Ten Reflections on 5G

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DOI: 10.12142/ZTECOM.202001001
http://kns.cnki.net/kcms/detail/34.1294.TN.20200313.1514.002.html, published online March 13, 2020

Abstract: 5G takes the concept of service-oriented architecture to replace the priority principle of network efficiency in the Internet to meet requirements of the industrial Internet and smart cities, such as high reliability and low latency. On the other hand, in order to adapt to the uncertainty of future business, 5G features the openness of services and the Internet protocols, different from the closeness of traditional telecommunication networks. Although 5G tries to have the advantages of both the Internet and telecommunication network, its realization still faces many challenges. In this paper, ten major issues concerning 5G networking and service offering are discussed.

Keywords: 5G; Software Defined Networking (SDN); Network Functions Virtualization (NFV); network slice; Service-Based Architecture (SBA); Mobile Edge Computing (MEC)

Citation (IEEE Format): H. Q. Wu, "Ten reflections on 5G," *ZTE Communications*, vol. 18, no. 1, pp. 01–04, Mar. 2020. doi: 10.12142/ZTECOM.202001001.

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2019 is recognized as the first year of 5G commercialization. All the 5G commercial network operators, except the Chinese ones, have launched their 5G networks based on Non-Standalone (NSA) infrastructure, using their existing 4G core networks and new 5G base stations to provide enhanced mobile broadband capability for 5G terminals. On the other hand, China has decided to build 5G standalone (SA) core network in 2020 [1]. The SA mode can offer the capabilities of ultra-high reliability, ultra-low latency, wide-area coverage and massive connection, which NSA cannot guarantee. Besides, SA has greater efficiency of improving the mobile broadband capability than NSA. In this way, 2020 can be seen as a true beginning of 5G era.

In comparison with 4G, the 5G SA core network will be based on Service-Based Architecture (SBA) [2] to meet the service requirements of multi-service operation, low latency and high reliability, thus enabling such features as service openness, network slicing, Network Functions Virtualization (NFV), edge computing, and Internet based telecom protocols. The advent of the Internet was 50 years ago and the Internet protocols, such as Transmission Control Protocol/Internet Protocol (TCP/IP), implement data transmission based on connectionless mode and packet routing. Now, 5G has brought about a paradigm shift in mobile network architecture; its core network has connection-oriented capacity and the IP packet at Layer 3 is no longer the only forwarding element. Therefore, the communication network architecture today is undergoing profound changes never seen before after the Internet was born. We are facing many challenges to achieve the expected performance of large-scale 5G applications. In this article, we talk about ten important issues concerning 5G networking and service offering.

1) Software-Defined Networking (SDN) will play a big role in 5G networking.

SDN implements the splitting of data transmission and data control and treats the control plane as a network operating system to centrally manage different networks. With the support of Segment Routing IPv6 (SRv6), SDN also enables source routing by configuring an end-to-end route for each service flow based on big data and artificial intelligence; it then encodes and stores the routing information into the label stack of the IPv6 extension header of the source node and forwards the segment header to the nodes along the selected path. In this way, the intermediate nodes only need to conduct forwarding without any routing tasks, which saves the time for queuing and guarantees the low-latency forwarding in connection-oriented networks. Although SDN is expected to be a solution to real-time optimization of all kinds of service flows and nodes, multi-objective optimization of a large-scale low-latency network will bring a problem of routing conflict or divergence for SDN. This problem can be solved in two ways. One is to partition a large-scale topology and assign an SDN controller for each partition; however, inter-partition routing requires the multiple controllers to communicate service flows and network resource data with one another, leading to complex implementation of SDN. The other way is to ease the burden on SDN handling capability by forwarding part service flows in connection-oriented mode while handling the other service flows still in connectionless mode.

2) 5G changes traditional configuration of network elements.

With generic hardware (white box hardware) and software-defined networking elements, the NFV technology can flexibly implement layer-1. 5, layer-2, or layer-3 forwarding based on the specific requirements of a service flow, thus improving forwarding efficiency and dramatically reducing latency. NFV requires a network element to implement dedicated functions for different services synchronically. Once the services change, these functions will change accordingly. Therefore, it is necessary for NFV to capture accurate data of service flows and network resources in the entire network. NFV uses virtualization techniques to realize the decoupling of software and hardware and evolves toward the combination of a pool of hardware resources and microservice architecture of software applications. However, microservice has not achieved its goal of implementing network openness and interoperability yet, due to its lack of standards. Moreover, the simultaneous operation of SDN and NFV in 5G networks inevitably suffers the conflict of network resources. As for white-box network elements, a white box may have higher forwarding latency, compared with dedicated equipment; NFV performance even becomes a big challenge when white-box network elements and legacy network elements coexist in a network.

