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Exploring 5G: Technologies, Challenges, and 5G for Enhancement of IoT

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***Abstract*—5G is the fifth-generation wireless technology for digital cellular networks. The present-day cellular communication requires better quality of service, improved data rate, increased capacity, decreased latency, and improved communication network and security. Various technologies have evolved which will serve as a backbone in the establishment of 5G. This paper presents the details of the possible technologies that are proposed for the implementation of the fifth-generation (5G) cellular network along with the 'n' number of challenges that 5G technology will actually face during the practical implementation of these technologies. Some of the emerging technologies and challenges related to 5G are addressed in this paper. The interrelation between IoT and 5G and how 5G will aid IoT technology in its complete establishment is also discussed.**

***Index Terms*— Latency, Security, IoT, 5G, technologies, challenges, Quality of Service.**

I. Introduction

It is unrealistic for current cell frameworks systems to fulfil the Gigabit level of data traffic in a financially proficient manner, with the quickly expanding demand for remote data traffic over the previous decade [5]. 5G is introduced to visualize the so-called Networked Society i.e., a future with the client and machine-driven communications where anyone can share any sort of information to anyone, anywhere [6]. Other services are imagined to give occasional or consistently on hyper-connectivity for machine-type communications (MTC), and other different services that come under this are, mobile robots, sensors, connected cars, and homes that must be supported in a profitable and expansive manner. Wearable gadgets, completely immersive experience (3D) and augmented reality are other technologies that impact the conduct of human end-users and straightforwardly influence the prerequisites put on the system [4]. It has a wide range of requirements which include high peak and user data rates, reduced latency, improved coverage, and energy efficiency in order to support multimedia utilization [1]. Even with high-speed mobility at cell edges, 5G networks fulfil quality-of-service (QoS) requirements in various operations where wide-area coverage is required by providing high data-rate services. 5G provides dense coverage and high capacity in areas of high traffic demand such as Metropolitan Area Networks. 5G is also capable of connecting millions of cellular devices provided that the cost per device and power consumption is low [8]. 5G provides better coverage and offers highly reliable communications with low outage probability and latency at the cost of increased peak-rates per subscriber [6].

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II. TECHNOLOGIES RELATED TO 5G

A. Massive MIMO Technology

Massive MIMO is an upgraded version of MIMO technology, with an aim to achieve higher spectral efficiency for cellular systems. It is designed to contain the perks of MIMO technology but on a greater scale [10]. In MIMO technology, there are multiple antennas present at the transmitter as well as the receiver. As the number of antennas increases, the degree of freedom increases which increases the measure of data that can be accommodated in wireless channels. The increased degree of freedom can be helpful for cancelling the signals from proposed jammers. A massive MIMO framework can altogether enhance both spectral efficiency and energy efficiency and is immune to unnecessary human-made interference or network jamming [9].

Massive MIMO framework comprises a transmitter and/or receiver outfitted with a large number of antenna elements. Fig. 1 depicts the5G architecture where the Massive MIMO antenna is connected to Small cell Transrecievers, providing network to user equipment. It provides methods for enhancing the robustness of wireless communication with the help of multiple antennas. Since Massive MIMO uses a large number of antennas and works on the principle of beamforming, it can avoid fading dips and hence permits a considerable decrease in latency on the air interface. The massive MIMO system can be set up without the help of high power or high-cost components. Removal of massive items such as large coaxial cables decreased the cost by a large amount. In Very Large MIMO (VLM), the number of users is less than base station antennas per cell [11].

