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Investigation and Technological Comparison of 4G and 5G Networks

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Abstract

Mobile cellular data networks have allowed users to access the Internet whilst on the move. Many companies use this technology in their products. Examples of this would be Smart Meters in the home and Tesla cars having their “over the air updates”. Both of these two companies use the 4G and 5G technology. So this report will include a technical overview of the technology and protocols (LTE Advanced) used in 4G and 5G networks and how they provide services to the user and how data is transferred within the networks. And there are lots of different parts about the network architecture between the 4G and 5G systems. This report will talk about some different parts between these two systems and some challenges in them.

Keywords

4G, 5G, Protocols, Networks, Mobile Communication

1. Basic Knowledge of 4G and 5G Networks

1.1. 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 [1].

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 [2].

1.2. Introduction of 5G

1.2.1. Development and Formulation Organization of 5G Protocol

The official name of 5G is IMT-2020, which is the fifth generation mobile communication standard formulated by the International Telecommunication Union. As for the formation of 5G protocol, there is a unified standard in the industry field, instead of the multi-standard parallel standard in previous times. It can be said that the formation of 5G is the result of joint efforts of many organizations, among which 3GPP is the most important organization in standardization work. As a matter of fact, the reason why 3GPP was originally established was to customize technical reports and specifications for the third generation mobile communication system, and then it gradually evolved into the leading institution for formulation. As a standard, Release specified by 3GPP can complete the specification of one version in 1 - 2 years on average, and the first standard version of 5G is called R15 [3].

1.2.2. 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 [4].

2. Comparison of Network Institutions

2.1. 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

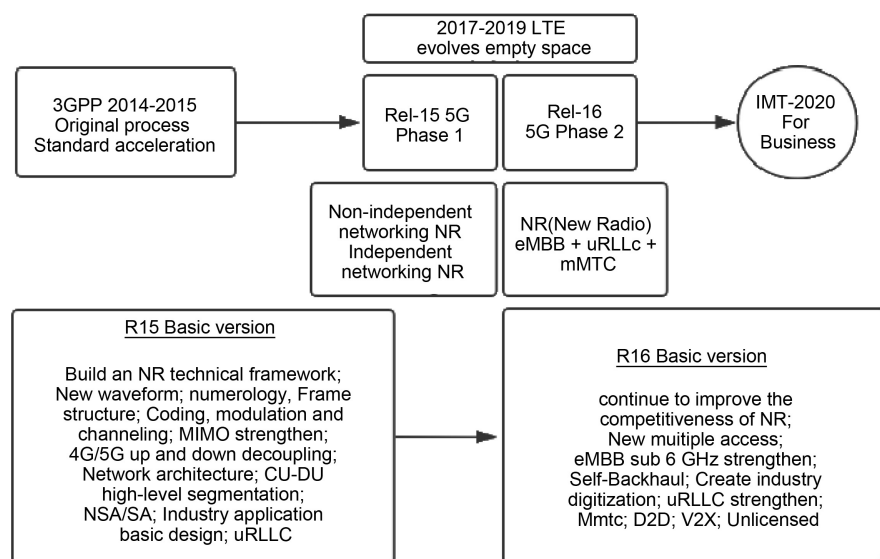


Figure 1. Protocol framework.

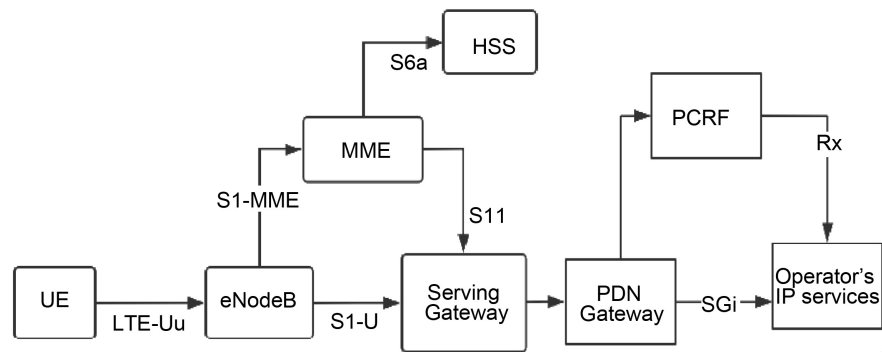


Figure 2. EPS network architecture.

is the evolution of system architecture, and IMS mainly solves the problem of carrying multimedia services such as voice to 4G network. 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.

2.2. 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**.

