Application of Edge Computing in 5G Communications

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Abstract. As the next generation of the wireless communication technology, the fifth generation communication (5G) would bring revolutionary changes to our life. In this paper, we firstly give an introduction of the typical scenarios of 5G’s applications. Then we review the basic concepts of new computing hypotheses including cloud computing, fog computing and in some extent even for edge computing. Combining with the demand of 5G’s application, we analyze the opportunities and challenges of these new computing hypotheses in 5G era.

1. Introduction

1.1 History Review
Mobile communication has experienced the development process from 1G to 5G [1]. In 1986, the first generation of mobile communication (1G) system was born, people realized the function of making a phone call while walking. However, the communication system at that time used analog signals for transmission, and had the problems such as the low voice quality, signal instability, insufficient coverage and cross talking caused by wrong connections. In 1995, the second generation of mobile connection system has begun to be used. Using the digitally modulated signal, not only the communication security was stronger, but also the sound quality was greatly improved. Using the technology of Time Division Multiple Access (TDMA), the number of users of 2G networks was also greatly increased. In 2008, 3G networks based on the newest technology is named “Code Division Multiple Access” (CDMA) technology began to be applied, and three major standards of SCDMA, WCDMA and CDMA2000 were formed. 3G has greatly improved user capacity and network speed, and has spawned a series of mobile phone applications in the era of mobile Internet. Four years after 3G’s commercial use, the 4G network based on the newest technology is named “Orthogonal Frequency Division Multiplexing” (OFDM) technology quickly entered the historical arena. The high-speed network transmission rate allowed people to chat in real time, watch live video on mobile phones, and make a series of applications such as Internet of Vehicles possible.

Based on the aforementioned many generations of mobile communication technologies, 5G is about to enter our lives [2, 3]. On the basis of 4G, 5G has made a series of technological advancements, including millimeter wave communication, more advanced beamforming, ultra-large-scale antenna, full-duplex wireless, and compressed network processing. Millimeter wave communication can increase the width of the frequency band and avoid the situation that no frequency band is available. More advanced beamforming can improve the signal-to-noise ratio. Ultra-large-scale antenna and full-duplex wireless can simultaneously increase the bandwidth and signal-to-noise ratio. And the network compression processing technology can greatly reduce network latency. Based on these techniques, 5G achieves a great improvement from 4G, as shown in Table 1. The successful deployment of 5G would boost a variety of applications, e.g., video chatting [4], ridesharing [5], internet of things [6].
Table 1 the Comparison Between 4g and 5g.

| Metrics                  | Peak Speed (Gbps) | User Speed (Gbps) | Spectrum Efficiency | Space Capacity (Mb/s/m²) | Mobility Performance (km/h) | Network Efficiency | Coverage (users/km²) | Latency (ms) |
|--------------------------|-------------------|-------------------|--------------------|--------------------------|-----------------------------|-------------------|----------------------|--------------|
| 5G                       | 20                | 100               | 3                  | 10                       | 500                         | 100               | 100                  | 1            |
| 4G                       | 1                 | 10                | 1                  | 0.1                      | 350                         | 1                 | 10                   | 10           |
| Change                   | 20×               | 10×               | 3×                 | 100×                     | 1.43×                       | 100×              | 10×                  | 10×          |

Figure 1 a Comparison Between 4g and 5g.

