Intel® Network Builders: Cloud Network Function

Background

Trends in Mobile Network Evolution

After more than twenty years of development, global mobile communications enters a new stage with the increasing popularity of mobile intelligent terminals in recent years. According to statistics, worldwide mobile data traffic in 2013 already exceeds that of traditional voice data traffic, an indicator of explosive growth. In response to the dramatic growth, mobile communication networks have begun to gradually transition from 3G to 4G, and work has already begun on the development of 5G technology. Even so, existing 2G and 3G networks will still be in use for a long time, making the entire mobile network more complicated due to the coexistence of different technologies. Another concern for mobile network operators is the rise of over-the-top (OTT) services that are reducing average revenue per user (ARPU).

The explosive growth of data traffic imposes greater requirements on network architecture from multiple aspects, such as capacity, delay, energy consumption, and quick provisioning of new services. From the 2G era with only voice data to the 4G/5G era with only packet data, the promise of mobile network evolution is to achieve simple and efficient mobile networks. Two major trends in mobile network evolution are network flattening and cloud computing.

- **Flattening**: LTE network architecture eliminates traditional controllers, whose functions were migrated to base stations and the core network. The result is a simplified, two-layer network architecture that requires fewer nodes for data transfer and reduces time delay in the system. In accordance with the flattening trend, future mobile networks will be architected with fewer layers. Network elements, which used to be deployed separately, will be deployed in a horizontal manner. It will be possible to design the entire mobile network in a unified way, enabling it to adapt to dynamic changes in service evolution.
- **Cloud computing**: Traditional network architecture with static configurations cannot satisfy the requirements on the new stage of development. New service models based on cloud computing technology are inevitable choices for future mobile networks. By taking advantage of the distributed cloud computing model, mobile network operators can offer cloud-based telecom services. The future direction for developing telecom networks is combining cloud-based services and telecom capability.

Challenges for Operators

Due to the rapid evolution of mobile networks, wireless networks from different generations will co-exist for quite a long time into the future. Telecom equipment deployed in traditional

Table of Contents

networks usually performs one network function and generally employs special architectures to support distinctive functions and maximize network performance. These two factors result in mobile networks with a large variety of equipment, which presents mobile network operators with more and more challenges:

- Continuously increasing TCO
  - **High-cost capacity expansion and generation update**: Mobile network operators addressing growing signaling and data traffic are finding it difficult to efficiently expand capacity across a wide assortment of network elements that are located in different areas. When the capacity of old equipment cannot be expanded, a new network plan is required, or the old equipment needs to be replaced. In addition, ensuring network security over time may require extra margin be reserved for each network element function, which further increases cost. Smooth and flexible capacity expansion that meets the demands of unpredictable traffic growth is one of the core requirements of mobile network operators.
  - **High operation and maintenance cost:** The operation and maintenance of mobile networks is more complex and difficult when special hardware and software is developed for each network function and network element. This is because each system is a potential capacity bottleneck, and capacity expansion requires a hardware upgrade or additional network elements, which greatly increases the workload on operations and maintenance departments.
  - **Increased energy consumption**: To ensure quality of service (QoS), network operators usually enable all types of network elements to operate at maximum capacity, resulting in higher power consumption than necessary. Since individual network elements may not be able to communicate with each other directly, it is difficult to implement dynamic capacity adjustments that could dramatically reduce energy consumption.
- Ineffective provisioning of new services
  - **Purpose-built platforms with tightly-coupled software and hardware:** Telecom equipment platforms are often closed, custom designs based on tightly-coupled software and hardware, and since they are not open, the ability of telecom operators to deliver innovative services is limited by equipment vendors. Moreover, operator infrastructure investments are not protected because new hardware and software is often required for the provisioning and deployment of new services and applications.
  - **Long cycle of development and high cost of customization:** Development cycles for network evolution standardization, new functions, and equipment are long. Frequent function customization results in high cost.

Facing these challenges, mobile network operators are in urgent need of an economical, integrated network solution that addresses network evolution trends to achieve simple and effective mobile networks.

Technology Developments

To overcome the challenges facing network operators and meet the demands of network evolution, many new technologies and architectures have been introduced to telecom networks, providing strong motivation for mobile network innovation.