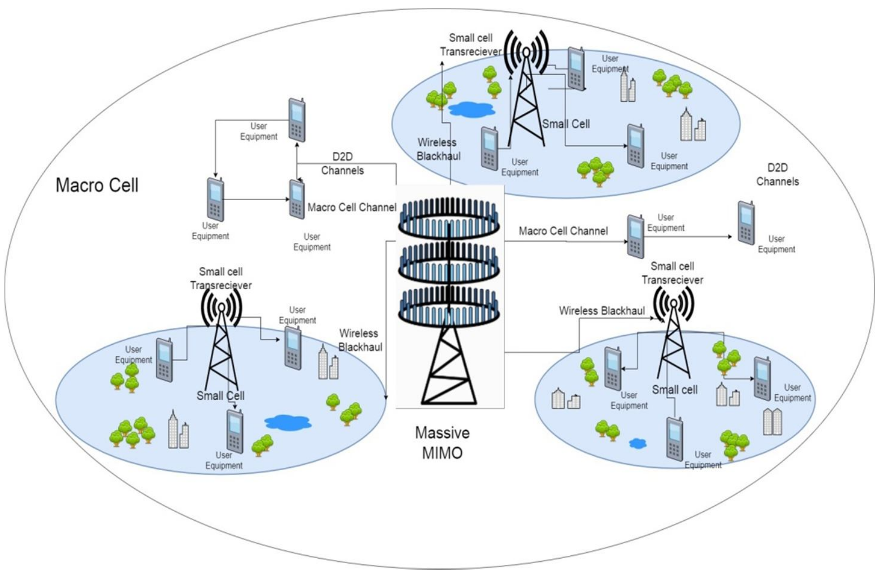

Figure 1. Massive MIMO and Small cell combination for 5G architecture

B. Direct Device to Device (D2D) Communication

A lot of research effort has been put in order to characterize D2D as a part of Long-Term Evolution. Device to device communication aims at achieving direct data transfer between different user instruments without any interaction with the base stations or the core network. It just requires an initial set up of direct links between devices. In simple language, it aims at achieving direct connectivity [11]. The implementation of D2D technology in the field of 5G will assist in improving coverage, high-speed data rates and most importantly offer peer-to-peer services [17].

Two devices connected through this technology can communicate with each other without the base station or with less base station involvement in the licensed cellular bandwidth. D2D has applications in mobile cloud computing and is used to encourage the viable sharing of assets. Various crowded places such as huge malls or stadiums constitute large traffic in the network, in order to take this load off of the network, service providers can use device-2-device technology allowing direct transmission among mobile phones. The most amusing benefit could be observed during conditions of natural disaster when usually the entire network collapses but since in D2D there are separate links between devices, the communication would still be intact [18].

C. Machine to Machine (M2M) Communication

M2M (machine-to-machine) communication expands the scope of connectivity and promotes universal connectivity among mobile devices [17]. M2M is all about local or global wireless ad-hoc networks of devices or machines equipped with embedded communication systems. This permits them to connect individually without any human assistance. Even though Long-Term Evolution has a large bandwidth, upload capacity will still end up in congestion problems i.e., M2M traffic will influence human traffic [19]. Recent applications of machine-to-machine include the generation of in-car navigation devices. New applications of M2M have the ability to cause a step-change in the size of the telecommunication market. It is approximated that there will be over 100 billion connected devices practicing M2M communications in the 5G network.

D. OFDM

OFDM is a multicarrier orthogonal digital communication scheme. It divides the whole available bandwidth into many streams of low data rates that are then modulated simultaneously by multiple carriers. The modulation schemes deployed to define the spectral efficiency and application of the waveform in wireless communication standards. OFDM cannot be considered for 5G due to its serious drawbacks of transmitting highly correlated signals with very high PAPR. PAPR reduction is only possible at increased transmission power, reduced data loss, low BER performance, computational complexity [20].

E. Small Cells

As the demand for higher data rates increases, one of the solutions available to operators is to reduce the size of the cell. By reducing the size of the cell, area spectral efficiency is increased through higher frequency reuse, while transmit power can be reduced such that the power lost through propagation will be decreased. Also, coverage can be improved by deploying small cells indoors where reception may not be good and offloading traffic from macrocells when required. This solution has only been made possible in recent years with the advancement in hardware miniaturization and the corresponding reduction in cost [1].

Fig. 2 indicates the small cell arrangement and the way it connects with beamforming in 5G. Since mm-wave holds great potential for speed, capacity, and low latency, but is impractical to deploy via a macro network given propagation characteristics that limit the ability of mm-wave to penetrate walls, trees, buildings, or other structures. So as to get the full advantages of mm-wave promises, dense organizations of Small Cells will be needed, particularly indoors where most data is consumed.

