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The evolution of wireless mobile networks and the future 5G mobile technology for sustainability.

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Abstract

In this paper, our study focused on the framework of big data-driven and mobile optimization. We will study the significant points of 5G and previous mobile networks, and mostly we have a look at past mobile technologies. After that, we will focus on the future 5G Mobile Technology.

We will make an essential reference to the architecture of the 5G Mobile Network. We will see the two OSI levels (network level and Internet Protocol (IP)). The purpose of IP is to ensure adequate control data (in IP header) for proper routing of IP packets belonging to specific application connections or sessions between client and server applications somewhere on the Internet. Also, we mention the primary points of 5G. The device-based architectures, the millimeter-wave, the massive multiple inputs - multiple outputs, the smarter devices, and the manual support for machine-to-machine communication.

Finally, in this paper, we will see how much faster will be the future 5G mobile network and services can support. Those services, including experience at speeds of at least 1 Gbps or higher, 10 Gbps data transfer, zero secondary switches, enormous capacity, and reduce power consumption, are the areas of 5G network we see in this study.

Keywords: Mobiles, 5G, ICTs,

1. Significant Points Of 5G And Previous Mobile Networks

1.1. Past Mobile Technologies

Before analyzing the Fifth-Generation (5G) Mobile Networks, it is useful to mention past mobile technologies. The first (1G) and the second-generation (2G) mobile telephony networks are dominated by analog signals, followed by digital audio signals and text messages. The third-generation (3G) was more concerned with escalating the number of users on the network for voice communications and text messages but had accepted a large amount of video and data. Audio and video formats will become more and more demanding. However, the thirst for data communications set to continue, and networks will most likely remain an obstacle to this development. In this case, networks must design and provide a more efficient and intelligent architecture that can meet the future data communications requirements [1].

Today we appreciate the intensity of telephony and data communications. The fourth-generation (4G) networks allow us to access more valuable content in real-time and allow for timely implementation of machine type communication. In Table 1, we can see a brief analysis of all mobile technologies up to the next 5G [1] [2].

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The 2G, 3G, and 4G cellular networks are built on the condition that they have complete control over the infrastructure. The researchers argue that future 5G systems should reject this design hypothesis and take advantage of device-side intelligence. The 5G networks can be implemented through different layers of a protocol stack, e.g., allowing device-to-device (D2D) connectivity or taking advantage of smart caching on the mobile side. While this design procedure mainly requires a change in the level of the node, it also has an impact on the architectural level [3].

Feature	**1G**	**2G**	**3G**	**4G**	**5G**
Deployment	1980	1990	2001	2010	2020 and beyond
Frequency Band	800 MHz	900 MHz	2,100 MHz	2,600 MHz	From 3GHz up to 90 GHz
Band Speed Technology	2 Kbps	64 Kbps	2 Mbps	1 Gbps	Higher than 1 Gbps
	Analog cellular	Digital cellular	Code division multiple access, Universal Mobile Telecommunications System	Long-Term Evolution Advanced, Wi-Fi	Multi-radio access technology, Giga Wi-Fi
Services	Voice	Digital voice, SMS, packet (General Packet Radio Service), low rate data	Higher quality audio and video calls, mobile broadband	The high data rate, wearable devices	Very high data rate to fulfill extreme user demands, device-to-device, machine-to-machine, Internet of Things
Multiplexing	Frequency division multiple access	Time-division multiple access	Code division multiple access	Orthogonal frequency-division multiple access	Orthogonal frequency division multiplexing, filter bank multi-carrier, non-orthogonal multiple access
Handover	No	Horizontal	Horizontal	Horizontal/vertical	Horizontal/vertical
Switching	Circuit	Circuit/packet	Packet	All packet	All packet
Core network	The public switched telephone network	The public switched telephone network	Packet network	Internet	Internet

Table 1: Basic Comparison between Generations of Mobile Systems [2].

1.2. The Future 5G Mobile Technology

A large number of cell phones are widely used and produce vast amounts of data every day. This thing profoundly affects society and social interaction and poses enormous challenges for Mobile Network Operators (MNOs). The volume, speed, and variety of data from mobile users and communications networks are exponentially projected [4].

