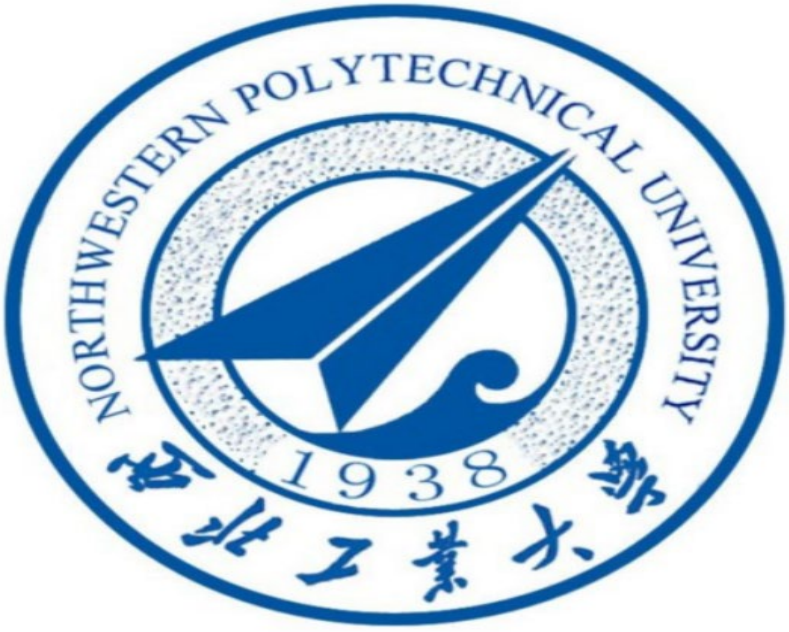

Computer Networks

Group Project
Group 1

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Contents

What are the advantages of 5G networks (Compare with 4G networks) and what it can be used for?

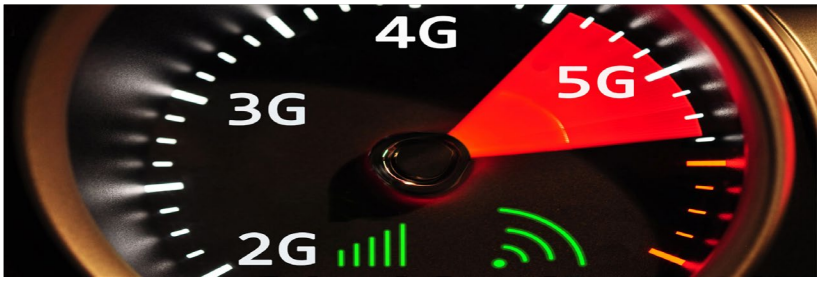
1.The shift to 5G

The world's economy is at another pivotal moment as artificial intelligence, the Internet of Things (IoT), and augmented reality are transitioning from buzz words to the basis for long-term national economic potential. The catalyst for this economic growth is wireless connectivity enabled by 5G— a new standard for wireless telecommunications. 5G is not simply an extension of 4G, nor is it merely a faster wireless capability. 5G makes possible the connection and interaction of billions of devices of almost any kind and collection of data from those devices. Indeed, 5G connectivity promises to lead consumers, industries, and governments to new frontiers of productivity and innovation.

However, an examination of how the United States compares internationally on investments critical to 5G surfaces a disturbing trend. Other countries are outspending the United States in both relative and absolute terms. In these countries, the execution is faster and more capital efficient than it is in the United States. Since 2015, China outspent the United States by approximately $24 billion in wireless communications infrastructure and built 350,000 new sites, while the United States built fewer than 30,000. Looking forward, China's five-year economic plan specifies $400 billion in 5G-related investment. Consequently, China and other countries may be creating a 5G tsunami, making it near impossible to catch up.

Being first to LTE afforded the United States macroeconomic benefits as it became a test bed for innovative mobile, social, and streaming applications. Being first to 5G can have even greater and more sustained benefits to our national economy given the network effects associated with adding billions of devices to the 5G network, enabling machine-to-machine interactions and utilizing data from such interactions.

In this paper, we examine how the United States compares to other countries, revealing dramatic examples where it is losing ground in the race to be first to 5G. We also consider a range of actions and policies that may help overcome deployment challenges and enable rapid and extensive 5G deployment, including a light-touch policy framework that urges carriers and their ecosystem partners to negotiate solutions without government intervention and encourages carriers to operate at greater scale and economic efficiency.



