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New developments and trends in 5G technologies: applications and concepts

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ABSTRACT

Fifth-generation (5G) wireless technology is the most up-to-date iteration of mobile data networks. This research analyzes the effectiveness of next-generation mobile networks in tandem with mobile communication technologies. Various difficulties encountered at each stage are discussed. With the advent of 5G networks, users may connect to the internet at lightning speeds from almost any location. 5G is one of a kind because of its new characteristics, which allow it to link people and enable them to operate gadgets, machines, and things. 5G mobile technology's varying speed and capabilities will allow for new user experiences and link new businesses. Companies must know where they can best put 5G to use. This research paper examines and analyzes various topics in great detail, demonstrating how mmWave, massive multiple-input and multiple-output (massive MIMO), microcells, mobile edge computing (MEC), beamforming, diverse antenna technologies, and so on can all work together to improve cellular networks. The primary goals of this article are to demonstrate some of the most recent technical developments and to analyze potential future research directions for the 5G mobile system.

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1. INTRODUCTION

The previous three decades have seen a meteoric rise in wireless communication, from the 1G period to the current 4G era [1], [2]. This research was motivated by the need for exceptionally low latency and enormous network capacity. Among the potential improvements that 5G might bring to customers are increased download speeds, improved quality of service (QoS), decreased latency, expanded coverage, increased reliability, and reduced prices. The fifth-generation network (5G) services may be categorized as follows:

- Ultra-high-definition (UHD) video streaming with virtual reality (VR) and augmented reality (AR): these are all feasible with the architecture of super-fast wireless internet (SWI) due to its support for multiple media types and its ability to distribute data at high speeds while maintaining reasonable latency.
- The third generation partnership project (3GPP): with this innovation, massive machine-type communication (MTC) is possible. It's a cheap and effective way for machines to talk to one another across long distances and with plenty of data. With MTC, mobile carriers may simplify devices while providing fast data rates, low battery consumption, and comprehensive area coverage, making them ideal for internet of things (IoT) applications.

- Third, ultra-high reliability and low-latency service (UHRLL): this allows for a high quality of service (QoS) that is impossible to achieve with the current state of mobile network architecture. Remote surgery, V2V communication, Industry 4.0, smart grids, intelligent transportation systems, and so on are all potential use cases for UHRLL's real-time communication capabilities [3].

When using 1G, the fastest speed achievable was just 2.4 Kbps. Second generation (2G): in 1991, the first 2G digital system became available, allowing for better quality mobile voice transmission than was previously achievable with 1G. Also shown and discussed are code-division multiple-access (CDMA) and the global system for mobile (GSM). With 2G speeds, users could only expect 1 Mpbs. The improved system speed and download speed made possible by the third-generation (3G) universal mobile telecommunications system (UMTS) architecture has enabled users to engage in continuous video discussions. The first mobile broadband systems that integrated voice and various media types were the 3G cellular networks. High-speed packet access (HSPA/HSPA+) is crucial to the operation of mobile networks in 3D. MIMO is used in 3G's multi-input, multi-output technology to boost wireless network capacity and data transmission speeds through packet switching.

Fourth-generation (4G) mobile broadband technology is a data-only system. Studies have revealed that the data transfer rate in 4G digital mobile communication rises from 20 Mbps to 60 Mbps [4]. It's compatible with long term evolution (LTE) and WiMAX networks, and its bandwidth may be increased to 100 MHz. It made its debut in the year 2010. 4.5G, or long term evolution-advanced, generation 4 (LTE-A), is a newer and faster wireless standard than 4G LTE. LTE-A utilizes multiple-input multiple-output (MIMO) technology, which pools multiple antennas to improve transmission and reception. Due to MIMO, LTE-A can transfer data three times as quickly as standard 4G by using multiple transmitters and antennas at once. With LTE-A, you may access data, phone, and video traffic through a wireless connection from anywhere on the earth, expand your system's capacity, and reduce application server latency. Rates of up to 90 Mbps have been achieved using LTE-A, which is much faster than the typical 42 Mbps. Today, in the 5G age, 5G is a crucial component of the digital transition compared to other mobile network technologies. With the advent of 5G, three distinct categories of services have been accessible to customers. UHD streaming movies, augmented and virtual reality (AR/VR) material, and more may all be accessed with today's readily accessible high-speed internet, greater capacity, and appropriate latency. Low-priced, high-bandwidth, long-distance machine-to-machine (M2M) communication is available with massive machine-type communication (MTC). MTC is ideal for IoT applications because it allows for high data speeds, low power consumption, and high quality of service with a minimum number of complex nodes. The present state of mobile network architecture prevents the realization of UHRLL's desirable properties, such as low latency, ultra-high reliability, and rich QoS. UHRLL was created for on-demand, real-time applications, including remote surgery, V2V communication, Industry 4.0, smart grids, and intelligent transportation systems.

