A Review of the Use Cases and Possible Technologies for 5G and Beyond Communications

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ABSTRACT

5G communication system is rapidly taking shape and for many organizations, including administrations, it is important to be aware of developments in this regard. At this stage, it is essential to know about 5G use cases and possible key technologies. This paper describes several anticipated 5G use cases across a handful of different sectors. It is important to remember that these comprise only a subset of possible use cases and these are all still new. As-yet more new use cases are expected to emerge and the need to prepare their adaption in 5G and beyond. From wireless transmission, wireless access and network perspectives, the possible key technologies of 5G, including Massive Multiple Input Multiple Output (MIMO), Beam-forming, Device-to-Device communication system (D2D), non-orthogonal multiple access (NOMA), Full duplex, Small cells, cognitive radio(CR), etc. and their latest progress are presented comprehensively and thoroughly. Each has enormous advantages but also limitations. The Full duplex which will help to double the

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capacity of the channel compared to the Half-duplex technology of 4G and Small cells combined with millimeter waves to have a wide bandwidth. These Small-Cells are essential for energy reduction and also for improving latency. But these Small-Cells require the use of intelligent antennas, that is to say, the diagrams of which are directive and reconfigurable at the request of the user Future research challenges regarding 5G and beyond wireless communication are also discussed.

1. INTRODUCTION

The way people interact and communicate has seen a paradigm shift due to the technological advancement of the wireless system within a remarkably short period. The technological transformation in wireless networks started with the 1G network to the present 5G network. Each has its peculiar characteristics and techniques.

The 2G network [1] that constituted the first digital communication system was centered on the voice and exchange of SMS. Whereas, the third generation network (3G) was established in late 2000. It imparts transmission rate up to 2Mbps. Third generation systems merge high speed mobile access to service based on internet protocol (IP). Aside from transmission rate, unconventional improvement was made for maintaining quality of service (QOS). The major disadvantages for 3G handsets is that, they require more power than most 2G models. Along with this 3G, network plans are more expensive than 2G [2-5]. since 3G involves the introduction and utilization of wideband code division multiple Access (WCDMA), UMTS and CDMA 2000 technologies, the evolving technologies like High speed Uplink/Downlink Packet Access (HSUPA/HSDPA) and evolution Data optimized (EVDO) has made in intermediate wireless generation between 3G and 4G named as 3.5G with improved data rate of 5.30 Mbps[2].

The arrival of 4G [6] which is based on the long term evolution (LTE) standard, has improved the prevailing communication networks by imparting a complete and reliable solution based on IP. Amenities like voice, data and multimedia will be imparted to subscribers on every time and everywhere basis and at quite higher data rates as related to earlier generations. Application that are being made to use 4G network are multimedia Messaging service, digital video broadcasting (DVB), **and** video chat, high definition TV content and mobile TV [7-9] with exponential increase in the demand of the users,

4G will now be easily replaced with 5G [10] with an advanced access technology named Beam Division Multiple Access [11], Massive Beam-Division Multiple Access [12], sparse Code Multiple Access and filter bank multiple carrier(FBMC) multiple access [13].

5G will provide more advanced and enhanced capabilities compared to 4G LTE (Long term evolution). It can be noted that 5G will aim to provide 20 times the peak data rate (speed), 10 times lower latency (responsiveness) and 3 times more spectral efficiency than 4G LTE. 5G has three major use case classes: enhanced Mobile Broadband (eMBB), mIoT (Massive IoT) and ultra-reliable low latency (URLLC). The requirements for the use case classes and the use cases within each class vary significantly. In terms of spectrum bands earmarked for deployment of 5G, they can be sub-divided in three macro categories: sub-1 GHz, 1-6 GHz and above 6 GHz. Sub-1 GHz bands are suitable to support IoT services and extend mobile broadband coverage from urban to suburban and rural areas. The 1-6 GHz bands offer a reasonable mixture of coverage and capacity for 5G services. Spectrum bands above 6 GHz provide significant capacity. This variety of requirements and spectrum needs show that there are many options of 5G introduction and different spectrum bands will be needed to support all use cases.

The 5G technology will allow better management of all the networks (smart grids, smart agriculture, and industry of the future) and their interconnections for more efficient and reactive distribution. It will promote telemedicine, transportation, and media which are very close to the everyday lives of our fellow citizens by reducing their cost of use. It will introduce robots in the medical field for the execution of specialized surgical operations and will allow diagnoses of remote and real-time operations. The automotive world could use this new network to allow vehicles not only to make decisions

without human intervention but also to communicate with each other.

As far as the industry of the future is concerned, the improvements brought by 5G are mainly aimed at introducing new generations of connected robots, the interconnection of production sites, and the multiplication of connected sensors for the improvement of industrial processes. It is, therefore, a question of generalizing the communication between machines. It is not beyond the realm of possibility that machine clients will come to outnumber human clients. The need to have the users of the 5G network adapt on how to deal with its major characteristics of high-speed and on-demand mobile data is inevitable. This will entail significant changes in the design of user interfaces and the development of upper layer functionalities. 5G network has features that the internet could not serve them to the fullest. In short, 5G involves the activation of new services and devices, the connection of new sectors, and the creation of new user experiences, with the connection of people and things in a variety of scenarios.