- **Virtualization:** Virtualization refers to the logical representation of a resource. This representation is not limited by physical restrictions. The purpose of virtualization is to simplify the allocation, access, configuration, and management of IT resources (such as infrastructure, system, and software), and provide standard interfaces for these resources to receive and transmit data. Nowadays, virtualization has been widely implemented, not only on servers, but also on the application layer, the presentation layer, desktop, storage, and networks. There is no doubt that virtualization is reconstructing the IT industry and supporting cloud computing.
- **Cloud computing:** Cloud computing is regarded as the next revolution in technology, which will change the existing working modes and business models. Cloud computing provides three categories of services: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). All these services are based on a virtual platform. OpenStack is a cloud computing project that provides an open source platform, and its community helps set up and manage public and private clouds. Many organizations, companies, and developers, especially IT entrepreneurs, joined the project, promoting the development of the OpenStack.
- **NFV:** The main principle of Network Functions Virtualization (NFV) is the separation of software and hardware. NFV is based on a common hardware platform (e.g., Intel® Architecture) or a cloud computing virtualization platform, on which different applications and functions run as software. Virtualization technology is used to classify hardware resources into individual virtual compute, storage, and networking resources, which are utilized by the applications. In mobile networks, the implementation of NFV enables different network element functions to run on a common hardware platform whose resources are fully shared and reused. NFV significantly helps network operators to reduce hardware investment, and operation and maintenance costs, and quickly deploy new services as needed.
- **SDN:** The key principle of Software Defined Networking (SDN) is the separation of control and forwarding functions. SDN is driving the transition from traditional closed network equipment that is vertically integrated to open network equipment that is horizontally extended. In addition, SDN defines open API interfaces for launching new services and third-party applications, which greatly improves the intelligent control, scalability, and openness of networks. When SDN concepts are applied to telecom mobile networks, for example, the gateway forwarding function is separated from the core network. This approach solves capacity issues at greatly improved forwarding efficiency and reduced cost compared to today's networks. In addition, the intelligent control in access networks can support more efficient resource coordination strategies.

A new mobile network infrastructure and equipment model for the future are being formed with the development and combination of communications and IT technologies, and the evolution of mobile networks.

Cloud NF Solution

General Architecture

In consideration of the diversity of network element features and functions, core requirements of network operators, and technology evolution, ZTE breaks the boundaries of traditional network equipment in mobile networks and redefines the architecture of mobile networks based on a unified telecom-oriented cloud platform, bringing a revolutionary change in telecom infrastructure deployment. In accordance with the architecture defined by ZTE, the mobile network evolves into three clouds: Cloud Network Function (Cloud NF), Cloud Radio, and Cloud Service, as illustrated in Figure 1. This architecture not only

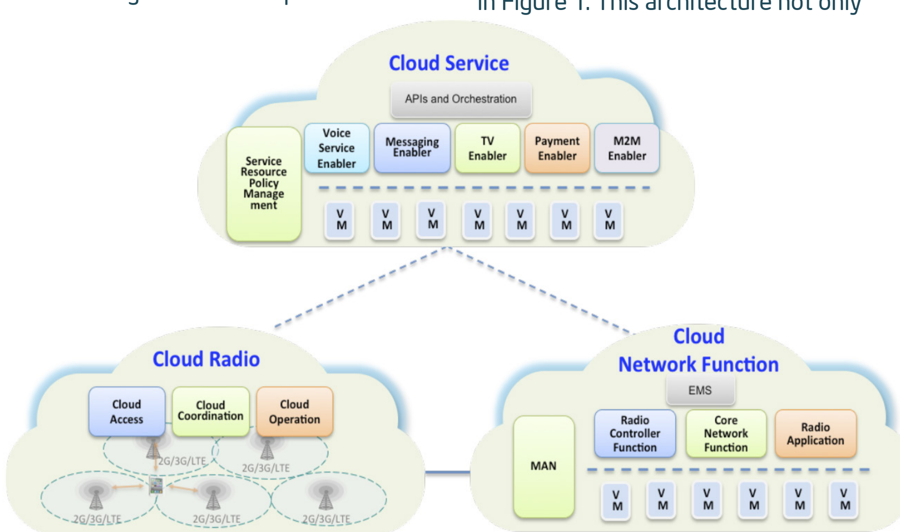

Figure 1. ZTE Mobile Network Architecture

satisfies the requirements of 2G, 3G, and 4G networks, but also supports the evolution to 5G networks.