This is because 5G is substantially faster than 4G and enables reliable remote control operations with zero lag time. Downlink speeds of up to 20 Gbps are possible. 5G wireless network standard (also known as 5G) is based on internet protocol version 6 (IPv6) and is compatible with the fourth-generation wireless web (4G WW) [5]. With 5G's lightning-fast speeds, massive throughput, negligible latency, improved stability and scalability, and low energy consumption, you can surf the web whenever and wherever you choose [6]. Millimeter wave (mmWave) 5G and 6 GHz 5G are the two main types of next generation of wireless networking. The optimal circumstances for a 5G connection are provided by the6.5 GHz mid-frequency bands, which use a 6 GHz spectrum to achieve a balance between capacity and coverage, resulting in higher bandwidth and superior network performance. It removes the need for network densification in places where the mid-band spectrum is unavailable while providing affordable, always-on, everywhere-accessible 5G connection. 5G primarily utilizes mmWave technology while building ahigh-performance network. Because of the wide variety of services, it enables all network operators to include 5G mmWave technology in their 5G deployment plans. Although 5G mmWave has already been implemented by several service providers, simulations show that it will be utilized far less often than 4G mmWave. It provides ultra-broadband for the next generation mobile networks and high-speed wireless transmission. With this research, we want to find out "what are new ways that must be applied, and how may they overcome difficulties?" for the academic community, "how have recent works addressed 5G concerns and generated solutions to meet the 5G challenges?" this article will summarize some of the essential parts of the research paper; trends and advancements in the 5G era are analyzed, as well as unique contributions made by the academic community. Some of the most complex aspects of the 5G revolution were dissected in excruciating depth. We discussed the evolution of mobile networks from the first generation (1G) to 5G. And also discussed the development of mobile communication and its proliferation into various settings. This section further provides a descriptive taxonomy of 5G research organizations, 5G research groups, and 5G research topics in the context of developing the 5G wireless communication network from an academic viewpoint. It also provides an overview of 5G networks, including their advantages, applications, primary technology, and defining features. Opportunities in machine learning are being explored as new demands emerge in the 5G era. The

focus of this work is also on the technical execution of 5G IoT. Strategies for 5G networks based on optimization theory and experience. As they relate to the creation of a 5G mobile network, we discuss the most current developments in MIMO, non-orthogonal multiple access (NOMA), mmWave, the IoT, machine learning (ML), and optimization.

2. EXISTING 5G SURVEY LIMITATION

Questions concerning architectural specifics, big-picture concepts, and growing pains in implementation have already been asked in previous polls. However, the authors of these many studies did not carefully investigate the various technologies that comprise the 5G network, including the challenges that have been experienced and the most recent advances that have been developed. Very few authors have made significant contributions to the study of MIMO (non-orthogonal multiple access), NOMA (multiple entity coded), micro enterprise communications (MEC), and microcells. While some have concentrated on millimeter-wave and beamforming technology, others have not. From a research and development viewpoint, however, not all 5G network technologies were covered in earlier studies. There is currently no market-available, all-encompassing review of the several 5G network technologies and the published research trade-offs. Our priority is investigating all 5G network architecture aspects. In contrast, this publication discusses the area's most up-to-date research techniques and ground-breaking findings. Technologies crucial to accelerating the development and manufacturing of 5G devices, as well as recent papers of relevance, are analyzed.