5G is a key issue for operators and equipment. It now seems clear that 5G's goals cannot be achieved with a single technology but by using several key technologies. These technologies will address the challenges posed by the growth of data traffic by increasing capacity, enhancing energy efficiency, and reducing spectrum usage. Furthermore, it will allow better scalability and reliability of the network. As a result, many research efforts and numerous proposals are emerging to meet these challenges.

This paper discusses a comprehensive study of several use cases and key technologies for a 5G and beyond mobile networks. The 5G technology opens a wide scope of applications and services.

2. USE CASES

Improved system capacity, increased data transfer rates, and high-speed mobile remain the attributes of the use cases for 3G and 4G technologies. This trend will continue for 5G with the type of service (such as video) determining the rate and capacity of the data. To create personal networks, the capacity of the devices should be increased, because the users will be consuming more interlinked devices for playing games and interacting with each other. Even, machines needing to communicate with widespread networks for fleet management, in-

home assistance, alarm monitoring, and other various applications will start to develop. The user community has to interact with the information that needs to have a swift mobile data or internet connection to solve the problems. Nowadays, the internet might not be the best for 5G users, as it requires the activation of new services and devices. It also involves the connection of new sectors and the creation of new user experiences, with the connection of people and things in a variety of scenarios.

The sections below define several anticipated 5G use cases over a handful of different sectors. It is important to remember that these comprise only a subset of possible use cases and they are all still new. As-yet unforeseen use cases will probably appear and 5G should be able to adjust accordingly.

2.1 Internet of Things (IoT)

By beyond 2020, there will be a broad range of The Internet of things (IoT) applications compatible with cellular telephony from smart utility networks to sensors used in detecting natural disasters for public warnings. All these applications can be deployed even on current cellular networks and this has already begun. Existing cellular networks and technologies, however, will not be able to keep up with the expected rate of development of IoT applications.

Wireless network infrastructure is needed to support potentially billions of IoT peripherals. This network infrastructure must be extremely adaptable in terms of capacity as well as capable of ensuring the optimal management of different service requirements of various vertical IoT markets. These service requirements can relate to various factors such as mobility, latency, network reliability, and resilience and may necessitate a new architecture of key cellular network components to assist on-demand mobility solely for devices and services. 5G networks with IoT was technically discussed in detail in [10,14]. The recent advances in the applications of blockchain in 5G Internet of Things are also surveyed in various domains, i.e. smart healthcare, smart city, smart transportation, smart grid and Unmanned aerial vehicles (UAVs).

2.2 Monitoring of Smart Networks and Critical Infrastructures

Today, a wide range of critical infrastructures are demanded to work properly. Any malfunction or

deterioration in this infrastructure can have serious financial consequences and it may degrade the quality of life or even cause fatalities. The 2003 power outage in the northeast United States shows how the failure of infrastructure can destroy an area and its economy. On the other hand, any failure in the structure of bridges and buildings can also cause such disruptions that lead to the malfunction of water and sewerage systems. Therefore, it is significant to examine the reliability of critical infrastructure.The monitoring of critical infrastructures is a costly undertaking and often necessitates a level of service only possible through a dedicated wired connection, for example, to identify any fault on a transmission line of high-voltage and take corrective measures to avoid cascading outages.

2.3 Smart Cities

The world continues to trend towards mass urbanization, weighing heavily on municipal services, reserves, and infrastructures. Six out of ten people will be living in cities by 2030, as per the World Health Organization. The initiative of the smart city aims to improve cities' efficiency in terms of costs, resources, and processes while maintaining a high quality of life for the growth of their population. To manage traffic, 5G will allow real-time data collection from vehicles, drivers, cameras, pedestrians, and road sensors. Moreover, 5G-enabled sensors and actuators could help to optimize the temperature of buildings, humidity, and lighting levels depending on the events taking place.

2.4 Mobile-Health and Telemedicine

Telemedicine is an important tool used in providing quick rural and urban healthcare access. It provides quality healthcare services at less cost. Since the use of medical files is widespread, the 5G network ensures that these records (both images and videos) are readily available to doctors and healthcare professional's on-demand, regardless of location and in a high-resolution form. Real-time remote consultations between specialists and general practitioners will also help to keep the costs low while offering increased convenience with better and faster medical outcomes.

2.5 Automotive Industry

In the automotive industry, autonomous vehicles and advanced driver assistance systems (ADAS) are becoming one of the revolutionary technologies in the sector. They come with combined advantages such as improved safety measures, reduced accidents, few congestions, enhanced fuel economy, and high driver's productivity. 5G being a wireless technology allows low-latency and high-speed vehicle-to-infrastructure and vehicle-to-vehicle communications that are the main keys of autonomous and ADAS vehicles. Nowadays, drivers and passengers demand a great variety of infotainment options, placing an added burden on wireless networks.

2.6 Multimedia Application

Mobile immersive services based on virtual reality (VR) and augmented reality (AR) terminals are gradually becoming the development direction of early killer application for end users in 5G.It is foreseeable that from 4K/8K HD video to anytime, anywhere mobile roaming immersive experience business, it will drive the rapid development of 5G. Typical scenarios for virtual reality applications such as virtual games, live sports broadcasts, remote displays, remote device controls, and more. Typical scenarios for augmented reality applications such as smart navigation, guided tours, educational training, etc. With the mobile roaming immersive experience, people can watch movies, live sports, games, shopping, and remote mobile work anywhere, anytime, anywhere, on the go, conveniently, freely and efficiently. The 5G technology empowers to create such applications. Fig. 1 is a good example of the future connected society on which most of our activities on the 5G network will depend.

