

5G Emerging Technology and Affected Industries: Quick Survey

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Abstract

The fifth generation of cellular mobile communication called 5G will be publicly available in the near future to connect more than 8.4 billion devices. 5G has been designed to improve the network capacity and speed significantly. Various providers and Android cell phone producers have contributed to this huge project and have successfully tested their networks and devices. Additionally, 5G is a revolutionizing technology in which smart devices, including Android phones, are capable of utilizing artificial intelligence software applications. In addition, other emerging technologies, including autonomous driving that rely highly on network communications, will be positively affected. The business aspect of 5G is also promising, as were the business aspects of the previous generations. 5G will be financially beneficial, as step by step, users will update their devices, or they will have to purchase a device that is compatible to 5G, which will produce a high financial turnover for the telecom companies. This review briefly addresses the technical background and 5G key technologies. In the second section, the cutting-edge development and state-of-the-art 5G related technologies will be discussed.

Keywords: 5G; Telecommunication; Networks.

1. Introduction

Over the past two decades, the evolution of cellular communication technologies has rapidly expanded from the 2G Global System for Mobile (GSM) to the 4G Long Term Evolution-Advanced (LTE-A) system. The massive development of the technologies has resulted in enormous evolution of various wireless communication devices, such as smart phones, laptops, and tablets.

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The major goal has been to improve the bandwidth capability, while the systems are designed to reduce latency [1]. However, the latter highly depends on the actual data transfer, the volume of data and the speed of the nodes where the data are processed. Furthermore, to improve the performance enhancements, optimizing network parameters, including jitter, inter-channel interference, connectivity, scalability, energy-efficiency, and compatibility with legacy networks, has been challenging [2, 3]. Today, beyond the 4G technology, drastic improvements of the design of the 5G network architecture have been considered to address certain demands, such as network capacity, data transfer rate, decreasing latency and improving the quality of service cellular network architecture. In the beginning of third decade of the 21st century, the 5th generation of wireless technology will be deployed across the world to facilitate the utilization of the wireless technology [4, 5].

1.1. History of 5G

In late 2014, both academia and industry showed their interest in developing a new generation of wireless technology not only by improving the performance of the 4G but also supporting more capabilities. The data rate and the capacity of the network are the core of 5G technology, in which mm-wave spectrum, massive MIMO, small cells, new multiple access schemes, advanced coding and modulation, optical networks, local offload and control/user plane split play the most important roles. The concept of the 5th generation based on the Wireless System for Dynamic Operating Mega Communications (WISDOM) was developed by Prasad [2]. Additionally, the 5G mobile technology that is expected to be available in the market by 2020 will also highlight salient features, flexibility, accessibility, and cloud-based service offerings, which are intended to ensure the futuristic mobile communication technology as the dominant protocol for global communication. Figure 1 shows the key performance improved from 4G to 5G and the highlights of 5G technology to provide high capacity.

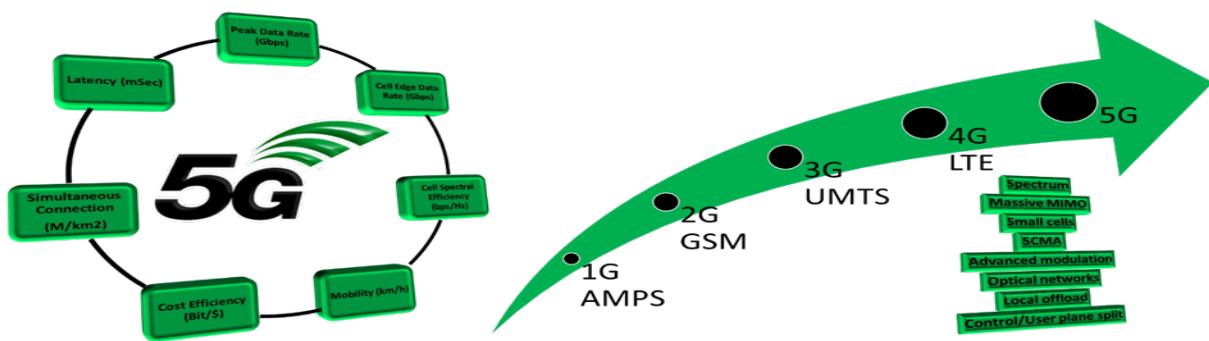


Figure 1: Left Key performance indicator for the evolution from 4G to 5G. Right: The key 5G considerations to provide high capacity

