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ZTE TECHNOLOGIES

VIP Voice

Indonesia's Communications and Informatics Minister Johnny G. Plate: Unlocking the Nation's Digital Potential

Expert Views

Intelligent IP Network in 5G and Cloud Era

Special Topic

5G Intelligent IP

Cover Figure | *Johnny G. Plate, Minister of Communications and Informatics of the Republic of Indonesia*

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Indonesia's Communications and Informatics Minister Johnny G. Plate: Unlocking the Nation's Digital Potential

Reporter: Shena Agusta

Johnny G. Plate, Minister of Communications and Informatics of the Republic of Indonesia

Telecommunication is a crucial engine to accelerate economic growth. Johnny G. Plate, Minister of Communications and Informatics of the Republic of Indonesia, shares with us the plans to advance 5G in the country as well as the steps taken to advance digital connectivity across Indonesia.

As we all know, technology continues to evolve and we are currently entering the era of 5G network. We all expect that the 5G network will accelerate digital transformation and consequently boost economic growth all across the industries. As of 2021, we have seen a few operators launching 5G network within the country, however, in comparison to other countries within the region, the scope of the 5G network in Indonesia is still considered limited. Could you tell us more about the plans formulated by the Ministry of Communications and Informatics to expand the 5G network across the archipelago?

As of now, the 4G network is still the backbone of telecommunication network in Indonesia, however, we have recently also started deploying 5G network. We plan to accelerate the deployment of 5G network to unlock the growth potential across multiple industries. Starting from the second semester of 2021, three of our national cellular operators, namely Telkomsel, Indosat, and XL Axiata, have received government approvals to commence their commercial 5G service within the country.

This 5G commercial service will be available in selected residential areas and hotspots in 13 cities, such as Medan, Batam, Pekanbaru, Palembang, Jakarta, Bandung, Yogyakarta, Solo, Surabaya, Denpasar, Banjarmasin, Balikpapan dan Makassar. This 5G “Experience” will also be held at the Mandalika MotoGP 2022 and indeed at the G20 summit this year.

To support the 5G network, we are now preparing various spectrum bands through the farming and refarming of frequency spectrum in all levels of bands—in low band, capacity band, and super high band.

As the largest country in ASEAN with a vast landscape and topography, it is quite challenging for Indonesia to widespread the telecommunication infrastructure all across the country. The ambitious BAKTI program designed by the Ministry of Communications and Informatics is set out to achieve telecommunication connectivity across the archipelago. What can you share with us regarding the implementation of the 4G network for the aforementioned BAKTI program in the 3T zone in Indonesia?

Indonesia, as one of the world's largest archipelago with a unique topography, landscape and a population of more than 273 million inhabitants, will inevitably have to face challenges in advancing digital connectivity across Indonesia, particularly in the outermost, frontline and less developed regions. In order to provide a robust internet connectivity, we will be taking crucial steps to advance Indonesia’s digital connectivity, particularly in the frontier and rural regions.

Providing connectivity has been proven to improve digital entrepreneurship and the welfare of the people, particularly among the small and medium sized businesses.

An example of such successful digital entrepreneurship in the rural area can be seen in the story of a West Papuan young man, Simon Tabuni, who has been using

digital platforms to collaborate with 60 farmer groups and 525 individual farmers to sell their fruits and vegetables online. Thus, adoption of connectivity technology has the ability to uplift livelihood in many areas throughout Indonesia.

Another priority initiative by the Ministry of Communications and Informatics is the Analog Switch Off/ASO (Migration to Digital TV). Once this has been established, how do you imagine frequency spectrum would help the development of ICT infrastructure, such as the 5G in the rural areas, and 5G for public safety?

As a result of broadcast Analog Switch Off (ASO), 112 MHz digital dividend in 700 MHz spectrum will be available to support 4G and 5G technology in Indonesia on top of coverage band and super high band spectrum. We are currently preparing frequency spectrum balance sheet to anticipate the fast growth of telecommunication and digital technology in Indonesia.

How do you envision the development of the ICT industry in Indonesia in the next 5 years? What role do you hope a technology provider company, such as ZTE, will take on?

As the 4G and 5G networks continue to grow in the next 5 years, the usage of 5G will also broaden and vary, and this will certainly affect the ICT industry in Indonesia. We therefore plan to continue to expand the commercial 5G network.

This expansion of the 5G network is aligned with Indonesia's digital transformation agenda, which aims to unlock the digital potential of the entire nation, as outlined in Indonesia's Digital Roadmap 2021–2024.

It is also imperative and we certainly encourage global technology companies to comply with 35% of local content (local assembly and manufacturing) of 4G and 5G ICT system and devices, to support an inclusive and resilient digital breakthrough, and innovation in Indonesia.

Indonesia market is very big now. We are expecting billions of dollars of investment in Indonesia. I personally invite technology companies such as ZTE which is already in Indonesia, and also already working closely with the Ministry of Communications and Informatics to do more, invest more, and to improve collaboration between Indonesia and China. ZTE TECHNOLOGIES

Intelligent IP Network in 5G and Cloud Era

Tao Wenqiang
Chief Planning Engineer of ZTE IP Product

With the advent of the 5G and cloud era, new services bring new opportunities for operators. VR/AR will become the next application with over 10 million users after IPTV, which brings ultimate experience to users while imposing high bandwidth requirements. It is expected that the network traffic will increase 10 fold over the next 10 years. With the application of 5G into various industries, the IP network will be expanded from the public network oriented to 2C services to the production network oriented to 2B vertical industries, bringing huge market opportunities. According to the forecast of MIIT and Gartner, by 2025 more than one million new enterprises will move onto the cloud, and 85% of enterprise applications will be based on cloud in China. To migrate massive enterprise applications to the cloud, the network should be able to support large bandwidth, fast provisioning, fast fault location and committed SLA for services.

How to meet the challenges imposed by new services on the network? ZTE believes that we need to adjust the network architecture first by designing an elastic, programmable, and intent-based network architecture based on AI and automation technology.

The IP network architecture oriented to the 5G and cloud era can be divided into three layers: network layer, service layer, and management & control layer (Fig. 1). The features of each layer are described below.

- **Network layer:** It allows flexible network programming, intelligent traffic tuning and differentiated SLA guarantees. New networking technologies such as SR, SRv6 and BIER are used to make paths programmable and implement flexible service chain processing. Intelligent traffic tuning is used to avoid congestion of important services and improve link resource utilization rate. For differentiated SLA guarantees, SR-TE/FlexE/TSN technologies are used to allow the network layer to flexibly perform software and hardware slicing in accordance with service characteristics to guarantee service isolation and specific SLA attributes.
- **Service layer:** It supports agile service

provisioning and intelligent and elastic scaling. It can implement flexible on-demand service provisioning and dynamic bandwidth adjustment. The services can be created agilely, provisioned in minutes, and scaled on-demand.

- **Management & control layer:** It supports automatic orchestration, network visibility and real-time perception. The automatic orchestration at the management & control layer is capable of full-scenario, cross-manufacturer and cross-domain orchestration. Big data collection and analysis is used to realize in-depth network visualization and real-time perception. AI is injected to implement intelligent fault location and predictive O&M.

Ultra-Broadband Network: High-Integration and Large-Capacity Core Chips Being the Cornerstone

The continuous increase in telecom network traffic increases operators' bandwidth costs and seriously affects operators' return on investment (ROI). Therefore, it is critical for operators to reduce transmission costs per bit while increasing the network capacity. In terms of the core engine of IP products—chips, ZTE has been committed to the development of in-house network processor (NP) and made technological innovations in the following aspects to improve the performance of NP.

- **Parallel processing of multiple processors:** Increasing the number of processors, enabling one processor to process multiple threads, and updating technology process to continuously improve the processing power of chips.
- **Large-capacity internal storage:** Internally integrating HBM and TCAM to break through the bandwidth bottleneck in processor table queries and packet processing cache access, ensuring sustainable improvement of NP performance.

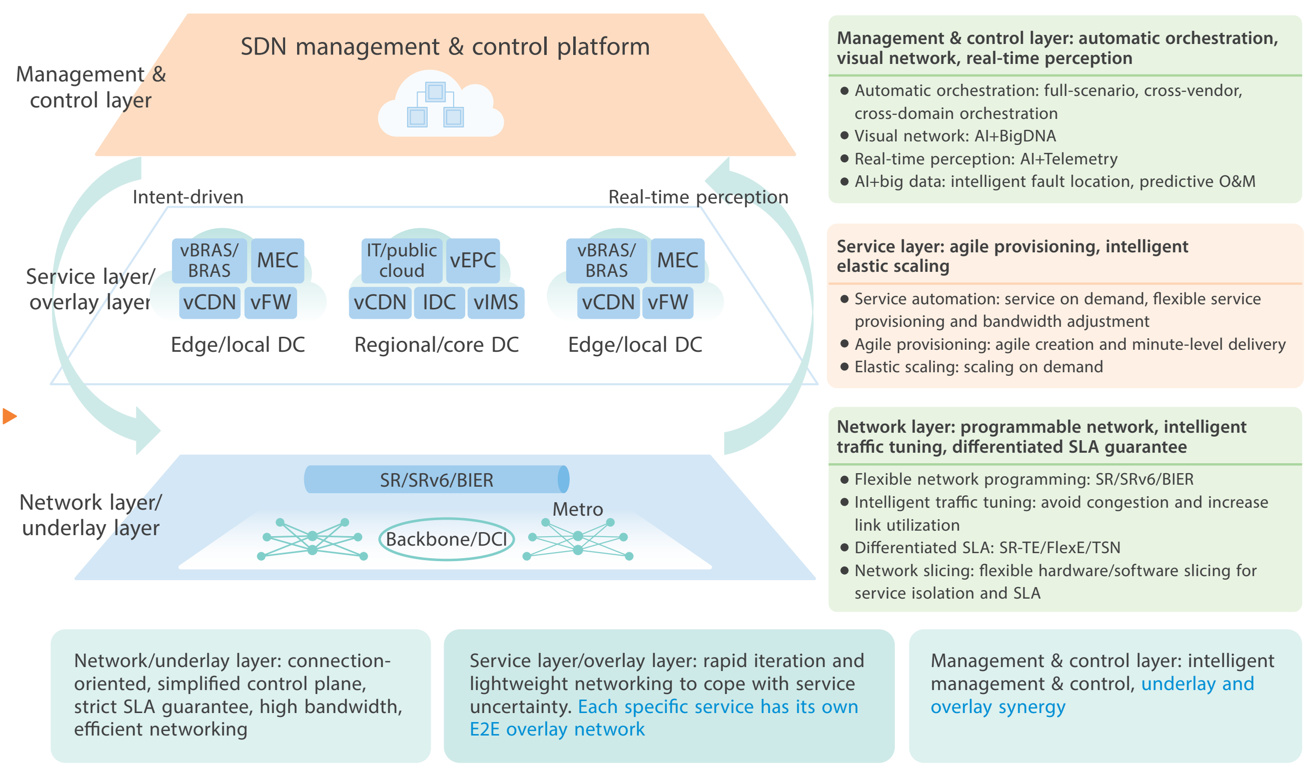


Fig. 1. Overall network architecture.