Fig. 1. Sectors and areas of 5G use [15]

3. KEY TECHNOLOGIES FOR 5G NETWORKS

It now seems clear that the goals of 5G cannot be achieved with one technology, but with the use of several key technologies. These technologies will make it possible to meet the challenges posed by the growth in data traffic by increasing capacity, improving energy efficiency, and reducing spectrum usage. Moreover, these technologies will allow better scalability and reliability of the network. Consequently, many research efforts and proposals are starting to emerge in order to meet these challenges. Below are some examples of new concepts proposed for 5G mobile communication:

3.1 Massive Multiple Input Multiple Output (MIMO)

To achieve the objectives in terms of high throughput, reduction of energy consumption and latency. The combination of various technologies will be necessary. One of the solutions is the introduction of Massive MIMO for the next generation, ie the use of massive scale multiple antennas [16]. MIMO technology has aroused great interest in research over the last decade and has already been incorporated for the first time into the 3G standard and then into the 4G standard with multi-user (MU) MIMO for mono. Cell, or CoMP (Coordinated Multipoint transmission) for multi-cell [17].

The purpose of this technology is to increase the advantages of traditional MIMO systems. It refers to a scenario where specific technological components enable the cost-effective deployment of cellular systems using hundreds of antennas in cellular base stations. This technique is one approach to increase channel capacity and to provide high multiplexing and diversity gains in the uplink and downlink directions. This performance will depend heavily on the number of antennas in the base station compared to the number of users.

The principle of operation of Massive MIMO systems relies on channel state information (CSI) known to the base station to consistently process signals, i.e. to perform precoding and detection. When the number of transmitting antennas is much greater than the number of receiving antennas, simple linear precoders and detectors are sufficient to provide near optimum performance. However, when the number of transmitting antennas is less than or equal to the number of receiving antennas, the design of precoders and detectors with reasonable complexity becomes more difficult [18]. Fig. 2 shows the architecture of such a system.

In [20], the authors conducted theoretical studies on the transmission channel of a Massive MIMO system. We can see that Massive MIMO is extremely interesting because it allows to take advantage of its wide range of antennas to concentrate the beams towards several users simultaneously. This is achieved by massive arrays and simultaneous beamforming to the users so that the received multipath components of the wanted signal add up coherently. This allows it to achieve spectral efficiencies 10 times greater than those of MIMO systems used for 4G.

In [21], the authors show that each unique antenna user in a Massive MIMO system can reduce its transmit power in proportion to the number of antennas at the base station if the base station acquires channel state information (CSI). Perfect CSI or the square root of the number of antennas in the base station if the base station has an imperfect CSI, to achieve the same performance as a corresponding Single-Input Single-Ouput (SISO) system. Although this technology offers many potential benefits for the 5G standard, several major challenges must be addressed before their practical deployment. The first challenge would be the limitation of the physical layer. The deployment of a large number of antennas and electrical components will respectively lead to problems of spatial correlation and mutual coupling [20]. In [22], the authors show that the effect of mutual coupling can result in significantly lower capacitance. In [23], time division duplex is adapted in the Massive MIMO instead of frequency division duplex that minimize the signal overhead and helps acquiring channel state information. In [24], the authors proposed user and antenna selection algorithms to maximize the system sum rate of a massive MIMO system with various preceding scheme. In [25], the authors studied the performance analysis of Massive Multi-input and Multi-output with Imperfect Channel State Information. In [26], the authors investigated the performance of the downlink Massive multiple-input, multiple-output (Ma-MIMO) system with zero forcing (ZF) and the minimum mean square error (MMSE) pre-coding schemes and considering small scale fading (SSF) and large scale fading (LSF) in Rayleigh channel model.

Several asymptotic lower bound expressions for the spectral efficiency (SE) are derived, simulated and analyzed with perfect channel state information (CSI).

In [27], the Quantization-Aware (QAGAS) algorithm has been proposed and compared with other antenna selection algorithms, including simple algorithms such as random selection and Fast Antenna Selection (FAS) algorithm. The simulation results show that the proposed QAGAS gives a higher capacity value than the quantization Fast Antenna Selection (QAFAS) in any situation. These algorithms can be used in future work to satisfy the antenna selection capacity by improving the capacity of the system as the number of user's increases. It is also important to investigate the use of hybrid beamforming to simplify the antenna selection process in massive MIMO systems.

In [28], the authors considered the Massive MIMO, millimeter wave communications, and small cells technologies for the realization of Gigabit transference rate in (5G) networks. In addition, the performance of distributed and Conventional architecture used with small cell communication technologies and millimeter wave (mm) massive MIMO antennas in ultra-dense cellular networks. A comparison between the energy efficiency of wireless backhaul networks and that of other network architectures was carried out. Basically, the use of these two architectures is widely employed in the development of fifth generation systems with the aim of increasing the capacity and the energy efficiency of the entire system. Based on the results, the energy efficiency of the distribution approach is higher as compared to that of the Conventional approach in 5G mobile networks. With high bandwidth, the capacity of the mobile networks is significantly increased.