Cloud Radio, as a cloud for the radio access layer, can intelligently select the optimal coordination mode in accordance with the mobile network architecture and the mobile bearer conditions, effectively suppress inter-cell interferences in the mobile network, and greatly improve the network performance.

Cloud Service runs services in a cloud and leverages cloud technology to offer operators greater network manageability and elasticity, such as service convergence, and dynamic resource sharing and scheduling. The Cloud Service significantly reduces the deployment time for new services and enables an improved customer experience.

Cloud NF is a cloud for the network layer supporting multiple radio access technologies, including 2G, 3G, and 4G. It implements the functions of the core network and controllers. The subsequent section focuses on Cloud NF.

Cloud NF

Cloud NF integrates the functions of the core network and controller through NFV. It uses the virtualization technology to separate hardware from software in the architecture and integrates all network element functions of a mobile network. In addition, Cloud NF applies SDN concepts to separate the gateway forwarding function from the core network, which improves forwarding efficiency. The functional architecture of the Cloud NF is illustrated in Figure 2.

Cloud NF uses a cloud management system to combine the computing, storage, and network resources into common resources on a unified infrastructure platform. Each network element function is deployed on the unified lower-layer platform as a software function. Cloud NF includes the following functions:

- **Controller:** 2G BSC, 3G RNC, small cell access gateway (Femto GW), Security Gateway (SeGW), and the Radio Resource Policy Controller (RRPC) supporting cross-layer intelligent coordination and control of multi-technology resources.
- **Core Network:** The control plan network elements and complex data processing functions of user plan network elements. A user plane network element can separate the forward part, based on the SDN architecture, to form a forwarding plan.
- **eAPP:** Enhanced wireless-related applications.

The hierarchical architecture of Cloud NF consists of three domains: Management (MAN), Virtualized Network Functions (VNF), and enhanced radio applications (eAPP), as illustrated in Figure 3. The physical infrastructure platform, using the latest COTS or ATCA blade, provides common computing, storage, and network services to upper layers. This platform can use ZTE telecom oriented physical infrastructure or third-party physical infrastructure.

- **MAN:** Management system includes OSS/BSS, Orchestrator, VNF Manager, Virtualized Infrastructure Manager, and SDN Control. The Orchestrator automates standard operation procedures across different systems, platforms, and equipment from different vendors. The Orchestrator is responsible for the lifecycle management of network services across the entire operator's domain. The VNF Manager is responsible for the lifecycle management of VNF. This includes VNF instantiation, configuration, scaling and so on. The Virtualized Infrastructure Manager (VIM) is responsible for controlling and managing the NFVI computing, storage, and network resources, usually within an operator's infrastructure sub-domain. I-SDN Ctrl is responsible for network and service for two levels of routing control functions.

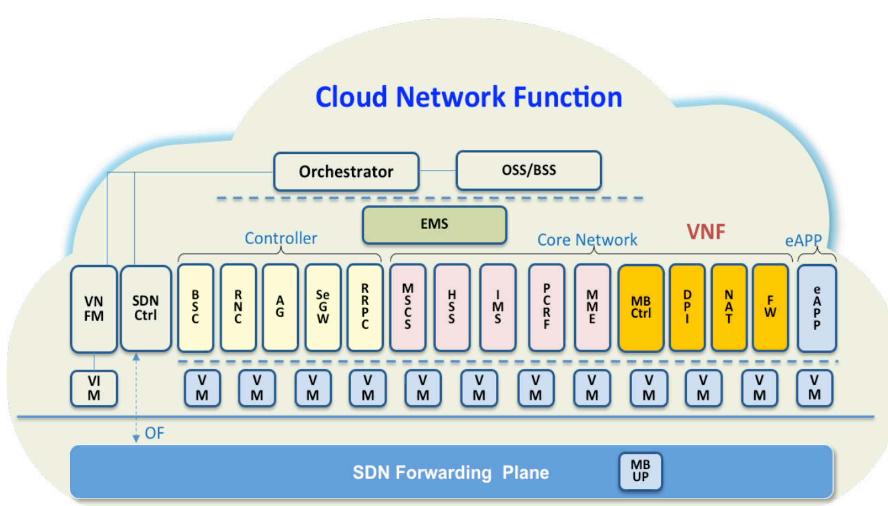

Figure 2. Cloud NF Functional Architecture

- **VNF:** The VNF provides EMC, core network, and controllers. In addition, each VNF is divided into virtual functional components that can be shared. These flexible components can be configured as needed by processing procedures, making it easier to develop innovative services.
- **eAPP:** Specific radio-related services can be deployed here, for example, network optimization, big data application, or operator-specific application.