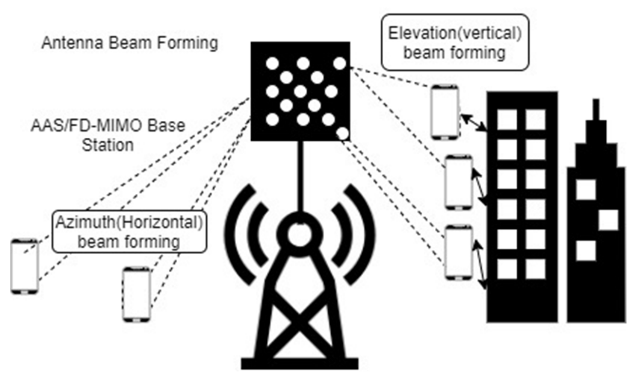

Figure 2. Small Cell 5G systems

F. Millimeter-Wave

In millimeter-wave propagation, frequencies of 28 GHz and 38 GHz are broadly studied to understand their propagation properties in different environments, paving the way for their use in future wireless systems [2]. Recent researches have put forward that mm-wave frequencies of 2.6 GHz radio spectrum possibly will supplement the presently saturated 700 MHz band for wireless communications with the use of millimeter-wave carrier frequencies, larger bandwidth allocations will come up with higher data transfer rates and service providers that are presently using 20 MHz channels for 4G customers will now significantly expand the channel bandwidths.

In millimeter-wave propagation, frequencies of 28 GHz and 38 GHz are broadly studied to understand their propagation properties in different environments, paving the way for their use in future wireless systems [2]. With the increase in bandwidth, capacity will also get increased, while the latency will get decreased, which gives rise to better internet-based access and applications like real-time streaming [10]. Millimeter (mm)-wave bands, between 30 and 300 GHz, where the available bandwidths are much wider than today's cellular networks are suitable for 5G communication systems. Indeed, the available spectrum at these frequencies can be 200 times greater than all cellular allocations today under 3 GHz. Moreover, the very small wavelengths of mm-Wave signals combined with advances in low-power CMOS RF circuits enable a large number of miniaturized antennas to be placed in small dimensions [11].

G. Spatial Modulation

Instead of simultaneously transmitting multiple data streams from the available antennas, SM encodes part of the data to be transmitted onto the spatial position of each transmit antenna in the antenna array. Thus, the antenna array plays the role of a second constellation diagram, which can be used to increase the data rate with respect to single-antenna wireless systems [9]. Spatial modulation (SM) is another new promising transmission technique that uses antenna indexes in a multiple antenna system, as an additional means of data transmissions. The main idea behind spatial modulation is to use the index of the active antennas at any time instant, transmitting or receiving antenna depending on whether the spatial modulation scheme is applied at the transmitter or at the receiver, to convey extra information. Thus, the information bits to be transmitted are divided into blocks of two parts. The first part is mapped to a symbol chosen from the signalling constellation, where the number of bits per symbol depends on the type of modulation used. The second part determines the index of the antenna is selected from a set of antennas available for data transmission or reception. Therefore, unlike antenna selection in the conventional MIMO systems which depend on the channel states and the received signal strength, antenna selection in spatial modulation depends on the incoming user data stream. The idea of space shift keying (SSK) modulation was introduced as a modulation scheme, which uses only the spatial modulation concept. In the SSK scheme, there were no transmitted symbols. Only the antennas' indices were used to convey information. Because no symbols were transmitted, SSK reduces the system complexity by removing the amplitude/phase modulation [15].

H. Cognitive Radio Networks

A large portion of the radio spectrum is underutilized most of the time. In CR networks, a secondary system can share spectrum bands with the licensed primary system, either on an interference-free basis or on an interference-tolerant basis [9]. With half-duplex radios, sensing the primary channels, detecting spectrum holes, and accessing the idle or underutilized channels according to certain algorithms are performed sequentially by cognitive (secondary) users. This can inherently cause interfering with primary users in the licensed bands, as secondary users cannot hear their turn of primary users while transmitting data. With full-duplex radio, on the other hand, the users can transmit data and sense/receive data simultaneously. This can potentially improve the throughput of the secondary network and at the same time provide better protection to the primary users. Since the secondary users can sense the primary channel(s) whilst transmitting over the primary's idle channel, they can detect the return of primary users and would immediately stop transmission over the respective frequency band. End to end delay reduction is also another major benefit of full-duplex communication, as some of the above sequential processes can be made concurrent with full-duplex radio. When we deal with 4th and 5th generation dense networks and apply full-duplex and cognitive radio technologies in the emerging Internet of Things, new challenges will arise. For instance, multiuser interference is increased when full-duplex communication is exploited in multi-user scenarios, and especially in dense environments. Full duplex radio in cognitive users has been exploited for enhancing the sum-throughput of the network. The users can simultaneously transmit and sense channel/receive data.