3.2 Beamforming

Beamforming seems like a spatial filter, which eliminates signals from unwanted directions. It modifies the propagation channel and reacts automatically in real-time [29]. Beamforming is also called channel formation, which is a signal processing technique used in arrays of phase control antennas. In this technique, the signals interfere constructively in particular directions, while in other directions the interference is destructive [30-31]. MIMO beamforming is a MIMO system based on intelligent transmitting and receiving antennas. It is a question of converging the power of radio waves to the mobile position, improving the efficiency of the 5G system. Tilt control can also be extended to control the azimuth of the main lobe or the horizontal opening of the antenna. Beamforming allows focusing the main lobe of the antenna towards the desired received signals and enhancing the signal-to-noise ratio. This modification of the radiation pattern based on the control of an antenna array is generally called beamforming.
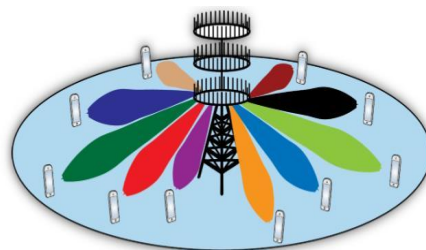

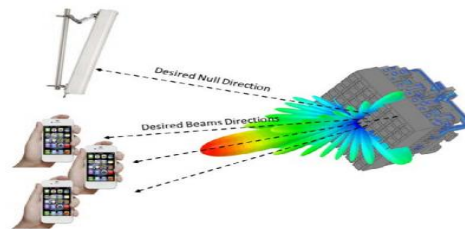**Fig. 2. Massive MIMO system with N antennas to serve K users [19]**

Fig. 3. Principle of beamforming [32]

3.3 Device-to-Device Communication System (D2D) [33]

Device-to-Device communication, also known as D2D is direct communication between two devices without passing through the network infrastructure. In mobile networks, these systems form an extra layer to enhance the network capacity. The devices can communicate with each other by either using the same spectrum similar to the macro-cells or the unlicensed spectrum. The new visions of wireless communication that use new location services or communication between neighboring devices are becoming more and more useful. Indeed, different devices or a group of devices can communicate with each other forming a network. This network absorbs D2D traffic and increases capacity by area. Furthermore, D2D technology also reduces delays and end-to-end energy consumption. For example, at the cell edges the mobile terminals need more energy to communicate with the base station .However, if the communicating mobile users are geographically neighboring, their terminals can act as local relays. It helps in avoiding distant communications, thereby reducing energy consumption. D2D technology also presents challenges such as security, interference management, and privacy. User data protection from potential attacks remains a major challenge. Open and closed accesses are the two modes used in accessing devices.

Communication between peripherals can be carried out in several operating modes, depending on the scenarios. Depending on the situation, the most appropriate operating mode will be chosen to establish efficient transmission [35]. The figure 5 shows the different possible cases for D2D communication. A typical application of D2D-based IoT enhancement is vehicle-to-vehicle (V2V) communication in the Internet of Vehicles (IoV). When traveling at high speed, a vehicle can warn nearby vehicles in D2D mode before changing lanes or slowing down (Figure 6). Depending on the warnings received, nearby vehicles alert drivers or even automatically control emergency driving so that drivers can react more quickly to reduce the number of traffic accidents. Additionally, using D2D discovery technology, vehicles can reliably detect and identify specific vehicles nearby, such as vehicles that may present a hazard at intersections and specific vehicles (school buses or vehicles carrying dangerous goods which require special attention [36].
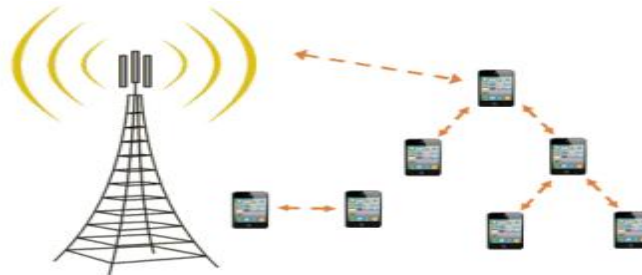

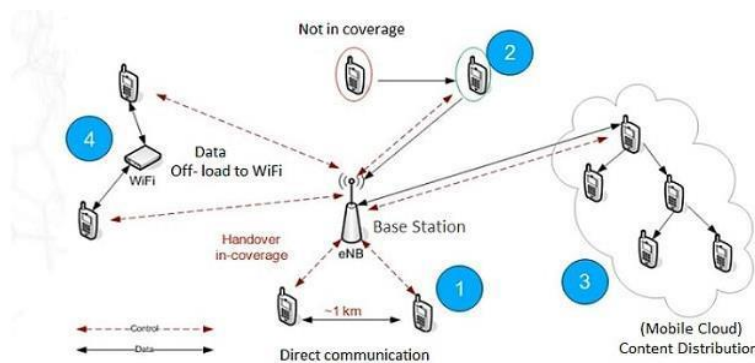**Fig. 4. Device-to-device communications in cellular networks [34]**

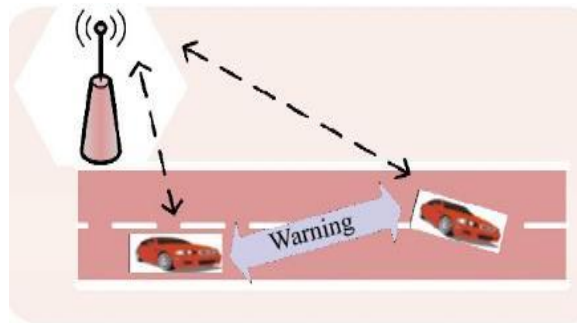

Fig. 5. D2D Communications [35]

Fig. 6. D2D Communications [36]

3.4 Ultra-dense Heterogeneous Networks (HetNet)

The fifth generation of mobile communication (5G) will experience a tremendous expansion in the number of users and a great diversification of technologies operating on different bands. Network densification is a fundamental technique for the 5G network and the evolution of wireless communication networks. It permits the network to fulfill the specifications of capacity, connectivity, and accessibility. The heterogeneity of network nodes significantly supports to achieve ultra-dense networks [37].