3) Network slicing is a key feature of 5G network and service.

Network slicing [5] can realize tailored Virtual Private Networks (VPN) for diversified services and use cases depending on their special requirements for such attributes as bandwidth, latency, and reliability, by implementing the orchestration of network resources in centralized network Operation and Maintenance (O&M) system. In this way, network slicing can support individualization services, especially for vertical industries. The VPN is actually not a new service in telecommunication networks, but it is built based on reservations and only offered for a very few service flows in legacy networks. In 5G system, new VPN services should be massive, real-time, and end-to-end, which makes it too idealized to set up network slices for any service demands. We should not forget the history of Asynchronous Transfer Mode (ATM) technology. If network slicing is extended from the core network to the access network, end-to-end slices will have to keep changing with the movement of users, which will certainly increase the complexity of slice management. It is also an unprecedented challenge to open the authority of organization VPN to customers to implement the provisioning of VPN finding, selecting, creating and management, as well as on-demand real-time dynamic adjustment. Furthermore, the inter-operator VPN connection requests operators to open their network resources and service data to each other, which is completely impractical. A potential solution is to set up network slices only for those services and use cases that have restrict requirements on such parameters as latency, packet loss rate, and reliability. This solution can implement the real-time creation of a VPN, free from the reservation that is mandatory for a VPN in any 4G network. Moreover, with traffic-based charging schemes, the provisioning of VPN services only to high-end customers to guarantee their Quality of Service (QoS) is unfair for low-end ones. Therefore, it is necessary to consider the design of value-oriented and QoS-based customer charging architecture.

4) SBA is an important innovation in 5G.

As an open service platform, SBA enables on-demand deployment of diversified intelligent service units, just like the use of apps on smart phones. The intelligence created by the assembly of intelligent units and flexible scheduling of network services implemented by service decoupling and modeling can respond to the unpredictability of 5G new services. Different from Intelligent Networks (IN) in the traditional telephony network architecture, the open SBA greatly enriches the sources of intelligent service units. However, SBA, with limited network resources and massive users, may also face potential conflicts between various intelligent service units, similar to the IN. The SBA opens up the closed service functions in operators' legacy networks, which also leads to new security threats. Moreover, working with SBA, the 5G mobile communication protocols are generally IP-based, which enables Internet applications to migrate to 5G system directly and further enhances its service capabilities. However, this also opens the door to the viruses and trojans on the Internet. Therefore, more effort is expected to be put into network security and data protection for 5G than that for 4G.

5) There is an inextricable link between Mobile Edge Computing (MEC) and 5G technologies.

MEC is a new paradigm for facilitating access to cloud computing capabilities, including storage and content delivery, at the edge of mobile networks, in order to enable latency sensitive services. In practice, a reasonable definition of granularity for MEC is a problem in terms of engineering. Various application terminals such as mobile terminals, robots, and intelligent connected vehicles will need to be switched across MEC hosts, which involves inter-MEC collaboration and reasonable allocation of functions in MEC and centralized clouds. This issue may lead to large overhead between MEC hosts and many interactions between MEC and centralized clouds, as well as incur delay. MEC is especially fit for those vertical business segments who want network operators to open network capabilities at the edge to them. Therefore, it is necessary to configure MEC with light cloud techniques like open source platforms and dockers for supporting third-party edge applications well. Moreover, opening MEC capabilities will inevitably make a big impact on operators' network management and data security.

6) 5G has a strict requirement for clock synchronization.

In SDN/NFV, service flows of all the network elements and big data of network resources are required to keep synchronous for absolute time alignment. A global vision in 5G system cannot be implemented without precise synchronization of different packets; a network scheduling decision based on inaccurate data may be worse. The IEEE Precision Time Protocol (PTP) 1588 is based on an assumption of the exact same delays for bidirectional propagation; however, in practical scenarios, the assumption is challenged and even the protocol itself hardly guarantees the precision of synchronization required.

