5G Core Technology Trend White Paper

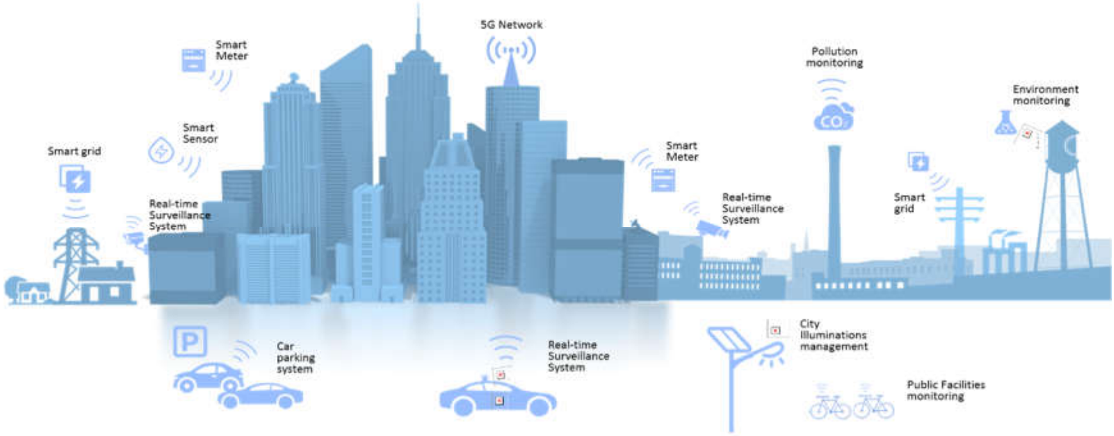
Directory

1 Changes Brought by 5G

1.1 From Mobile Internet to Internet of Everything (IoE)

When 5G was born, artificial intelligence (AI), Internet of Things (IoT), cloud computing, big data, network slicing, edge computing and other new technologies were also booming. 5G networks integrating these technologies are incomparable with traditional networks, and 5G is not only expected by the entire industry but also the whole society. The features provided by 5G networks, such as large bandwidth, low latency, massive connections, and high reliability, are ten or dozens times more than those provided by 4G networks, or cannot be provided by 4G networks. 5G not only upgrades existing 4G services, but also improves personal digital experience and spawns new services. Typical new services, such as Cloud AR/VR, Cloud Gaming, and personal live video and other immersive real-time video services, are just the first wave of 5G applications. These services are the natural evolution from 4G MBB to 5G eMBB to meet the capacity requirements for large bandwidth services at a lower bit cost. With the introduction of uRLLC and mMTC, 5G will also bring industrial transformation to the IoE. It will provide autonomous driving based on Internet of Vehicles (IoV), intelligent manufacturing based on Unmanned Aerial Vehicle (UAV) and industrial robot, telemedicine based on low latency connection, smart city, smart agriculture, and other industrial applications.

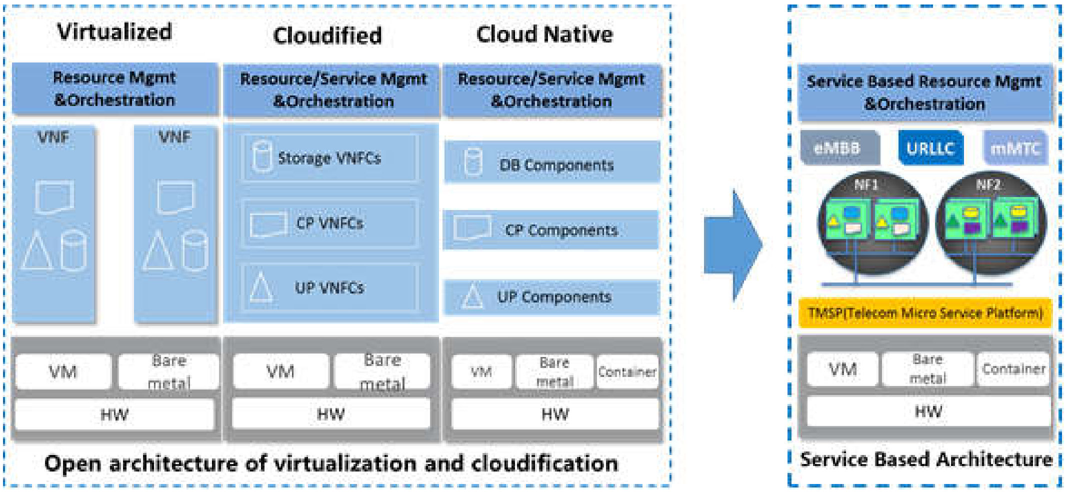
4G mobile broadband accomplishes the Internet, while 5G will define the IoE era. It enables all walks of life, promotes digital transformation in the whole society which is now striding into the era of massive connections, large bandwidth, and low latency.



1.2 From "Cloud Ready" to "Cloud Native"

5G promotes practices of cloudification. Since virtualization technology is introduced into the core network, the core network architecture has undergone several stages of evolution and changes, from the initial virtualization, to cloudification, and then to cloud native. The architecture has gradually opened up, and gradually decoupled from the bottom layer to the top layer.

To provide 5G services more economically and more agilely, and meet requirements for scalability, flexibility, and performance in 5G scenarios, operators need a new core network architecture based on cloud native and 5G services, including independent user plane and control plane. In addition, software architecture and core functions should be re-designed by leveraging cloud native design principles and learning IT development approaches . This architecture allows operators to rapidly deploy a variety of services, orchestrate and upgrade services on demand through fine-grained micro-services, so that operators can rapidly and agilely release new services and shorten the time to market (TTM) of product.