With its ultra-low latency and broad appeal, 5G will revolutionize how we connect our gadgets to the IoT. 5G will offer a highly flexible environment for developing cutting-edge applications and attaining organizational goals by 45% [7], [8]. We've highlighted the many advantages of 5G network infrastructure. With 5G's revolutionary, massive machine-to-machine connections [9], also known as the IoT [10], it is now feasible for numerous devices to connect without human involvement. This service expands the capabilities of 5G by improving coordination across the construction, industrial, and agriculture industries [11]. This service's ultra-reliable low-latency communications allow for numerous autonomous activities, such as real-time machine management, high-speed vehicle-to-vehicle connection, industrial connectivity and security principles, and a secure transportation system. Another barrier is removed by low-latency communications: the ability to perform medical procedures and treatment from a distance. One of the most important uses of the 5G system is to increase mobile bandwidth using massive MIMO antennas and mmWave beamforming techniques [12]. By providing a very flexible internet connection across several pieces of equipment, 5G allows communities to develop smart homes, schools, laboratories, safer and smarter automobiles, and superior healthcare facilities [13]. Due to its ability to function across a broader spectrum 24 GHz to 100 GHz, 5G is well-suited for usage in enterprise settings. Since this higher frequency range enables secure low-latency communication and high-speed wireless connectivity between IoT devices and industry, it presents a market for end-users to enhance their business models [14]. 5G has introduced several novel and cutting-edge technologies to the market, including beamforming, massive MIMO, mmWave, microcells, NOMA, MEC, and network slicing. Users may have the same sense of presence as in VR while interacting with others who are physically situated millions of kilometers away. Smart homes, intelligent workplaces, inventive schools, and shining sports academies are just some of the cutting-edge innovations that have emerged since the introduction of this 5G Mobile network architecture [15].

3. PROVIDERS OF 5G SERVICES FOR COMMERCIAL USE

With 5G, you can download enormous files in a flash, stream films without interruption, and browse the web at breakneck rates. Companies will be impacted by the arrival of the 5G network, which will also bring in numerous new opportunities. Here we'll look at some of the most significant 5G network service providers out there [16], [17]. Ericsson, a Swedish multinational networking and telecommunications firm, is investing over USD 25.62 billion in a 5G network. This makes Ericsson the largest telecom company in the world. For all it knows, it's the only company working to make the 5G network the de facto standard for all wireless communications in the next generation. Ericsson created the first 5G radio prototype, which network operators have used to conduct live field testing on their network and learn more about the features of 5G crucial for making 5G equipment. So far, it has partnered with network providers such as China mobile, GCI, LGU+, AT&T, Rogers, and many more to deliver 5G services in over 27 countries. By the year 2020, it will have signed a total of 100 contracts with a wide range of businesses. Verizon, established in 1983, is an American global telecommunications corporation. Verizon's 5G service went live in April 2020, and by year's end, it had expanded to 30 cities throughout the United States. With any luck, thirty additional cities will have 5G service up and operating by the end of 2023. Verizon's 5G mobile network uses mmWave

frequencies between 30 and 300 gigahertz. This spectrum is far less crowded than others, so high-speed wireless communication is now a reality. Regarding future mobile networks, mmWave offers capacity like nothing before. MmWave has a lesser range than lower frequencies since it works at a higher frequency and smaller band. The number of Verizon's 5G cells was expected to be seven times higher by 2023 than in 2018. Verizon's ultra wide-band flagship service is typically regarded as the most critical 5G offering since it is the most sophisticated and commonly utilized 5G network.