The data collected by sensors embedded in smartphones (especially G.P.S. receivers) provide an incredible wealth of data that service providers and applications can collect, store, and analyze in real-time. The computation is more personal to the user now, not only because the users have access to data via mobile devices, but also because it is usually very personalized and relevant to the location and environment. Some examples are location-based services such as Foursquare, which provide restaurant and store suggestions near where users have checked in and reviewed their previous mobility history. Other examples include search engines that are increasingly aware of the environment and location [5].

Also, users themselves produce information using mobile devices. For example, Facebook had an increasing number of mobile users each year and, in the 1st quarter of 2020, has 2603 million

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active mobile users (Figure 1) [6]. Hence, we should not be talking about the Big Data revolution, but (at least in consumer applications) about the «big mobile data» phenomenon. A new example is slowly emerging that we could define as predicting a mobile computing system [5]. Therefore, Big Data is already in our mobile life and will be further consolidated by the future 5G cellular communications shortly [4]. In the next chapters, we will analyze the use of big data in mobile networks.

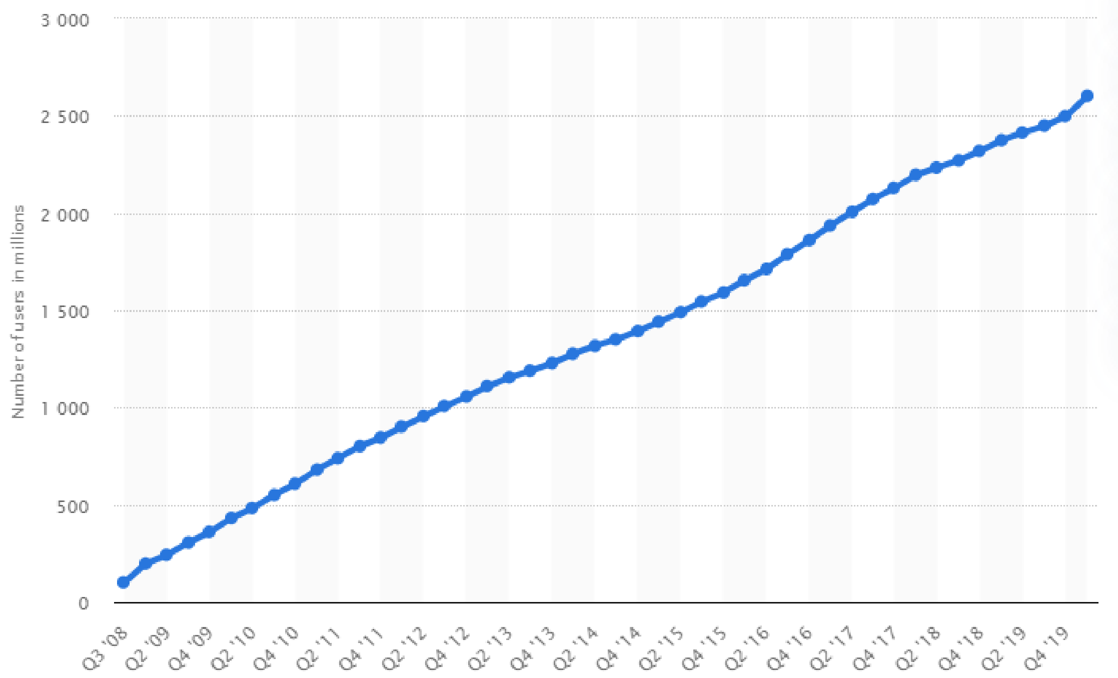

Figure 1: Number of monthly active Facebook users worldwide as of the 1st quarter of 2020 (in millions) [6].

2. 5G Mobile Network Frequency Bands

It is essential to provide a comparison between 1G, 2G, 3G, 4G, and 5G network frequencies (Figure 2). The volume of network traffic is explosively increasing, and the growth of wireless network users is creating more disruption to the frequency band [7].

The radio spectrum includes frequencies between 3 kHz and 300 GHz. The first cellular networks, including 1G and 2G, operated from 800 MHz to 1900 MHz frequencies. Subsequently, the 3G networks used in additional frequency bands, and around 2100 MHz, and 4G LTE technology operated in other frequency bands and spectrum around 600 MHz, 700 MHz, 1.7GHz, 2.1 GHz, 2.3 GHz, and 2.5 GHz [8].