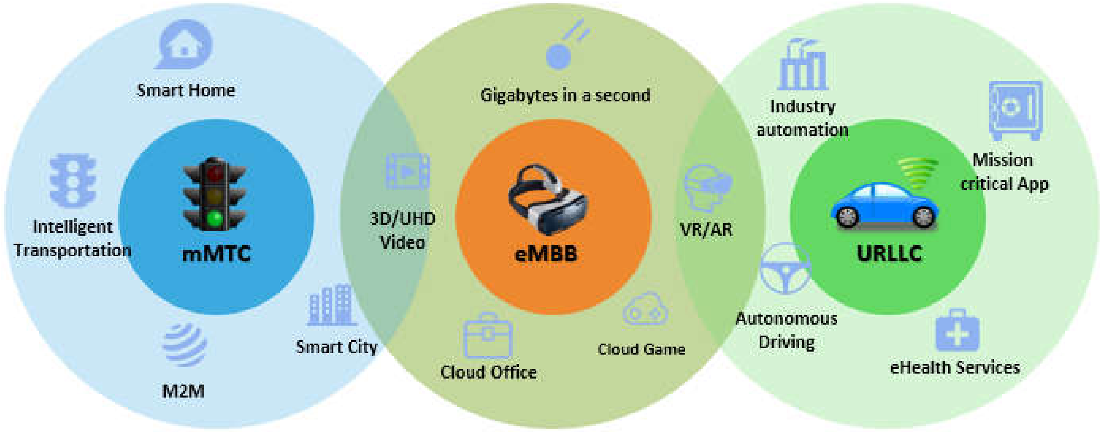


1.3 From a Single Network to a Sliced Network

In the 5G era, there are a variety of vertical industry applications, and each type of service has different requirements for latency, bandwidth, and number of connections. Therefore, 5G defines three typical application scenarios:

- eMBB (enhanced Mobile Broadband): AR/VR, HD video and 3D applications, peak rate: 10G+bps
- URLLC (Ultra Reliable Low Latency Communications): Services with high requirements on E2E latency (<5 ms), security and reliability (>99.999%), such as industrial control, telemedicine, remote monitoring and IoV.

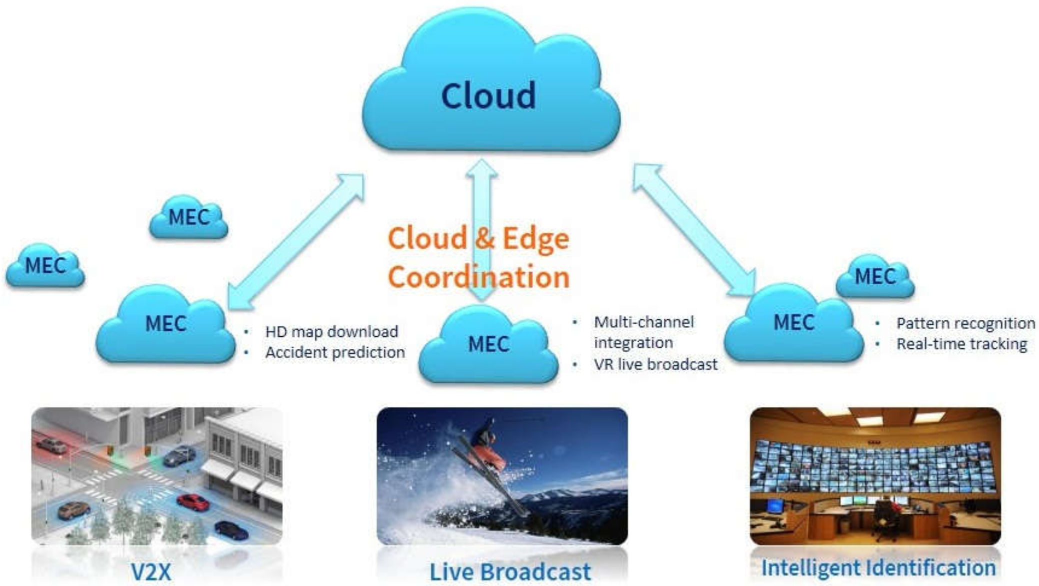
- mMTC (massive Machine Type Communications): Smart home, smart city, environment monitoring, smart agriculture and other IoT services require low power consumption and massive connections (>1M connections/km^2).



Therefore, a single physical network cannot meet SLA requirements for vertical industries. Their personalized and differentiated service requirements promote the emergence of 5G network slicing. Network slicing is similar to logical network or virtual private network. With the introduction of NFV/SDN technology, network slicing can generate an unlimited number of end-to-end on-demand logical networks anytime and anywhere on one physical network. In addition, it can provide multiple slices for the same user to implement multiple services with different bandwidth, latency, number of connections and security isolation under different resource requirements.

1.4 From "Core" Computing to "Edge" Computing

With the maturity and commercial use of 5G and vertical industries, the network will have more devices to access and massive data to process. However, the current centralized "core" data processing mode cannot bear the computing brought by low latency and high bandwidth.



Therefore, it is necessary to set up a local distributed network at the end that is close to data to provide computing and storage capabilities, improve the performance and reliability of applications, reduce the load of the core network, and focus on edge computing. Operators can use edge computing to significantly improve user experience, reduce network transmission load, reduce response delay of devices and systems, and improve control accuracy.