The Nokia corporation, or simply Nokia, is a finish multinational telecommunications company founded in 1865. In the race to provide 5G services, Nokia is among the first companies to do so on a large scale. It is developing, researching, and collaborating with several different 5G technologies to enable 5G connectivity as soon as feasible. To facilitate the development of 5G networks, Nokia, Deutsche Telekom, and the Port Authority of Hamburg collaborated in acquiring an 8,000-acre parcel of land in Hamburg. Including AT&T, Sprint, T-Mobile U.S., and Verizon in the United States; Korea Telecom, L.G. U+, and S.K. Telecom in South Korea; NTT DOCOMO, KDDI, and SoftBank in Japan; and others, Nokia is the only vendor to deliver 5G infrastructure to all of the major international carriers. So far, Nokia has established over 150 active agreements and 29 networks worldwide. Nokia's 5G R&D activities are ongoing to help deliver these networks to every corner of the globe. In 2018, American multinational business AT&T launched the first 5G network open to the public. To do this, a 5G network capable of gigabit speeds was deployed in Waco, TX, Kalamazoo, MI, and South Bend, IN. The first to capture information at speeds of 1-2 terabits per second, they did it in 2019. AT&T claims its 6 GHz frequency range provides a 5G network connection for its 225 million users worldwide. So far, T-Mobile is the only primary U.S. carrier to launch a nationwide 5G network. Since the nationwide deployment of high-band 5G would be difficult, the company instead constructed a significant portion of its 5G network with 600 MHz capacity. By 2024, TMUS hopes to have tripled T-Mobile and Sprint's total 5G capacity and doubled their overall ability. The Sprint acquisition has helped boost T-stock Mobile's price to its current $129.98 per share. The development of 5G technology at Samsung began in 2011.

In 2013, Samsung developed the first adaptive array transceiver technology to enhance cellular communications in the millimeter-wave Ka frequencies. Samsung provides hundreds of times faster speeds than conventional 4G for the core components of 5G mobile communication networks. The company has made considerable strides in the 5G market, earning it widespread recognition as a trailblazer. Its headquarters is in San Diego, California, although Qualcomm is an American worldwide corporation. The company is also at the vanguard of 5G chipmakers. Qualcomm announced its first 5G modem chip in October 2016, and a functional prototype was shown in October 2017. Qualcomm is busily building up its 5G infrastructure, even as other companies discuss it. According to one report, Qualcomm has been mainly concerned with three 5G mobile network characteristics. First, radios that can utilize any network's bandwidth, next combining smaller spectrum segments into bigger ones, and ultimately, a set of services that can be used with online software.

ZTE corporation was founded in 1985. The Chinese government owns a portion of this telecoms technology company. It was an early adopter of 4G LTE and continues to be relevant by testing and researching 5G, the next generation wireless networking. The cutting-edge firm proposed Pre5G technology and a family of associated devices. NEC Corporation is a Japanese multinational information technology, and electronics company established in 1939 and is presently headquartered in Minato, Tokyo. In addition to beginning 5G studies, ZTE has also introduced a new approach to doing business. NEC's key goals include developing secure and intelligent technologies to provide 5G services and building 5G new radio (NR) for the global mobile system.

The networking equipment manufacturer Cisco is also an early adopter of 5G technology. Cisco's key focus is on easing the rollout of 5G via the following three channels: an expedited rollout of 5G services would benefit businesses seeking to extend their services to customers. A possible way to hasten 5G's arrival is to prioritize building the necessary infrastructure. We can create a 5G network that is more robust, flexible, and scalable with the help of automation. Companies see the potential of 5G and want to connect 30 billion devices over the next few years. Since hardening is crucial to a 5G network, Cisco intends to work on it. To ensure a safe transition to 5G networks, Cisco created a security architecture based on A.I. and deep learning.

Many universities and labs worldwide are now devoted to developing the infrastructure for a 5G wireless mobile network [18]. These groups routinely enhance various aspects of 5G. These academic centers are listed as follows: for instance, there is NYU wireless, 5th generation non-orthogonal waveform for asynchronous signaling (5GNOW), 5G innovation center (5GIC), and NYU. wireless, 5G infrastructure public-private partnership (5GPPP), enhanced multi-carrier technology for professional adhoc and cell-based communication (EMPHATIC), electronics and telecommunications research institute (ETRI), and mobile and wireless communications enablers for the twenty-twenty society (METIS).