The high-frequency spectrum is also called the millimeter wavelength (mmWave or mmW) in the mobile industry and allows about 28 GHz. As we can observe is significantly faster than 4G networks, which use about 1800 MHz to 2600 MHz frequency to transmit information [8].

To consider the promising 5G features, including possibly operating 1M devices per square kilometer, the Federal Communications Commission (F.C.C.) has opened up vast amounts of high bandwidth for 5G mobile networks. This spectrum is called 5G new radio frequency bands. Newly developed, Verizon's 5G Ultra-Wide Band (U.W.B.) network utilizes around 60

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GHz mmWave bandwidths having a 40x 4G Long-Term Evolution (LTE) 1700MHz bandwidth. Hence, this has a result to assist the network in delay, speed, and capacity, as a more significant number of devices, will be able to operate in this high-frequency range. For example, the 4G delay is about 20-30 milliseconds, which means it takes time to travel between the source and the receiver. The 5G delay, however, is expected to reach less than 10 millimeters a day. Verizon will also deploy 5G technology in lower frequency bands, including the 1800 MHz to 2600 MHz frequency band, covering a wide area [8].

In this case, we must mention the variety of frequencies in 5G networks. 5G will use the 5 GHz frequency band, which is less crowded for less interference [9]. However, as we can see from Tables 2 and 3, the 5G network has a wide variety of frequency bands. The frequency bands can start from 1.8 to 2.6 GHz and are expected to be from 30 to 300 GHz [10]. Of course, we must keep in mind as a higher frequency band use the network, then we can receive higher data rates [10].

Furthermore, recently introduced IEEE 802.11ac, 802.11ad, and 802.11af standards are very helpful and act as building blocks in the road towards 5G. The technical comparison between these standards is shown in Table 2 and the detailed comparison of wireless generations, as shown in Table 3 [10].

Generations	Access Technology		Data Rate	Frequency Band	Bandwidth	Forward Error Correction	Switching	Applications
1G	Advanced Mobile Phone Service (AMPS) (Frequency Division Multiple Access (FDMA))		2.4 kbps	800 MHz	30 KHz	NA	Circuit	Voice
2G	Global Systems for Mobile communications (GSM) (Time Division Multiple Access (TDMA))		10 kbps	850/900/1800/1900 MHz	200 KHz	NA	Circuit	Voice + Data
	Code Division Multiple Access (CDMA)		10 kbps		1.25 MHz			
2.5G	General Packet Radio Service (GPRS)		50 kbps		200 KHz		Circuit/ Packet	
	Enhanced Data Rate for GSM Evolution (EDGE)		200 kbps		200 KHz			
3G	Wideband Code Division Multiple Access (WCDMA) / Universal Mobile Telecommunications Systems (UMTS)		384 kbps	800/850/900/ 1800/1900/ 2100 MHz	5 MHz	Turbo Codes	Circuit/ Packet	Voice + Data + Video calling
	Code Division Multiple Access (CDMA) 2000		384 kbps		1.25 MHz		Circuit/ Packet	
3.5G	High Speed Uplink / Downlink Packet Access (HSUPA / HSDPA)		5-30 Mbps		5 MHz		Packet	
	Evolution-Data Optimized (EVDO)		5-30 Mbps		1.25 MHz		Packet	
3.75G	Long Term Evolution (LTE) (Orthogonal / Single Carrier Frequency Division Multiple Access) (OFDMA / SC-FDMA)		100-200 Mbps	1.8GHz, 2.6GHz	1.4MHz to 20 MHz	Concatenated codes	Packet	Online gaming + High Definition Television
	Worldwide Interoperability for Microwave Access (WIMAX)(Scalable Orthogonal Frequency Division Multiple Access(SOFDMA))	Fixed WIMAX	100-200 Mbps	3.5GHz and 5.8GHz initially	3.5MHz and 7MHz in 3.5GHz band; 10MHz in 5.8GHz band			
4G	Long Term Evolution Advanced (LTE-A) (Orthogonal / Single Carrier Frequency Division Multiple Access) (OFDMA / SC-FDMA)		DL 3Gbps UL 1.5Gbps	1.8GHz, 2.6GHz	1.4MHz to 20 MHz	Turbo codes	Packet	Online gaming + High Definition Television
	Worldwide Interoperability for Microwave Access (WIMAX)(Scalable Orthogonal Frequency Division Multiple Access(SOFDMA))	Mobile WIMAX	100-200 Mbps	2.3GHz, 2.5GHz, and 3.5GHz initially	3.5MHz, 7MHz, 5MHz, 10MHz, and 8.75MHz initially			
5G	Beam Division Multiple Access (BDMA) and Non- and quasi-orthogonal or Filter Bank multi carrier (FBMC) multiple access		10-50 Gbps (expected)	1.8, 2.6 GHz and expected 30-300 GHz	60 GHz	Low Density Parity Check Codes (LDPC)	Packet	Ultra High definition video + Virtual Reality applications