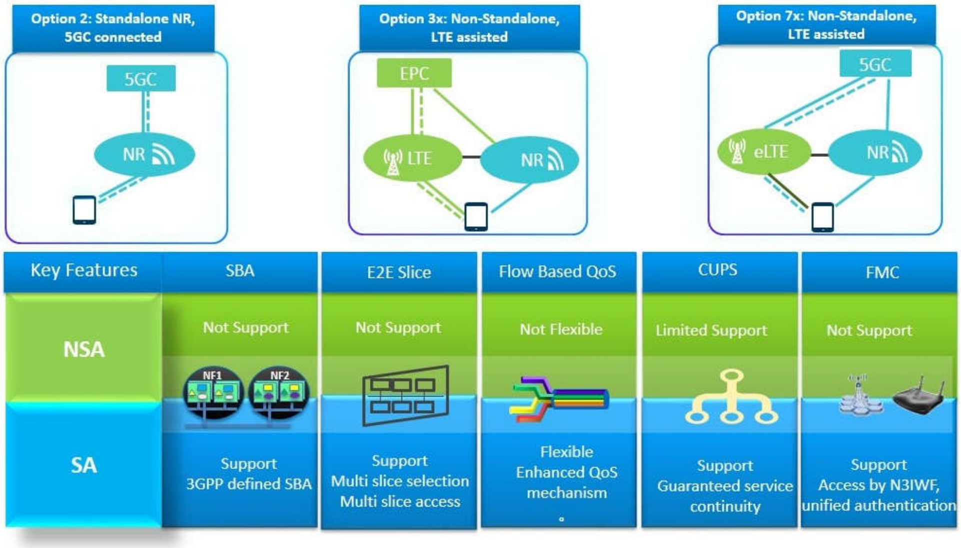
1.5 From Manual O&M to AI O&M

The commercial 5G era is opening. No matter in terms of the communication bandwidth, network delay, or number of connected devices, the 5G era will be a qualitative leap. 5G will provide large-traffic mobile broadband for ultra-HD video, VR/AR, high-speed mobile Internet and other services, provide ultra-reliable and low-latency communication for sensors and data collection, and alos provide services for vertical industries such as IoV and industrial control through massive machine communications. In these different slicing scenarios, 5G network devices will generate diversified mass data on the physical layer, link layer, virtual layer, network layer, and user layer.

During the continuous network evolution, as a hero behind the scenes, network operation and maintenance (O&M) ensures the communication quality, security, and reliability of the entire network. However, the existing management mode cannot meet the cloudified and intelligent deployment requirements of 5G network. In addition, the traditional manual O&M mode cannot meet the requirements of costs and efficiency. New technologies such as AI and big data are urgently needed to promote the development of network O&M to automation and intelligence.

1.6 From NSA to SA

NSA (Non-Standalone) and SA (Standalone) are two 5G architecture options. NSA is a transitional option for evolution from 4G to 5G, and the SA architecture with 5G Core is the real objective of 5G development. Although there are a little risks in the initial stage of NSA, the transition to SA architecture still requires a lot of work.



At present, upgrading the existing EPC network and using dual-connection technology to access 5G NR to provide 5G mobile broadband services have become the early rapid commercialization solution of some operators. However, this approach cannot meet their long-term goals. After deploying the 5GC, 5G can give full play to its advantages, such as CUPS and network slicing. Operators need end-to-end 5G networks to be expansible, high-performance, and flexible, so that they can efficiently deliver extensive services expected by users, which finally brings competitive advantages to operators.

2 5G Core Network Technology Trend Analysis

2.1 Large connections: low latency, high bandwidth, and massive connections

NB-IoT/eMTC stands for Mobile IoT (M-IoT), which is an integral part of future 5G IoT strategy. The revolutionary 5G technology is not only that it covers more application scenarios and more complicated technologies, but also that it is more inclusive. Therefore, one core of 5G is that it can support and be compatible with a variety of access technologies, such as satellites, WiFi, fixed networks and other 3GPP technologies for interoperability. This also creates conditions for NB-IoT and eMTC to be part of the 5G network.

Compared with the traditional 4G EPC, the 5GC adopts the Cloud Native design idea and provides more extensive access based on SBA and function design, achieving more flexible control and forwarding as well as more powerful capability exposure capability. Combining 5GC with NFV infrastructure, it can provide new service capabilities such as network slicing, edge computing, precise timing and 5GLAN for users, service/application providers, and enterprises/vertical industries. 5GC will transform from a traditional Internet access pipe into an enabler of full digital information.

- **Progress of standards: The mMTC standard of 5G IoT is postponed, and the uRLLC ecosystem will be matured in 2023.**

The uRLLC feature is scheduled to be frozen in March 2020, and the mMTC feature is postponed to the R17. The market ecosystem of 5G NB IoT is developing slowly. The R16 standard increases the capability of supporting NB-IoT/eMTC to access 5GC, and provides standards for implementing 5GC access capability by upgrading from eNB to eLTE. The global NB-IoT/eMTC market is still in the early stage of incubation, and the market scale of LPWA is still expanding, requiring further investment in 4G IoT construction.

- **5G IoT and multiple new technologies and fields are converged quickly, and innovation capabilities are continuously improved.**

Mobile IoT is the convergence of the mobile Internet and IoT, supporting lots of large-scale consumption applications such as wearable devices, smart hardware, smart home, Internet of Vehicles, and health care.

Industrial IoT is the deep convergence of IoT and traditional industries such as industry, agriculture, and energy, and it is the infrastructure and key element required for industry transformation and upgrade, for example, smart agriculture, smart energy, smart factories, and other productive IoT applications.

The IoT-based urban three-dimensional information collection system is being built quickly, and smart city is becoming a comprehensive platform for the integration and innovation of IoT applications, such as smart security, smart parking, smart fire, and other security protection applications.

- **Due to the long term coexistence of 4G/5G IoT, end-to-end slicing and hybrid O&M will bring strikes and challenges to traditional O&M mode**

5G wide coverage will not occur overnight. It is estimated that full deployment of 5G will be achieved by about 2025. At the network level, it is impossible for operators to fully switch to 5G at once. The hybrid O&M and management of virtualized devices and traditional non-virtualized devices from 2G to 5G have a great impact and challenge on the current O&M mode. 5G network management system integrates with the cloud platform to carry out integrated and automated cloud network service procedure including orchestration, monitoring, and upgrade, which is the key O&M goal.