4. EMERGING 5G MOBILE NETWORKS AND THEIR POTENTIAL USES

Some of the numerous applications for a 5G mobile network include: one, it's a very efficient mobile network with download speeds of 10 to 20 Gbps. 5G is a more advanced mobile network technology than previous generations. The data transfer rates of a 5G wireless connection are on par with those of a fiber optic cable. 5G wireless communication has the distinct advantage of concurrently allowing high-quality voice conversations and ultra-fast data transfers, unlike existing mobile transmission techniques. The millisecond-level latency of 5G makes it perfect for use in autonomous cars and other time-sensitive benefits.

The 5G network's usage of mmWave will increase data speed and capacity over the lower-frequency LTE networks. The advent of 5G, a mobile network technology with very high data transfer rates, will allow for the secure and convenient virtual deployment of cloud computing and enterprise software. Increased coverage, faster data transfer, lower battery consumption, and faster access to the cloud [19] are only some of the advantages made possible by the tiny cell, one of 5G's most significant features. Studies show that in 2015, video downloads accounted for a whopping 66 percent of all mobile data usage. This trend will likely increase in the following years, leading to the broader use of online video streaming. 5G will allow users to view 4K movies with ultra-smooth audio and interact with high-definition virtual worlds wherever they go. 5G's capacity to stream films at 120 frames per second with better quality and dynamic range, as well as its ease of access to high definition television (HDTV) channels on mobile devices without interruption, bodes well for the entertainment industry. When combined with 5G's high-definition connectivity and low latency, augmented and virtual reality are significantly easier to implement. Several companies are investing substantially in high-definition VR titles to cash in on the surging demand for virtual reality games. Playing games online will be much more satisfying with the 5G network's lightning-fast connectivity [20]. Also, the 5G mobile network will play a significant role in developing the IoT, which connects formerly unrelated items and systems.

The internet of things will connect everyday objects, appliances, sensors, and electronics to the internet. These programs will collect massive amounts of data from various sensors and tools. 5G will have never-before-seen capabilities in data collection, transmission, control, and processing. 5G is the best solution for IoT since it is a highly adaptable network that can use underutilized frequencies and is deployed at little expense [21]. Some of how 5G might improve the IoT are explained. Therefore, "smart home" technology, including "smart" appliances, is becoming more popular. Due to improvements in connection speeds and remote device monitoring, the intelligent home is now a more realistic possibility thanks to the 5G network. The 5G network's lightning-fast speeds and minimal latency make it possible to control and customize cutting-edge household appliances remotely. The expansion of the 5G wireless network allows for the creation of novel city applications like automatic traffic management, weather updates, local area broadcasting, energy savings, efficient power supply, intelligent lighting system, water resource management, crowd management, and emergency control. Security, process tracking, innovative packaging, shipping, energy efficiency, automation of equipment, predictive maintenance, and logistics are just some of the many ways in which the industrial internet of things will benefit from the advent of 5G wireless technology in the not-too-distant future. Using 5G smart sensor technology, industrial IoT activities may be more cutting-edge, secure, cost-effective, and energy-efficient. No one should have any doubt that 5G technology will play a crucial role in the development of future smart farming and other types of precision agriculture. As a result of 5G sensors and GPS technology, farmers can keep an eye on their crops at all times and react quickly if there are any problems. High-tech sensors like this can also control things like irrigation, pests, insects, and even energy use. Autonomous vehicles will soon be a reality thanks to the high speeds and low latency of the 5G wireless network. Thanks to the arrival of 5G wireless networks, self-driving cars will soon be a practical possibility. 5G enables autonomous cars to communicate with one another, with stationary and moving infrastructure and smart gadgets on the road. Regarding avoiding accidents, every millisecond counts, and 5G's decreased latency allows cars to make judgments in microseconds.