5G technology introduction marks the beginning of a new era in connectivity that will impact almost every element of daily life

5G technology introduction marks the beginning of a new era in connectivity that will impact almost every element of daily life. First-adopter countries embracing 5G could sustain more than a decade of competitive advantage. Countries that were first to adopt prior generations of wireless technology were also rewarded with broader macroeconomic benefits, but 5G has potential for an even larger first-mover advantage.

What's different this time? 5G is more than just a new wireless interface protocol offering more capacity and better performance for smartphones. It is that, but it is also a myriad of technology innovation like antenna designs and device communication protocols to standardize both the way licensed and unlicensed networks interact and the way network applications collaborate. With this array of capabilities, 5G technology will influence everything we do. Instead of just connecting people to people through their smartphones, 5G connects an unlimited number of things to other things, which can communicate all day, every day. As a result, the value that 5G can create is not constrained by the number of people and the amount of time we have for consuming information. The opportunity for technology to influence productivity and automation could have a seismic impact on our macro economy. Network effects, where the value of a product or service is dependent on the number of users, could grant a first-adopter sustained leadership and the potential to capture a greater share of the benefits associated with 5G.

We know from social networking examples that the more people connect, the more useful or valuable the network becomes, which attracts even more connections. This "network effect" is also true for the connection of mobile phones and IoT devices. A network, for example, where only one phone is connected to it, is useless. But a network with millions of phones connected to it around the globe is extremely valuable. Expanding that concept to a common network that has many uses is even more valuable. The Internet is extraordinarily valuable because it supports a vast range of uses. Because it operates under a common set of protocols and standards, those use cases can also interact, touching off unlimited potential for innovation.

Deloitte predicts 5G will expand the network effect dramatically by extending the reach of the Internet to almost any kind of connection, by almost any kind of device, anywhere a wireless signal can reach. Markets that attract the most users first will also influence further innovation as 5G networks mature and become ubiquitous. As different kinds of devices connect, new use cases will emerge for collections of devices previously considered unrelated, attracting even more investment and economic benefit.

Moreover, as devices connect to the 5G network, companies will be able to exploit what *The Economist* referred to as the "data-network effect" in a 2017 article: "a powerful economic engine … using data to attract more users, who then generate more data, which help to improve services, which attracts more uses." Accordingly, countries that adopt 5G first are expected to experience disproportionate gains in macroeconomic impact compared to those that lag.

2.The fuel for economic growth

Voice and data 1G and 2G	Smartphones: Internet from everywhere 3G, 4G, and 4G LTE	Hyperconnectivity between people and things 5G
The first era of wireless communications, in the 1970s and 1980s, was characterized by the introduction and early adoption of cellular communications, but as a niche product with only 2.1 percent of the US population having a mobile phone by 1990.6 Many US companies benefited with Motorola having 70 percent share of mobile phones globally in 1985. Europe pushed for mass adoption of mobile communications (personal communications networks) in 1990 using standardized (e.g., GSM) communications with 2G technology. This resulted in European leadership, with Nokia, Ericsson, and Alcatel becoming leading manufacturers, while Motorola's share of handsets fell to 15 percent by 2000. Similarly, by 2000, the United Kingdom had 70.2 percent mobile phone penetration versus 38.6 percent for the United States.	With the advent of 3G and 4G networks and the launch of the modern smartphone in 2007, we moved to the era of data communications. The United States embraced this change and built on its existing Internet leadership to shift the center of gravity for the wireless industry back home. American tech companies displaced the European players as the new industry giants.	5G will enable a new era of connecting machines, with the value of these connections being in the data interchange between them. While US companies are generally well positioned now, a slow rollout of these connected devices will impact the sustainability of their competitive position.

3.Introduction of 4G Networks

The fourth-generation mobile communication system (4G for short) includes TD-LTE and FDD-LTE, which is also the combination of the third-generation mobile communication system (3G) and WLAN. Here, we should note that LTE is only an upgraded version of 3G and in fact it has not yet reached the 4G standard. The upgraded LTE Advanced is the standard version of 4G, which meets the definition of 4G by the International Telecommunication Union.