- 4/5G NE co-management
- Hybrid Pool management
- Orchestration and management of virtual and container resources.
- Northbound interfaces supporting 4/5G co-management.
- SDN implements 5G deployment and slice network configuration.
- End-to-end network slice deployment and management

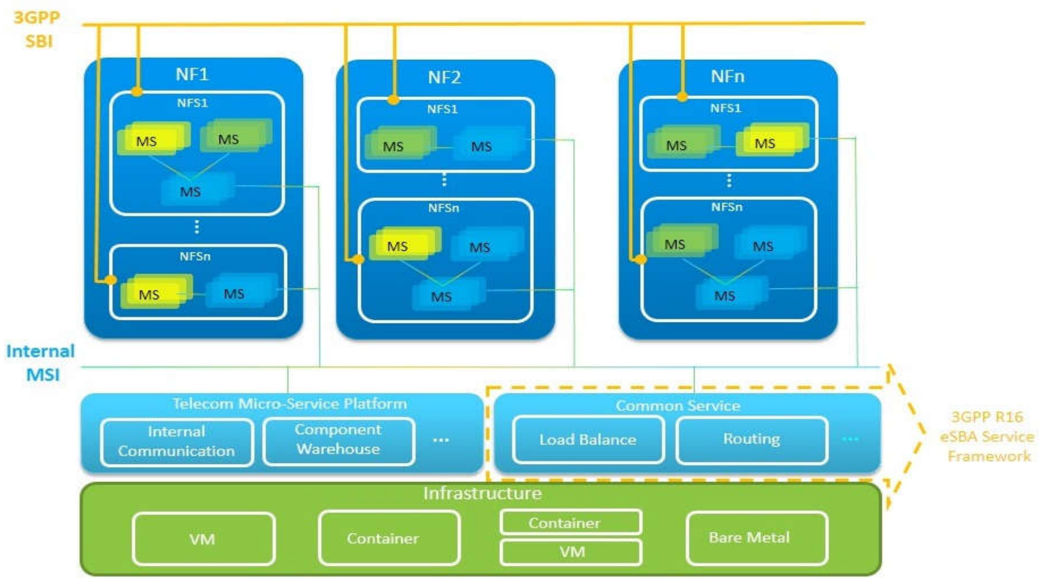
Under the trend of digital transformation, more data will be processed at the edge, and industrial manufacturing and grid IoT will gradually evolve into intelligent IoT. At the edge, the network has to face various challenges such as massive connections of heterogeneous terminals, real-time services, intelligent applications, data optimization, and security privacy. Through deeply open edge computing capability and security protection, operators can simplify the development and adaptation of edge APPs, helping users implement intelligent connection management including manufacturing, maintenance, management, detection, and security, to improve production efficiency, and improve public service user satisfaction.

2.2 Cloud Native: Enhanced service-based architecture (SBA+)

Based on cloud computing, it has become a consensus in the industry to reconstruct telecom networks through NFV technologies and distributed data centers. After five years of development and commercial deployment, the "Cloud Ready" telecom cloud network achieves decoupling of software and hardware, resource sharing and dynamic utilization. As the next step, it will realize the evolution of NFV from "Cloud Ready" to "Cloud Native."

In the Cloud Native phase, VNFs are further decoupled and provide micro-services (featuring in loose coupling) on the basis of cloudification, so that they are elastic, scalable, flexible, easy to manage, and easy to observe. In addition, Cloud Native VNFs can meet the requirement for frequent changes in the future, and are irrelevant to cloud environments (public and private), and cloud technologies (VM and container).

The above features of Cloud Native VNFs allow operators to flexibly deploy applications based on services and customers' needs on the telecom cloud infrastructure with multi-layer data centers, and enable operators to respond to market changes and new customer needs more quickly. Aiming at vertical industries and different scenarios, 3GPP defined the new 5GC SBA with the



cloud native technology/. It decouples an NE into a group of independent NFs, and each NF is decoupled into multiple NF Services. In addition, in the eSBA stage of 3GPP R16, NFs will decouple into more and smaller NF Services. Therefore, to better adapt to different service scenarios and vertical industries, it is the best choice to construct SBA+ 5GC with Cloud Native technology such as micro-service NF.

Compared with the SBA 5GC of 3GPP R15, the SBA+ 5GC integrated with Cloud

Native features has the following advantages:

- **Finer-granularity customization capability:** Each NF is decoupled into micro-services. It supports to customize NF and distinguish positions for deployment per micro-service granularity in accordance with application scenarios or customer requirements.
- **Faster response to market requirements:** The decoupled micro-services can be upgraded and released independently, and Cloud-Native NFs uses CI/CD mode to meet different scenarios and customization requirements of customers more quickly.
- **More efficient resource utilization:** Public functions are extracted and decoupled into public micro-service components, and can be shared by multiple NFs, further reducing the cost of virtualized resources.

2.3 Slicing as a Service: 5G Network Slicing

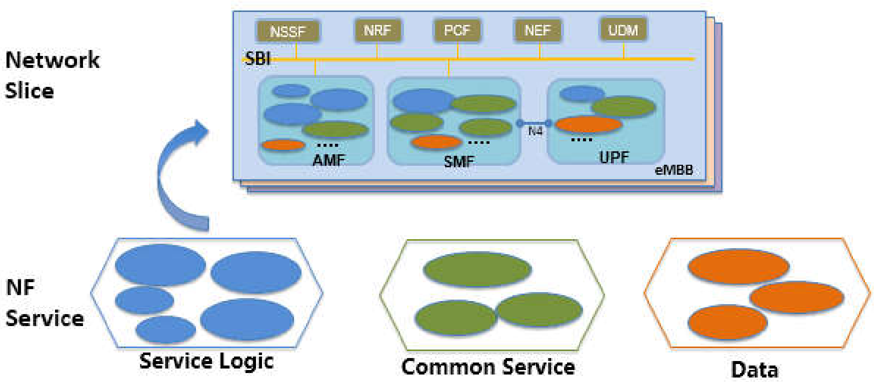
Driven by digitalization, cloudification, and security requirements in vertical industries, especially urgent needs in manufacturing, logistics, and automobile industries, network slicing revenues will eventually increase. ABI Research, a market research company, says that with the increasing digital demands in vertical industries, network slicing will create a value of about 66 billion US dollars. Meanwhile, thanks to the automatic operation of network slicing, service delivery period is greatly shortened. In addition, automatic O&M achieves more efficient design, verification, and implementation of new services. Thus, operators' OPEX is reduced.

