tata Communications, Dell IoT Services, and Sierra Wireless, are creating IoT technologies globally.	
4	Effective LPWAN (low power wide area network) enabling technologies	The newest and most promising technology is described as LoRa.
5	Spectrum resources are insufficient to support IoT devices and enable 5G technologies. The radio access channel also has several restrictions for handling 5G devices with IoT capabilities.	Spectrum resources are insufficient to support IoT devices and enable 5G technologies. The radio access channel also has several restrictions for handling 5G devices with IoT capabilities.
6	The effective recharging of widely used IoT devices is a laborious operation when considering 5G-IoT situations.	It is possible to charge IoT devices wirelessly using both near- and far-field methods. Additionally, a brand-new networking concept known as Wireless Power Communication

		Network is presented that unifies wireless power transfer and communication.
7	To meet the demands of the 5G-enabled IoT, which include higher data rates, lower latency, constant quality of service, and vast amounts of spectrum resources	The architecture of the 5G cellular network is given together with its supporting technologies, such as M-MIMO and D2D communication. These include ultra-dense networks, cognitive radios, millimeter-wave (mm-wave) solutions for 5G networks, cloud technologies, and other related upcoming technologies.
8	Backhaul is a bottleneck that must be overcome to maintain the high quality of service in a 5G paradigm. Since backhaul connects the very busy, dense cells to the core, its requirements must be taken into consideration.	The presentation of a combination radio access and backhaul framework effectively handles the QoS challenges. Backhaul as a Service (BHaaS), an SDN architecture with RAN intelligence, Self-Optimizing Network (SON), and caching capabilities, offers a comprehensive view of the end-to-end network and also allows for optimization.
9	Mobile tasks are frequently delegated to remote infrastructures, such as cloud platforms, due to the limited computational power and battery life of mobile devices (MDs), which results in an inevitable offloading transmission delay.	A crucial method for the deep learning edge services in 5G networks is computation offloading. A heuristic offloading technique is developed and shown to reduce the transmission latency of deep learning tasks.

The 5G-IoT network of the future should be able to handle the huge connection of devices by offering high and reliable QoS, according to current trends. A 5G network must support both critical and large-scale IoT. [1] [32]

A. CAN 5G ACHIEVE A BLEND BETWEEN CONNECTIVITY EASE AND SECURITY?

Unauthorized codes can be inserted into mobile phone devices to control network services and collect data traveling via networks, among other security-related problems, as a result of their uncontrolled access to networks. The transmission of data through various devices and nodes using synchronized and coexisting technologies require security at each node so as to maintain the safety of network services [34]. As a consequence, manufacturers may design systems that have the intelligence required to understand, validate, and allocate a session and authority with certain values. Because of this, end users may simply do their work without difficulties or disruptions in connectivity. It is hard to ensure the security and safety of connected IoT-based 5G networks just through software improvement. Cooperation, affiliation, and coordination are all necessary for increased security. The adoption of a secure boot and a reliable execution environment improves the security of intelligent devices and prevents illegal usage of other devices. The combination of intelligent systems and software security will increase the safe communication of networked Internet of Things devices while also inspiring new concepts for future wireless communication networks [33] [41].

With the deployment of more and more 5G networks, the limits of 5G networks have been revealed, which undoubtedly supports the exploratory research of 6G networks as the next generation solutions. These studies address the fundamental privacy and security concerns raised by 6G technology. As a result, we developed a survey on the current status of 6G security and privacy in order to synthesize and develop this essential study as a basis for future research.

B. IS 5G SUFFICIENTLY FLEXIBLE TO ALLOW FOR VARIOUS TYPES OF NETWORK CONFIGURATION?

The traffic produced by the nodes in IoT differs from the ones generated in cellular systems. In fact, majority of the traffic in IoT occurs in the uplink.

Furthermore, messages conducted through IoT networks are usually quick and of little size. IoT devices have limited energy and computing resources as well. In terms of how they connect to 5G networks, these IoT devices differ from traditional cellular devices. It may be challenging to establish the best system parameter configuration for a certain IoT use case [36].

C. HOW WILL 5G TAKE ACCOUNT OF A HIGHER DENSITY OF CONNECTED DEVICES?

The rapid proliferation of mobile devices necessitates an extensible and energy-efficient communication infrastructure. One million devices might be connected across 0.38 mi^2 using 5G technology, compared to just 2000 using 4G. This extensive coverage will significantly diminish the battery life of electronics.

The slim band of IoT, also called narrow band IoT, is a major part of the intelligent 5G IoT network which is essential for ideal energy consumption. An intelligent 5G-IoT ecosystem will therefore provide the ability to process massive amounts of data with minimum ping, network stability, and continued service availability [38] [37].

Intelligence for IoT-based devices is necessary for appropriate device administration and management, especially when all linked elements generate substantial traffic over the Internet [37].