- **Ultra-high integration:** Integrating 10 GE/40 GE/50 GE/100 GE/200 GE/400 GE MAC. ZTE's in-house NP is the first chip in the industry that is integrated with FlexE and supports time slot cross-connection at the PCS layer inside the chip. The delay of the chip can reach 1 us, providing strong hard slicing capability for 5G transport. Meanwhile, the chip compliant with 1588v2 can obtain ultra-high precision timestamps with their single-level precision reaching the industry-leading 1 ns, meeting the ultra-high-precision clock requirements of 5G transport. In addition, the chip is also integrated with large-queue TM to provide differentiated QoS guarantees.

ZTE's in-house high-performance NP can meet the urgent requirements of full-scenario services including 5G mobile, home broadband, private line and cloud for increasing network bandwidth, and help operators build ultra-broadband networks with ultimate experience.

In addition, the high density, high speed and high power consumption trends of IP equipment in the 5G and cloud era lead to rapid growth in power consumption and heat density. Dedicated to the R&D of innovative cooling technology, ZTE has proposed the dual-phase liquid cooling technology. The new liquid cooling technology has a heat dissipation capability of over 40 KW per integrated equipment. Based on the power consumption of existing chips, it can meet the heat dissipation requirements of super-large core routers with a capacity of 10T+ per slot. Compared with the traditional air cooling technology, it can reduce the noise by over 80% and the energy consumption by over 30%, showing obvious advantages in energy saving and consumption reduction.

Simplified Protocols: Simplifying Network Deployment and Opening the Network

ZTE has been cooperating with operators to actively explore new 5G business models and launch innovative network services to meet differentiated SLA requirements in 2C and 2B scenarios.

SR/SRv6 as the major transport protocol of the network eases the difficulty in cross-domain configuration due to various types of IP network protocols. The simplified protocol makes the automatic configuration more rapid and accurate. SRv6 intelligent routing is implemented, which allows the optimal path to be chosen based on the service delay requirement to guarantee the low latency requirement of key services.

ZTE is a leader in the development of the new multicast protocol BIER, contributing more than one third of BIER standards. The BIER multicast technology solves the innate defects of existing multicast protocols, such as the need to maintain a large amount of multicast state information at intermediate nodes and slow multicast route convergence. In combination with SDN, BIER enables on-demand multicast services (such as OTT video multicast service), saving a large amount of bandwidth (Fig. 2). OTT service providers can implement controllable multicast services on operator networks to provide HD video applications.

Deterministic Service Transport: Strict SLA Guarantee for 5G Applications in Various Industries

In a traditional network, all services share and preempt bandwidth resources, so the

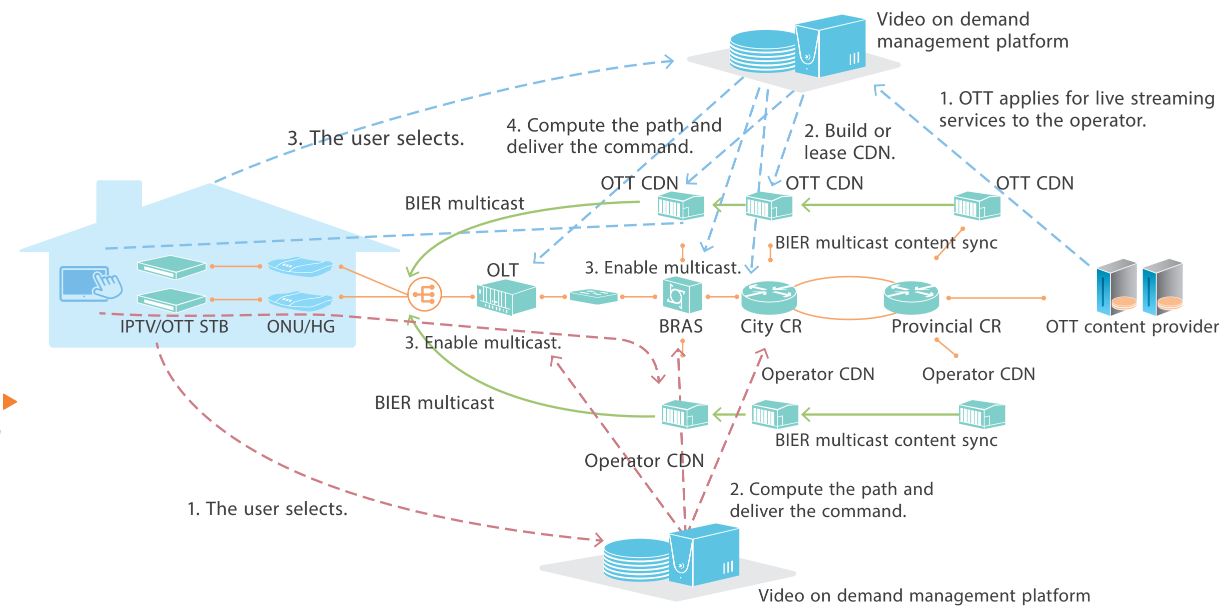


Fig. 2. Solution for OTT high-definition live streaming.

No restriction on the number of multicast groups, supporting massive video services	No need to maintain multicast group status, only need to perceive at edge nodes	Accessed users are controllable, service contents are on demand

OTT can implement on-demand multicast services on operator networks, saving substantial bandwidths for HD live streaming.

> **With the application of 5G into various industries, the IP network will be expanded from the public network oriented to 2C services to the production network oriented to 2B vertical industries, bringing huge market opportunities.**

bandwidths of key services cannot be guaranteed. Based on the hard isolation of FlexE network slices, ZTE implements zero bandwidth preemption among different services, and provides 100% bandwidth guarantee for key services of vertical industries. Based on the FlexE technology, ZTE proposes innovations to enhance TSN technology in several ways, such as TSN over deterministic fine-granularity channel of metro-transport network (MTN), to meet the deterministic requirements for delay, jitter and transmission of delay-sensitive applications in vertical industries (such as the differential protection service of smart grid and industrial control).

Intent-Based Network Based on AI and Automation Technology: Integrating Management, Control and Analysis

ZTE provides the industry's first network automation and intelligentization product that integrates management, control, analysis and AI functions to perform automatic and intelligent O&M during the full lifecycle of the network. Empowered by AI-based intelligent intent engine, the product can support rapid network planning, design and service deployment and accelerate new service provisioning.

Intelligent fault injection and analysis based on continuous learning allows faults to be rapidly perceived, accurately identified and located in minutes. At the same time, the health status of the physical network can be perceived in real time and the optimal network path can be selected based on service SLA to guarantee service experience and make service SLA visible, controllable, and committable. ZTE's intelligent management and control platform will be continuously improved to promote the evolution towards intent-based networks.

As the world's leading intelligent IP network provider, ZTE has been adhering to ultra-broadband, simplified and intelligent network ideology for the 5G and cloud era, and will use innovative technologies to help global operators build more intelligent IP networks. ZTE TECHNOLOGIES

Insights on Current 5G Deployment and Future

Stephanie Lynch-Habib
CMO of the GSMA

Editor's note: GSMA CMO Stephanie Lynch-Habib shares her thoughts on the development of 5G and calls for a joint effort to build a smarter, greener world powered by 5G at an online event themed on 5G Growing at MWC 2022.

Today, I am excited to share some insights on current 5G deployment and what the future might hold. This year marks 40 years since the founding of GSM, an initiative to design a pan-European mobile technology. It's not that long ago. But I wonder when those leaders gathered to start the GSM, did they have any idea of what the future of mobile might look like? Did they understand how ubiquitous it would become? Did they imagine a world in which 5G technology would exist, allowing us to develop smarter homes, energy and transport systems, truly unleashing the power of connectivity around the world?

For the past 10 years, 5G has been the key buzzword in the mobile industry. We've imagined it, researched it, debated it and developed it. And now we are finally seeing it come to life in the mainstream market. 2021 was a pivotal year for 5G rollout. By the end of last year, 176 mobile operators in 70 markets had launched 5G services. And by the end of this year, there will be 1 billion 5G connections globally. By 2025, we expect 5G to account for a quarter of total mobile connections across the world.

Right now, most of the growth is happening in pioneer markets, such as the developed Asia-Pacific region, North America, Greater China, the GCC Arab states and Europe. But we are also starting to see a new wave of 5G rollouts in large markets with modest income levels such as Brazil, Indonesia and India. And this is exciting because affordability is so often a barrier to entry in emerging markets.

If 5G is the way of future, we need to be sure that we can get affordable handsets to consumers in these markets. With this new wave of rollouts, we'll start to see the industry more incentivized for the mass production of affordable 5G devices. And as we get more 5G devices into the hands of consumers, we'll begin to see the development of a range of 5G applications to cater to their diverse needs.