5GC uses virtualization technologies such as Cloud Native and micro-service to construct and deploy various slices including eMBB, URLLC and mMTC. In addition, it needs to support the subscription and selection of slices, isolate different slices, and restrict unauthorized UEs from accessing slices. 5GC supports open slicing capabilities to promote the development of vertical industries.

On the 5GC side, the development of the following key technologies will further promote the integration of vertical industries and slices:

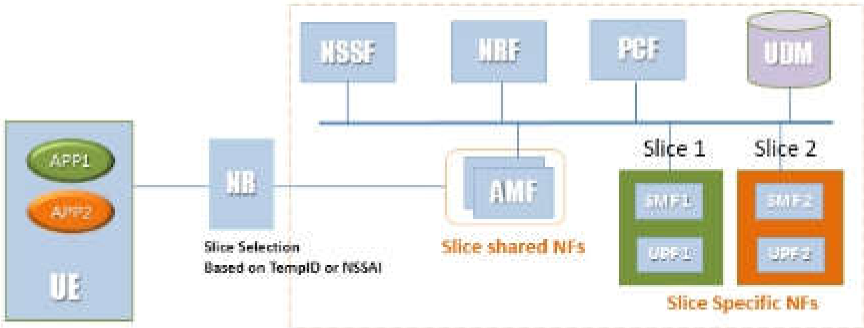
Slice Construction Based on Micro-services

The micro-service component warehouse is established by implementing modularized and micro-service design to 5GC NFs. It supports Network Function Service (NFS) defined by 3GPP, and also provides enhanced public service components such as LB (Load balance), HTTP and IPsec. According to the SLA requirements of slices, proper NFSs are selected to assemble NFs required by various types of slices, just liking build blocks, and then NFs are combined into the corresponding network slices, such as eMBB.



Intelligent Slice Selection

5GC supports the subscription of different slices for different UEs through UDM, and supports intelligent slice selection based on NSSF (Network Slice Selection Function). NSSF can select slice flexibly through the NSSAI requested by the UE and the subscribed NSSAI, location area, slice capacity and current slice load. Location-based information can be used to deploy large slices in regions and cities, and to deploy small slices such as sports competitions, concerts, and smart cells.



Through PCF, 5GC can customize NSSP (Network Slice Selection Policy) for different APPs of the UE, and deliver it to the UE, such as WeChat -> eMBB, meter reading application ->mMTC, and V2X application ->URLLC.

Flexible Networking of Slicing

5GC supports flexible networking in GROUP A, B and C sharing types. Where, GROUP A is that media plane and control plane NEs are not shared by slices, applicable to industrial control, telemedicine, smart grid and other scenarios with high isolation requirement. GROUP B is to share some control plane NEs but not media plane and other control plane NEs, applicable to V2X, smart city and such scenarios where terminals need to access multiple slices at the same time. GROUP

C is to share control plane NEs, and not share all media plane NEs, applicable to such scenarios as home entertainment and smart meter reading with low separation requirements and high cost sensitivity.

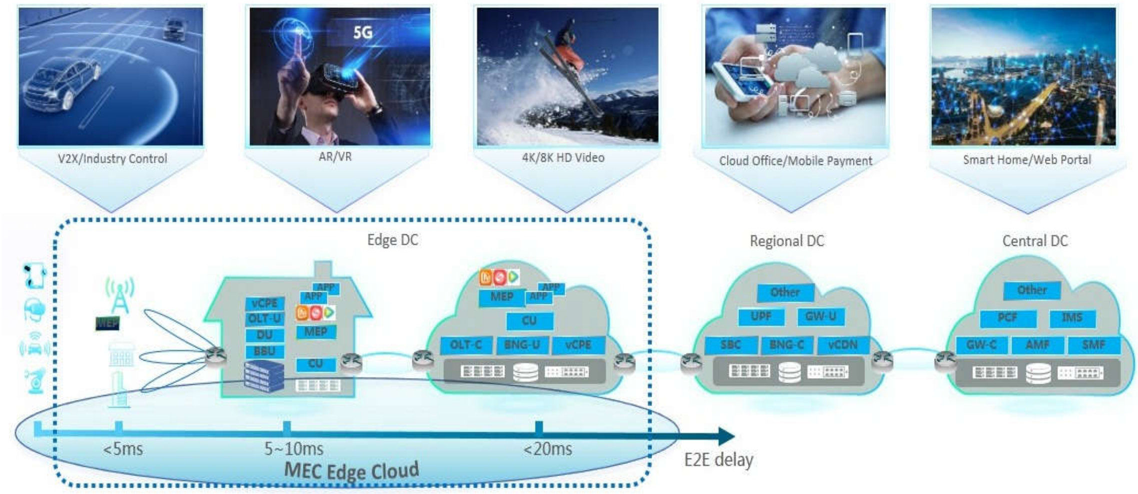
Slice Capability Exposure

5GC can open slice capabilities to the outside via NEF (Network Exposure Function). The application can obtain the status and location of the UE, and set the UE slice selection policy. It can also provide network services to external applications directly or through the capability exposure platform. It supports customized network function parameters, flexible QoS policy based on dynamic DPI, personalized slicing, and traffic path management, to intelligently meet the requirements of vertical industry applications for network slicing.

2.4 Focus on the Edge: Let computing power flow effectively

The traditional telecom network uses the centralized construction mode. As the service scale increases, the network becomes increasingly bloated, which cannot meet the development requirements of emerging services.

The 5G network is constructed base on cloudification, and is more lightweight and flexible. Based on the 3-level DC (center, region, edge) + base station equipment room, NEs can be deployed at the corresponding location in the network as required.



5GC has a natural attribute of CUPS, driving the cloud network evolving to the distributed cloud architecture. By building a 5G-oriented distributed cloud architecture, the user plane is moved to edge nodes and is deployed in combination with the MEC platform, effectively extending cloud computing power from the center to the edge to implement fast service processing and proximity-based forwarding, so as to meet diversified application scenarios of 5G.