I. Distributed Antenna System (DAS)

The distributed antenna system (DAS) is a promising way to greatly improve spectral efficiency. In DAS, all of the remote antenna units (RAUs) are connected to the baseband processing unit (BPU) by fiber or cable, and then powerful joint processing can be done at BPU. For hot-spot coverage, when large numbers of RAUs are deployed, the advantages of both massive MIMO and ultra-dense networks can be exploited. Therefore, large-scale DAS is a very promising technique for the 5G system, especially for indoor [1] or outdoor hotspot coverage [2]. Recently, both theoretical and experimental results show that large scale DAS can provide very large spectral efficiency [21].

J. Beam Forming

Beamforming is a method used to generate the radiation pattern of an array antenna by adding the weights of the signal constructively in the direction of SOI and nulling the pattern in the direction of SNOI (interference). But this array can be antennas in the smart antennas context, or any other types of sensors (radar, medical sensors…etc) can be an array of microphones in the speech signal processing context. Beamforming can be employed at both the transmitting and receiving ends in order to achieve spatial selectivity, i.e. appropriate feeding permits antenna arrays to guide their beam and nulls towards certain directions, this is frequently referred to as spatial filtering [22].

K. Multiple Radio Access Networks

4G network distribution is based on Macro-cells. The disadvantage of this includes low coverage problems, low latency, and requirement of high bandwidth. To avoid these problems in 5G operators are using small cell deployment to increase the density of their radio access network. This serves better coverage and improves the quality of service [19]. The small cells are a way to improve the 4G networks to form the foundation for the 5g networks and other services [23].

As heterogeneous networks coincide with the operation of several classes of base stations, these networks in 5G will also be a combination of different radio access networks and technologies. The incorporation of Wireless Local Area Network (WLAN) can provide logical and smooth handover from and to cellular infrastructure. It will also guide the device to device communication. This decreases the load from cellular networks. Also treasured licensed bands feel less burden. The rate at which things are processed increases for users [24].

L. FemtoCell

A femtocell is an affordable, small, and low-power base station whose radio range is 10 - 15 meters. On account of the small transmission separation among transmitters and receivers, the femtocell can give an effective speed up, increased capacity, coverage, and furthermore expanded battery life. Femtocells are often arranged in three distinct manners: the primary is Orthogonal organization, where Femto Cell uses one segment of the range and Macrocell uses another piece of the range. The subsequent deployment may be a co-channel arrangement were both full scale and femtocell access all channels and within the third deployment, the entire bandwidth is split into two parts where one part is employed by macrocell, and both utilize another part [27].

III. Research Challenges for 5G Wireless Networks

4G to 5G transition brings challenges which include the technology adaptability by devices, the setup required, the fulfillment of performance requirements, and the cost-effectiveness of the generation. This change in the design of architecture is required. Fig. 3 conveys the challenges faced by 5G technology and the same major issues faced are further discussed below:

Figure 3. 5G challenges and concerns

A. Interference in 5G System

The problem of inter-cell interference occurs when the deployment and location of small cells are unplanned and the sizes of the cells (macro and concurrent small) are irregular. Multipath interference and Co-channel interference affects the system. Power control and allocation of resources will improve Inter-cell interference.

B. Massive Access and Multiple Services in a Cellular Network

As 5G comes with large expectations, to provide services to networks, technologies, and devices in different geographic areas, human traffic can cause Radio Access network overcrowding. M2M devices communicate to cause congestion and overload. The autonomous operation, limited power, and complexity of the system are also the challenges faced. For multiple services to diverse networks and devices, the service has to be dynamic and rich in data [17].

C. Attenuation in Signals

The comparable size of raindrops and radio wavelengths cause scattering resulting in attenuation of mm waves. This will decrease if the coverage areas by the cell are less in radius. Also, the signals below 10 GHz range are facing loss by rain, clouds, fog, hail, ice, and other applicable phenomena. As the frequency increases the attenuation due to rain also increases as these waves absorb more RF energy by water drops present in the lower atmosphere and other layers leading to system and cable losses.