Table 2: Evolution of wireless technologies [10].

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Technical Specifications	802.11an	802.11ac	802.11ad	802.11af
Frequency	2.4, 4.9, 5GHz	5 GHz	60 GHz	0.47-0.71 GHz
Modulation scheme	OFDM	OFDM	OFDM, single carrier, low-power single carrier	OFDM
Channel bandwidth	20, 40 MHz	20, 40, 80 MHz (160 MHz optional)	2 GHz	5, 10, 20, 40 MHz
Nominal data rate, single stream	Up to 150 Mbps (1x1, 40 MHz)	Up to 433 Mbps (1x1, 80 MHz) Up to 867 Mbps (1x1, 160 MHz)	4.6 Gbps	54 Mbps
Aggregate nominal data rate, multiple streams	Up to 600 Mbps (4x4, 40 MHz)	Up to 1.73 Gbps (4x4, 80 MHz) Up to 3.47 Gbps (4x4, 160 MHz)	7 Gbps	
Spectral Efficiency	15 bps/Hz (4x4, 40 MHz)	21.665 bps/Hz (4x4, 80 MHz)	1 bps/Hz (2GHz)	NA
EIRP	22-36 dBm	22-29 dBm	1-10dBm	16-20 dBm
Range	12-70 m indoor	12-35 m indoor	60 m indoor, 100m outdoor	< 100m indoor < 5km outdoor
Through Walls	Y	Y	Y	Y
Non-Line-of-Sight	Y	Y	Y	Y
World-Wide Availability	Y	Y (Limited in china)	Y	Y

Table 3: Technical comparison between new 802.11 standards [10].