Lightweight: By building multi-layer DCs, it provides a lightweight infrastructure platform at the edge to achieve unified scheduling and centralized management of resource pools in different physical locations. It implements flexible network service deployment and dynamic network resource coordination through orchestrators, so as to address the rapid development of various services.

Capability exposure: The MEC is deployed on edge DC to provide network edge computing capability for vertical applications. By relying on the MEC edge service platform and opening network capabilities (location, wireless network information, QoS, and bandwidth), it provides users with differentiated experience and improves operators' value-added income.

CUPS: The control plane is deployed in a centralized manner to improve the resource utilization. Traffic is forwarded on the user plane as required. Local service traffic is distributed to avoid traffic flow roundabout to the central network, reducing the transmission pressure and construction costs of backbone network.

SW+HW acceleration: The 5G user plane needs both strong forwarding capability and strong computing capability. It adopts multiple acceleration technologies, and improves service processing capability through software acceleration + hardware acceleration resource pools, thus reducing the forwarding cost per bit. With the help of FPGA hardware acceleration, services will be unloaded to SmartNIC for processing, meeting the end-to-end delay requirement (<1ms) of uRLLC.

2.5 New chemical reaction: AI + 5G O&M

AI is not only the brain of the cloud, but also a neural network that can learn and evolve, which is an extension of human intelligence. AI will enable 5G networks and optimize 5G networks. A 5G network with AI attributes will be a self-enabling network. Through the interaction between AI and 5G, 5G networks will be highly elastic, flexible, and intelligent.

Intelligent Assurance

- **Intelligent optimization**

In the 5G phase, NFs are orchestrated on demand. Operators can flexibly combine function modules in accordance with different scenarios and service features, and NFs will be deployed in more diversified modes. In addition, in terms of network resources, after the network is established, traffic varies with the network, and the resource utilization cannot be fully reasonable. If the dynamic scheduling network is based on traffic, the resource utilization rate will be greatly increased.

Therefore, AI-based accurate prediction and intelligent assurance will be the basis of intelligent 5G O&M, and AI will become the native capability of 5G networks. By collecting network operation data, the 5G intelligent assurance system establishes prediction models to predict and evaluate user behaviors, network services, and corresponding resource requirements in accordance with history data and real-time data, and then suggests appropriate measures (such as scaling out/in or changing network slices) in accordance with the operator's policies, so as to ensure that the corresponding resources can be provided in a timely manner when services change. For example:

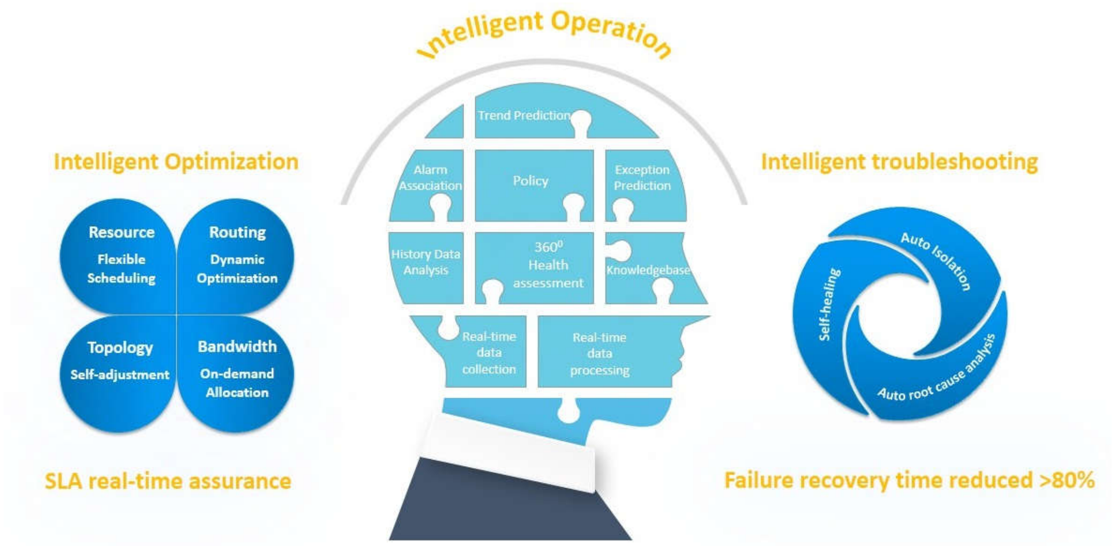
- In an IoT scenario, NS instances are automatically adjusted in accordance with signaling overheads.
- In the eMBB scenario, the SDN bandwidth is automatically adjusted according to the bandwidth usage.
- Network slicing has certain service features. It can be predicted that the

number of users and bandwidth usage in a specific area will rise to a certain level within a short period of time. In this case, the system suggests to scale out the network slice automatically in advance, including the time point of capacity expansion, selected resource pool, and allocated resource specifications. In this way, the overall network resource usage is reasonable, and intelligent management of network slices can be implemented.

- **Intelligent troubleshooting**

Compared with 2G/3G/4G, the 5G network is much more complicated and flexible. In the face of a large number of alarms that are generated every moment in the network, only by fully using machine learning to implement alarm association and locate the root cause, and by combining automatic fault diagnosis and recovery procedures, can potential faults be automatically solved in a closed loop, to reduce the number of work orders sent to the front line. Thus, O&M efficiency can be really improved.

Therefore, the Root Cause Analysis (RCA) system based on AI and expert experience is embedded with the AI engine. The alarm association rules are established through machine learning, and the troubleshooting rule database is optimized continuously, so as to achieve accurate root cause location. 75% of manual O&M cost is effectively reduced, and O&M efficiency is improved more than twice. This system protects the 5G network and helps operators accelerate digital O&M transformation.