Heterogeneous networks propose an effective feature to the mobile networks. The massive deployment of low-power devices results in an increase in the number of nodes in the network which makes the network ultra-dense. The distance between base stations and mobile users will be reduced by using this method, and hence the spectral efficiency will be improved [38]. Bhusnan et al. [39] stated that network densification is an arrangement of spatial densification and spectral aggregation. The densification of space is to increase the number of base stations and antennas on a base station deployed in a geographic area.The different types of base stations coexist in HetNets and they are densely deployed. However, the new macrocells deployment imposes substantial costs for both capital expenditure (CAPEX) and operator expenditure (OPEX). Moreover, the deployment of new macrocells involves site planning as well as the search for potential deployment locations. Picocells are easy to deploy at a much lower cost and they offer direct access to the operator's network. Whereas, relay nodes are deployed when the wired link is inaccessible, as these nodes have the trait of functioning like a base station for mobile devices and vice versa.

Small cells such as femtocells are small, low-power nodes that are easiest to deploy intensively. The deployment can be done without site planning and imposing significant OPEX and CAPEX for operators. These cells provide the users with a base station nearby, with a direct connection. Hence, solving the problem of cover holes and improving the quality of the signals inside buildings (indoor).Spatial densification and spectral aggregation require densification of the backhaul part of the network. Backhaul is the part that connects the base stations with the heart of the network. Thus, it should be able to deal with all the excess traffic generated by the densification of the network. Otherwise, the overall performance of 5G networks will be affected because of ultra-dense networks.

3.5 Millimetric Wave Communications

Mobile cellular systems are deployed in the band 300 MHz-3 GHz. However, the continuous surge in cellular data traffic and the number of connected devices is making the spectrum crowded. The densification of the network with small cells allows the reuse of the spectrum. Nevertheless, this is not sufficient as the capacity of the network increases linearly only, with the number of cells. Concurrently, the much higher frequency bands ranging between 3 and 300 GHz are underused. Since the signals' wavelength ranges from 1 to 100 mm, they are called millimeter waves (mmWave).

Millimeter waves have a huge bandwidth which reflects the high speed and short wavelength. The use of many small antennas is allowed because of the short wavelength in a small area. Z. Pi et al. [40] maintained that, for mobile communications, the use of millimeter waves would offer a new spectrum of 100 GHz, a spectrum 200 times bigger than that used in bands below 3 GHz. The introduction of

mmWave communications into next generation cellular networks is the backbone of the 5G network. The increase in the bandwidth increases the network capacity and decreases its latency. This will allow a better quality of experience (QoE) for users of real-time services.

In [41], the authors studied the performance evaluation of using 5G MmWave in small cells backhualing configurations. The first one is the star configuration and the second one is the mesh. The main difference between them is the cooperation in the mesh topology between cells to transfer data. The energy efficiency of wireless backhaul networks is compared for different network architectures and mm wave frequency bands with addition to different values of path loss coefficient. The simulation results show that the mm wave frequency band plays an important role to choose the network configuration. If the application needs high energy efficiency, the suitable network configuration chosen is the mesh configuration. If the frequency band used is 5.8 GHz, and there is no need for high energy efficiency, the suitable chosen network is the star configuration.

The main challenges in mmWave communications are propagation problems [42-43], because the square of the frequency increases with the path-loss in free space. This results in the addition of 20dB of signal strength loss when going from 3 to 30 GHz. According to Andrews et al., if the opening of the antennas is kept constant, the effect of loss of free space can be compensated. Additionally, there is a probability of blocking of mmWave communications by several objects in the surroundings. This blocking can cause a huge loss if the trajectory is without a line of sight. It is said that 15 to 40 dB are added to the path-loss in free space which is approximately 40 dB [44]. Furthermore, mmWave is strongly absorbed by rain and air.

3.6 Full-duplex Communications

In conventional systems, transmission and reception are done either on different frequency bands (frequency duplexing known as frequency division duplexing(FDD), used on all bands of mobile networks) or at different times (time duplexing known as time division duplexing (TDD), expected for LTE radio local loop

networks in France). Full-duplex aims to allow the simultaneous transmission and reception of information on the same frequencies, at the same time, and in the same place.Full duplex wireless transmission is currently at the heart of discussions on the definition of 5G and recent results obtained by academics have proven the technical feasibility [45-46]. Usually in currently deployed wireless communication systems, the wireless medium is a shared and limited resource. Wireless communications systems continue to share resources over time or by frequency division using the Half-Duplex principle [47]. This requires transmission and reception of the signals which take place in two separate time slots or in two different frequency bands. Also, the transceiver cannot transmit and receive a signal at the same time at the same frequency. For example, LTE uses separate uplink and downlink channels of equal width to allow communication between the base station and users. This considerably limits the capacity of cellular networks, unlike full duplex technology. This technology allows simultaneous transmission and reception over time and over the same frequency band, which can theoretically double the system throughput compared to conventional half duplex systems [48]. Fig. 7 shows the two time and frequency distributions in Half duplex and also Full duplex [49]. In this figure, we see that all of the time and frequency resources are used in full duplex in both directions of links.