2.3. Comparison of 4G and 5G Network

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

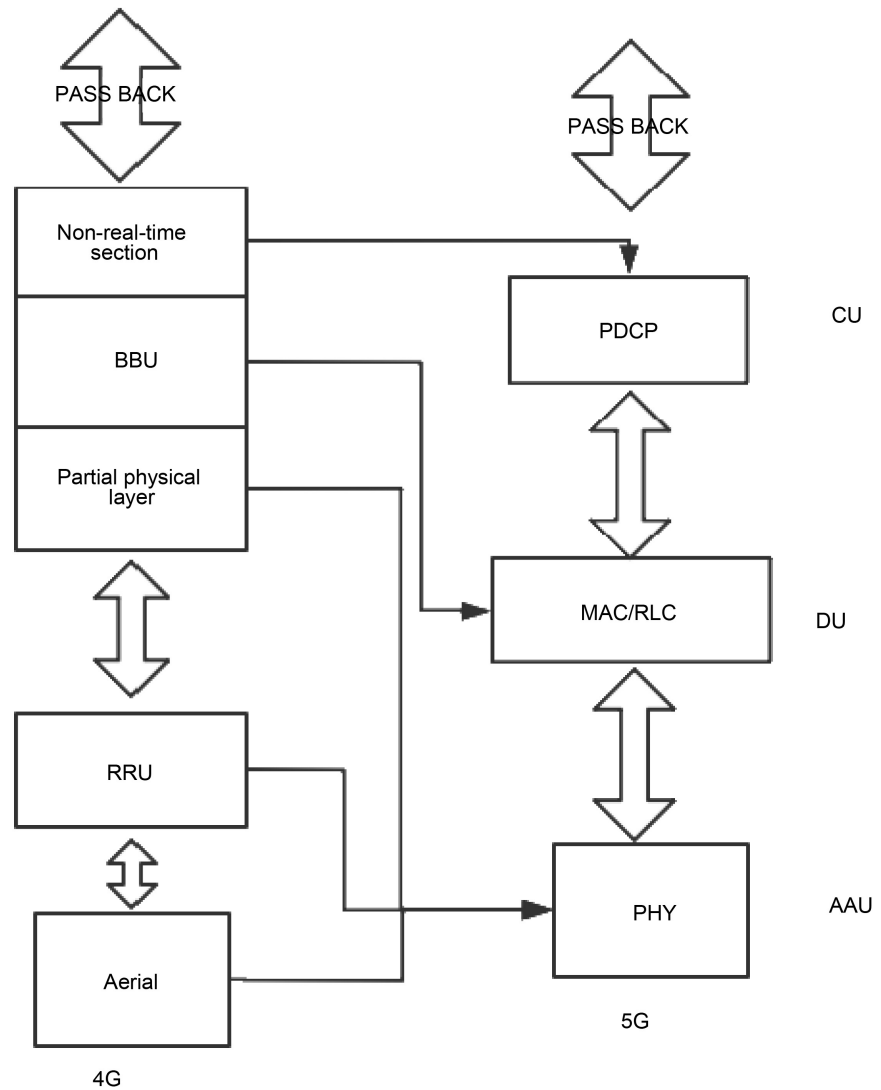


Figure 3. 5G unlimited network architecture.

network architectures. 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 [5]. The following is a performance comparison between 4G and 5G (Figure 4).

3. Challenges of Implementing Mobile Communication Network

3.1. 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.

3.2. Challenge of Flexibility of Network Architecture

There are many kinds of services, and each service has different requirements for the network, so the diversity of services brings new challenges to the design and planning of 5G networks. It includes: function, resource utilization, architecture and so on. Secondly, the deployment, user category change and security isolation technology of 5G network need to be improved, which is one of the challenges to the flexibility of 5G network architecture. Compared with 4G, the bandwidth of 5G network has increased dozens of times, which leads to the rapid increase of network speed demand. URLLC service requires ultra-low delay in milliseconds. This performance requires reasonable allocation of stations, optimization of routing and forwarding technology, and finally meets the flexibility requirements of 5G network.

3.3. Challenges of Terminal Technology

In order to meet the market demand, the terminal technology of 5G will be diversified. In fact, according to big data: "Most of the terminal products in the early 5G are mainly mobile phones in the eMBB scene, and the terminal planning of other scenes will gradually become clear with the maturity of standards and industries". From the perspective of current scientific and technological development, the increase in the number of antennas in the future will cause problems such as insufficient terminal space and reduced antenna efficiency. Therefore, researchers need to optimize the terminal design and hardware equipment, and then promote the development of the terminal industry chain [6].

4. 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 your findings and description of where you 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.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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