As 5G becomes more mainstream, we are starting to see 5G standalone take off. By the end of 2021, there were 22 commercial 5G standalone networks in 16 countries. Around the world, 5G standalone is opening up new opportunities for collaboration between mobile operators and different enterprises. For example, Softbank and Honda have been working together to develop car systems that will reduce car collision with pedestrians. In Spain, Telefonica is exploring use cases that range from guided robot vehicles to remote maintenance systems. This is just the beginning. As we move from an era of simple connectivity to one of meaningful connectivity, the mobile sector will play a central partnership role across enterprise verticals.

But as we look to the future and imagine what it could be, we must also ensure that we are using our enabling role as an industry to build a sustainable future for all. Connected technologies will play a key role in tackling some of the biggest challenges facing the planet today. Last year, the GSMA called on business leaders and policymakers to use mobile connectivity and smart technology to achieve net zero by 2050. Our research found that smart technology and mobile connectivity can dramatically reduce emissions and increase energy efficiency. The findings assume halving by 2030, as called for by the "Exponential Roadmap Initiative", in line with limiting global heating to 1.5C. Our research shows that smart tech and mobile connectivity could contribute 40% of the required carbon emissions savings to 2030, across energy, transport, manufacturing and the buildings sector.

To achieve net zero by 2050, carbon emissions from the global energy sector need to be reduced by 50% by 2030. Our research showed that 46% of the cut required in carbon emission could come from the rollout of connected wind and solar grids, equivalent to decommissioning around 1000 coal-fired power plants by 2030. And with smart grids, businesses could more accurately monitor their systems, responding to fluctuating energy demands. Since implementing smart-grid equipment on electricity lines, Telia in Sweden has already seen a 25% increase in power-line capacity.

The manufacturing sector is another big source of GHG emissions. Based on our research outlined above, 16% of the carbon reductions required in manufacturing could be provided by smart manufacturing processes, equivalent to 1.4 gigatonnes of CO2, equivalent to the emissions from manufacturing 140 million cars. This is not just good for the planet. It's good for the businesses too. In China, Foxconn's Industrial Internet "Lights-Off" factory has increased its production efficiency by 30% using connected technologies. But today, connected technologies are only being used in 1% of factories around the world. So the opportunity is enormous.

As you can see, the mobile industry is in a unique position to play an enabling role across the globe. But we must make sure that we also play our part. In 2019, the GSMA Board set an ambition for the mobile sector to reach net zero emissions by 2050. We are now one of the leading sectors within the space, recognized by the United Nations "Race to Zero" as one of the first Breakthrough Sectors. We now have 80% of operators by revenue disclosing their climate impacts. Mobile operators covering around two thirds of industry revenues have committed to science-based targets, and one third of the mobile industry by revenue has credibly committed to net zero emissions by 2050 or earlier through the UN Race to Zero campaign.

So what does the future look like? Smart factories, smart energy, smart businesses, smart homes. This list will continue to grow. And connected technologies powered by 5G will drive it all. 5G truly is the frontier area of growth with so much opportunity to innovate. But of course it has to be a joint effort. We must work together as businesses, governments, and policymakers to support rapid and sustainable 5G growth across the world and ensure we leave no one behind. Together we can unleash the power of connectivity to build a smarter, greener world for us all. ZTE TECHNOLOGIES

Cable MSO Transformation: Scaling for Capacity and Agility

Emir Halilovic
Principal Analyst, GlobalData

Executive Summary

After decades of successful growth, cable MSO operators are today facing a crucial challeng—how to continue to grow profitably, and at the same time efficiently compete with other broadband vendors, predominantly using FTTx/PON. For many cable MSOs, the way forward is migration to FTTx—with or without extending the lifetime of their DOCSIS-based infrastructure as an intermediate step.

Summary Bullets

- Cable MSO networks are fully feeling the strain of the unprecedented service demand generated by COVID-19 pandemic impact on work, education, and media consumption habits. Most are investing into upgrades of their hybrid fiber-coax plant, but many are looking at complete overhaul of their infrastructure.
- Migration to full fiber infrastructure is the final goal of practically all cable MSOs, and many are building FTTx infrastructure in parallel with their HFC plant or choosing a "cap and grow" migration strategy. The final goal of this transformation will in any case be purely FTTx infrastructure; operators need to consider their migration options carefully and examine ways to optimize their networks deployment to ensure smooth and cost-efficient transition.

Cable MSO infrastructures are one of the main foundations of broadband service offerings in many countries globally. Thanks to physical characteristics of coaxial cable, MSO operators have extended the usefulness of their networks, historically associated with cable TV distribution, to broadband connectivity services. Coaxial cable infrastructure with the latest upgrades to DOCSIS 3.1 has transformed into a hybrid fiber-coax plant (HFC) capable of both distributing video and providing broadband services.

However, changing customer behavior, increasing demand for high bandwidth services, and the growth of cloud traffic—further exacerbated by the COVID-19 pandemic—have put several deficiencies of HFC into spotlight:

- **Scaling and overall capacity:** Most cable networks today have been built with a relatively stable bandwidth demand in mind. The changing usage patterns and increased demand associated with COVID-19 have quickly shown that HFC infrastructure needs constant upgrades to cope with increasing demand. Due to highly concentrated nature of legacy HFC infrastructures, these upgrades are costly and relatively complicated.
- **Upload/download disbalance:** Although coaxial cable is significantly better medium for broadband than copper twisted pair, it still has capacity constraints. Due to this, and tendency of residential users in the past to use broadband mostly with download-heavy applications, cable data transfer (standardized under DOCSIS specifications) is highly asymmetrical. DOCSIS 3.1, for example, provides maximum of 10 Gbps download and 1 Gbps upload per connection, but in practice customer services are provided with download speeds over

20 times faster than upload. These upload constraints become quickly evident in two-way video communication, video creation and uploads, game streaming, or the use of productivity cloud-based applications.

- **Sunset of cable TV:** Cable operators' investment has traditionally been equally aimed at increasing their data transfer capabilities, but also in maintaining and improving their TV distribution capabilities. However, in last several years, consumer viewing habits have changed—most residential users consume video content through streaming platform, effectively putting more strain on data part of the network; at the same time, the number of cable TV subscriptions keeps dwindling. Cable operators thus are looking for ways to scale their data transfer capabilities, and at the same time de-emphasize investment associated with video distribution.
- **Beyond residential use cases:** Cable MSOs have usually relied on residential customers for most of their revenue. The onset of highly symmetrical faster-than-1 Gbps services in FTTx combined with SD-WAN has shown that commercial broadband can be successfully used for SME and business connectivity. Cable operators today are mostly forgoing this opportunity because their services are highly asymmetrical and would impede upload-heavy applications.

This set of challenges has shaped the ways cable MSOs transform their networks today. Cable MSOs and their suppliers have developed and implemented several technologies that allow cable operators to make some improvement and at least partially address the challenges. However, most cable MSOs need to change faster, and the cable industry's transformation is accelerating. Within this context, MSOs need to consider the following:

- **Both major migration paths lead to FTTx:** A broad consensus among cable MSOs is that their networks will—in time—become full-fiber FTTx. The latest cable architectures, outlined under DOCSIS 4.0 are designed with a view that they will be a temporary, and very likely the last stage of traditional cable access technology. Upcoming DOCSIS 4.0 is still asymmetrical (10 Gbps/6 Gbps) and is inferior to currently mainstream FTTx technology XGS-PON, which provides symmetrical 10 Gbps connections. Some operators have thus chosen to move directly to FTTx from their current DOCSIS 3.1 cable networks, while others view DOCSIS 4.0 as a transitional stage. In essence, both major migration paths envision full fiber infrastructures replacing HFC in the next several years.
- **Passive infrastructure is the top concern:** As with greenfield FTTx, the main challenge in cable MSOs fiber transformation is the investment into passive network plant, in particular the optical distribution network (ODN). According to networking equipment vendors, the investment into ODN can make up the majority of overall FTTx deployment investment. Cable MSOs can, however, significantly lower this part of their network spending, by utilizing existing network ducts to the degree possible in combination with pre-connectorized ODN elements that allow MSOs to lower OPEX and accelerate deployments.
- **Market dynamics play a big role:** As with other parts of the marketplace, the wider broadband market dynamics can serve as a major moderating factor in cable MSO transformation plans. The paramount among these factors is FTTx competition, which is increasing significantly in practically all major cable markets except for the United States, and access to public and private financial support, which is overwhelmingly directed at fiber infrastructures in markets like the UK, the EU, or India. Finally, the vendor landscape of FTTx suppliers is wider and more vibrant than dedicated cable solutions market, enabling faster innovation, and much higher shipment volumes which, in turn, drive lower prices and faster price decreases.

These trends thus outline the future transformation paths that most cable MSOs need to undertake. In both major migration paths, the future MSO infrastructures will need to be rebuilt as FTTx infrastructures. The transformation will either happen through complete overbuilds, with operators deploying FTTx in parallel with the existing HFC, and then migrating customers to FTTx, or through "cap and grow" deployments, where operators deploy FTTx in newly covered and highly competitive areas, while upgrading transport and moving fiber closer to customers in areas still served by cable. In both cases, MSOs need to seek ways to perform these upgrades efficiently, taking into account the technological advancements in deployment techniques in solutions, and expanded opportunities for monetization that FTTx brings them. ZTE TECHNOLOGIES

Building Data-Centric Intelligent Networks

Tao Wenqiang

Chief Planning Engineer
of ZTE IP Product

With continuous development and wide applications of new-generation information technologies, digitization, networkization and intelligentization have become important directions of economic and social transformation and upgrade. The development and application of artificial intelligence (AI), blockchain, cloud computing, and the Internet of things (IoT) all depend on data. Thus data has become a production factor and the basis of digital economy. Data in the digital era can be compared to petroleum in the industrial era. However, unlike petroleum, data is intangible and infinite, and there is a huge amount of data being generated every minute. How to make good use of data to create value has become the key to success in the era of digital economy.