D. Performance of the Network

High speed contributes to high-performance rate but unreliable and varying data rate creates a problem. Data rate and capacity can be increased by reducing the distance between transmitter and receiver but due to the high demand data rate for 5G, leading-edge technology is needed. Higher-order modulation and smart antenna systems can be possible ways to increase speed. The speed reduces by a significant amount if one walks a couple of meters away from a 5G node. The signal can get easily blocked by any obstacles such as buildings, trees, rain, etc. The solution would be to place a lot of nodes all over the place in order to maximize the coverage. But this seems like a brute force algorithm to go about the plan and solve the issue [25].

E. Security and Privacy

As 5G network architecture is largely based on software it is vulnerable to security imperfections. Mass surveillance and face network access points are two of the security challenges. To support high-security features, 5G needs a robust network architecture. End to End security cannot be provided easily for different types of services, so the need for a rigid authentication method is required for the 5G technology [28].

F. Effects on Health

Due to the low power of 5g transmitters there will be more of them and as 5G uses between 24 to 90 gigahertz frequency, radiofrequency radiation (RFR) damage tissue in living organisms. It can kill cells and can cause DNA mutations. There are adverse effects on the health of people exposed to the Radiofrequency energy by 5G base stations. The placement of small cells should be monitored by giving less control to local communities. A larger number of access points, potentially closer to people's homes, must be avoided.

G. Deployment Issues

The upload speed is still equal to 4G speed even when connected to 5G. 5G gadgets are normally equipped with larger batteries in comparison to 4G phones which lead to more battery consumption and heat dissipation.5G is about a massive machine to machine communication and greatly reduced latency. Being deployed in the mm wave band, it deals with much higher frequency so it has much more difficult design and manufacturing as well as deployment and optimization in the field.

H. Economic Challenges

Economic Challenge includes the issue of who is going to pay for fiber, for bringing power to the site, and for radio equipment and so forth. Building a network is expensive, and carriers will raise the money to do it by increasing customer revenue. Much like LTE plans incurred a higher initial cost, 5G will probably follow a similar path. 5G-enabled smart phones and other devices, their availability will hinge on how expensive they are for manufacturers to make, as well as how quickly ubiquitous the network becomes.

IV. INTERNET OF THINGS IN THE 5G ERA

IoT transfers information from one heterogeneous device to another without any human assistance, by providing interconnectivity between devices. The vision of IoT depicts smart cities and smart homes where you can control household appliances from anywhere. However, Critical IoT contains certain use cases that require real-time responses and interconnectivity of billions of smart devices and sensors. The deployment of such critical IoT is presumed to be served by 5G mobile networks. 5th generation wireless systems (5G) are on the horizon and IoT is taking the center stage as devices are expected to form a major portion of this 5G network paradigm. 5G technology is better than previous cellular mobile standards that were used to support the Internet of Things. Particular use cases demand connection of a massive number of devices hence an increase in machine communications which is expected to accommodate the growing span of IoT by enhanced communication technology such as 5G. Such use cases may include the fleet management sector, smart society, automotive sector, connected consumers, and industrial automation. The overall objective is to establish an entirely new network system that ensures the efficient and effective use of multiple service dimensions. These service dimensions include network operation, critical communications, massive MTC, enhanced mobile broadband, eV2X [29].

In addition to high speed, increased data capacity is also one of the potential advantages of using 5G as a communication standard in terms of IoT as the capacity is improved by adding packet data capability to the existing GSM. Increased Security provides a security mechanism that is established throughout the entire network rather than focusing only on the privacy of end-users. Furthermore, it communicates issues on authentication, authorization, and accounting (AAA). The challenge here is the massive number of terminals, which leads to the necessity of extremely high-dense networks. Thus 5G requires scalability and a high connection density. Ultimately, the Next-gen IoT devices prime objectives or demands of increased capacity, improved data rate, decreased latency came down to be fulfilled by next-generation wireless mobile communication technology namely, 5G which promises to suffice the needs of complex IoT architectures.

V. CONCLUSION

5G technology will provide a new way and era to the communication industry. Real time speed, reduced latency, security, efficient Quality of Service and effective networking will make it an exact choice for the operability of various IoT. 5G will provide new wings to IoT. This paper presented various technologies such as massive MIMO, OFDM, mm Wave communication which will help in establishing 5G networks. We have also explained several challenges associated with its establishment. 5G being the technology for the future has come with many expectations which were not being fulfilled by the present wireless communication technologies. IoT being one of the many applications waiting for an effective network like 5G for its requirements to be completely fulfilled.

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