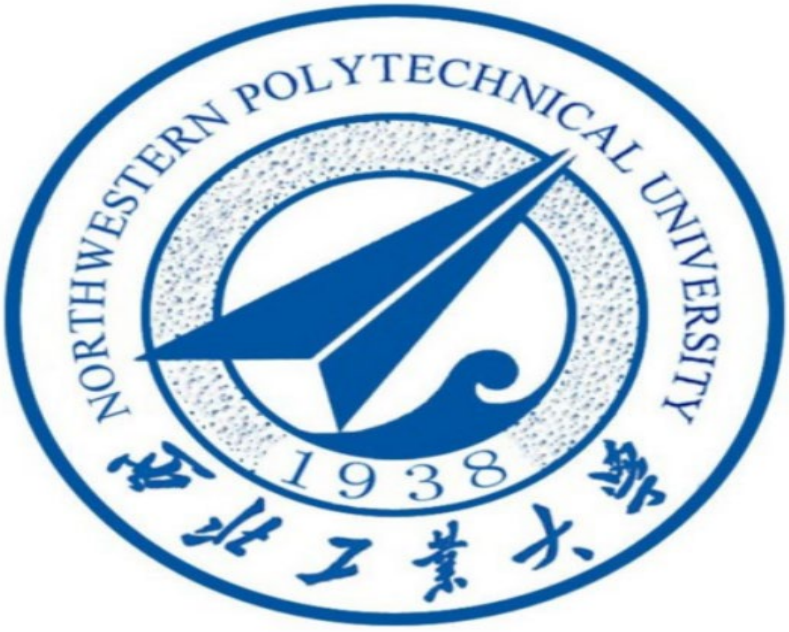

Computer Networks

Group Project

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

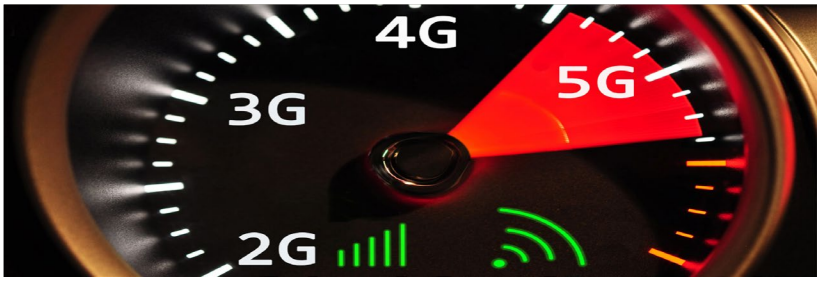
1.The shift to 5G

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

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.

Smartphones: Internet from everywhere

3G, 4G, and 4G LTE

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.

Hyperconnectivity between people and things

5G

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

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

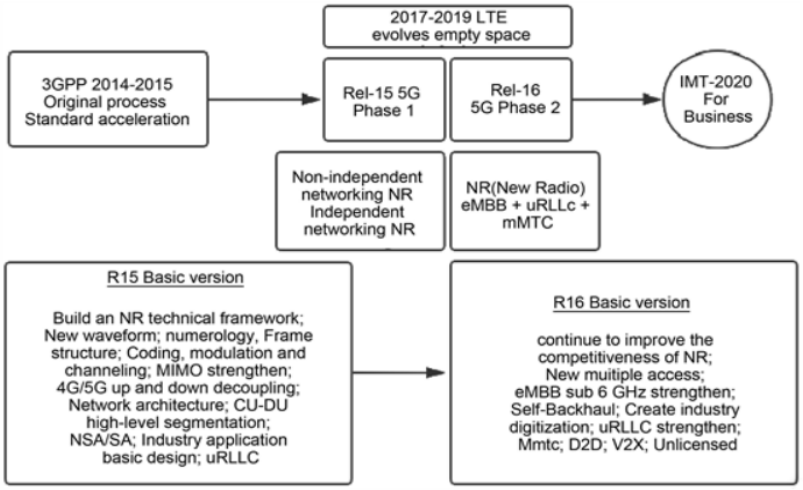


Figure 1. Protocol framework.

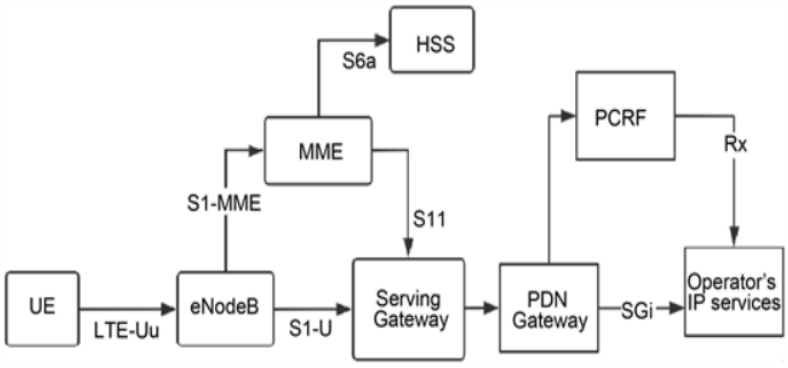


Figure 2. EPS network architecture.

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.