1.2. 5G Architecture & Requirements

5G networks fulfil the requirements of a highly mobile and fully connected world. The proliferation of connected objects and devices will pave the way to a wide range of new services and associated business models that will enable automation in various industry sectors and vertical markets (e.g. energy, e health, smart city, connected cars, industrial manufacturing, etc.). In addition to more pervasive human centric applications, such

as virtual and augmented reality augmentation, and 4k video streaming, 5G networks will support the communication needs of machine-to-machine and machine-to-human types of applications for making our lives and communication more convenient. Autonomously communicating devices will create mobile traffic with significantly different characteristics than today's dominantly human-to-human traffic. The coexistence of human-centric and machine types of applications will impose very diverse functional and KPI/performance requirements that 5G networks will have to support [6-8].

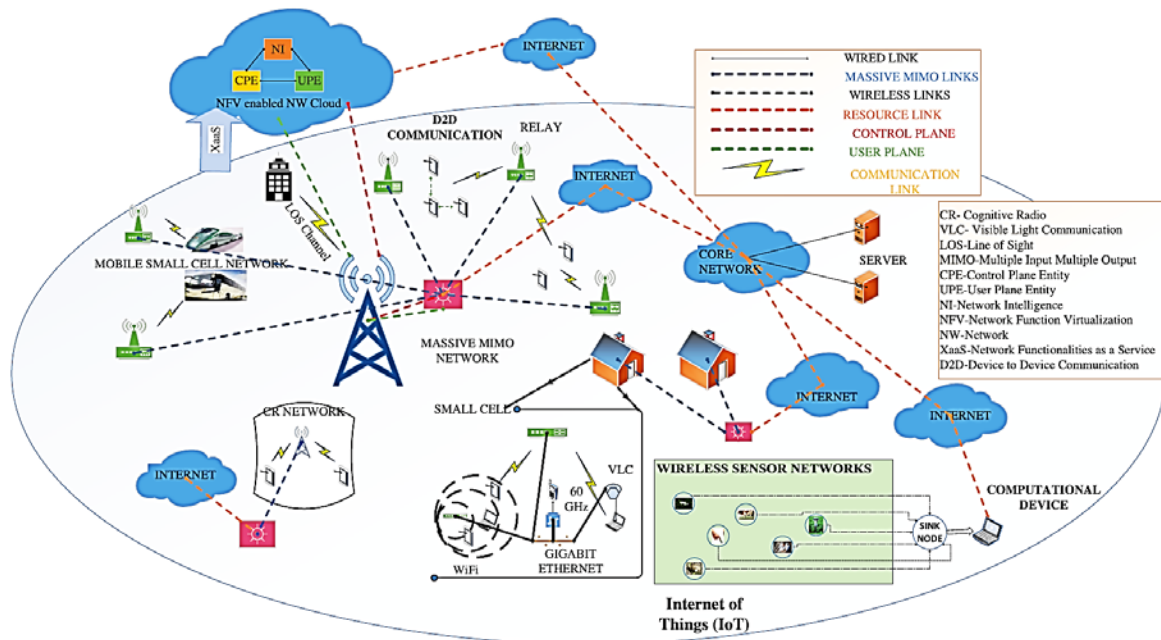


Figure 2: A general 5G cellular network architecture [4]. (Image courtesy Akhil and his colleagues)

1.3. Cognitive Radio

The cognitive radio (CR), built on a software-defined radio, is defined as an intelligent wireless communication system that is aware of its environment and uses the methodology of understanding-by-building to learn from the environment and to adapt to statistical variations in the input stimuli with two primary objectives in mind: 1) Highly reliable communication whenever and wherever needed; and 2) Efficient utilization of the radio spectrum. Following the discussion of interference temperature as a new metric for the quantification and management of interference, three fundamental cognitive tasks are presented as follows. 1) Radio-scene analysis; 2) Channel-state estimation and predictive modeling; and 3) Transmit-power control and dynamic spectrum management [9]. 5G and CR are the two emerging technologies to meet the heavy mobile data traffic of future wireless networks. The new era of communication will be dominated by 5G in the future [10, 11].