Data driving development does not mean that data can be automatically turn into productivity. The value of data cannot be achieved without the corresponding data infrastructure, including facilities involved in data collection, transmission, storage, and computing. New infrastructure, such as new networks, facilities, platforms, and terminals, needs to be built. Neuron systems for data collection need to be built based on the ubiquitous deployment of smart terminals. High-efficiency data transmission networks need to be built based on the full coverage of new 5G networks. Data computing capabilities need to be improved based on computing facilities such as Internet data centers and high-performance computing (HPC) centers. Intelligent data analysis centers need to be built based on the development and application of AI platforms, industrial Internet platforms and IoT platforms.

Looking at the nature of data driving, a data center carries the computing power and transforms data into intelligence, while a network is the key infrastructure that transmits the computing power to users and transforms data into value.

Data-Centric Network: Architecture and Vision

The overall architecture of the new data-centric network is shown in Fig. 1.

Horizontally, the data-centric network architecture complies with the end-to-end empowerment principle of service-based networks. That is, the end-to-end Internet protocol-based architecture is maintained, and the services are mainly processed on the two ends. While improving core capabilities (such

as deterministic transmission, native security, and computing power scheduling), the network opens these capabilities in a hierarchical manner with different granularities for the service layer to use.

Vertically, the architecture adopts the thin-waist model supported by the intelligent control plane. That is, the “thin-waist architecture” of the Internet protocol stack is retained. The IP layer is kept stable enough to extend new functions with the existing IP fields. Network function extension (mainly for the operator’s data network) is performed on the centralized control plane with effective use of new IT technologies such as AI and big data.

For deterministic and secure transmission of

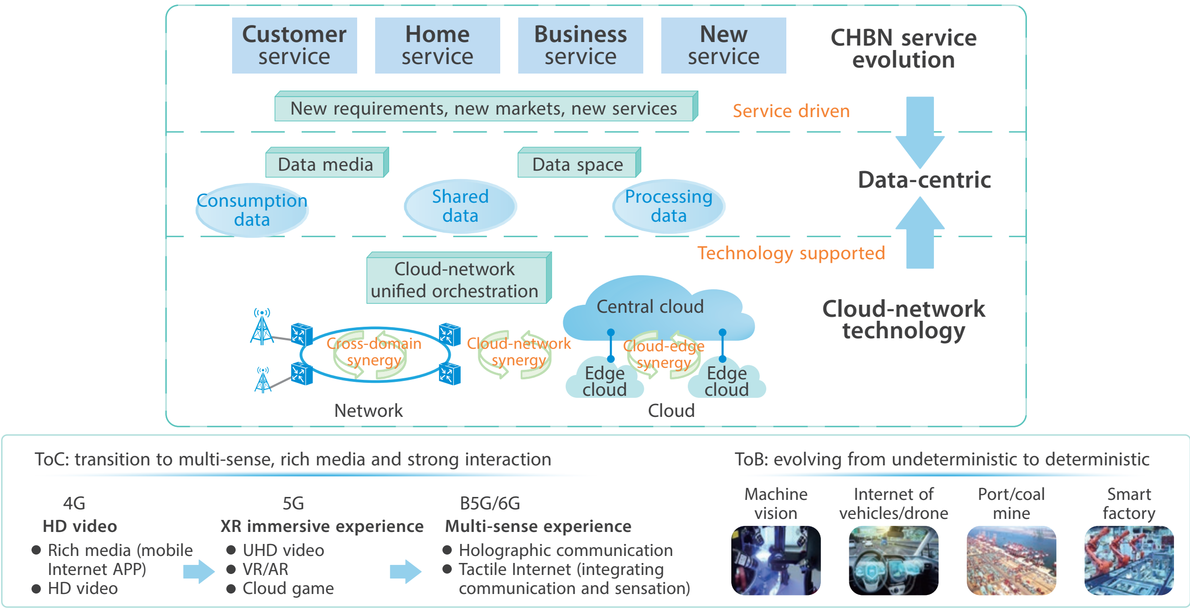


Fig. 1. Data-centric network architecture.

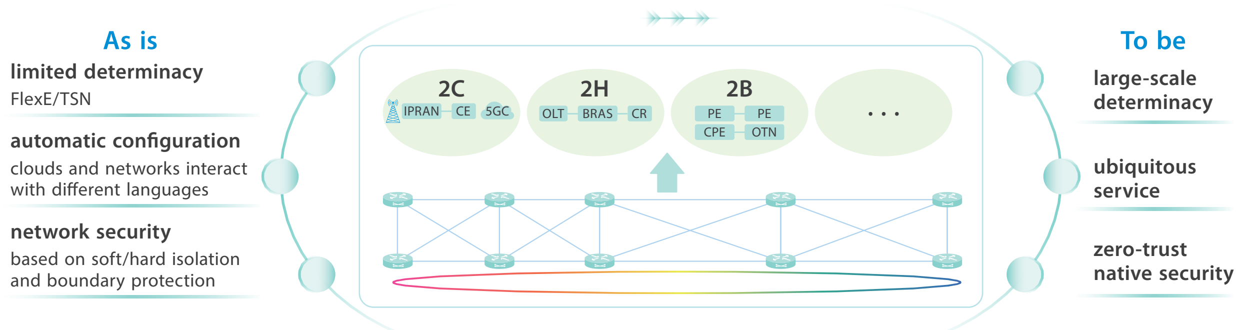


Fig. 2. Evolution from cloud-network convergence to computing-network integration.

Cloud-network convergence (Phase 1)

Local deterministic precision network	LAN+MEC, specific vertical industries begin to migrate to WAN
Cloud-network synergy, intelligent network upgrade	Agile cloud access of user (resource orchestration + SDN controller)
Superposition security	Passive defense

Computing-network integration (Phase 2)

Large-scale deterministic precision network	WAN, vertical industries all get on the WAN
Computing network, service-based upgrade	Fully open cloud-network capabilities, service discovery and guarantee friendly to applications
Zero-trust native security	Active defense

computing power, a data-centric network needs to have three key features: large-scale determinacy, ubiquitous service, and zero-trust native security (Fig. 2).

Large-scale determinacy means that the IP network with a large number of devices can support up to millions of data streams (such as massive industrial-level control and sensors) and provide deterministic service guarantee, with the latency and jitter strictly meeting service requirements. The industrial Internet also needs cross-WAN end-to-end determinacy. Based on native IP, the large-scale deterministic IP network proposed by ZTE implements periodical forwarding and accurate scheduling on the new-generation 5-nm chips. End-to-end jitter can be guaranteed no matter how large the networks are.

Native Security

To meet the security requirements of future networks, ZTE is committed to building native security and reliability mechanisms. Using blockchain and cryptography, it redesigns the future network architecture, provides end-to-end services from infrastructure to application layer, and builds a complete set of secure and reliable network architecture from bottom up. In this way, using zero-trust security mechanism ZTE endows the network with secure and credible attributes and capabilities in the “gene” of the network to provide a more solid security foundation for future network protocol systems and network services. This fundamentally solves the security problems

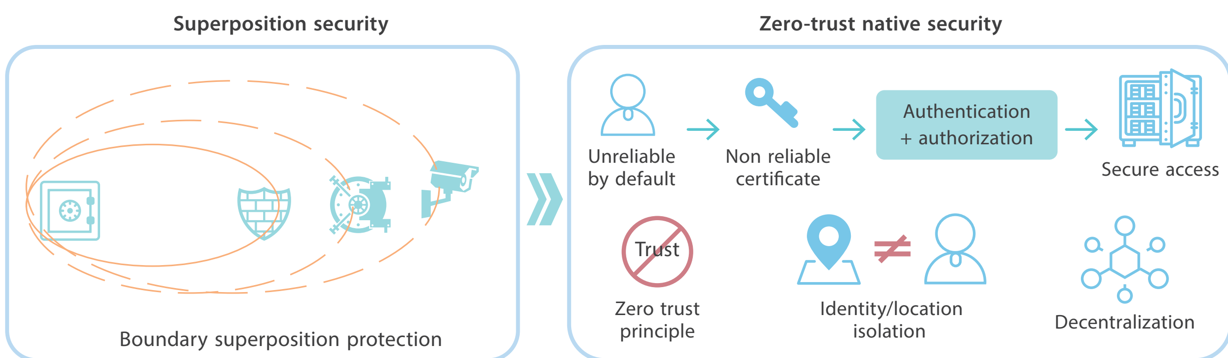


Fig. 3. Evolving from superposition security to zero-trust native security.

- Superposition security is applicable to communication security problems in conventional boundary protection logic.
- In digital transformation, security boundaries are increasingly blurred and data is more dispersed, so the security idea needs to be changed.

- Get security access right through authentication of the identity/application management controller.
- The location management controller and gateway isolates and hides identity/location information.
- Implement trusted routing control protocols based on blockchain.