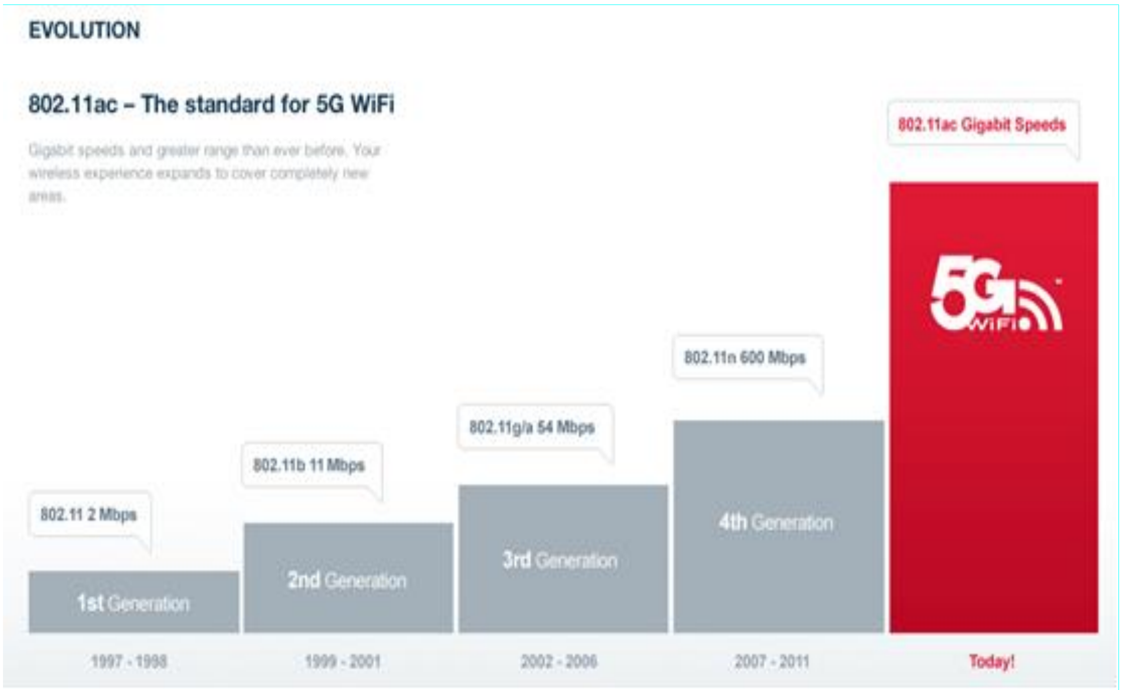

Figure 2: Comparison of mobile communications networks. Over the years, there has been a continuum increase in speeds for next-generation mobile communications networks. The forecast for the fifth generation networks is shown in red and shows an increasing rate, which is enormous compared to previous technologies [7].

Users will use more applications that will interfere with bandwidth, radio interface synchronization services, H.D. video, online meetings, social networking applications, online radio streaming, and etcetera. With 5G, it will be possible to stream video faster, have fewer dead zones, and make dialogs brighter. The full speed and advantages of 5G require a home network router, which supports 5G. The 2.4 GHz frequency band is increasingly crowded as various devices use it in every home or office. 5G removes dead spots so that the phone can operate in areas of the network where it cannot handle so far. That is why video surveillance on today's wireless networks can be problematic. Image freezes are flagged because the wireless network may not be able to transmit accurately. 5G reduces problem images when saving the video to buffer cache [11] [12] [13] [14].

The new 5G technology is expecting to be up to 1000 times faster than 4G networks. 4G networks are more rapid and more extensive than previous generations, such as 1G, 2G, and 3G. In this case, the infrastructure technology development costs and use are expected to be around $ 1.5 billion. For a country with a population of about 50 million people and covers approximately 80 cities. Therefore, as we can see, depending on their size and population coverage, the costs can range to such large amounts that it is difficult to find and spend from many countries, including much of the developed world [15] [11] [16].

3. The Architecture Of 5G Mobile Network

Below we will have a look at the architecture of the 5G network. Figure 3 shows the system model that proposes the design of network architecture, which is a model based on all IPs for wireless and mobile network interoperability. The system includes a user terminal (which plays a crucial role in the new architecture) and a range of standalone radio access technologies. For each terminal, the radio access technologies are considered an IP connection to the outside world of the Internet. However, there must be a different radio interface for each Radio Access Technology (RAT) on the mobile terminal. For example, if we want to access four other RATs, we must have four different special access interfaces in the mobile terminal and have them all active at the same time, to have this architecture work. The first two levels of the Open Systems Interconnection (OSI) (data connection and physical levels) determine the radio access technologies through which Internet access is provided with more or less Quality of service (QoS) support mechanisms, which depends further on access technology (e.g., 3G and WiMAX are explicit) [17].

Then, above the OSI-1 and OSI-2 levels is the network level, and this level is the Internet Protocol (IP), either IPv4 or IPv6, regardless of the radio access technology. The purpose of IP is to ensure adequate control data (in IP header) for proper routing of IP packets belonging to specific application connections or sessions between client and server applications somewhere on the Internet. Each internet reception is a suitable and unique combination of local IP address and appropriate local transport communication gateway, destination IP address, and proper communication gateway and protocol type. So as we can see, establishing end-to-end communication between the customer and the server using the Internet protocol is necessary to elevate the appropriate Internet socket uniquely determined by the client and server application. This communication means that in the interoperability between heterogeneous networks and the vertical delivery between the respective radio technologies, the local IP address and the destination IP address must be stable and unchanged. Defining these two parameters should ensure the transparency of delivery to the Internet connection from end to end when a mobile phone user at least at one end of this connection. Each radio access technology available to the user to achieve connectivity with the relevant radio access is presented with the appropriate IP interface [17].

The IP address and netmask characterize each IP interface in the terminal. The parameters associated with the routing of IP packets throughout the network. In regular system transfer, changing the access technology (i.e., vertical delivery) would mean changing the local IP address. To address this shortcoming, researchers propose a new level that will remove network access technologies at higher levels of the protocol stack. Hence, to enable the functions of applied transparency and control or direct packet routing through the most suitable radio access technology. Researchers propose an architecture that introduces a control system in the functional network architecture, which operates in full coordination with the term packages based on defined policies. It is located on the website of the proposed architecture on the Internet. Therefore, it represents an ideal system for testing the quality characteristics of access technologies and obtaining a realistic picture of the quality expected from user applications to one Internet server (or equivalent) [17].