Intelligent Operation

Slicing operation is a new feature of the 5G network. Different from traffic operation targeted at individual users in the 4G era, slicing operation mainly aims at providing differentiated SLA services for vertical industries. In addition, slicing operation can be packaged together with vertical industry applications and provided to individual customers. When users use a kind of applications, they automatically enjoy the bound slicing services. Thus a B2B2C business model is established.

Generally, slice operation is supported by the slice capability exposure platform. Based on the PaaS cloudification architecture, ZTE slice capability exposure platform can provide capability encapsulation of slice services to third parties, and help them customize, provision, and maintain slices by themselves. In addition, it can provide the capability of DevOps platform for third parties to develop and maintain slices-related applications online.

During the end-to-end slice operation, the following AI-based intelligent capability enhancements can be introduced:

Intent Engine

With Intent Engine introduced, the system can automatically translates users' slicing requirements into specific network languages and configuration policies, and guides the planning, design, construction, and activation of slicing networks, to achieve WYTIWYG slice operation.

Smart Portrait

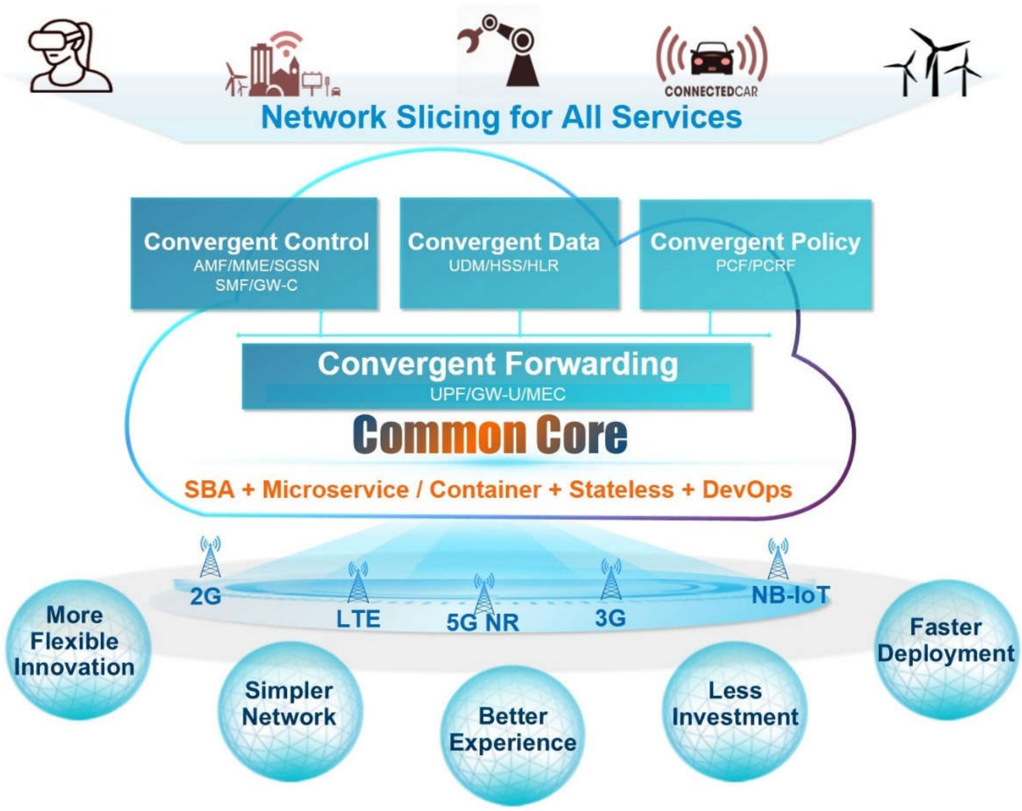
For slices of vertical industries, industry-specific slicing portraits are established for mass data analysis and mining for slices of the same type, to guide personalized optimized setting and industry application expansion.

Intelligent Customer Service

For the slice self-service portal, the intelligent slice customer service is introduced to provide intelligent interaction, consultation, slice package recommendation, individual slice customization and other services.

2.6 Evolution: Simplified Common Core

Both NSA and SA of 3GPP R15 focus on requirements of eMBB services at the early stage of 5G. Different operators select the corresponding deployment mode according to deployment time, spectrum situation, competition requirements and maturity of the industry chain. Because the 5GC NSA still uses the traditional 4G EPC, the architecture and functions have not changed much, and cannot address fast customization capability, slice-based operation capability and highly automated intelligent O&M capability. Therefore, a new 5GC needs to be built in the end. Considering the urgent requirements for cost reduction and service innovation of operators, a simplified Common Core is provided. It is oriented to 5G NSA/SA and meets the requirements for full access and integration of 2G/3G/4G/5G/Fixed.



Simplified Network Deployment:

Currently, traditional networks are being upgraded, and are not suitable for large-scale investment. Industry-leading operators are actively promoting the commercial use of virtualization. The deployment of 5GC through NFV can accelerate the speed of virtualization construction. The 5GC can be deployed with the following concepts:

Centralized deployment of control plane: This solution facilitates the unification of network-wide services, convenient for slice service development and network unification, reducing OPEX, and achieving centralized intelligent O&M.

Hierarchical deployment of user plane per stage: In the early stage, the 5G network is not large enough, and the user plane can be deployed in a centralized manner. In the middle and later stages, services are deployed in a hierarchical manner as required, and close to the access point. This reduces time delay and improves customer experience. The forwarding plane uses virtualization deployment to share resources across layers and solve the tidal effect during holidays.

Stage-by-stage construction of 5GC NF: In the initial stage of 5G deployment, basic NFs can be deployed first. Optional and unimportant NFs can be deployed later according to subsequent requirements. In this stage, 4G/5G integrated NE required by 3GPP can be deployed for interoperability. Later, more NFs will be deployed gradually to achieve full convergence of 4G/5G NEs.