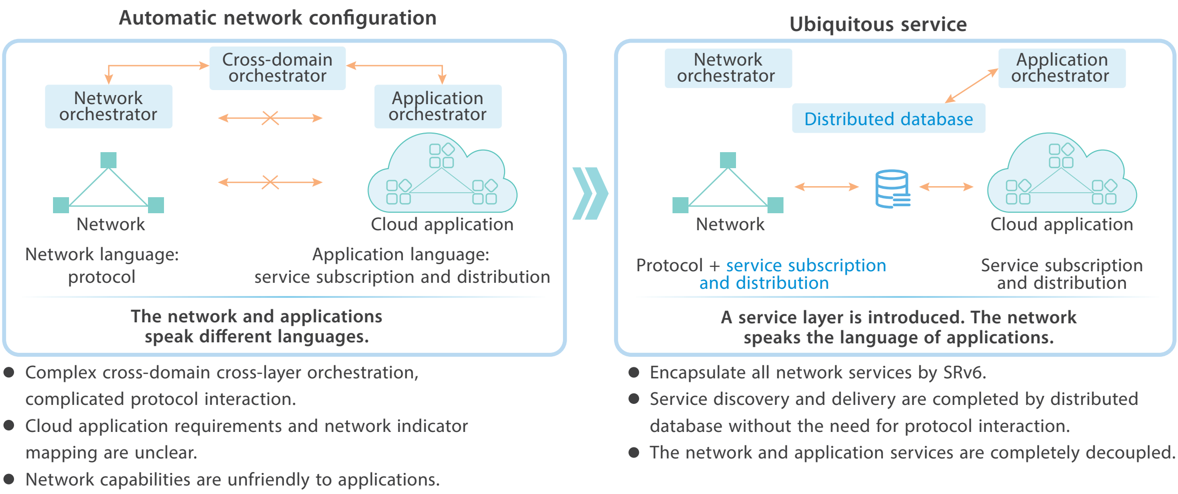


Fig. 4. Ubiquitous service-based network decouples services and networks.

that today networks face and evolves the security system from superposition security to zero-trust native security (Fig. 3).

The idea of ZTE native security is as follows: horizontally, the security of the communication source end and destination end is handled. The intelligent plug-ins residing on the ends (including terminals or edge nodes) complete the initiation and termination of network trusted communication, and the remaining intermediate nodes perform transparent forwarding. Vertically, the intelligent control plane based on big data and AI provides real-time threat detection and intelligent determination as well as large-scale network security indicator evaluation and prediction to monitor network behaviors and prevent risks. The data plane integrates trusted network communication into the unified network layer protocol.

Ubiquitous Service

In the future, cloud-network convergence is an inevitable trend, and dynamic network adjustment with the cloud is an inevitable requirement. Although automatic configuration has been implemented on the network side, which simplifies network operation and maintenance, the fundamental problem has not been solved. In the traditional network and application peer-to-peer model, the network and applications speak their own languages. The network and applications need to intact with each other through complex protocols and cross-domain cross-layer orchestration. As a result, the network is not agile enough to meet the requirements of substantial industry applications.

ZTE proposes a service-based network model, which adds a service layer between the basic network and applications to build a ubiquitous service-base network that is loosely coupled, highly scalable and easy to maintain. The ubiquitous service-based network encapsulates network capabilities such as VPN, TE, service chain and security into services, and pushes them to the applications through distributed databases. Lightweight network services directly communicate with the applications. The applications only need to focus on their own requirements without caring about specific implementation or supporting complex protocols and network interaction. The ubiquitous service-based network removes complex protocol interaction and cross-domain cross-layer orchestration between the network and applications, and encapsulates all network services through SRv6. The discovery, delivery and update of network services are completed by the distributed databases. This completely decouples the network from applications, providing the most open cloud-network convergence capability and the most extensive access capability (Fig. 4).

Summary

The data-centric network model can deeply reveal the essential role of the network and its value in the digital economy era. The network is responsible for secure and deterministic transmission of data, and provides service-based lightweight interaction, thus greatly improving the cloud-network convergence capability. ZTE TECHNOLOGIES

Research and Deployment of SRV6 Header Compression Technology

Feng Jun

Planning Director of ZTE IPN Products

ZTE, together with China Mobile and related vendors, innovatively launched the generalized segment routing over IPv6 (G-SRv6) header compression technology, completed multi-stage lab tests and deployment trials on the live network in Henan and Fujian provinces, and successfully verified its feasibility and large-scale deployment in 2020–2021. This marks a solid step towards formal G-SRv6 commercial deployment.

Background of SRv6 Head Compression

The segment ID (SID) of the standard SRv6 adopts 128-bit SID in IPv6 address format and consists of three parts: the LOC field that identifies the location of the node, the FUNC field that identifies services and functions, and the ARG field that stores related parameters (Fig. 1). Compared with the SID in MPLS label format, it has the routable attribute, which can simplify the creation of inter-domain paths and allow for end-to-end connection of the IPv6 network. The FUNC field supports programmability that can flexibly define network and service functions. Supported by network and service orchestrators, SRv6 can connect cloud-network paths and define services. This provides an excellent technical choice for cloud-network convergence and end-to-end service definition, so SRv6 has become the core technology of a new-generation IP transport network.

Despite the above advantages, the standard SRv6 still faces two major challenges in actual deployment. First, the overhead of SRv6 packets is high, and the bandwidth utilization of network links is low. The bandwidth utilization is only about 60% in the case of the 256-byte payload with 8 SIDs. Second, as SRv6 packet processing has high requirements for chips, it is difficult for a large number of devices in the existing network to support the replication and operation of deep SRH headers, which reduces the processing efficiency of existing chips. To address these issues, the segment routing header (SRH) compression of the standard SRv6 needs to be optimized.

Fig. 1. 128-bit SRv6 SID.

Main Features of SRv6 Compression

The SRv6 compression technology adopts common prefix compression or mapping to optimize the SID length. The common prefix compression scheme is the mainstream choice at present.

SRH compression optimization needs to consider the following:

- **Compatible with the standard SRv6:** Maintain the existing SRH format to prevent packets from being discarded by the standard SRv6 node.
- **Fixed SID compression length:** Considering network scalability, byte alignment, compression efficiency and implementation difficulty, the SID compression length should be fixed as much as possible.
- **Supporting original IPv6 address planning:** The address planning of the compression scheme needs to be compatible with the current network address planning to avoid deployment failure or a waste of public network addresses.

A variety of 128-bit SID SRH compression optimization schemes have been proposed in the industry, and G-SRv6 is a typical one.

Principle of G-SRv6 Compression

The locator field in the legacy 128-bit SRv6 SID can be subdivided into B:N, where B identifies SRv6 SID block, which is generally allocated to a subnet by the operator, usually expressed by Prefix, and N is the identification used to distinguish nodes in the subnet.

In fact, many SIDs in one SRv6 network share a common prefix, and the common prefix in an SID list is redundant. Therefore, the common prefix and other redundant parts in the SRv6 SID are removed from the SID list, and node ID and function ID are kept as compression SID to reduce the overhead of packet headers. The compression SID is the generalized SID (G-SID) in the SRv6 header compression scheme, as shown in Fig. 2.

The G-SRv6 scheme uses 32-bit G-SID to represent the standard 128-bit SID and replace its encapsulation in the SRH header. Theoretically, one conventional SID space accommodates four G-SIDs, remarkably optimizing SRH encapsulation overhead of the standard SRv6.

Comparison between G-SRv6 and uSID

Many SRv6 compression schemes have gradually converged, and the recent voting in IETF SPRING WG has ended. The G-SRv6 scheme (G-SID)

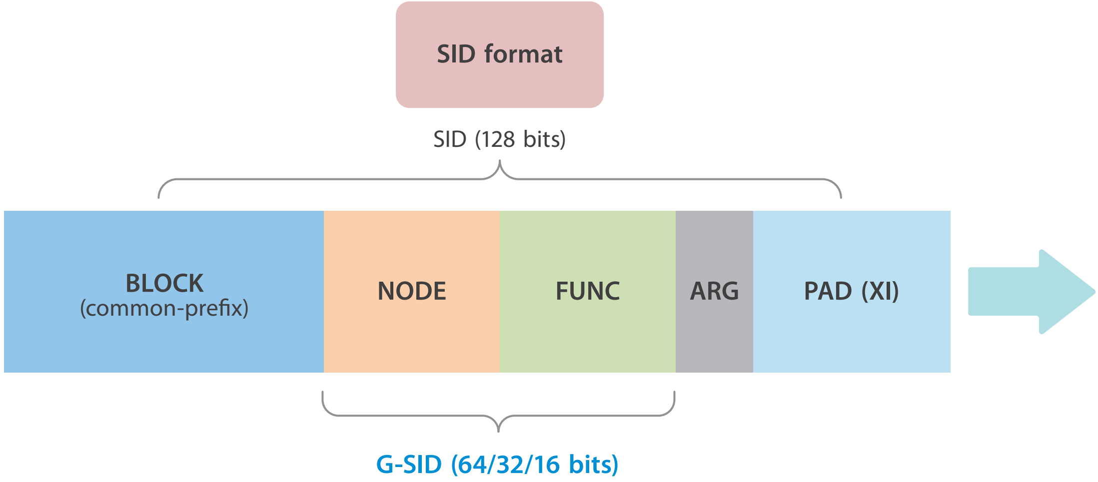


Fig. 2. G-SID structure in the SRv6 header compression scheme.

and CISCO's uSID, as a whole scheme C-SID, have been basically adopted as working group drafts.

The uSID scheme is similar to the above G-SID scheme. The basic principle is to extract the common block prefix. The difference is that G-SID stores the common prefix in DA, while uSID puts it in the uSID block of each 128-bit SID header (Fig. 3), and the uSID that follows is the compression tag.

The main restriction of the uSID scheme is that the block prefix has high requirements. In order to maintain high compression efficiency, the block length is often set to a 16-bit private network segment or a smaller 32-bit public network segment, which has more strict requirements for the operator's address planning.

Deployment Verification of G-SRv6 Related Technologies

From early 2020 to late 2021, China Mobile R&D Institute took the lead in formulating technical standards related to the G-SRv6 scheme, and verified the technical solutions in labs and deployment trials on existing networks in phases. As a core member, ZTE participated in the whole process, contributed some of the core technical features, and rapidly put them into production, which greatly promoted the development of G-SRv6.

Technical Verfication in Labs

- In the first phase of 2020, ZTE verified the feasibility of G-SRv6 technical framework, including basic forwarding plane and control plane tests that involved compression coding and forwarding of strict and loose policy paths in compressed intra-domain, inter-domain, and legacy SRv6 hybrid networking scenarios. The control plane contains a whole set of signaling flows such as ISIS protocol compression information distribution, BGP-LS sending controller, and BGP delivering policy compression path information.
- In the second phase of 2020, ZTE verified reliability technologies including intra-TI-LFA, anti-microloop, HSB, and round-trip same-path BFD, as well as active OAM, option A cross-domain reliability and OAM technologies.