Fourth, 5G's improved speed and dependability will be helpful in healthcare and other mission-critical applications. When using the 5G network, students can easily communicate with those in different classrooms, making group projects and lectures much more manageable. As a result of advancements in 5G technology, patients may now talk to doctors and take their advice. Scientists are working tirelessly to develop cutting-edge medical technology to benefit patients with chronic conditions. The healthcare industry will benefit significantly from the 5G network by using intelligent sensors, high-definition medical imaging equipment, and sophisticated analytics systems. 5G will make it much easier to obtain healthcare data from anywhere worldwide by enabling access to cloud storage. Thanks to its high data throughput, the 5G network is well-suited for storing and distributing large medical datasets like MRI results.

Internet through satellite: the availability of ground-based base stations is limited in many remote areas. Therefore, 5G will be crucial in closing the digital gap. Thanks to a constellation of thousands of small satellites, access to the 5G network will be provided in both urban and rural areas. These pages detail the

most up-to-date advancements in 5G technologies, such as massive MIMO, 5G NOMA, 5G mmWave, 5G IoT, 5G using machine learning, and 5G optimization. Each subsection also has a summary that might be used to assist future researchers in determining where to put their emphasis.

5. THE 5G MASSIVE MIMO SYSTEM

MIMO is essential to today's wireless networks. It makes it possible for many transmissions and receptions to take place over the same radio frequency. To maximize throughput in wireless networks like Wi-Fi, 3G, 4G, and 4G LTE-A, the MIMO approach is essential. MIMO is often used to increase spectrum efficiency and power savings. It promised a lot but couldn't follow through. The biggest problems with MIMO are its low throughput and very unstable connectivity. To solve this problem, several alternative forms of MIMO technologies were used. One may employ SU-MIMO, MU-MIMO, or network-based MIMO. However, we could not satisfy our clients' needs even with such innovative MIMO massive MIMO increases throughput and spectral efficiency in the 5G network by connecting hundreds or thousands of antennas to base stations. Massive MIMO uses many transmit and receive antennas to increase the transmission rate and spectral efficiency. When several U.E.s release downlink traffic at once, huge MIMO's capacity increases. Massive MIMO uses numerous antennas to concentrate radiation inside small regions, which increases spectral efficiency and throughput [22]. Due to increasing latency, decreasing data rate, and decreasing reliability, data collection from smart sensors is difficult in traditional systems. Massive MIMO provides low-latency, high-data-rate, and higher-reliability sensing from various sensors using beamforming and massive multiplexing techniques. For intelligent sensor applications, including autonomous cars, hospitals, municipal grids, roadways, homes, and enterprises, massive MIMO will enable the real-time transfer of data obtained from numerous sensors to centralized monitoring locations [23].

Massive MIMO is suggested as a leading technique to obtain data rates in the gigabits per second range via wireless networks. The wavelength of a wave decreases with increasing antenna size. A giant antenna is preferable to receive low-frequency signals and vice versa. Each "cell" in 1G to 4G technologies consists of 10 antennas and potentially serves tens of thousands of users. The 5G network, on the other hand, uses more than a hundred antennas in a single cell so that several users may share a single mini-cell [24]. Since massive MIMO has the potential to increase spectral and energy efficiency, it will play a crucial role in the eventual implementation of 5G mobile communication. Figure 1 shows a MIMO architecture.