D. IS 5G FUTURE-PROOF?

One of the main and difficult physical layer goals of coverage improvement (CE), among the numerous difficulties stated for IoT access technologies, is to increase the maximum coupling necessary to enable tactile internet and multimedia applications. Other significant issues include security/privacy, energy efficiency, and widespread networking. Major research developments have been carried out with respect to this area due to high expectations of IoT networks that incorporate 5G enable techniques with several use cases [35]. In addition to these activities, academics are working to address issues with the physical and architecture layer, energy efficiency, channel access, and spectrum efficiency of 5 G-enabled IoT technologies.

High data rates are needed for applications like high-definition video streaming, augmented reality (AR), and virtual reality (VR); these applications often ask for speeds of up to 25Mbps. Now due to a lack of communication or data flow among systems, the 5G-IoT-based network may completely disintegrate. [39] [40]. Deep learning is used enormously in IoT as well as mobile applications in order to execute real-time operation on processing of data. Sending massive volumes of data to the cloud for deep learning would consume a lot of energy and cause a lot of transmission delay, which reduces the efficacy of deep learning activities. This is due to the poor performance of data transfer speeds. By minimizing human participation while boosting network performance, the main aim of SON's is to surge the quality of service and reduce the expenses related to the operations in the network. The main goal of incorporating AI-related technologies into 5G-IoT infrastructures is to provide the network the ability to intelligently adapt its configurations in response to shifting environmental conditions or requirements. The new 5G network should be able to offer efficient strategies for radio resource management (RRM), mobility management (MM), management and orchestration (MANO), and service provisioning management in order to replace special utility networks with complex network reconfigurations [35, 39, 40].

12.7 CONCLUSION

This research paper provided a thorough analysis of the 5G wireless technologies, which have emerged as essential facilitators for the wide adoption of IoT technology. It reviewed the development of cellular wireless technologies and made the argument for how 5G wireless technology improves upon its forerunner technologies, enabling widespread IoT implementation. In this research, we have also covered the various architectural elements of 5G networks, with a focus on the significant advancements made over 4G networks at the physical and network layers.

The paper also goes into great detail about the difficulties in implementing QoS requirements in contemporary 5G-IoT, whose traffic characteristics differ significantly from another legacy 5G network applications because it is primarily in the uplink rather than the downlink direction. For the cloud-based application layer programs running cutting-edge artificial intelligence, machine, and deep learning algorithms for effective real-time data processing and prediction, high data transfer rates with minimal latency from the 5G-IoT nodes are essential. These contemporary applications, such as smart transportation, smart healthcare, smart school, smart industry, etc., that operate on top of 5G-IoT are also explored. Additionally, key performance indicators (KPIs) and criteria for acceptable performance are provided. The difficulties with standardization caused by the numerous nodes utilizing the 5G-IoT network are another subject covered in this study (HetNets). The thorough analysis provided in this study will aid in better-coordinated efforts from both businesses and academics to advance 5G-IoT technology.

References

1. Shafique, Kinza & Khawaja, Bilal & Sabir, Farah & Qazi, Sameer & Mustaqim, Muhammed. (2020). Internet of Things (IoT) For Next-Generation Smart Systems: A Review of Current Challenges, Future Trends, and Prospects for Emerging 5G-IoT Scenarios. IEEE Access. PP. 1-1.
2. Harrison, Luke. "The Internet of Things (IoT) Vision." Interconnections - the Equinix Blog, Equinix, 12 Mar. 2015. Accessed 3 Aug. 2022.
3. Gage, Mary. "IoT - Internet of Things - Motivation, Benefits and Security." Revenues & Profits, 21 Apr. 2021.
4. Rashid, Salman & Razak, Shukor. (2019). Big Data Challenges in 5G Networks. 152-157, Accessed 3 Aug. 2022.
5. M. Chen, J. Yang, Y. Hao, S. Mao, and K. Hwang, "A 5G Cognitive System for Healthcare," Big Data Cogn. Comput., vol. 1, no. 1, p. 2, Mar. 2017.
6. Ghosh, Sudipto. "5G, IoT and AI: The Work of Art and Technology at Play in 2021." AiThority, 12 July 2021.
7. Inc, DeepSig. "How Artificial Intelligence Improves 5G Wireless | DeepSig." Accessed 3 Aug. 2022.
8. Ribeiro, Jair. "Introduction to the Future with 5G, AI, and IoT." The Startup, 12 Dec. 2020,
9. P. Kiss, A. Reale, C. J. Ferrari, and Z. Istenes, "Deployment of IoT applications on 5G edge," in 2018 IEEE International Conference on Future IoT Technologies (Future IoT), Eger, 2018, pp. 1–9.
10. Gomez, Carles, et al. "Internet of Things for Enabling Smart Environments: A Technology-Centric Perspective." Journal of Ambient Intelligence and Smart Environments, vol. 11, no. 1, 30 Jan. 2019, pp. 23–43. 3 Dec. 2019.