2. Up-to-the-minute

5G technology approaches the time of release in the market by big companies, and updates regarding options, features and industry-level testing are provided frequently. Two major wireless providers in the United States,

Verizon and T-Mobile, have announced the stages of development along the options that they offer for different devices, including Android cell phones. According to officials^a, the top five 5G phones to expect in 2019 are Galaxy S10, OnePlus 7, Huawei P30, which will be released into the market by offering artificial intelligent features that will be discussed later.

2.1. Verizon

On October 1, 2018, Verizon launched a service called “Verizon 5G Home”, which is the world’s first commercial 5G broadband internet service. Verizon is the first company to bring 5G broadband internet service to consumers and is expected to be the first to offer 5G mobile service. Verizon 5G Home is initially available in parts of Houston, Indianapolis, Los Angeles and Sacramento. Verizon Chief Network Engineering Officer Nicki Palmer revealed what it takes to build the nation's first 5G Ultra-Wideband network. Continuing its legacy of consumer firsts, Verizon launched the Ultra-Wideband 5G network.

Over the past years developing the 5G wireless technology, Verizon has worked closely with Android cell phone producers to fulfil hardware and software requirements to establish and release this technology. On November 13, 2018, John O'Malley announced that Verizon completed the first 5G data transmission on a smartphone. In partnership with Motorola, Samsung Electronics America, Inc. and Qualcomm Technologies, Inc., a subsidiary of Qualcomm Incorporated, Verizon completed the world’s first 5G data transmission on a smartphone on a commercial 3GPP 5G New Radio (NR) network. He added that this successful test was completed in Providence, RI, with a moto z3 paired with a 5G “moto modtm”, the world’s first 5G-upgradeable smartphone. This is the latest in a series of 5G milestones that Verizon and its technology partners have achieved in recent months. This is the same 5G-upgradeable smartphone device that consumers will use on Verizon’s 5G mobile network when commercial service begins in 2019. Bill Stone, Vice President of Technology Development and Planning for Verizon, said that Verizon will be the first to offer a 5G upgradeable smartphone on its network in 2019.

Verizon^b recently stated that the companies performed several tests over the 5G connection, including browsing the internet and placing a video call. Shakil Barkat, Vice President of Global Product Development at Motorola, said: “The transmissions were completed over Verizon’s 28 GHz spectrum and Samsung’s 5G New Radio (NR) solutions. The moto z3 with a 5G moto mod is powered by the Qualcomm® Snapdragon™ X50 5G modem, along with the groundbreaking QTM052 mm Wave antenna modules. They also completed different testing that was one step closer to getting upgraded speed and connectivity that will affect all aspects of our daily lives”. Samsung's competition with Apple led them to an early and extensive innovation in 5G and to building the foundation for the next-generation of wireless communications. Additionally, Verizon, as a trusted partner to public safety agencies nationwide for decades, opened the doors to the researchers and scientists, who are interested in 5G wireless technology in which AI use cases are designed and implemented. Verizon officials said that, in November 2018, they launched its 5G First Responder Lab, a first-of-its-kind innovation incubator in partnership with Responder Corp that will give startups, small businesses and other innovators access to 5G

^a <https://www.t3.com/news/best-5g-phones>.