The advantage of 4G is that it can transmit data very quickly, with high quality video, audio and image. The transmission speed of 4G is very fast. By definition, we regard the communication technology that can achieve the data transmission speed above 100 Mbps (which is about the download speed of 12.5 MB/s - 18.75 MB/s) as 4G. This technology is about 20 times that of home broadband ADSL, and can meet the requirements of most users for wireless services. 4G provides great convenience for the masses in communication, entertainment and business. Compared with previous generations of communication technologies, 4G has incomparable advantages, mainly in that 4G can be deployed in places not covered by DSL and CATV modems, and then extended to the whole region. In fact: 4G is the same as LTE technology, and they are both evolved from the existing 3G wireless communication technology. In other words, 4G is an advanced form of 3G.

As the most important protocol of 4G communication technology, LTE Advanced has two different standards: TD-LTE and FDD-LTE. These two modes correspond to two different duplex modes: TDD and FDD. TDD is what we call time division duplex. It means that uplink and downlink are crossed in the same frequency band according to time allocation, which can make better use of spectrum resources and facilitate layout; in addition, FDD is called frequency division duplex, which means that uplink and downlink are carried out simultaneously in different frequency bands. The advantage of FDD mode lies in its stronger data transmission capability. In fact, 4G uses OFDM to modulate downlink, while SC-OFDM to modulate uplink is quite different from 3G

4.Introduction of 5G Networks

5G Protocol Framework

As the first 5G standard of 3GPP, R15 is mainly used to study the Phase1 phase of 5G. At this stage, we mainly study the definition of NR (the new global 5G standard based on OFDM is also the foundation of the next generation cellular network technology) framework, and clarify the waveform used by NR, flexible duplex mode of channel coding and frame structure. Solutions such as uplink and downlink decoupling, CU-DU separation, NSA/SA networking, etc. are clearly defined in the architecture, and the service types of 5G uRLLC are clearly defined. In Phase2 of R16 protocol, the new multiple access technology of NR will be studied, and the framework of NR protocol will be further improved on the basis of R15. In addition to optimizing uRLLC on the basis of R15, R16 will also play its unique competitiveness in other vertical industries. The following is a chart to introduce it (Figure 1).

5G is committed to research in eMBB, mMTC, uRLLC to provide services for people. EMBB refers to enhanced mobile broadband, which can provide users with larger system capacity and faster wireless access rate, so that users can enjoy a better ultra-clear experience. MMTC refers to mass Internet of Things, which is mainly to prepare for the wide popularization of Internet of Things in the future. This research can be applied to intelligent logistics, smart cities and even people's daily fitness. URLLC refers to high reliability and low delay. This research has been used in industrial production precision control, UAV (Refers to drone driving technology) remote monitoring and emergency personnel tracking, and it is believed that it will have a great impact on human life in the future .

5.Comparison of Network Institutions

4G Network Architecture

The architecture of 4G network system consists of three parts, namely EPC, eNB and UE. Among them, EPS is composed of EPC and radio access network E-UTRAN, which is often called 4G network system. The core network EPC is mainly responsible for verifying user identity, transmitting user data and managing user data. The radio part (E-UTRAN) of 4G system mainly includes some functions of eNB and NodeB and some functions of core network. The specific framework is shown in Figure 2.
Actually, 4G network architecture can be understood as an architecture composed of LTE, SAE and IMS. LTE is the long-term evolution of air interface, SAE

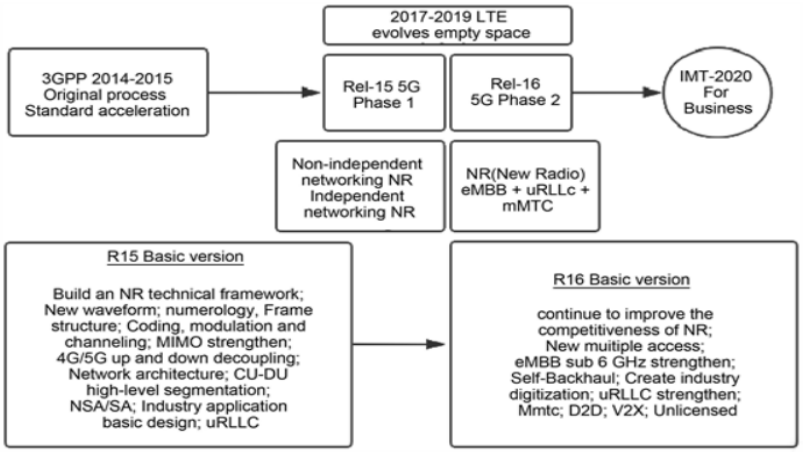


Figure 1. Protocol framework.