The network removal level will be provided by creating IP tunnels through IP interfaces obtained through a link to the terminal via the access technologies accessible at the terminal (i.e., mobile phone user). The tunnels will be created between the terminal user and the control system called a policy router, which routes based on specific policies. In this way, the customer side will create an appropriate number of tunnels associated with radio access technologies. The customer will only set up a local IP address configured with Internet communications client applications with Internet servers. The way IP packets are routed through tunnels or choosing the right tunnel would be served by policies whose rules will be exchanged via the virtual network protocol. In this way, it can be achieved the required network removal in the client applications in the mobile terminal. The process of creating a tunnel in the Policy Router, for routing based on policies, takes place immediately after the establishment of the IP connection through the radio access technology and starts from the protocol at the level of the virtual network mobile terminal. Establishing tunnel connections and maintaining them represents the virtual network level (or network level of abstraction) [17].

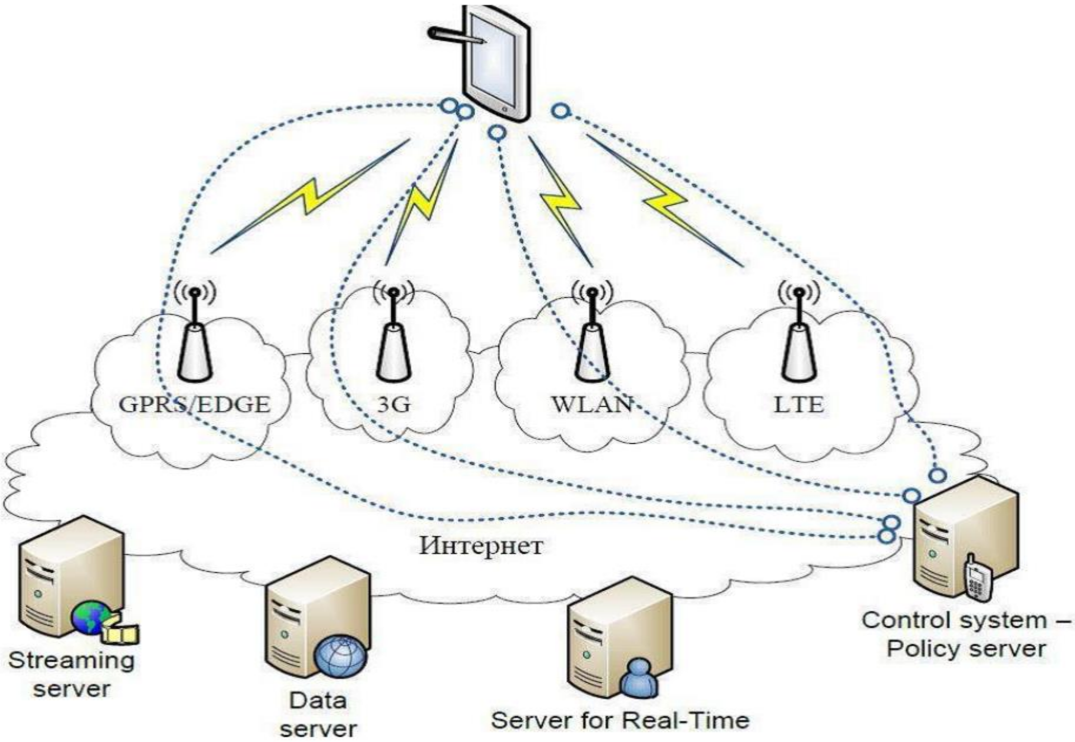

Figure 3: Functional Architecture for 5G Mobile Networks [17].

4. The Basic Points Of 5G

Regarding 5G, there is no clear and official information on how the new infrastructure works. However, significant telecommunications providers are already experimenting with their assumptions. The 5G will be extremely fast, very stable, and multidimensional, which means that its uses will be multiple compared to previous networks. Even 10 Gbps speeds are possible. It is also possible to replace home Wi-Fi networks to offer faster speeds with better coverage [18].

The 5G wireless systems are in the next and upcoming critical phase in the evolution of mobile technology. They are known to include much stricter telephony standards for 4G, and mobile technologies are expected after 2020 [15].