^b <https://www.verizon.com/about/news/verizon-completes-first-5g-data-transmission-smartphone>.

technology to develop, test and refine 5G solutions for public safety such as dealing with unlicensed off-loads. To share the new finding, Verizon established the Verizon 5G Technology Forum (V5GTF) in late 2015 in cooperation with ecosystem partners Cisco, Ericsson, Intel, LG, Nokia, Qualcomm and Samsung. This technical forum has created a common and extendable platform for Verizon's 28/39 GHz fixed wireless access trials and deployments.

2.2. T-Mobile

Recently, T-Mobile released an update announcing that Nokia and T-Mobile successfully transmitted 5G data using a low-band spectrum, which they say will provide 5G coverage to the entire nation by 2020. T-Mobile plans to bring 5G to every individual and commercial customer, and, together with Nokia, the Un-carrier - a marketing campaign - just took a big step toward making that a reality. This collaboration led them to complete the world's first 5G data transmission on a low-band spectrum (600 MHz), and they did it on the Un-carrier's live commercial network. One of the important advantages of using the low band 600 MHz spectrum is that it will enable building a nationwide 5G network that will reach much farther than other frequencies. "The Un-carrier is focused on delivering 5G for everyone everywhere, while the other guys focus on 5G for the few - reaching just a few people in small areas of a handful of cities," said John Legere, CEO of T-Mobile. He added that T-Mobile is building truly mobile 5G so that everyone can benefit from the 5G revolution. They are also collaborating with Sprint to supercharge 5G with incredible network capacity and speed.

T-Mobile has also planned to expand the 5G coverage to rural areas to power the mobile application. The low band spectrum is essential for wide-area reach and reliable coverage that travels over distance into buildings. Using this technology will allow T-Mobile to complete their plan successfully. Furthermore, as T-Mobile 5G technology provides a more powerful network with high capacity and speed, it will offer the mobile applications that include IoT and AI concepts. Building 5G on multiple spectrum bands, including low-band and millimeter wave, ensure that the benefits of 5G can reach everyone^c.

3. 5G Emerging Technologies

5G technology will potentially connect more than 8.5 million instruments that are mostly smart devices. As mentioned earlier, two major characteristics of the 5th generation of wireless communication are network capacity and speed, which allow smart phones and other devices to manage a high volume of data generated through software applications. Today, several AI areas rely heavily on network communication to transmit and process data, and their major common concern is communication that includes data management and timing performance^d.

3.1. Smart City

Cities are increasingly marketing themselves as "smart cities" that are hyper-connected, sensor-equipped communities in their latest economic development pitch to attract workers and businesses. A smart city is a

^c <https://www.t-mobile.com/news/first-600mhz-5g-test>.

^d <https://www.forbes.com/>.

designation given to a city that incorporates information and communication technologies (ICT) to enhance the quality and performance of urban services, such as energy, transportation and utilities, to reduce resource consumption, wastage and overall costs. The overarching aim of a smart city is to enhance the quality of living for its citizens through smart technology including artificial intelligence. Experts say that 5G phone networks will jump-start the smart cities movement, which deploys tech to try to make communities more sustainable and efficient by tying together traffic, energy, communications, waste disposal, and many other municipal systems.

3.2. Autonomous Driving

A self-driving car is a vehicle that is capable of gathering surrounding environmental information and processing the data to drive the car without interference from a human driver. Processing the data might be performed locally utilizing software applications or through communication with servers. The network bandwidth, traffic and speed are crucial challenges. Some experts call 5G technology “oxygen” for self-driving cars. As infrastructures and even entire smart cities become more connected thanks to the IoT, processing bandwidth, reliability, and speed will not be matters of convenience, but matters of safety. Therefore, it is very important to provide the infrastructure for a self-driving car to communicate with the surrounding environment and to make autonomous driving and ultimately smart cities work. It is all about data that must be transmitted and processed faster and closer to the vehicle.