Cloud NF can be flexibly deployed to satisfy a network operator's network scale and coverage requirements, and unified resource management allows resources to be better adapted with respect to their geographical distribution and the characteristics of the mobile network.

Cloud NF architecture changes the mobile network deployment mode from independent planning and deployment of individual network elements to horizontal deployment. The entire mobile network can be planned in a unified manner so it is capable of adapting to dynamic changes in service evolution. Cloud NF determines the quantity and capacity requirements of each type of network element (NE) in accordance with the network capacity and different planning parameters (such as in a traffic model). It converts the requirements into requests for virtual machine resources, storage resources, and network resources through the internal processing model of each NE type, and then loads the corresponding software into these NEs. In this way, Cloud NF can adjust and provide NE resources dynamically in accordance with service requirements.

Cloud NF architecture provides an efficient solution for deploying multi-mode 2G/3G/4G multi-layer networks. It perfectly satisfies the demands for legacy networks and future network evolution.

The openness of Cloud NF architecture allows network operators to deploy third-party applications and flexibly deploy VNF on local platforms.

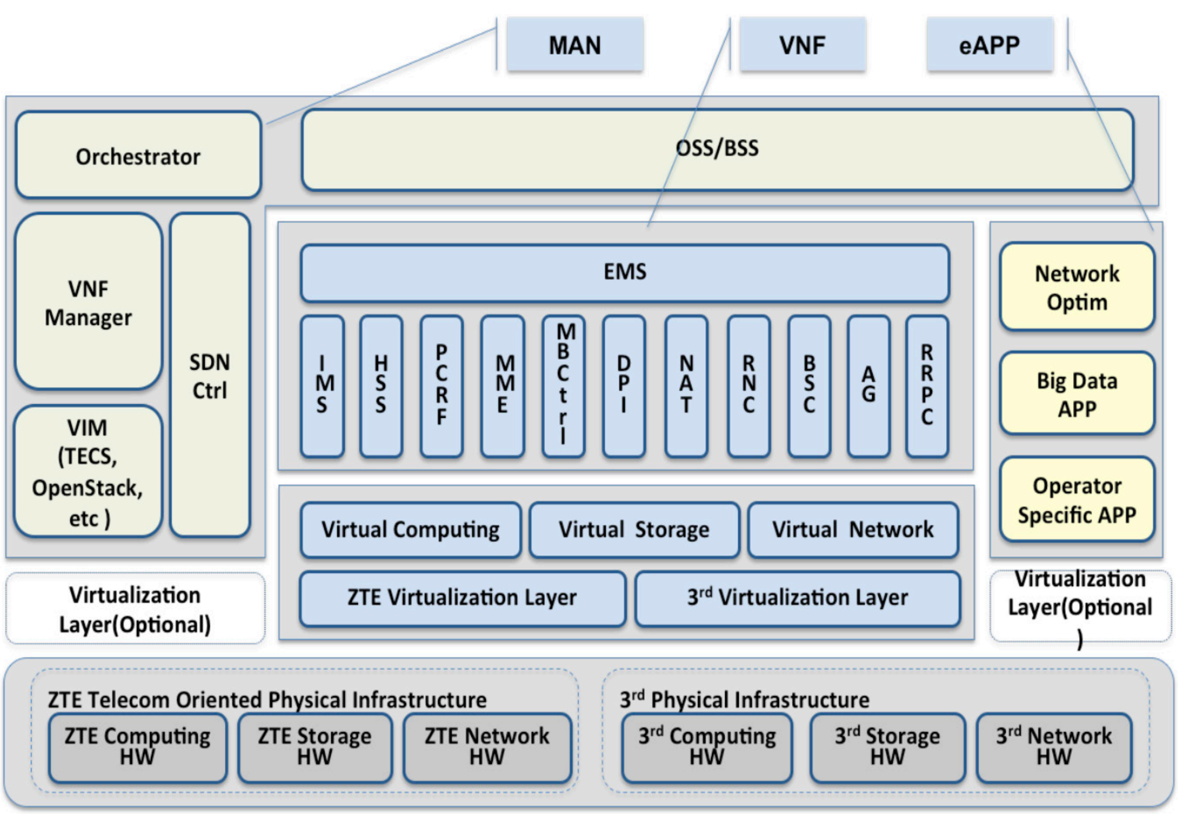

Figure 3. Cloud NF Hierarchical Architecture

Values Created for Customers

Common Hardware Platform

Cloud NF uses a common hardware platform, which is different from traditional special hardware platforms. The common hardware platform is not developed for special software, and is instead decoupled from software. The common hardware platform has obvious advantages in scalability, flexibility, and evolution capability.

The hardware platform reflects its scalability with its capability of capacity expansion on demand. The hardware platform of Cloud NF can be implemented as a small system with a single shelf or a large cluster system with hundreds of shelves and thousands of hardware servers.