Therefore, some of the critical points of the 5G mobile networks that we can mention, such as components, architectures, or underlying technologies, can be the very high overall data speeds and the much lower latency. Below we can see five technologies that could disrupt that could lead to both architectural and design changes, as outlined in Figure 4 [3].

1. Device-based architectures.

The core architecture of cellular systems can be changed to 5G. It may be time to consider the concepts of uplink and downlink and control and data channels, to better route information flows with different priorities and goals to different node sets within the network [3].

2. Millimeter-wave.

While the spectrum has become rare at microwave frequencies, it is abundant in the mmWave range. Such an 'el Dorado' spectrum has led to a golden mmWave rush, in which researchers with different backgrounds are studying various aspects of mmWave transmission. Although not fully understood, mmWave technologies have already been standardized for short-range services and developed for specialized applications such as small cell backhaul [3]. In 5G technology, the concept of continuous switching can further develop into multiple paths for simultaneous data transfer, which will ensure today's various speeds [19]. An essential issue in systems beyond 4G is to make high bitrates available to a more significant part of the cell, especially for users in a public location exposed between multiple base stations [20].

3. Massive-MIMO (Multiple Input - Multiple Output).

Massive-MIMO (also known as Large Scale Antenna Systems, Very Large M.I.M.O.) proposes the use of a massive number of antennas for multiplexing messages for different devices in each frequency channel, focusing the radiated energy (to achieve a total reduction in energy consumption) in the desired directions while minimizing interference within and between cells. Massive-MIMO may require significant architectural changes, particularly the design of macro base stations, and may also lead to new development [3]. It will also be critical to support the devices effectively to enable the Internet to operate with a much larger number of connected devices, as well as a multitude of new applications, such as sending critical checkpoints or traffic security, leading to reduced delay and high reliability [15] [19].

4. Smarter devices.

The 2G, 3G, and 4G cellular networks were built to provide complete control over the infrastructure side [3]. Hence, Smart-radio technology allows different radio technologies to efficiently share the spectrum by finding an available range and adapting the transmission system to the demands of the techniques currently sharing the field [19].

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5. Manual support for machine-to-machine communication (M2M)

The inclusion of M2M communication in the 5G network involves fulfilling three fundamentally different requirements related to different categories of low data rate services [3] [21].

1 To provide the support of a massive number of low rate devices.
2 To provide the maintenance of a minimum data rate in almost all circumstances.
3 Data transfer with very low latency [3].

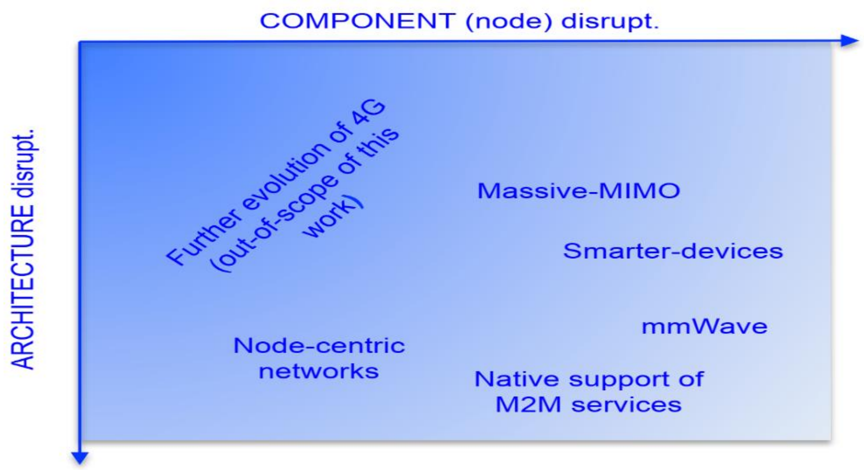

Figure 4: The five disruptive directions for 5G considered in this paper, classified according to the Henderson-Clark model [3].

5. 5G Mobile Services

Due to the high speeds of the new 5G network, the result is to provide unique and better mobile services concerning the previous generations [22]. Below we can see a brief description of them:

• All users are connected to mobile from a few hundred to several million people. A unique experience at speeds of at least 1 Gbps or even higher will help increase data traffic, enabling high-quality video support in critical virtual reality applications as well [22].