Deployment Trials on Existing Networks

- In November 2020, ZTE completed a successful phase-1 G-SRv6 deployment trial on the existing network of China Mobile Henan Branch, and verified the interoperability between G-SRv6

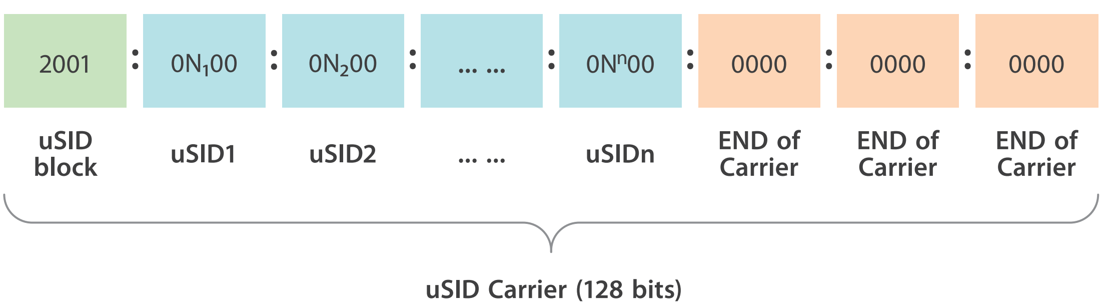


Fig. 3. uSID SID structure.

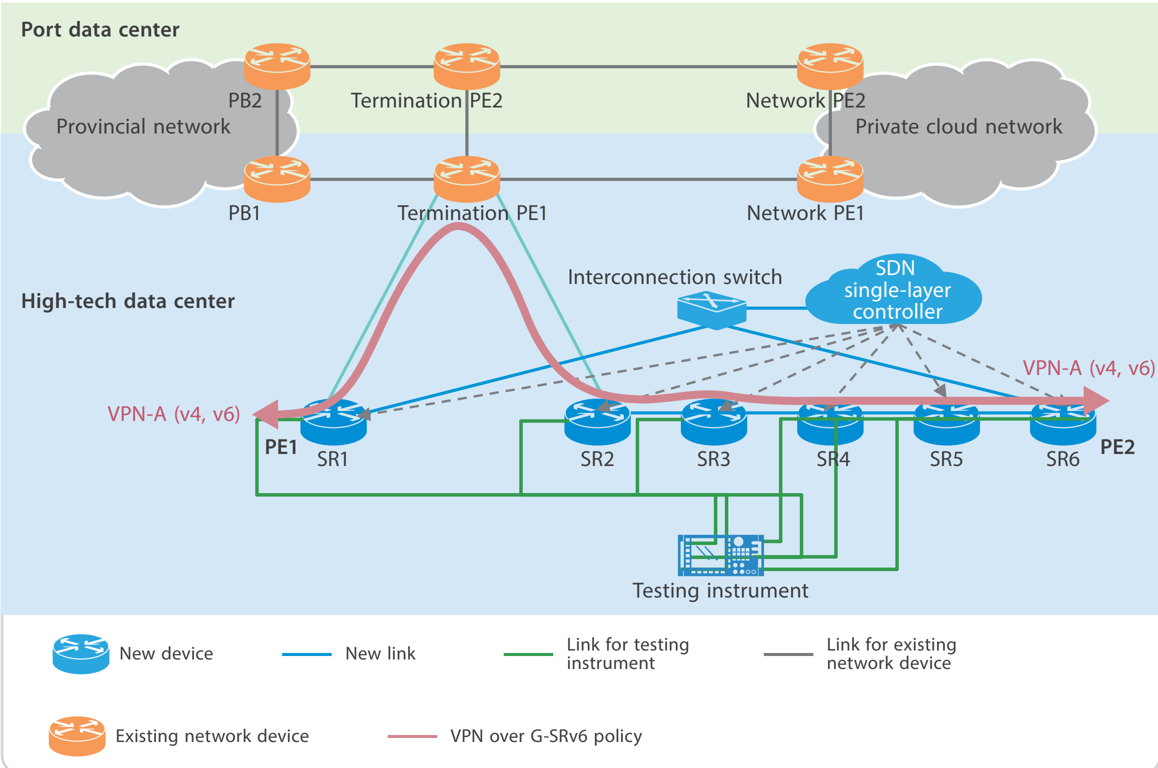


Fig. 4. Topology of G-SRv6 service trials.

forwarding and control planes. Taking VPN as basic service, it verified the deployment of G-SRv6 in different network combinations such as across common IPv6 networks or G-SRv6 compression domains, or across compression domains and common SRv6 domains, and analyzed the impact of G-SRv6 on existing network devices and services, the corresponding solutions, and the deployment feasibility. The topology of G-SRv6 service trials is shown in Fig. 4.

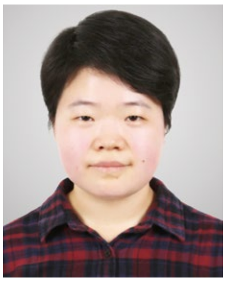
- In September 2021, ZTE successfully completed the phase-2 G-SRv6 deployment trial on the existing network of China Mobile Fujian Branch. It tested the application effect of multi-vendor router G-SRv6 back-to-back cross-domain deployment, reliability and O&M functions, verified the networking schemes and service application scenarios, and gradually promoted the maturity, deployment and commercialization of G-SRv6.

Follow-up Plan of G-SRv6

It is planned to conduct the third phase of technical verification in 2022, including hierarchical end-to-end cross-domain solutions and in-situ flow information telemetry (iFIT). Their commercial deployment will be carried out in the existing network in the second half of 2022.

With the trend of large-scale 5G deployment, digital transformation and cloud-network convergence, the G-SRv6 technology can activate a large number of existing networks, help operators quickly build digital intelligent networks, and empower thousands of industries. ZTE and China Mobile will continue to cooperate deeply to promote the large-scale deployment of G-SRv6, make the network intelligent and ultra-lean, and embrace the new 5G era. ZTE TECHNOLOGIES

IPv6-Based BIERin6 Multicast Technology and Standards



Zhang Zheng

Chief Engineer of Standards Pre-research, ZTE

Wei Yuehua

Director of Bearer Network Standards, ZTE

Brief Introduction to BIER

Bit indexed explicit replication (BIER) is a new protocol, and IEEE has assigned Ethertype 0xAB37 for BIER. For the first time BIER decouples multicast services from multicast forwarding, so that multicast can be truly based on hierarchical architecture. There is no multicast state in the network. The intermediate forwarding nodes do not need to perceive multicast services, but only need to forward them based on the network topology. As a result, multicast services are no longer restricted by the capabilities of intermediate forwarding nodes, and can fully meets the needs of current and future multicast services.

Three Phases of Developing Multicast Technology

The multicast technology has a history of over 30 years. In the current network, protocol independent multicast-sparse mode (PIM-SM) is the most widely used multicast technology. However, tight coupling between multicast services and multicast forwarding and slow convergence of protocol signaling make PIM-SM difficult to meet the needs of soaring multicast services in the future network.

In recent years, with the gradual development of multicast virtual private network (MVPN), the multicast architecture has begun to evolve to a hierarchical architecture. Multipoint extensions for LDP (MLDP) and point-to-multipoint traffic engineering (P2MP-TE) decouple multicast services from multicast forwarding to some extent, so that they no longer have one-to-one relationships. However, they still have requirements for transport capabilities of the intermediate node tunnels in the network. In addition, like PIM protocol, MLDP and P2MP-TE need to establish and update tunnels based on the interaction of their own protocol signaling. Therefore, when the network topology changes, they need to converge based on their own protocol signaling after routing convergence, and the convergence time is still more than seconds, which cannot meet the requirements of high-reliability multicast services.

BIER completely decouples multicast services from multicast forwarding and achieves a hierarchical architecture of multicast technology. It only needs to build the BIER multicast forwarding layer by using the routing protocols like interior gateway protocol (IGP). When there is a node or link failure in the network, it completes the convergence of the BIER forwarding table as IGP converges, and the convergence time can reach a millisecond level. Moreover, the fast reroute (FRR) and loop-free alternate (LFA) functions of IGP can be inherited. With the two functions of the unicast technology, it not only meets the requirements of ever-increasing multicast services but also serves high-reliability multicast services.

Hierarchical BIER Architecture

The innovative hierarchical architecture of BIER divides the multicast network into the multicast overlay layer, BIER multicast forwarding layer, and routing underlay layer, completely overcoming the disadvantages of tight coupling between traditional multicast services and multicast forwarding (Fig. 1).

Multicast services are identified only by the multicast overlay layer on network edge devices. The multicast overlay layer can be implemented by dynamic protocols or the SDN controller, and is totally independent of multicast forwarding. The multicast forwarding transport layer is the unique forwarding layer of BIER. Its innovative data plane can implement topology-based multicast forwarding without the need for signaling extension overhead. The routing underlay layer is used to construct the BIER forwarding table, and can be implemented merely by routing protocol like IGP extensions. If there are nodes that do not support BIER forwarding in the network, they can be easily bypassed through IGP routing computation.

BIERin6

IPv6 has become a major trend of global network deployment. With the growing number of users supported by IPv6 and the increasing wireless access rate brought by 5G, the traffic in the network is growing explosively. Forwarding multicast flows efficiently and stably in the IPv6 network is an important issue in network development. To achieve this goal, the BIER working group of Internet Engineering Task Force (IETF) has spent many years on research. The mainstream manufacturers have compared and verified various possible implementation solutions, and finally decided to adopt the BIERin6 solution as the only international standard of BIER IPv6.