1.2 The Basics of Centralized Ran (C-Ran)
A remodeled, centralized RAN is proposed as a C-RAN in which the physical layer communication functions are separated from the scattered BS and integrated into the virtualized vital processing center. It can be used to address volume fluctuations and improve the mobile networks efficiency of the using on the energy of system by its centralized nature. In addition to the 5G standardization approach, C-RAN can also grant new occasions for the Internet of Things, starting a whole new horizon of omnipresent perception, device connecting each other, service allocation and provisioning to connect better between people and things. Communicate and collaborate to achieve a more distributed and dynamic approach. However, the fully centralized principle of C-RAN requires the exchange of radio signals between the cloud processing unit and radio head, which imposes rigorous requirements on the forward connection from the perspectives of amount of the receiving and sending of the data and delay. in different circumstances, the MEC standard is beneficial to reducing
latency and contributes to improving the local operator experience, but processing ability and storage are orders of consequence lower than centralized clouds in C-RAN. In the table below, we give a ran down the relationship of MEC and C-RAN in various aspects. The vital point is that MEC does not reverse C-RAN, but complements them. Such as there is an application that needs to sustenance very low end-to-end latency can have a component which running in the MEC cloud while others processed a remote cloud.

|                  | MEC                                      | C-RAN                                    |
|------------------|------------------------------------------|------------------------------------------|
| **Location**     | Co-located with base stations or aggregation points. | Centralized, remote data centers.       |
| **Deployment Planning** | Minimal planning with possible ad-hoc deployments. | Sophisticated.                          |
| **Hardware**     | Small, heterogeneous nodes with moderate computing resources. | Highly-capable computing servers.       |
| **Front-haul Requirements** | Front-haul network bandwidth requirements grow with the total amount of data that need to be sent to the core network after being filtered/processed by MEC servers. | Front-haul network bandwidth requirements grow with the total aggregated amount of data generated by all users. |
| **Scalability**  | High                                    | Average, mostly due to expensive front-haul deployment. |
| **Application Delay** | Support time-critical applications that require latencies less than tens of milliseconds. | Support applications that can tolerate round-trip delays in the order of a few seconds or longer. |
| **Location Awareness** | Yes                                     | N/A                                      |
| **Real-time Mobility** | Yes                                     | N/A                                      |

In this paper, we first introduce the typical application scenarios of 5G in Section 2. In Section 3, we review the basic concepts of new computing modes such as cloud computing, edge computing, and fog computing. In Section 4, combining the application requirements of 5G, we analyze the application prospects and challenges of these new computing models in the 5G era.

2. Typical Application Scenarios of 5G Communications [7, 8]

2.1 Enhanced Mobile Broadband

The Enhanced Mobile Broadband (eMB) scenario suggests to the enhancement of the user experience and other performances based on the existing mobile broadband service scenarios. It seeks the ultimate communication experience among users. It would be used when we use the mobile phone to access the Internet or watch videos. With a faster transmission rate, users can have a faster Internet access speed and a more stable video connection when using mobile devices.

2.2 Massive Machine Type Communications

The Massive Machine Type Communications (mMTC) is an application scenario for the Internet of Things and the large-scale connection of machine communication. The main focus is on the communication between things. In the smart city and IoT scenarios, there is a need for a huge number of sensors and smart devices to be connected to the network. At the same time, these networks connections which is limited by the capacity of the battery need to maintain a low power and a long connection state.

2.3 Ultra-Reliable and Low Latency Communications

The Ultra-Reliable and Low Latency Communications (URLLC) aims at the Network of Vehicles and autonomous driving scenarios. In these scenarios, there are very high requirements for the reliability and delay of network transmission. Once the network is unstable, it may cause car crash in these applications, resulting in a bad consequence.

3. Edge Computing [9-12]

In this section, we first give an summary of the concept of edge computing. Then we discuss the three modes of edge computing, namely, multi-access edge computing, micro cloud, and fog computing.
3.1 An Overview
Edge computing provides cloud services and IT environment services to application developers and service providers on the edge of the network. Its goal is to provide computing, storage and network bandwidth near the data input or users. Edge computing has the following characteristics: (1) Low latency, which means that computing power is deployed near the device side, and the device can get a real-time response. (2) Low-bandwidth operation, which means that the ability to migrate work closer to the user or data collection terminal can reduce the impact of the site bandwidth limitation, especially when the edge node service reduces the request to send a large amount of data processing to the hub. (3) Privacy protection, which means local data collection, local analysis, and local processing and effectively reduces the exposure of data to public networks and protects data privacy.