The versatile hardware platform of Cloud NF supports flexible deployment of network functions. All virtualized network element functions of the core network, radio access network controllers, and higher-layer control network elements, and various third-party compute-oriented applications can run on the hardware platform. By using the common hardware platform, network operators can deploy different network functions on the same site, the same rack, the same shelf, or even the same board. The common hardware platform greatly reduces the required types of hardware platforms in mobile networks, simplifying network deployment and reducing installation, debugging, integration, and maintenance costs.

In collaboration with Intel, ZTE uses a common Intel architecture hardware platform to build an entire system. ZTE is one of the leading innovators using the underlying development software for wireless system solutions provided by Intel. The software includes the Intel® Data Plane Development Kit (Intel® DPDK), real-time virtualization software, optimized Open vSwitch, and enhanced management software, among other components. Using this software, the ZTE Wireless NFV solution achieves good performance.

The common hardware platform adopts the latest hardware technologies and helps network operators benefit from the latest developments in the IT industry.

Virtualized Network Functions

Cloud NF consists of a physical infrastructure platform, an infrastructure virtualization layer, a virtualized network function layer, and a management layer.

The infrastructure virtualization layer, using telecom-level virtualization technology, provides common compute, storage, and network services to upper layers. This layer provides solutions focusing on reliability and performance in accordance with telecom application characteristics. It provides multiple external management interfaces that are compatible with the OpenStack API.

Since virtualization technology decouples hardware from software, the virtualized network functions become independent of special hardware systems. The standard interfaces of the virtualized network functions are compatible