Full duplex technology has been considered impractical in wireless communication systems due to a very high level of interference that can be created by the transceiver trying to send and receive a signal at the same time. , and in the same frequency (known as self-interference) [50]. In addition, the concept of designing a flexible radio transceiver at the same working frequency capable of handling two different types of signals at the same time remains very difficult. This opens up a new avenue of research in order to reduce this strong self-interference. Figure 8 shows the performance comparison of the achievable throughput between a Half duplex (HD) system and a Full duplex (FD) system using the same number of antennas. It can be seen that the Full duplex system offers more throughput than the Half duplex system [51-52].
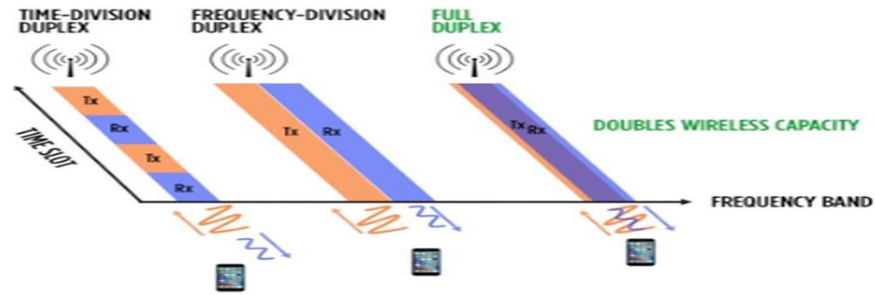
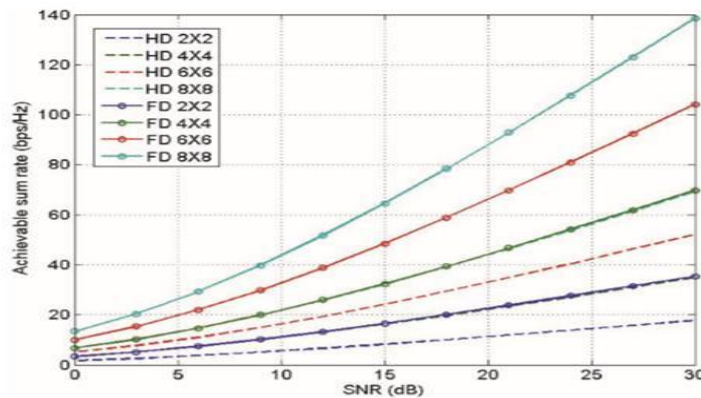**Fig. 7. Presentation of the different distribution [49]**

Fig. 8. Comparison between Half duplex and Full duplex

The various importunities of this full duplex technology have prompted many researchers, academics and industrialists from different research groups to find potential techniques to mitigate and best reduce the performance degradation imposed by self-interference. For example for WIFI, the average transmitted power is 20dBm (100mW) and the noise level is around -90dBm. Self-interference in a full duplex system should be canceled by -20dBm (- 90dBm) = 110dB to reduce it to the same level as noise and make it negligible [53]. However, if the self-interference is not completely canceled there will be noise on the transmitted signal, which will lead to a reduction in SNR and system capacity [54].

Recent advances in interference suppression techniques have enabled high self-interference cancellation, showing that full duplex technology can be seen as a potential candidate to support the evolution of the next generation of communications systems. Wireless. However, the methods proposed to reduce self-interference can be grouped into two categories: passive cancellation and active cancellation [50].

Unlike half duplex where only one channel (i.e. just part of the bandwidth) was needed to transmit data from the station to the user or the reverse, with full duplex the entire band could be used for two-way transmissions. This effectively doubles the spectral efficiency.

The advantage of this technology would also be recognition of the channel used in both directions. This allows the next generation to meet the latency and security requirements imposed especially in the case of stand-alone communications.

In the work carried out by Aalborg University in collaboration with the industrial giant Nokia, shows that an 80% reduction in latency could be obtained with full duplex technology compared to half-duplex [55].

3.7 Small Cells [56]

The networks in the future will depend on a heterogeneous network of macrocells and small cells (radio transmitters of low powers) to ensure the capacity. Nowadays, for some countries,

small cells are essential for 4G networks. They will increase the significance of the 5G network, especially in the bands of higher frequency. For the functioning of small cells and easy access to the existing infrastructure (buildings, streetlights, bus shelters, and so on), access to power and data backhaul as well as simplified permit procedures are essential for successful deployment.

Small cell antennas are access points with low power (for example, according to the 3GPP definition, base stations with transmitter input power less than 6 W per antenna port). Over the next few years, the deployment of small cell antennas in mobile networks should be multiplied, so that it rapidly reaches up to 10 small cells per macro site in a densely populated urban area.

Small cells are suitable to reduce coverage and capacity problems. The power radiated to and from mobile phones is reduced and better quality is provided when they are deployed close to the users. When the distance between radio receivers and transmitters is reduced, small cells reduce the power released by mobile phones and the total electromagnetic field exposure.

The outdoor small cells have a small visual impact i.e. they cannot be seen easily and can be installed inside almost any type of building. They do not require any safety provisions because their emissions are less as compared to macrocells, which makes their compliance boundaries very small.