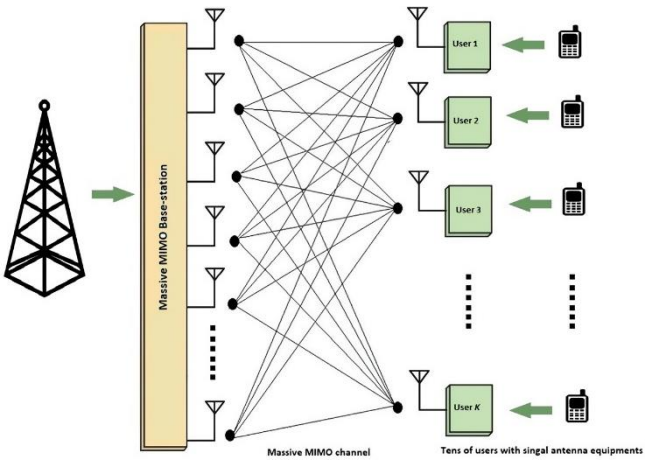

Figure 1. Diagram showing the massive MIMO base-station architecture

6. 5G CUTTING-EDGE METHODS

Several alternative methods to classic MIMO's flaws were proposed [7]. The feed-forward MIMO controller is recommended by Mae *et al*. [25]. Traditional MIMO simulations result in erratic control inputs, whereas the suggested approach produces smooth ones. It also outperformed expectations in terms of error rate. Multirate and single-rate approaches may be used for optimal results. Independent MIMO, distributed MIMO, and spread MIMO with and without corporate MIMO were all analyzed by Panzner *et al*. [26]. An approach that may be used to integrate massive scalability into 5G infrastructure was also highlighted. The experimental study considers a wide variety of different MIMO configurations. We assume that the ratio of global transmit antennas to spatial antennas varies from one equal to ten in fixed increments. The downlink

behavior of cooperative and non cooperative large MIMO systems was simulated by He and Gitlin [27]. The ability of current LTE systems to support a wide variety of antenna configurations at their base stations is crucial. The system's behavior improves when B.S. cooperates, although throughput is somewhat reduced. But a novel strategy may be developed to enhance the performance and behavior of the system. Several techniques for making the most of large MIMO's power reductions were presented in [8]. The authors analyzed state-of-the-art massively multi-input, multi-output (MIMO) technology and provided a complete energy consumption model for massive MIMO networks. This article explores many approaches to boosting the gains of massive MIMO systems.

7. FIFTH-GENERATION MILLIMETER WAVE

Mmwave operate in the same high-frequency range and are ideal for 5G wireless networks. MmWave uses the 30 GHz to 300 GHz frequency band for data transmission. mmWave is shorthand for mmWave, which covers a spectrum from 30 to 300 GHz and has a wavelength of 1 to 10 mm. Since mmWave is a high-speed frequency band that provides exceptionally high-speed wireless communications, it has been solely employed by radar systems and satellites thus far. And recently, several mobile network providers have started relying on mmWave for inter-base station data transfer.

There are two approaches to enhancing data transmission speed: increasing spectrum usage or utilization and increasing spectrum capacity or bandwidth. Increased bandwidth is the simpler and more efficient option. Data transmission rates must be increased because of the crowded frequency spectrum below 5 GHz. The 5G wireless network, which uses mmWave technology, boosts spectrum capacity rather than spectrum efficiency [28]. To maximize the signal bandwidth in wireless communication, it is advised that the carrier frequency be increased by 5%. The spectrum of frequencies between 28 GHz and 60 GHz is ideal for 5G wireless connectivity. Thus, there is a 2 GHz bandwidth in the 60 GHz range. Conversely, 28 GHz band provides up to 1 GHz. Fourth-generation long-term evolution (4G LTE) offers a carrier frequency of 2 GHz and a spectrum bandwidth of 100 MHz. But double the spectrum's bandwidth with mmWave technology increases data transfer speeds [29], [30].

7.1. Some features of 5G mmWave communication

In today's high-tech world, everyone shares information over various satellite networks (WiMax, GPS, WiFi, 4G, 3G, L-Band, S-Band, and C-Band). These technologies operate inside a small radio frequency spectrum, between 1 and 6 GHz. So, it's a little crowded there. There is a large amount of unused bandwidth in the 30 to 300 GHz mmWave frequency range that has not been allocated to other communication technologies. The frequency range from 24 to 100 GHz will eventually be set aside for 5G.