7) 5G is pushing the transformation of Operations Support System (OSS).

5G system will implement real-time assignment of NFV functions to network elements, as well as the organization and lifecycle management of service-enabled network slices. In order to leverage 5G features, the OSS for 5G should enables automated orchestration of communication equipment and services based on statistics and intelligent analysis of big data from services and network resources. Real-time responses of OSS will rely on signaling control, rather than manual network management processes. A centralized OSS for the entire network facilitates overall control of network operations, but may struggle with processing capability and delay. However, if multiple OSSs are set up in different network regions, they will need data interchange and the coordination of a higher-layer central OSS.

8) Internet of Vehicles (IoV) is a new application scenario for 5G networks.

5G will be designed to guarantee low latency in both the access and core networks for the sake of IoV. Vehicles to Everything (V2X) communications are very different from personal communications. The average hops for a personal communication path are more than ten, but there are only one or two hops over a V2X path. Therefore, the advantages of NFV, network slicing and SRv6 in good control of delays in multi-hop cases are difficult to embody in the scenario of V2X communications. Moreover, legacy TCP/IP protocols cannot implement high transmission efficiency for short packets, which are the typical form of traffic in IoV. In the access network, point-to-point connection is generally used for personal communications. However, as for Vehicle-to-Vehicle (V2V) scenarios, point-to-multipoint, multipoint-to-mulitipoint, and even broadcast communication modes are used, which makes frequency arrangement more complex and latency slightly higher, because direct Device-to-Device (D2D) connectivity is hardly used and Vehicle-to-Network-to-Vehicle (V2N2V) connectivity is required. At present, many provinces in China share an internetwork node between network operators to implement their interconnection for personal communications. This is not a picture for the IoV. Because the IoV is very sensitive to latency, inter-operator V2V communications need direct interconnection in the neighborhood, in the same city at least. Therefore, it is necessary to set up local internetwork nodes in a city especially for the IoV.

9) Massive Internet of Things (IoT) is a featured application of 5G.

5G can access millions of IoT connections for every square kilometer, with an end-to-end transmission delay of less than 10 s and packet loss rate of no higher than 1%. For the sake of massive IoT terminals, group authentication schemes should be used to prevent any signaling storm. Security algorithms and protocols should also be lightweight, avoiding unwanted latency and the increase of energy consumption of the IoT terminals. Moreover, the diversified types of IoT terminals require that 5G user identity management method should adapt to the transformation from the current use of Universal Subscriber Identity Module (USIM) cards to flexible and diverse ways.

10) The industrial Internet spurs the emergence of 5G-based private networks.

Industrial digitalization should first implement the networking of production equipment of enterprises; among them, industrial robots, materials trolleys and workpieces on production lines need to be networked with wireless technologies. However, current available wireless technologies cannot meet the demands of the industrial Internet on reliability, scalability and anti-interference capability. Fortunately, the industrial Internet has become a featured application of 5G. For enterprises, 5G facilitates data transmission in either their Intranets or Wide Area Networks (WAN). Moreover, 5G operators can provide on-demand network slices for industrial enterprises, while the fact that operators' 5G networks are originally designed for the communications of public subscribers should be noted. In the Time Division Duplex (TDD) mode for operators' 5G networks, the downlink will be assigned more time slots than the uplink at the same carrier frequency for the sake of public communication services, especially video services, with downlink data much bigger than uplink data. TDD in the industrial Internet is just the opposite, with more time slots for the uplink than that for the downlink, because sensors in the industrial Internet always send more uplink data but receive less downlink commands. When these two reverse schemes for assignment of TDD uplink and downlink time slots co-exist in the same base station, different carrier frequencies will be used to avoid mutual interference of the schemes, which will nevertheless limit the flexibility and validity of carrier frequency configuration. Moreover, large enterprises hope to build their 5G-based private networks in terms of management and security. Accordingly, the department administering radio spectrum need to allocate dedicated frequencies to the enterprises' private 5G networks.

In conclusion, constructing 5G SA networks and developing 5G SA applications can be seen as the start point of a new round of innovation for 5G technologies. As the first country to try the road of SA, China will face trial and error risk, as well as many questions worth thinking about. The road to achieving 5G innovations will be long.

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(Translated from ZTE Technology Journal, vol. 26, no. 1)