3.2 Multi-Access Edge Computing [13]
Multi-access edge computing (MEC) was originally proposed by the European Telecommunications Standards Institute (ETSI) in 2014. The ETSI start-up members include HP, Vodafone, Huawei, Nokia, Intel and Viavi. MEC provides cloud computing capabilities for the mobile network edge an IT service environment. By performing partial caching, data transmission and calculation at the edge of the mobile network to offset the delay associated with the backhaul, the millisecond application can be realized. MEC applications include local edge services related to network connectivity and network capabilities, including but not limited to, a mobile virtual private network that replaces an enterprise Wi-Fi network, an indoor positioning based on wireless network positioning and combined with a room division; an edge proximity processing video edge service that saves back bandwidth and reduces latency, edge caching combined with CDN, edge storage and recognition analysis for video surveillance; terminal-oriented computing migration reduces edge cost of edge-assisted computing services; services providing edge cloud rendering for AR, VR, and games.

3.3 Micro Cloud [14]
Micro cloud is the research outcome of the Open Edge Computing (OEC) project, which was originally initiated by Carnegie Mellon University and has since been supported by companies such as Huawei, Intel and Vodafone. It is an edge computing architecture that syndicates mobile computing platform and cloud computing. It represents the middle layer of the “mobile terminal - micro cloud - cloud” three-tier architecture, which is between the mobile terminal and the cloud platform. A small data center that is settled at the edge of the network is mobile. The micro cloud is deployed on a cellular network base station or a Wi-Fi base station to provide a low latency response for the end user's computing tasks. When multiple micro-clouds are built into a distributed mobile edge computing environment to expand the available resources of users, resource balancing can be achieved by providing a dynamic migration mechanism similar to the cloud platform.

3.4 Fog Computing [15]
Advised by Cisco in 2012, The concept of fog computing is claimed. Subsequently, Cisco joined forces with Arm, Dell, Intel, Microsoft, and Princeton University to form the OpenFog Consortium in 2015. Compared to MEC and micro cloud, fog computing focuses on the application of Internet of Things (IoT). Fog computing distributes computing, communication, control, storage resources, and services to users or devices and systems that are located close to users, thereby extending cloud computing to the edge of the network, which can be understood as a small cloud at the edge of the network.

4. Opportunities and Challenges
In this section, we combine 5G application scenarios to discuss the opportunities and challenges these new computing models face in 5G communication applications.

4.1 Opportunities
Commercial application of 5G systems is expected to begin in 2020. The exploration phase has begun to understand the detailed requirements of future 5G systems and classify the most promising technology options. Although the 5G definition may involve multiple standardization bodies, 3GPP is likely to become the focus of technical specifications, and the 5G research project will begin in 2015. In this part, we point several opportunities for edge computing in 5G era.

1) CDN Revolution

5G triggers the next generation of content distribution network (CDN) revolution. Facing the advent of the 5G era, CDN will also face the next generation of changes, the history of CDN has faced two generations of changes. The first generation CDN was launched at the end of the last century, focusing on the distribution and transmission of static and dynamic content. The principle of the first generation CDN is to create and copy content through intelligent routing or edge servers centered on the hardware server, and the second generation. CDN, which focuses on video (large traffic) applications, transfers video or audio content between users and servers to solve distribution and application challenges. Youtube and Netflix are representative of the typical needs of CDN in this era. The second-generation CDN also provides a path to deliver content to mobile users. At the technical level, cloud computing and virtualization can help shift from high-end hardware to more cost-effective, while the CDN of this era is highly flexible and feature-rich. CDN deployment model.

2) Surveillance Video Analysis

Powered by edge computing and 5G communication, the surveillance video in multiple scenarios can be analyzed and utilized in real time. In super markets, the identification of consumers can be spotted at the time they enter the coverage area of surveillance video. Then combing with their previous shopping records, the personalized promotion and discount would be pushed to their mobile devices instantaneously. For traffic surveillance video, the processing can be conducted on the streets with edge computing. The traffic accidents can be better identified and further processed. The crowded area can be earlier found and drivers would get a notification about the real-time traffic situation.