The rollout of small cells is necessary for the success of the 5G network. To bring data capacities, there will be many small cells in the 5G frequency band of 3.6 GHz and much more in the higher frequency bands f > 24 GHz. There are mainly three types of Small cells according to their powers emission and coverage area:

Femto cells: this type of cell can transmit a maximum power of 24dBm in order to have a maximum coverage of 100m. Femtocells are primarily deployed to provide coverage for a limited number of users within residential environments.

Picocells: in this type of cell, the transmission power varies between 24 and 30dBm, its coverage radius is between 200 and 300m. Picocells can be used to improve coverage both inside and outside of buildings, for example in hotels, businesses etc.

Microcells: this category of cell makes it possible to obtain a slightly wider coverage which can go up to two kilometers in radius with a maximum emission power of 40dBm. Like the previous cells, this type of cell can also be used in order to provide indoor and / or outdoor coverage with a number of simultaneous users which can go up to 2000. Table 1 presents a summary of the power range and deployment environment of small cells.

3.8 5G Cognitive Radio

The cognitive radio is an intelligent communication system able to scan its external environment to learn from it. It is capable of adapting to statistical variations in incoming signals by making corresponding changes to certain operating parameters in real time, with two main objectives in mind: reliability in communication at any time and any place; efficient management of the radio spectrum [58].According to this definition, cognitive radio (CR) is a form of wireless communication in which a transmitter/receiver can intelligently detect which communication channels are in use and which are not, and can place itself on the unused channels. Channel selection is based on information such as time, demand and resources. 5G technology proposes a universal terminal, which should include all the functionality of radio predecessors in a single device [59]. This terminal convergence is strongly supported by user needs and demands; therefore, cognitive radio becomes the ideal candidate for 5G terminals [59]. The high demand for spectrum raises challenges in allocating the available spectrum band. At the same time, due to various reasons, a wide range of frequency bands remain underutilized [46]. 5G and beyond 5G communication networks are expected to exploit the underutilized frequency bands and increase bandwidth by solving the problem of spectrum scarcity for the billions of planned devices connected to the Internet [60]. It should be noted that cognitive radio has two capabilities: Re-configurability and cognitive capability. Thus, with cognitive radio, 5G will be able to support ultra-dense radio access networks that will accommodate many devices operating in millimeter wave (mmWave). Spectrum sharing is one of the strategies used to address these challenges.

Table 1. Small cell and their characteristics [57]

Small Cells	Power Range		Range	Deployment Environment	No. of concurrent users
	Indoor	*Outdoor*			
Femtocell	10-100 mW	0.2-01 W	tens of meters	Residential and Commercial	04-32
Picocell	100-250 mW	01-05 W	tens of meters	Public place	64-128
Microcell	—	05-10 W	Few Kilometers	Urban area to fill the macro coverage	128-2568
Macrocell	—	10-20 W	Kilometers	Urban area to increase the capacity	> 250
WiFi	20- 100 mW	0.2-01 W	few tens of meters	Residential and Commercial	< 50

3.9 NOMA (Non-Orthogonal Multiple Access)

This technique is defined as a radio access technology, which enhances the spectral efficiency of 5G cellular systems as compared to that of 4G. Achieving multi-user multiplexing has been the core purpose of NOMA by providing each user with a different path loss [61-62]. NOMA is a more robust technique than OFDMA and which has been projected as one of the potential key technologies in wireless communication by the IMT-2020 promotion group for 5G networks.

Sustained interference cancellation is required to obtain multi-user multiplexing in the power domain. Users with the same character can be distinguished by using SIC (self-interference cancellation) and channel coding. NOMA distinguishes the path loss and then changes the transmission signal of the multi-channel. By increasing the signal gains, all mobile devices are allowed to catch the maximum access bandwidth in the same cell area, which leads to a large-scale network connection. NOMA performs better at high speed by establishing better backhaul cellular node links. Due to compatibility, NOMA can be combined with many communication technologies, including so-called cooperative NOMA communication [63], visible light communication [64], software-defined multiple access (SDeMA) [65], cognitive radio [66], MIMO and beamforming, to further improve network performance.

3.10 Underlying Technologies for Softwarization

Together with SDN, NFV, and cloud computing technologies, network softwarization is established for rapid service creation, especially new services.

3.10.1 Software-defined networking (SDN) [67-68]

SDN is a general term used to represent network technologies having the goal of building a responsive and flexible network for the virtualized server and storage infrastructure of the modern data center. This enables administrators and network engineers to act and adapt to developing business needs. The network administrator uses the centralized control console to manage the traffic without even touching individual switches. This technique makes it easier to deliver the services from anywhere in the network, despite what particular devices, a server or other devices, are connected to. The three main keys are functional separation, network virtualization, and automation through programmability.

3.10.2 Network functions virtualization (NFV)

NFV introduces new techniques to design, deploy, and operate networking services by separating the network functions from proprietary hardware appliances. The techniques include network address translation (NAT), firewalling, intrusion detection, domain name system (DNS), and caching. All network functions can run easily in the software.

Its unique design ensures that networking components required for fully virtualized infrastructure are placed properly such as storage, virtual servers, and even other networks. Whether the network infrastructure is wired or wireless, this technique is applied to any data plane processing as well as control plane function

3.10.3 Cloud computing

Cloud computing technologies in telecommunication infrastructure bring new challenges from the management perspective.