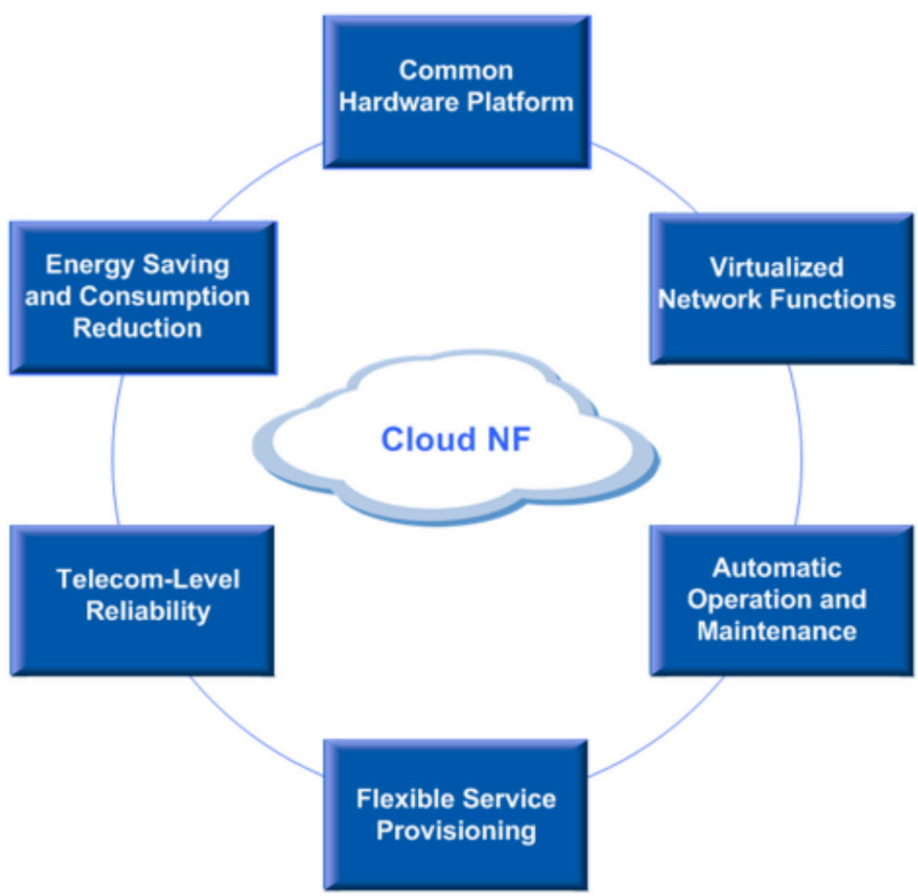

Figure 4. Cloud NF Benefits

with network elements in the existing networks, thus their capabilities do not change. The virtualized network functions can be flexibly deployed, in that a new network function can be deployed on existing hardware, and an existing network function can be extended or deployed on a new hardware system.

Virtualization makes software deployment more convenient. Cloud NF provides an automatic and quick deployment feature for mobile network equipment to reduce the commissioning cost and provides a quick software version switching feature to reduce potential risks in the upgrade of network equipment, and thus improves network stability.

Automatic Operation and Maintenance

Supported by the cloud platform, a system itself can complete hardware (boards and shelves) and software installations and service configurations. Automatic installation and configuration not only reduces the workload of operation and maintenance personnel but also greatly improves the deployment speed and quality. The advantages of Cloud NF are obvious in plug-and-play and on-demand elastic capacity scenarios.

The plug-and-play feature allows the system to directly add new hardware resources when capacity expansion is required due to an increasing number of users. After new hardware is added, the cloud platform puts the hardware into the resource pool and then allocates the hardware resources in accordance with application requirements. In this way, the configuration workload is greatly reduced.

The infrastructure layer of Cloud NF provides a huge basic resource pool shared by the upper layers. The virtualized network functions can use this resource pool on demand to achieve capacity elasticity. Network operators need not predict the capacity requirement of each network element (NE). Each NE on Cloud NF automatically computes its required capacity according to the traffic volume and sends a capacity request to the NFVO, which automatically allocates new processing resources to the NE. These resources can be automatically activated and added to the capacity of the NE. On the other hand, when the NE detects a decrease in traffic, it releases its unused capacity and notifies the NFVO to retrieve the released processing resources.

Network functions running on the upper layers need not know about the hardware expansion process of Cloud NF infrastructure. After being successfully managed by the infrastructure administrator, the new hardware resources become available and can be requested by upper-layer network functions at any time.

The automatic network capacity expansion on demand makes the network planning easier, reduces risk, and provides a powerful mechanism for handling traffic bursts in the network. Due to the elastic capacity feature, the infrastructure resources of Cloud NF form a dynamic resource pool that can be fully utilized by all network elements.

Flexible Service Provisioning

The Cloud NF solution can greatly reduce the cycle of service provisioning through remote software configuration because new or additional hardware is not required. The Cloud NF supports convenient network sharing and allows the provisioning of diverse special services on the same network. In addition, various third-party applications can be deployed quickly. The openness of the Cloud NF supports service innovation and enables network operators to provide better network services.

Telecom-Level Reliability

The Cloud NF supports backup at multiple layers, such as the node layer, virtual machine layer, and the service layer, thereby enabling high reliability required for telecom equipment. It provides multiple backup modes based on the characteristics of telecom services, such as 1+1, N+1, and pool. In a traditional telecom system, the 1+1 backup mode is used, which allows an active board to fail over to the corresponding standby board; however, a single-point failure still exists in the system. The automatic creation of backup function on Cloud NF eliminates the possibility of single-point failures in the system, further improving the reliability.

Energy Saving and Consumption Reduction

It is possible to significantly reduce power consumption during periods of low demand. This is accomplished by routing the workload to a subset of the available resources and powering down the rest. For example, peak traffic periods may require eight processor cores, whereas low traffic periods may only warrant two cores; thus six cores can be powered down. When this power control mechanism is implemented across a cabinet, energy consumption during off-peak times can be reduced by hundreds of watts, or greater.