Opening interconnection and interworking interfaces in stages: At the initial stage of 5G deployment, subscription interfaces, wireless terminal interfaces, 4G/5G interworking interfaces and NM charging interfaces are enabled to compress test and deployment time. In the future, more interfaces will be enabled to realize international roaming.

Simplified NFs:

Converged UDM+HSS is deployed to provide unified centralized management of 2G/3G/4G/5G user subscription data. In the early stage of 5G, it only needs to migrate the data of users upgraded from 4G to 5G. In the middle and later stage of 5G, original 4G users are gradually migrated to the new converged UDM+HSS according to the situation of traditional HLR/HSS equipment in the existing network. The provisioningfree solution can be used to avoid mass user migration in the early stage.

Converged user plane, converged policy plane and converged control plane are deployed to support seamless handover of 4/5G users. At the initial deployment stage of 5G, the converged control plane naturally supports the charging interface of 4G. Therefore, the charging interface of 4G can be still used to avoid large amount of reconstruction work resulting from the introduction of the new charging system of 5G, which may delay the commercial use of 5GC.

Simplified Service Deployment:

At the early stage of 5G deployment, the 5G voice standard defined by 3GPP R15 is almost mature for 5G voice services, and 5G voice terminals are going to put into commercial use in 2019. Mainstream operators around the world have deployed IMS networks to support VoLTE. In the early stage of 5G hotspot coverage, to reduce voice switching between 5G and 4G, it can upgrade software of IMS and combine with 5GC EPS Fallback to provide VoLTE voice service. As 5G coverage gradually expands to achieve continuous coverage, VoNR can be used directly to provide 5G voice.

3 Conclusion and Outlook

2019 is a recognized as the first year of 5G. On April 5, the three major Korean operators, SK Telecom, KT and LG U+ officially launched commercial 5G network services for ordinary consumers. Immediately after that, the Federal Communications Commission (FCC) of the USA announced the third millimeter-wave spectrum auction plan on April 16, and promised to invest more than 20 billion

US dollars to deploy 5G in rural areas. On April 23, China Unicom announced the provisioning of 5G trials in 40 cities at the Shanghai Partner Congress. The commercial use of 5G networks has gradually started worldwide.

According to ZTE, the 5GC should be an converged, intelligent, and simplified network to build a more efficient 5G network meeting IoT requirements of high bandwidth, low latency, and massive connections. ZTE was the first to launch the SBA+-based fully converged 2G/3G/4G/5G Common Core in the industry. Building one network to fully share and provide one-stop access for all network systems, greatly improving network operation efficiency and reducing network construction costs. On the 5G forwarding plane, ZTE launches the FPGA SmartNIC hardware acceleration solution on the basis of pure software acceleration of CPU, to better meet requirements of URLLC and eMBB for the forwarding capability of edge DC with low delay and high throughput. In addition, by combining 5G and AI technologies, Common Core achieves intelligent and automated 5G O&M, and comprehensively improves the intelligence level of 5G network.

ZTE is committed to building core 5G technology capabilities and actively applying 5G practices. ZTE has worked with more than 60 operators worldwide in 5G cooperation, and has experience in providing products and services for the commercial deployment of 5G. The launch of the 5G Common Core solution marks a solid step of ZTE towards the industrialization of 5G, laying the foundation for the commercial use and evolution of 5G.

- ✓ During the Mobile World Congress 2019, ZTE, together with Wind Tre and Open Fiber in Italy, made the first 5G NSA video call based on 5G smart phones across the Mediterranean Sea. This presentation was completely based on the 3GPP R15 standard, and is significant for the commercial use of 5G in Europe.

- ✓ In November 2018, ZTE and British Telecom JT Global signed the first 5G network agreement. Both parties will start 5G tests in 2019 and provide 5G services for the Channel Islands by 2021.
- ✓ In December 2018, ZTE and China Mobile jointly completed the world's first 5G new air interface data connection on the 2.6 GHz frequency band in compliance with 3GPP SA networking specifications, to jointly promote the commercial use of 5G.
- ✓ In December 2018, ZTE, together with China Telecom, completed the test of collaborative and bidirectional interoperability between 4G and 5G networks under the SA architecture.
- ✓ In December 2018, ZTE, China Unicom Tianjin and Tianjin Port jointly released the industrial application of 5G&MEC smart port, marking the successful implementation of this application in Tianjin Port. It will solve such problems as insufficient coverage, large latency and low speed in the original port area to improve the security management capability of unmanned vehicles, personnel inspection efficiency and problem tracking speed. This is one of the achievements of many cooperation projects between China Unicom and ZTE. Both parties will continue to

work hard to push 5G industrial applications into a deeper level.

- ✓ In December 2018, ZTE and China Unicom (Guangdong) took the lead in completing the 3GPP R15 5G NSA large-scale networking test in Shenzhen. This is the first success field test of large-scale NSA network architecture among 16 5G field tests and pilot cities for innovative services organized by China Unicom.
- ✓ In November 2018, ZTE cooperated with China Telecom to comprehensively promote the pilot and application of industrial applications. ZTE provisioned smart water control applications in Baiyangdian, dual-city 5G HD video conferencing, AR remote collaboration, AR control robotic arms, and 16-channel HD video download services, to further explore 5G vertical services in the field.
- ✓ In October 2018, ZTE, Baidu and China Telecom jointly completed the acceptance test of 5G converged self-driving car hosted by MIIT, which was the first major national science and technology project for 5G converged self-driving car.

In addition to promoting 5G commercialization together with operators and partners, ZTE is also an important developer and contributor to 5G standards. ZTE has become a member of more than 70 international standardization organizations and forums such as ITU, 3GPP, IEEE, NGMN, CCSA and ETSI. More than 30 experts have held important positions such as chairman and reporter in major international standardization organizations around the world. ZTE has submitted over 45,000 articles to the international standardization organizations. So far, ZTE has taken the lead in three 5G-related standard projects in the 3GPP core network field, including network slice fault monitoring, 3GPP and non-3GPP flow migration, and network slice enhancement.