One important challenge for telecommunication operators is the efficient management of cloud computing, taking into account the legacy of the management system framework and assuring customer satisfaction including the end-to-end quality of service.

Cloud computing is different from traditional telecommunication networks since it does not expose individual elements to the telecommunication management system. Moreover, cloud computing does not distinguish between management operations carried out on behalf of customers and network operators.

The main method adopted by the 5G network is based on the use of the cloud. Using the concept of a centralized radio access network, base stations will use a centralized cloud along with shared resources. C- RAN enables the deployment of a large number of cells, which improves the scalability of 5G networks as well as increasing their capacity and coverage. In addition to the architecture of the cloud radio access network that offers the functionality of the access network, cloud services have been offered as true 5G technology. Mobile devices face a major challenge i.e. not being able to perform efficient calculations and process the high volume of data. It is indeed, because of the proliferation of a block of advanced applications and services generating huge data traffic. The separation of software from hardware via cloud computing is a solution for such problems. In recent years, the industry has been revolutionized because of the proposal for cloud-based IT solutions [69]. Moreover, the integration of the cloud into a wireless network has opened the doors for the deployment of Mobile Cloud Computing (MCC). MCC is about providing mobile users with additional computing and storage capabilities located in the cloud. The provision of on-demand resources generates a unique stage of flexibility and elasticity in different services of the network.

3.11 Artificial Intelligence/ Machine Learning/ Advanced Analytics

Artificial intelligence and machine learning have a strong impact on wireless 5G connections and beyond. The complexity of network systems, if compared to the earlier wireless system technologies from 2G to 4G such as optimization, network management, and failure detection, makes machine learning an important key to have advanced analytics.

3.11.1 Potential use cases supported by network softwarisation

Advanced network infrastructure should be provided to face challenges for the information and communication era beyond 2020. Following examples should be taken:

- Video traffic requires a network architecture that has an effective video-on-demand delivery procedure. It is based on network congestion reduction and smaller response time.
- The advanced and robust network flexibility can respond quickly to disaster resilience.
- The advanced network system, including the IMT-2020 network, should offer functions capable of efficient data processing systems.
- The design of data processing and service provisioning should regard low latency as the main requirement of IMT-2020.
- SDN and NFV are expanding as possible key technologies for future networks including the IMT-2020 network and beyond. The flexibility covering these wide varieties of objectives is accomplished with the help of network softwarization. The software programmability of network nodes will be enhanced by the implementation of SDN and NFV. This will make data processing and service software on network nodes more feasible.

4. FUTURE DIRECTIONS

The challenges and future directions of 5G and beyond Wireless communication are summarized as follow:

- MIMO techniques are currently arousing a strong interest since they suggest both spectral efficiency and energy gains, but also a reduction in the complexity of the design. it would be desirable to optimize the performance of Massive MIMO systems, to limit inter-cell interference and to improve the use of the available frequency bands by covering cognitive radio and mobile-to-mobile communications (D2D), to guarantee a level of end-to-end quality of service in different mobile wireless environments.
- In a system using massive MIMO, the part of inter-cell interference management must be well studied. This is because inter-cell interference remains a fundamental problem with all wireless networks. The use of Massive MIMO will be no exception to the

rule; its introduction, particularly in heterogeneous networks, will also bring its challenges.

♣ Cloud Radio Access Networks (C-RANs) aim to implement various algorithms and functionality in the cloud. Hence, new solutions must be sought to effectively use C-RAN to deploy a dense heterogeneous network and manage the services of these networks deploying different QOS models.

♣ Many researchers have proposed the NOMA as a promising scheme for the 5G and beyond wireless network (B5G)/6G [70-72]. Some researchers have suggested the rate splitting multiple access (RSMA) as a new technology for 6G wireless network [73-75] Both scheme need to be matured enough before practical deployment.

♣ Millimeter wave is already a candidate for 5G but it is not exploited to its full potential as the beamforming algorithms are not mature enough. It requires improvement in the networks when personal base stations (BSs) and satellite connectivity can get merged into cellular communication.

♣ It now also seems clear that the goals of 6G wireless network cannot be achieved with one technology, but with the use of several key technologies(quantum communication and quantum ML[76-77], Blockchain [78-80],Visible Light Communication (VLC) [81-83], Terahertz Technology (THz), free duplexing and spectrum sharing, Real-Time Intelligent Edge). These technologies need to be investigated in order to improve the network performance of B5G/6G.

5. CONCLUSIONS

In this paper an attempt has been made to describe the most recent trends for 5G use cases and possible key technologies for 5G and beyond wireless networks. As such, we have reviewed the advantages and limitations of the current generation of mobile networks, which will not be able to meet the significant demand in term of capacity. The 5G is expected to enhance not only the data transfer speed of mobile networks but also the scalability, connectivity and energy efficiency of the network.

After recalling, the 5G use cases over a different sectors, we presented the 5G key technologies. Each has enormous advantages but also limitations. Among these technologies, we have mentioned Massive MIMO which will provide good spectral and energy efficiency, etc., Full

duplex which will help to double the capacity of the channel compared to the Half-duplex technology of 4G and Small cells combined with millimeter waves to have a wide bandwidth. These Small-Cells are essential for energy reduction and also for improving latency. But these Small-Cells require the use of intelligent antennas, that is to say, the diagrams of which are directive and reconfigurable at the request of the user. Future research directions regarding 5G and Beyond wireless network are also discussed.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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