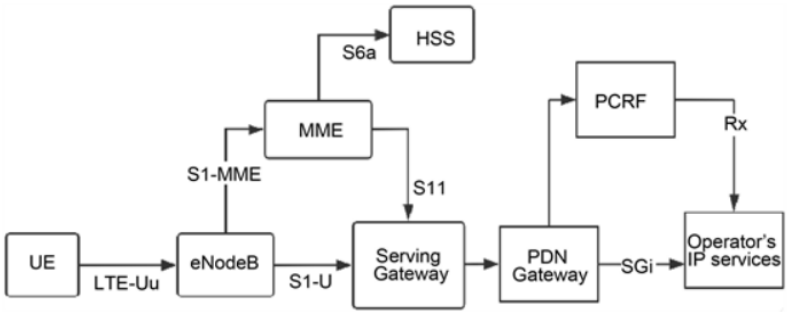


Figure 2. EPS network architecture.

The 4G basic architecture defined by GPP includes the following key points: First, MME is the control core of 4G network architecture, which is mainly responsible for handling control signaling such as user access control, service bearer control and handover control. Serving Gateway, as the anchor point when switching between local base stations, is mainly responsible for transmitting data information between base stations and public data gateways, and providing buffer for downlink data packets. Then PDN Gateway, as the anchor point of data bearer, can carry out packet forwarding, packet parsing, billing of basic related services, commercial QoS control, and so on. The full name of HSS is Home Subscriber

Server. It is a database for storing contracts signed by users, and the stored information includes user security control information, user policy control information, user location information, user identification information and so on. Then, the full name of PCRF is Policy and Charging Rules Function. It mainly carries out policy control and charging control. It means that according to the contract selected and signed by the user, the user's service usage and charging strategy is determined and transmitted to the policy executor in the gateway, and finally the strategy is implemented.

5G Network Architecture

The 5G network architecture adopts SBA architecture, which is called Service Based Architecture. In fact, 5G network is a user-centered intelligent elastic network, which splits the original whole into several individuals with independent functions, and these individuals play their own roles. Next, we analyze the 5G network in particular. First, we look at the unlimited network components of 5G network, which are CU, DU and AAU. CU is used to handle non-real-time services. DU is used to handle real-time business and physical requirements. The AAU is composed of RRU, passive wireless and a part of BBU physical layer. The architecture diagram of 5G unlimited network is shown in Figure 3.

6.Comparison of 4G and 5G Network

After analyzing and understanding 4G and 5G, we will compare these two network architectures

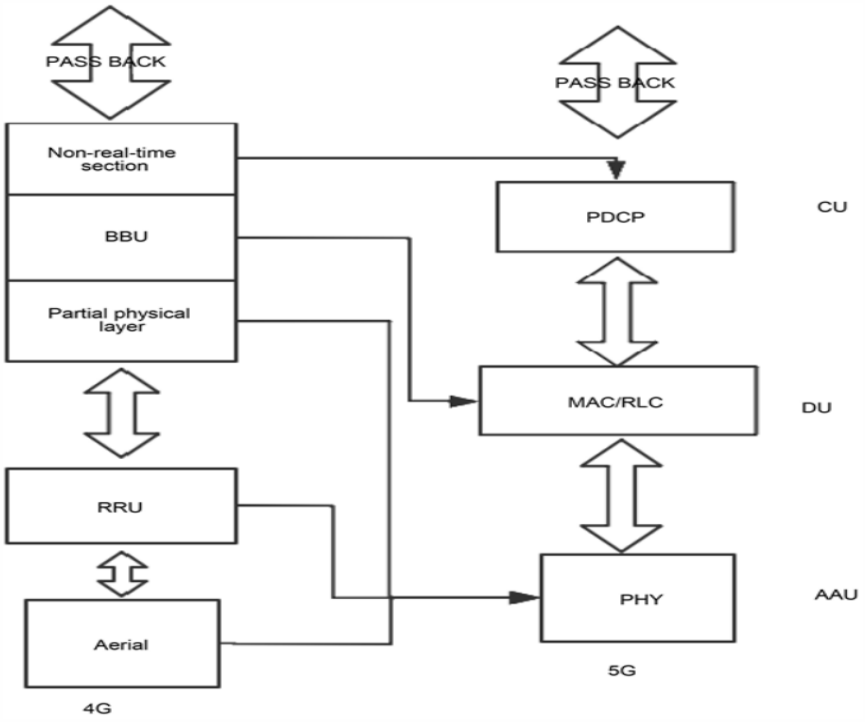


Figure 3. 5G unlimited network architecture.