The infrastructure of Cloud NF uses energy-saving, multi-core processors. Each compute node has an energy-saving shutdown feature. The energy-saving control mechanism includes: shutting down unused processors, concentrating virtual machines on fewer physical machines to reduce the number of active physical machines, and shutting down unused physical machines. When capacity expansion is required for the virtualized network elements, the resources in energy saving mode can be automatically activated to meet the requirements of capacity expansion. Power control can also be implemented at other levels: processor, blade, and rack.

New Challenges Due to Cloud NF

The horizontal deployment mode of Cloud NF brings new challenges to network operators. They are:

- **Equipment room construction and renovation:** If existing equipment rooms do not meet the requirements for constructing a cloud-based mobile network, a significant investment may be required for equipment room renovation and possibly for the construction of a data center.

  ZTE makes distributed data centers available to operators, enabling them to smoothly transition to a virtualized infrastructure, making existing rooms available for other things.

- **Impacts on network planning:** The change from planning network elements separately to comprehensive network planning requires that network operators take a holistic view when planning a network and consider their data center requirements, including the location and capacity, the deployment of bearer networks between the data center and the access network, and those between data centers.

  ZTE can provide dedicated network planning tools to help with this task.

- **Impacts on operation and maintenance architecture:** A set of OSS and BSS systems based on NFV and SDN is required to convert the planned network element summary templates into network element demands for virtualized resources, and create and bind virtualized resources in the data center. This system monitors physical and virtualized resources in a unified manner, and automatically adjusts the allocation of virtualized resources depending on the network element load. It separates the operation and maintenance of hardware resources from the network element operation and maintenance, supporting unified operation and maintenance of the cloud resource platform and network elements.

- **Change of QoS:** Because virtualized resources are deployed for network elements, all of the following must be monitored and coordinated at the same time: the operating status and events on the infrastructure platform, the infrastructure virtualization layer, the virtualized network function layer, and the management layer. Therefore, new methods must be used for fault location and service guarantee.

  To solve these problems, ZTE uses dynamic resource allocation and mapping strategy.

- **Impacts on multi-vendor interoperability testing (IOT):** In addition to traditional 3GPP standard interface interoperability testing (IOT) a network based on Cloud NF architecture contains the infrastructure platform, the infrastructure virtualization layer, the virtualized network function layer, and the management layer. Because equipment on each layer is purchased independently from different vendors, IOT is required for equipment on each layer to guarantee equipment operation and quality.

ZTE offers the following options:

- A complete, vertically integrated solution (no need for IOT between different layers).
- ZTE also provides open interfaces.

Network operators can overcome these challenges after good preparation. Although network operators have to increase the investment at the early stage of renovation, the use of the common hardware platform and network function virtualization will ultimately reduce their TCO and facilitate quick provisioning of new services. Network operators who change their way of thinking about network operation and maintenance, as well as the working mode, will be well prepared for mobile network evolution.

Conclusions

With the maturity of the NFV and SDN industry chain, mobile networks are evolving to be an open, elastic, controllable, and automated network. In the evolution process to 4G, 2G, 3G, and 4G networks will co-exist for a long time. As key equipment in 2G and 3G networks, radio network controllers play a critical role in evolution. To maximize the benefits, network operators not only need to deploy the best LTE networks but also solve 2G and 3G transition problems. A complete cloud solution providing a platform shared by radio network controllers and the core network is an inevitable choice. ZTE's mobile network virtualization solution, Cloud NF, is a world-class choice for network operators.

Acronyms and Abbreviations

ACRONYMS AND ABBREVIATIONS	
ACRONYM/ ABBREVIATION	FULL NAME
OTT	Over The Top
ARPU	Average Revenue Per User
TCO	Total Cost of Ownership
IaaS	Infrastructure as a Service
PaaS	Platform as a Service
SaaS	Software as a Service
NFV	Network Functions Virtualization
SDN	Software Defined Network
IA	Intel Architecture
API	Application Programming Interface
APP	Application
RRPC	Radio Resource Policy Controller
TECS	Telecom Elastic Cloud System
VM	Virtual Machine
VNF	Virtualized Network Function
NFVO	Network Function Virtualization Orchestration
IOT	Interoperability Test