BIERin6 is a combination of BIER and IPv6. It is flexible and efficient, provides optimal forwarding performance of network equipment, and perfectly supports end-to-end service implementation. In the migration period of deployment, the old equipment in the network does not need to be upgraded in any form, which greatly reduces the difficulty of BIER deployment and accelerates the deployment pace.

The data plane encapsulation on the BIER forwarding layer inherits the hierarchical characteristics of the BIER technology. Each layer is completely decoupled, independent of each other, and has its own features.

The outermost encapsulation is underlay encapsulation. In BIERin6, the encapsulation at this layer is the simplest IPv6 header, and the next header field in the IPv6 header is directly set to the value that represents the BIER protocol.

BIER header is the core layer that implements BIER forwarding. This part does not change with the outermost encapsulation. Multicast forwarding is

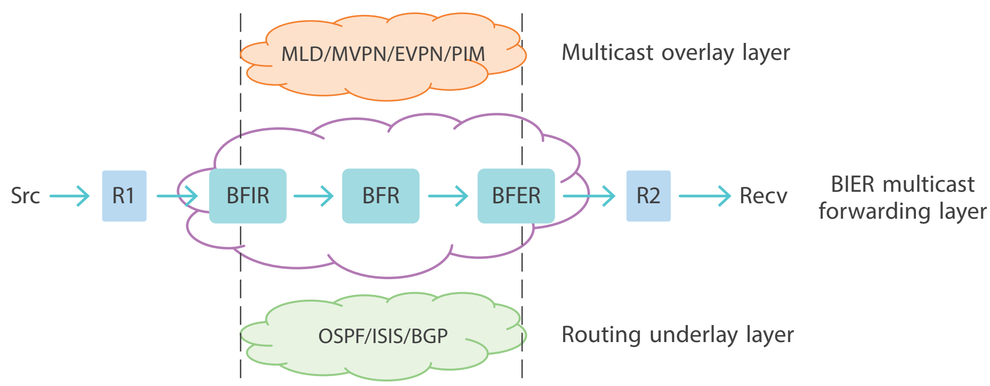


Fig. 1. Hierarchical architecture of BIER.

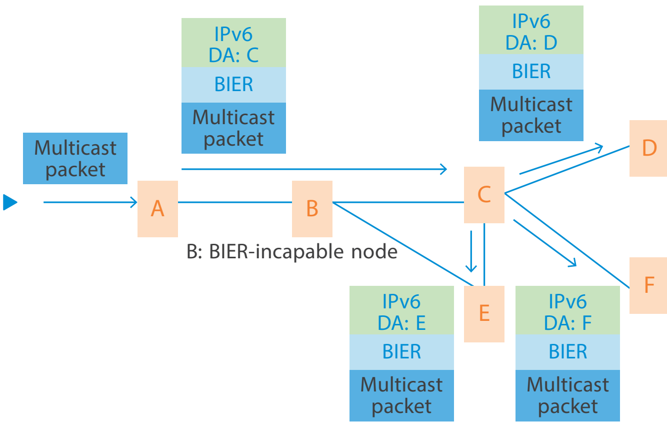


Fig. 2. BIERin6 forwarding.

completely implemented by this core layer and has nothing to do with other layers.

The innermost layer is the payload of BIER, which carries multicast overlay packets corresponding to overlay multicast services. Multicast services can be carried on this layer no matter in L2 or L3, in IPv4 or IPv6, or in MPLS. During the multicast forwarding, this layer does not need to be identified and perceived by intermediate forwarding devices, but is only managed by network edge devices.

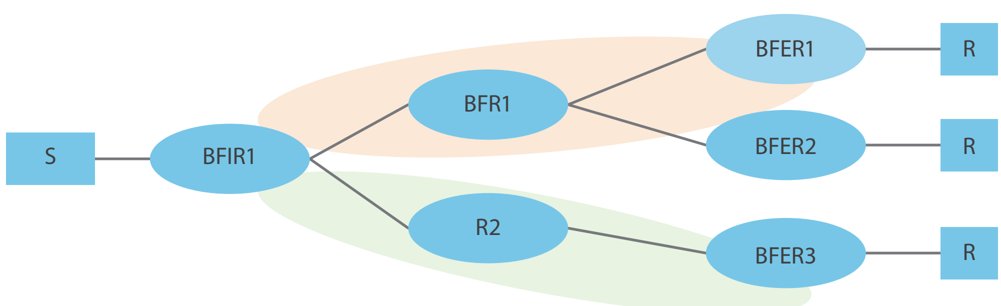
When multicast overlay packets enter the BIER domain, the ingress device encapsulates the BIER header and IPv6 header according to the egress device corresponding to the multicast overlay packets. The intermediate device in the network forwards the packets based on the BIER and IPv6 headers. When the packets arrive at the egress device, the egress device decapsulates the IPv6 and BIER headers and then continues to forward the packets to the receiver. If there is a node in the network that does not support BIER forwarding, like node B in Fig. 2, IGP path computation will directly skip this node. When the previous hop of this node encapsulates the IPv6 header, it sets the destination address (DA) to the IPv6 address of the next-hop node that supports BIER forwarding. In this way, seamless forwarding can be achieved without any upgrade requirement for node B.

SRv6-Based Cross-Node Interoperability

Segment routing over IPv6 (SRv6) is a technology that forwards the packets through the preset path based on the new IPv6 extension headers. When the BIER technology is deployed in an IPv6 network, if some domains do not support BIER forwarding, the SRv6 technology can be used to traverse the specified path. BIERin6 can be used together with the IPv6 segment routing header (SRH) for traversal. The traversed device does not need to identify the BIER header.

As shown in Fig. 3, the key node R2 in the network does not support BIER forwarding, but supports SRv6. To ensure that packets can be forwarded to BFER3 along the path where R2 is located, BFIR1 in the figure serves as the ingress node. Besides encapsulating BIERin6 packets that can reach the egress nodes BFER1 and BFER2, it is also necessary to encapsulate the BIER packets that contain the IPv6 SRH path of the R2 node to ensure that they can reach the egress node BFER3. According to the principle defined by RFC8200 (IPv6 Specification), the ingress node BFIR1

Fig. 3. Collaboration of BIER and SRv6.



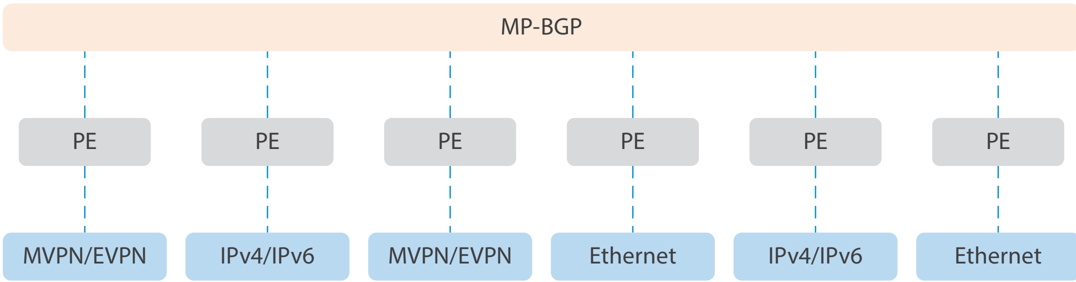


Fig. 4. Multi-service adaptation of BIER.

encapsulates the SRH route extension header after the IPv6 header, and then encapsulates the multicast packets carried by the BIER header. When the packets arrive at the R2 node, the R2 node processes the packets according to the SRH processing flow, and forwards the packets to BFER3 without additional judging or processing the BIER header.

Implementation of Various Services

BIERin6 fully inherits the features of BIER and supports various multicast services. It seamlessly adapts to global IPv4/IPv6 multicast, L2 multicast, BUM of EVPN, and MVPN services.

The high expansibility of MP-BGP makes it easy to extend and adapt to various multicast services. All public network services are forwarded by BIER. The services are isolated from each other and do not interfere with each other. All services are encapsulated and decapsulated on edge PE nodes (Fig. 4). Even for global multicast services, the intermediate node does not need to be aware of them at all.

The security of multicast services can also be guaranteed by PE. After being encrypted by security means, the multicast service is encapsulated into the BIERin6 header as the payload of the BIERin6 packet and then forwarded. If the packet is large and needs to be fragmented, similar to security, the service packet is fragmented first and then encapsulated into the BIERin6 header. In this way, the security and fragmentation is only processed on the ingress and egress PEs. The intermediate node only needs to forward the packet to the destination PE along the BIER path, without any impact on its performance.

Supporting New Programmability of Services

BIERin6 also supports new programmability of MVPN and EVPN services. It inserts the multicast service segment identifier between the BIER header and the subsequent service packet to realize network programmability.

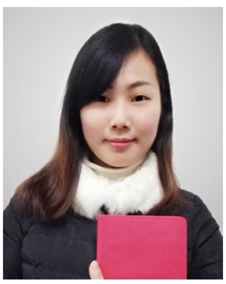
Due to the hierarchical architecture of BIERin6, the multicast service segment identifier has no impact on the forwarding, encapsulation and resolution of BIER packets at all, and there are no customization requirements for the outermost underlay encapsulation. The egress node decapsulates the packets layer by layer. After removing the IPv6 outer layer encapsulation and the BIER header, it can directly resolve this identifier and decide the subsequent service forwarding action according to the identifier. The overall flow is smooth and clear.

To sum up, BIERin6 is the best solution for BIER deployment in the IPv6 scenario. It fully leverages the advantages of hierarchical BIER architecture and works with SRv6 to skip nodes in specified paths. In the transition scenarios, BIERin6 does not require any upgrade of other devices. Because it is easy to implement and deploy, BIERin6 is the best way to implement BIER in the IPv6 network. ZTE TECHNOLOGIES

Large-Scale Deterministic IP Network Architecture

Peng Shaofu

Researcher from ZTE Futuristic Network project team



Xiong Quan

Researcher from ZTE Futuristic Network project team

With the development of 5G applications, there is a need for 5G IP networks to shift from transporting consumer-oriented eMMB services to transporting integrated services that focus on industry-oriented uRLLC deterministic services, so as to support IT and OT integration for 5G-driven industrial Internet. At the same time, 5G service cloudification and function virtualization bring extensive and differentiated deterministic transport scenarios and requirements, which pose challenges on large-scale IP networks. To meet the diversified deterministic transport requirements, large-scale IP networks first need to have an advanced network architecture.