First of all, we know that the carrier of network communication is electromagnetic wave, but in fact, the frequency resources of electromagnetic wave are limited, and the higher the frequency, the faster the speed, and the more data that can be loaded, so the higher the frequency, the greater the broadband and the faster the

speed. However, 4G uses low frequency band, so when many people use 4G network, there will be congestion, which will lead to lower rate. However, 5G does use high frequency band. In this case, even if many people use 5G network, there will be no rate reduction, and using high frequency can make better use of resources. In addition, the data download rate of 5G is as high as 10 Gbps, while that of 4G is about 100 Mbps, which is 100 times faster than that of 4G. In addition, virtual industries such as VR, which have just become popular, are mostly based on 5G development. In addition, 5G network has the advantages of larger capacity, lower delay and stronger computing capability. At present, the most eye-catching industry is the communication industry, and the hottest industries in the communication industry are 4G and 5G. At present, 5G is in the forming stage. We compare the performance of 4G and 5G in terms of transmission rate, frequency band, channel bandwidth and peak value. The following is a performance comparison between 4G and 5G (Figure 4).

7.Challenges of Implementing Mobile Communication Network

Challenges in Hardware Equipment

Hardware equipment is the foundation of an experiment. Hardware equipment in mobile communication mainly includes baseband digital processing unit, frequency conversion and RF front-end devices. In order to obtain higher storage space and lower latency, 5G network uses a more advanced operation mode, which also brings greater challenges to its chip fabrication. For example, in order to meet the high frequency band of power amplifier above 4 GHz, the chip needs to use GaN material, which is very expensive and difficult to produce, so more efforts need to be made in hardware.

	4G	5G
Time delay	10 ms	smaller than 1 ms
Number of mobile links	eight billion	eleven billion
Channel broadband	20 MHz 200 MHz	100 MHz (lower than 6 GHz) 400 MHz (larger than 6 GHz)
Frequency band	600 MHz to 5.925 GHz	600 MHz (millimeter wave)
Date flow	7.2 Eb/month	50 Eb/month
Peak data rate	1 Gb/s	20 Gb/s
Available channel	3 GHz	30 GHz
Link density	One million links/km*2	One million links/km*2
Uplink waveform	Use SC-FDMA	Use CP-OFDM

Figure 4. Performance comparison.

8.The advantages of 5G networks over 4G networks

The main advantages of the **5G** are a **greater speed in the transmissions, a lower latency** and therefore greater capacity of remote execution, a greater number of connected devices and the possibility of implementing **virtual networks (network slicing)**, providing more adjusted connectivity to concrete needs.

Greater speed in transmissions

Speed in transmissions can approach 15 or 20 Gbps. By being able to enjoy a higher speed we can access files, programs and remote applications in a totally direct and without waiting. **By intensifying the use of the cloud, all devices (mobile phones, computers, etc.) will depend less on the internal memory** and on the accumulation of data and it won't be necessary to install a large number of processors on some objects because computing can be done on the Cloud.

For example, being able to activate software remotely as if it were executed in personal devices, will allow not having installed the mobile applications (APPs) in the terminal and executing them directly from the cloud. Just as it will no longer be necessary to store the information in the memory of the device (photos, videos, etc).

Lower latency

Latency is the time that elapses since we give an order on our device until the action occurs. In 5G the latency will be ten times less than in 4G, being able to perform remote actions in real time.

Thanks to this low latency and the increase of the sensors, it is possible to control the machinery of an industrial plant, control logistics or remote transport, surgical operations in which the doctor can intervene a patient who is at another side of the world with the help of precision instrumentation managed remotely or the complete control of remote transport systems, automated and without driver

Greater number of connected devices

With 5G the number of devices that can be connected to the network increases greatly, **it will go to millionaire scale per square kilometer.**

All connected devices will have access to instant connections to the internet, which in real time will exchange information with each other. This will favor the IOT.