Here are three advantages of 5G mmWave technology: when combined with a MIMO antenna, mmWave can provide much more throughput than conventional communication systems. The mmWave spectrum is a relatively new and underused band. Two reasons are that there's more information packed into millimeter-wave communications than there is into waves of lower frequency and that MmWave signals fill more information than lower-frequency waves. Strategies and methods in keeping with the times in [11], the authors summarized state of art in 5G mmWave communications. Integrated circuits, systems, and other components may be updated more quickly because of the adaptability of mmWave communications. The writers looked at what was on offer and gave their thoughts based on many criteria, including how well it worked and how practical it was.

8. STRATEGIES BASED ON 5G INTERNET OF THING

5G will deliver lightning-fast connectivity for a wide range of uses, including but not limited to data gathering, transport, control, and processing. 5G is the most efficient IoT technology since it is a versatile network with a large unused spectrum and allows for exceptionally low-cost deployment [31]. The IoT can use 5G in several ways. Increased interest in "smart" home technology and products is a current trend. Now that high-speed internet and intelligent appliance monitoring are available through the 5G network, "smart homes" may become a reality. The 5G network's rapid, the low-latency connection makes it easy to access and configure intelligent home items from afar. Automatic traffic management, weather updates, local area broadcasting, energy conservation, efficient power supply, smart lighting systems, water resource management, crowd management, emergency control, and so on are just some of the applications that can be built using the 5G wireless network to make cities smarter. Safety, process tracking, innovative packaging, shipping, energy efficiency, equipment automation, predictive maintenance, and logistics are just a few fields that will benefit from 5G wireless technology. 5G intelligent sensor technologies may allow the industrial IoT to function in a superior, safer, more cost-effective, and more energy-efficient manner. Undoubtedly, 5G

technology will be essential in farming and smart farming. With 5G sensors and GPS technology, farmers can prevent crop damage in real-time. Controlling pests and insects and conserving energy are two other areas where these smart sensors might be put to use. The 5G wireless network's lightning-fast connections and minimal latency are required for fully autonomous driving. This points to the fact that 5G wireless networks will soon usher in the era of self-driving vehicles. Using 5G technology, self-driving cars may quickly and efficiently establish connections with other vehicles, smart objects, and traffic lights. 5G's low latency feature makes self-driving look more feasible [32] since autonomous vehicles must make judgments in microseconds to avert accidents. Some of the most notable features of 5G IoT are:

- The term "internet of things" is used.
- It facilitates M2M communication and distributes data among various devices without human intervention.
- The new 5G, with the IoT function of next-generation mobile communication, enables a high-speed internet connection between monitored devices.
- Sensors, smart homes, smart devices, and smart industries, are all made available to end users via 5G IoT to increase their knowledge base.
- The internet of things centres on low-powered, internet-enabled devices.

Wearable's, smartphone's, sensors, intelligent transportation systems, smart gadgets, washing machines, tablets, and so on have all been made possible thanks to the IoT approach [33]–[44]. A standardized interface has been developed to facilitate communication between these different systems. Industrial management, private healthcare systems, traffic control, and the tactile internet are all examples of prominent IoT applications.

Various ML strategies are used in 5G networks and mobile communication. It fixes several complicated problems that would have required extensive manual adjustment otherwise. Machine learning may be done in three ways: supervised, unsupervised, and reinforcement learning. Evaluate the 5G network in light of each learning technique being discussed. Issues in the 5G network might be analogous to those encountered in supervised learning, the branch of machine learning in which users analyze already labeled data, namely in classification and regression.

9. CONCLUSION

This work depicts the development of 5G technologies. The progression of mobile networks from 1G to 5G, applications, various research organizations efforts and the major aspects of the 5G network. 5G is more than simply a mobile broadband network; unlike previous generations, it provides services such as IoT, V2X, and Industry 4.0. This article contains a complete overview from numerous authors on various 5G technologies such as massive MIMO, NOMA, mmWave, tiny cell, mobile edge computing (MEC), beam forming, optimization, and machine learning. Each section contains an in-depth analysis of all current state-of-the-art research in these technology. This study also demonstrates the significance of these newly added technologies in constructing a flexible, scalable, and reliable 5G network.

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