3.3. 5G Cloud Robotics

As the Industrial IoT expands and is fueled by the capabilities of 5G, production-line robotics will be significantly impacted. Currently, these systems are steeped in the automation function, but they are often hampered by the limits of network capacity and reliability. 5G removes those limitations and allows production-line robots to perform complex computing and transfer data in real-time. This will be a game-changer from a workflow and supply chain perspective. For the robots to be able to interact with their environment in real-time, huge amounts of information will have to be transferred instantaneously. With lower latency and higher bandwidth than other forms of wireless connectivity, 5G is the optimal choice. Wirelessly connecting machines through 5G and sensors allows industries to use the data collected to monitor, analyze and predict, which results in optimized processes and increased efficiency that makes effective implementation of just-in-time production and lean manufacturing possible.

3.4. Immersive Online Gaming

Immersion into virtual reality (VR) is a perception of being physically present in a non-physical world that has expanded into the gaming industry. The idea is created by surrounding the user of the VR system in images through computer vision and simultaneous localization and mapping (SLAM) algorithms, sound or other stimuli that provide an engrossing total environment. Furthermore, online gaming, which is a very popular and beneficial industry, has expanded to cell phones, where data transmission and network speed play important roles. Among other its applications, the 5G technology has effective implications especially in online gaming with augmented and VR. For example, 5G may make VR less cost-prohibitive. Since the connections are faster,

complex computing can be rerouted to the cloud, which takes the stress of home devices, thereby making them more widely available at lower price points. 5G will also change how immersive augmented reality (AR) experiences can be, making AR creatures within games smarter and better able to interact with the gamer's real-time environment all with no lag time.

3.5. Augmented Reality (AR)

An enhanced version of reality is comprised of live direct or indirect views of physical real-world environments that are augmented with superimposed computer-generated images over a user's view of the real-world, thus enhancing the viewer's current perception of reality. Unlike VR, which requires the user to inhabit an entirely virtual environment, AR uses the user's existing natural environment and simply overlays virtual information on top of it. As both virtual and real worlds harmoniously coexist, AR users experience a new and improved natural world in which virtual information is used as a tool to provide assistance in everyday activities. AR has recently become more mainstream, and 5G will be a major driver of that movement. As more AR apps are developed, including those that center around gaming, automotive video streaming, content production and distribution, 5G will deliver a seamless experience (even on mobile), enable social sharing (even from crowded venues), and much more.

4. Discussion & Conclusion

The fifth generation of cellular mobile communications, referred to as 5G, is succeeding the 4G system to revolutionize the communication systems by highly improved network characteristics. The 5G key technologies aim to provide higher data rate and capacity. To achieve the targets, 5G systems have been designed and optimized for massive MIMO, mm-wave spectrum, local offload, advanced coding and modulation and for utilizing small cells to improve coverage, control plane split to address coverage and capacity separately and a new multiple access scheme (SCMA). 5G will improve the cost efficiency from 10X to 1000X (Bit/\$), mobility from 400 to 500 Km/h and latency from 10 to 1 msec according to the literature. Additionally, 5G technology benefits from a more software-based design that allows more AI applications to be provided to smart device users. Smart cities and autonomous driving are the most important AI related domains that will be most effective by 5G. On the other hand, utilizing advanced big data analytics and machine (deep) learning algorithms in 5G will increase the stability of the robustness of the network where any predictions in a given network communication are required. Numerous cell phone producers and providers, especially Android systems, have designed their new devices to be compatible with 5G and have successfully tested certain features of that technology. However, certain challenges in the 5G technology still remain that concern mostly the data rate greater than 1 Gbps, accessibility, mobility, and reliability.

The business aspect of 5G is flourishing and promising as were the previous generations. In other words, 5G will be financially beneficial to the economy no matter how successful its technical aspects become. Step by step, users will have to update their devices, or they will have to purchase a device that is compatible to 5G, which produces a high financial turnover for the telecom industry and revives this business every decade or so.

In the near future, the 5G technology will be broadly available in the market and will presumably face certain technical issues during the transition period. In this generation, various features and services have been developed that are improving the network speed and capacity. However, the telecom community's experience shows that the success of each new generation will be achieved more slowly on a step-by-step basis than the success of its business aspects.

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