It is anticipated that a common home will have a hundred connected devices sending and receiving information in real time. If we think of industrial plants we would speak of thousands of connected devices.

This greater number of connected devices will allow the **smart cities** and the **autonomous car.**

For example, by placing sensors in different points and objects in the city, a large part of it can be monitored. If you share the information of the sensors of the cars and those of the city, and these exchange data you can improve the quality of life of the cities, facilitate the navigation of the autonomous car (choose better routes, reduce the number of accidents, find available parking spaces, etc.)

Network slicing

The 5G also allows to implement virtual networks (network slicing), **create subnets, in order to provide connectivity more adjusted to specific needs.**

The creation of subnetworks will give specific characteristics to a part of the network, being a programmable network and will allow to prioritize connections, as could be the emergencies in front of other users, applying for example different latencies or prioritizing them in the connection to the network so that they can't be affected by possible overloads of the mobile network.

9. 5G Applications/Use Cases

The goal of 5G technology is to enable new types of applications. It is not only an evolutionary update to the previous generation of cellular, but a breakthrough technology that is envisioned to eliminate the boundaries of access, capacity, performance, and latency on connectivity globally. As illustrated in the picture below, the three major use cases of 5G are: Enhanced Mobile Broadband, Massive Machine Type Communication, and Ultra-Reliable Low Latency Communication.