3) Video Transmission

The bandwidth of video data in mobile networks is increasing, and this trend will become more apparent in the future 5G networks. The current processing of the video data stream is treated as a general data stream of the Internet, which may cause excessive carding and delay in video playback. The MEC server close to the wireless side estimates the wireless channel bandwidth, and selects the appropriate resolution and video quality for throughput guidance, which can greatly improve the user experience of video playback. TCP type data currently accounts for 95% to 97% of Internet traffic. However, the commonly used TCP congestion control strategy is not applicable to rapidly changing wireless channels in wireless networks, resulting in wasted packet or link resources, and it is difficult to accurately track changes in wireless channel conditions. Providing wireless low-level information through the MEC can help TCP reduce congestion rate and improve link resource utilization.

4) VR and AR

Virtual reality [16] and augmented reality [17] are next-generation human-computer interaction techniques, which are widely supported by mobile devices recently. They combine the virtual elements with the real location or background, enabling the real-time interaction with the environment. VR and AR have a wide application in different areas including military, medical, entertainment, education industries. However, to support the immersive experience, high throughput and low latency are required, which is put on the edges. While the edges are responsible for the computing tasks, they can also be used to do business analysis or advertisement push, and charge as a service. Semi-automatic and fully automated vehicles will add time to the consumption of AR and VR content while also challenging the mobility and capacity requirements of wireless streaming. More antennas (large-scale multiple-input multiple-output (MIMO) antenna technology and multi-connectivity of 5G NR (allowing users to receive data from multiple cells simultaneously) provide a more unified and seamless mobile experience.

5) Autonomous Driving

Autonomous driving [18] is a revolutionary idea for the transportation industry. Equipped with all
kinds of sensors including GPS, cameras, radars, an autonomous car would generate about 4000 GB a day, which requires a huge computing ability and cannot be made into reality without the edge computing. By taking the vehicles as edges, many processing tasks can be conducted locally, enabling the real-time sensing and controlling.

6) Remote Medical Care

Distance medical care is beneficial to the one who can’t come to the good qualified hospital in person. Supported by a real-time video with a very high-quality display. Tele medicine can never slow down the network of facilities. With the improvement of 5G in high speed added in the whole building, the consultations and the quality broadcasts can do improve the quality and convenience a lot.

While telemedicine is already happening today, 5G will help enable the speed and exponential computing at the edge that will encourage a more widespread adoption. Furthermore, 5G will support the healthcare IT infrastructure as remote clinicians and telemedicine extend the organization’s reach beyond the hospital premises. For example, with 5G, language translators will be able to chat with a patient and a doctor through video at the network edge with low latency.

4.2 Challenges

In this part, we have to point out several challenges remaining unsolved for the edge computing in 5G era.

The first one is the concern of user’s privacy protection. While edge computing can provide better services by analyzing more data, it also introduces a higher probability of information leakage. The question about how to balance the benefits and evaluate the risks requires further research.

The second challenge is the battle of the technical standards for 5G. In the era of 3G and 4G, there have been disputes over technical standards. If the technical standards of 5G are not uniform, it will be difficult to promote the application of edge computing.

The third challenge is the user’s acceptance. The introduction of edge computing in 5G scenarios will inevitably increase the cost of technology. It is a complex problem to design a commercial solution that balances the technology cost and user’s experience.

5. Conclusion

In this paper, we first introduce the common application scenarios of 5G, review the basic concepts of new computing models such as cloud computing, edge computing, and fog computing, and then consider and analyze these new calculations in combination with 5G application requirements. The application prospects and challenges of the model in 5G. We believe that in the 5G era, edge computing will make a big difference and will greatly promote the application and development of 5G.

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