• 10 Gbps data transfer speeds to support mobile cloud service, considered by many to be the future of mobile communication. Zero delay and response times are less than one-millisecond latency [22].

• Support for real-time mobile control and in-vehicle communication applications. Zero secondary switchings, with a maximum activation time of ten milliseconds, between different wireless access technologies, ensure consistent and seamless service delivery [22].

• Huge capacity, since existing mobile systems already support 5 billion users, should expand to support several billion applications and hundreds of billions of machines [22].

• Reduce power consumption, i.e., the energy per bit usage should be reduced by one factor to improve the connected battery life of the device, which is a major drawback of most smartphones and mobile phones [22].

• 5G will provide the fundamental infrastructure for creating smart cities, which will drive mobile network performance and demand to the extreme. Applications, such as intelligent text-based sensors, are examples of apps with too high data volumes, which will not be susceptible to delay [23].

6. Conclusion and Discussion

The incorporation of digital technologies in the sustain development, the education and other domains is very productive and successful, facilitates and improves the productivity and the educational procedures via Mobiles [28-37], various ICTs applications [38-70], AI & STEM [71-82], and games [83-88]. Additionally the combination of ICTs with theories and models of metacognition, mindfulness, meditation and emotional intelligence cultivation [89-112] as well as with environmental factors and nutrition [24-27], accelerates and improves more over wellbeing, quality of life, the productivity and the educational practices and results.

More specifically in this paper, our study focused on the framework of big data-driven and mobile optimization. We start with the significant points of 5G and previous mobile networks, and we have a look at past mobile technologies.

The past mobile technologies include the first-generation (1G) and second-generation (2G) networks, dominated by analog signals, digital audio signals, text messages, and third-generation (3G). Nowadays, the fourth-generation (4G) networks allow us to access valuable content in real-time and allow the timely implementation of machine type communication.

After that, we mention future fifth-generation (5G) mobile technology. As we see, many cell phones are widely used and generate vast amounts of data every day. Those amounts of data have profound implications for society and social interaction, as it poses enormous challenges for mobile operators. The volume, speed, and variety of data from mobile users and communication networks are displayed exponentially. Also, it is essential to refer to the 5G Mobile Network Frequency Bands, in which the radio spectrum includes frequencies between 3 kHz and 300 GHz. The first cellular networks, including 1G and 2G, operated from 800 MHz to 1900 MHz frequencies. Subsequently, the 3G networks used in additional frequency bands, and around 2100 MHz, and 4G LTE technology operated in other frequency bands and spectrum around 600 MHz, 700 MHz, 1.7GHz, 2.1 GHz, 2.3 GHz, and 2.5 GHz.

We make an essential reference to the architecture of the 5G Mobile Network. As we study, the system includes a user terminal (which plays a crucial role in the new architecture) and a range of standalone radio access technologies. Then, above the OSI-1 and OSI-2 levels is the network level, and this level is the Internet Protocol (IP), either IPv4 or IPv6, regardless of the radio access technology. The purpose of IP is to ensure adequate control data (in IP header) for proper routing of IP packets belonging to specific application connections or sessions between client and server applications somewhere on the Internet. Each internet reception is a suitable and unique combination of local IP address and appropriate local transport communication gateway, destination IP address, and proper communication gateway and protocol type.

Also, we mention the primary points of 5G. There are the Device-based architectures, the Millimeter-wave, the Massive-MIMO (Multiple Input - Multiple Output), the Smarter devices, and the Manual support for machine-to-machine communication (M2M).

Finally, we see how much faster will be the future 5G mobile network and what services can support it. Those services, including experience at speeds of at least 1 Gbps or higher, will help increase data traffic. 10 Gbps data transfer speeds to support mobile cloud service, considered by many to be the future of mobile communications. Zero secondary switches, with a maximum activation time of ten milliseconds, between different wireless access technologies, ensure consistent and seamless service delivery. Enormous capacity, as existing mobile systems already support 5 billion users, needs to be expanded to support several billion applications and hundreds of billions of machines. Reduce power consumption, i.e., power consumption per bit should be reduced by improving the connected battery life of the device, which is a major drawback of most smartphones and mobile phones. Moreover, finally, 5G will provide the fundamental infrastructure for building smart cities, which will maximize the efficiency and demand of the mobile network.

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