11. Ammad, Muhammad & Shah, Munam & Islam, Saif & Maple, Carsten & Alaulamie, Abdullah & Rodrigues, Joel & Mussadiq, Shafaq & Tariq, Usman. (2020). A Novel Fog-Based Multi-Level Energy-Efficient Framework for IoT-Enabled Smart Environments. IEEE Access. PP. 1-1.
12. THALES. "5G and the IoT (What Is IoT in 5G?) - Thales." Accessed 3 Aug. 2022.
13. "5G and ITS IMPACT on the INTERNET of THINGS." StarDust. Accessed 3 Aug. 2022.
14. "5G Spectrum Explained | Blog." Carritech Telecommunication. Accessed 3 Aug. 2022.
15. Parikh, Jolly. (2014). SCHEDULING SCHEMES FOR CARRIER AGGREGATION IN LTE-ADVANCED SYSTEMS. International Journal of Research in Engineering and Technology. 03. 219-223.
16. Shukair, Mutaz. "How 5G Massive MIMO Transforms Your Mobile Experiences.", 24 June 2022.
17. Irram, Fauzia, et al. "Coordinated Multi-Point Transmission in 5G and beyond Heterogeneous Networks." IEEE Xplore, 1 Nov. 2020.
18. Sassan Ahmadi,Chapter 14 - Enhanced Inter-cell Interference Coordination and Multi-radio Coexistence, LTE-Advanced, Academic Press, 2014, 1029-1068,
19. "Heterogeneous Network (Communication System) - an Overview | ScienceDirect Topics." 2014. (2014) Accessed 3 Aug. 2022.
20. Hadyanto, Dito Pratama, et al. "Device-To-Device Communication in 5G." 2021. Accessed 3 Aug. 2022.
21. Pana, Vuyo S., et al. "5G Radio Access Networks: A Survey." Array, vol. 14, 1 July 2022, p. 100170.

22. Granelli, Fabrizio & Gebremariam, Anteneh Atumo & Usman, Muhammad & Cugini, Filippo & Stamati, Veroniki & Alitska, Marios and Chatzimisios, Periklis. (2015). Software defined and virtualized wireless access in future wireless networks: Scenarios and standards. IEEE Communications Magazine. 53. 26-34._Accessed 3 Aug. 2022.
23. Miyazaki, Toshiaki & Yamaguchi, Shoichi & Kobayashi, Koji and Kitamichi, Junji & Guo, Song & Tsukahara, Tsuneo & Hayashi, Takafumi. (2014). A software defined wireless sensor network. 2014 International Conference on Computing, Networking and Communications, ICNC 2014. 847-852.
24. Kobo, Hlabishi I., et al. "A Survey on Software-Defined Wireless Sensor Networks: Challenges and Design Requirements." IEEE Access, vol. 5, 2017, pp. 1872–1899.
25. "The Role of Network Function Virtualization (NFV) in 5G." ALLOT. Accessed 3 Aug. 2022.
26. Bhandari, Shruti, and Sunil Joshi. "Cognitive Radio Technology in 5G Wireless Communications." IEEE Xplore, 1 Oct. 2018.
27. Sasipriya, S., and R. Vigneshram. "An Overview of Cognitive Radio in 5G Wireless Communications." IEEE Xplore, 1 Dec. 2016
28. Arvindpdmn. "5G Quality of Service." Devopedia, 8 Apr. 2021.
29. bbas, Mohamed. "Quality of Service (QoS) in 5G Networks." 5G HUB, 27 Feb. 2021.
30. Kaabneh, Khalid. "A SURVEY of QoS in 5G NETWORK for IoT APPLICATIONS." International Journal of Science and Applied Information Technology, vol. 8, no. 6, 2019, p. 159.
31. Rachit, et al. "Security Trends in Internet of Things: A Survey." SN Applied Sciences, vol. 3, no. 1, Jan. 2021.
32. M. Jaber, M. A. Imran, R. Tafazolli, and A. Tukmanov, "5G Backhaul Challenges and Emerging Research Directions: A Survey," IEEE Access, vol. 4, pp. 1743–1766, 2016.

33. “What Is 5G? - the Fifth Generation of Mobile Technology.” Twi-Global.com, 2019. Accessed 3 Aug. 2022.
34. “What Is 5G? How It Works & Why It Matters | Accenture.” Accessed 3 Aug. 2022.
35. “5G: Is It Time to Future-Proof Your Smartphone?” ZDNet. Accessed 3 Aug. 2022.
36. Sabella, Dario, et al. “Designing the 5G Network Infrastructure: A Flexible and Reconfigurable Architecture Based on Context and Content Information.” EURASIP Journal on Wireless Communications and Networking, vol. 2018, no. 1, 13 Aug. 2018, Accessed 6 May 2021.
37. “Connection Density - an Overview | ScienceDirect Topics.” Accessed 3 Aug. 2022.
38. “5G – Connection Density — Massive IoT and so Much More.” CIO. Accessed 3 Aug. 2022.
39. “Future Proof: Fairphone Has Gone 5G.” Fairphone, 27 Oct. 2021. Accessed 3 Aug. 2022.
40. “Future Proofing Your Network for 5G.” Vertiv, 2020. Accessed 3 Aug. 2022.
41. Attaran, Mohsen. “The Impact of 5G on the Evolution of Intelligent Automation and Industry Digitization.” Journal of Ambient Intelligence and Humanized Computing, 21 Feb. 2021. Accessed 3 Aug. 2022.