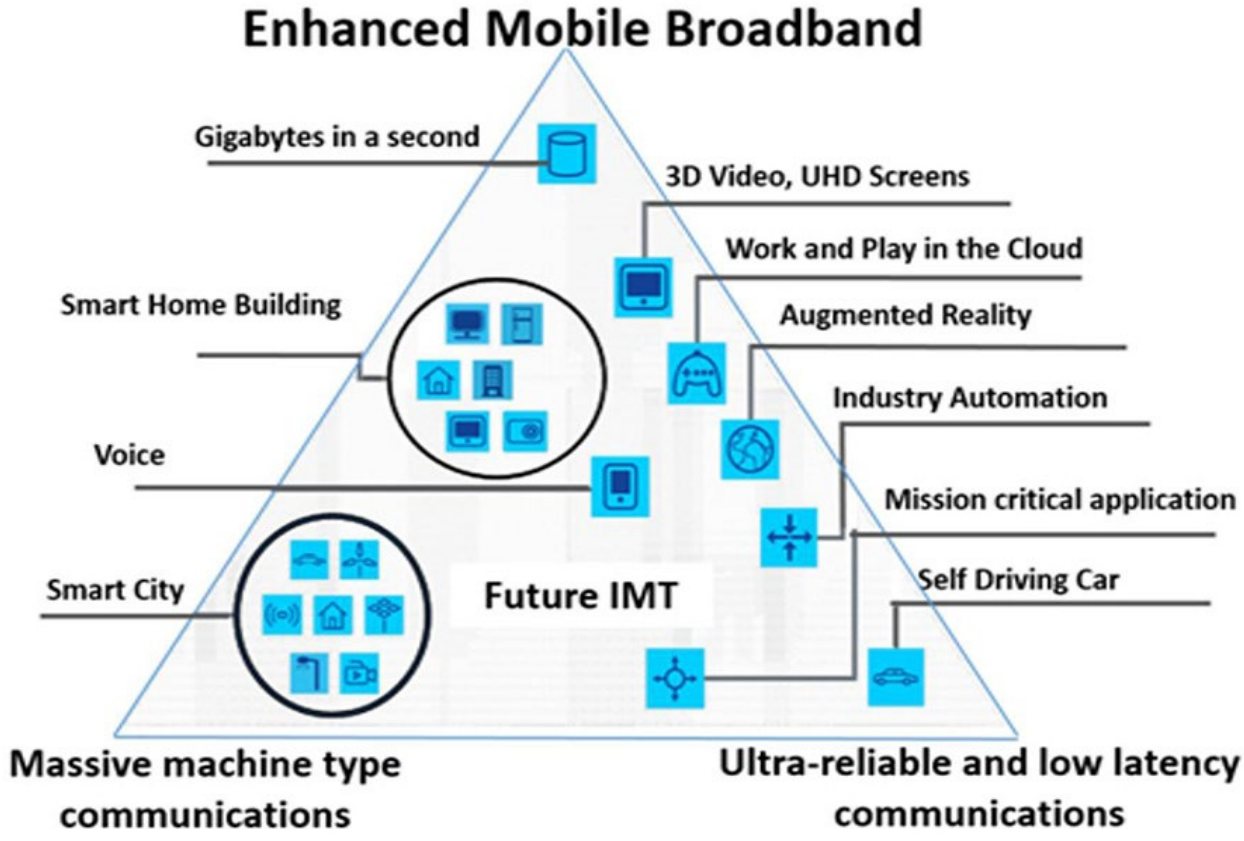


Figure 5. Use-case of 5G

Harnessing the Power of IoT

When the term “Internet of Things” was coined in 1999, it was largely conceptual. Two decades later, everything from home thermostats to smart city sensors depend on IoT technology. Now, 5G and IoT stand ready to enable applications that would have seemed impossible just a few years ago.

5G’s promise of low latency and high network capacity helps to eliminate the biggest limitations to IoT expansion. Giving devices nearly real-time ability to sense and respond, 5G and IoT are a natural pairing that will impact nearly every industry and consumer.

Broadband-Like Mobile Service

Upgraded mobile service is among the most noticeable of the initial impacts of the 5G network rollout. All major US wireless carriers, as well as many smaller communications service providers, intend to deploy 5G mobile networks that will deliver broadband-like services, such as high-definition streaming video without dreaded buffering. With a vastly increased network capacity, 5G is also predicted to reduce slowdowns during usage spikes—for example, sports fans can still stream during the big game.

Connectivity for Edge Computing

With the move to cloud-native 5G networks, enterprises can take advantage of strategically distributed computational power, allowing more data to be processed and stored in the right place based on the needs of the application. Intelligent edge computing operates at the convergence of 5G’s ultra-low latency, IoT, and AI technologies. Devices and applications can tap into edge cloud computing resources without needing to access a centralized data center potentially thousands of miles away.

As 5G edge computing becomes more pervasive, industries will be able to dramatically scale up their use of data and act on insights faster—often instantly and autonomously.

Unleashing AI

Applying AI to an immense amount of data at scale will be accelerated with fast, efficient connectivity. For example, smart city AI could correlate traffic light data automatically and implement new patterns after an apartment complex nearby is opened. Smart security and machine vision can keep secure facilities safe with automatic recognition of potential security breaches or unauthorized visitors.

While 5G will help enable AI inference at the edge, it will also play a role in delivering data from devices to the central cloud to train or refine AI models. For example, real-world data about road conditions collected by connected vehicles can improve cloud-based mapping services.

Immersive Gaming and Virtual Reality

For gamers, 5G promises a more immersive future. High-definition live streaming will get a big boost from 5G speeds, and thanks to ultra-low latency, 5G gaming won’t be tied down to devices with high computing power. Processing, storage, and retrieval can be done in the cloud, while the game itself is displayed and controlled by a mobile device.

Low-latency 5G will drive major innovation in virtual reality (VR) applications, which depend on fast feedback and response times to provide a realistic experience. These applications are likely to explode in number and sophistication as 5G networks and devices become the new normal.

10.Conclusion

This report is a technical overview of the technology and protocols used in 4G and 5G networks and how they provide services to the user and how data is transferred within the networks. Then, we make a comparison of the network architecture between the systems. Next, there is a description of the technical challenges in implementing mobile data communications and a table that compares technical properties of 4G and 5G. Finally, we make a conclusion on our findings and description of where we feel that the technology will progress. With the development of science and technology, 4G can no longer meet people's needs, while the research of 5G solves the problems of network delay and insufficient storage space. It can be seen that the performance of 5G is better than the previous network system. And I think that in the future, 5G will develop towards virtual industries like VR. Finally, it makes human life more convenient.

11.Contribution

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- Introduction to 4G and 5G
- The shift to 5G
- Economic growth
- 5G Applications/Use Cases

ABID ALI (2019380141)

- Comparison of Network Institutions
- Challenges of Implementing Mobile Communication Network
- The advantages of 5G networks over 4G networks
- Concluded the report about 5G and 4G

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