Deterministic IP Network Overview

Deterministic Networking (DetNet) refers to the technology that provides determinism in the IP network. It has three goals:

- Minimum and maximum end-to-end latency from source to destination, and bounded jitter (packet delay variation).
- Low packet loss ratios, such as zero congestion loss.
- An upper bound on out-of-order packet delivery.

To achieve the above objectives, multiple techniques need to be used in combination, including explicit routes, service protection and resource allocation defined in DetNet. Resource allocation operates by isolating, reserving and guaranteeing resources. Explicit routes control forwarding paths to be not affected by topology events. Service protection further provides guarantees for packet loss ratio and out-of-order delivery in cases of link and node failure.

A deterministic IP network requires a completely redesigned architecture that includes network resource layer management, deterministic IP routing layer management, and deterministic service layer management. A typical deterministic IP network is shown in Fig. 1.

From the perspective of deterministic service requirements, deterministic QoS in the network can be divided into five levels:

- **Level-1:** bandwidth guarantee. It includes basic bandwidth guarantee and a certain degree of tolerance to packet loss. There is no requirement for the latency and jitter. Typical services include FTP downloads.
- **Level-2:** jitter guarantee. It includes a jitter of less than 50 ms, a delay of less than 300 ms. Typical services include synchronous voice services, such as voice call.
- **Level-3:** latency guarantee. It includes a delay of less than 50 ms, a jitter of less than 50 ms. Typical services include real-time communication services, such as video, production monitoring.

- **Level-4:** low latency and low jitter guarantee. It includes a delay of less than 20 ms, a jitter of less than 5 ms. Typical services include video interaction services, such as AR/VR, holographic communication, cloud video and cloud games.
- **Level-5:** ultra-low latency and jitter guarantee. It includes a delay of less than 10 ms, a jitter of less than 100 us. Typical services include production control services, such as power protection and remote control.

It is ideal to use appropriate deterministic transport resources and technologies to precisely meet the deterministic service requirements classified as above. Moreover, when a large-scale IP network needs to provide the integrated transport of substantial diversified deterministic services, an advanced network architecture is needed to support its continuous evolution.

Large-Scale Deterministic IP Network Architecture

For a large-scale IP network to support determinism, the following issues need to be considered. A large-scale IP network has a large number of hops and high link delay, which makes it difficult to achieve network-wide precise time synchronization, and it cannot maintain the state of each traffic flow when the traffic is differentiated, dynamic and concurrent. It may span across multiple domains with heterogeneous forwarding planes. A large-scale IP network has various deterministic service requirements, such as those from 5G uRLLC services. The current time-sensitive networking (TSN) technology is mainly applied to L2 Ethernet, and cannot be applied to IP network. The deterministic architecture defined for IP networks faces various challenges in precisely guaranteeing the deterministic end-to-end transport.

Network 5.0 technology, defined by China's Network 5.0 Industry and Technology Innovation Alliance, can address the above problems. In it, a large-scale deterministic IP network can provide determinism in the resource layer, routing layer and service layer respectively to establish a unified

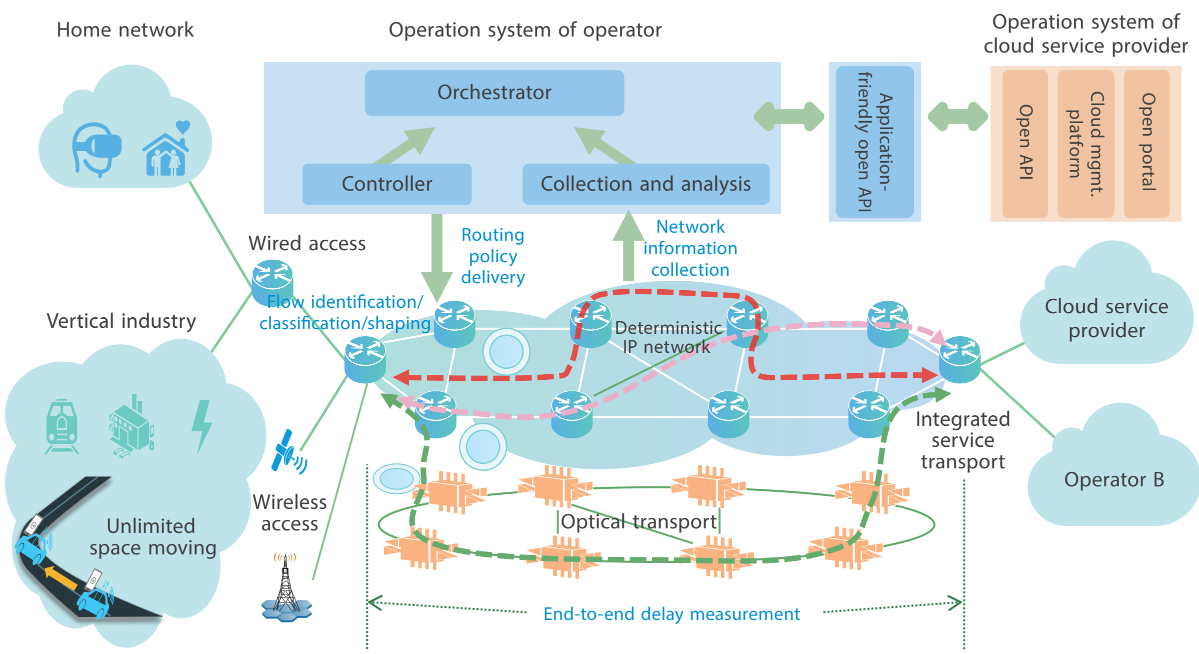


Fig. 1. Deterministic IP network.

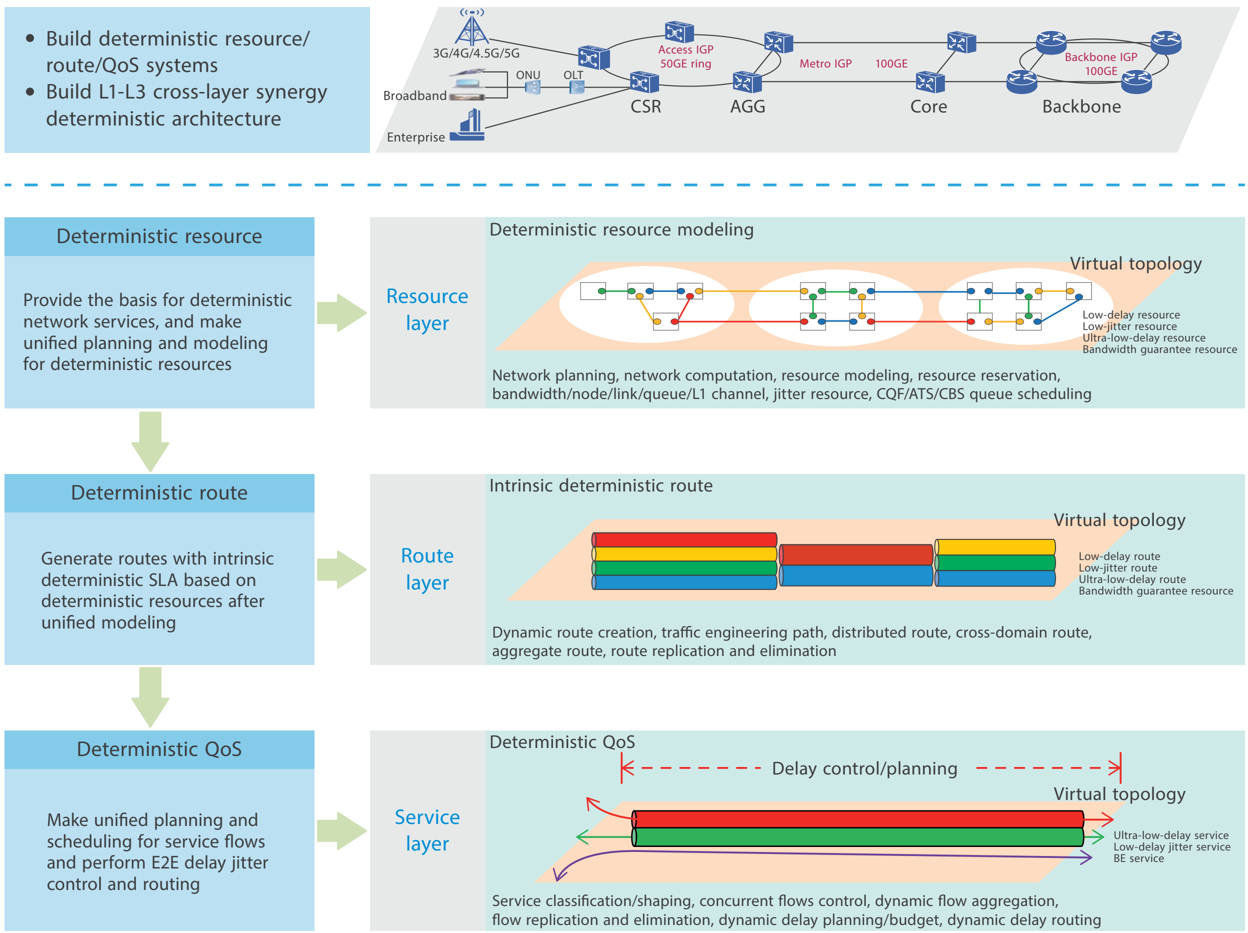


Fig. 2. Large-scale deterministic IP network architecture.

large-scale deterministic IP network architecture (Fig. 2). The resource layer maintains the deterministic resources of the entire network, and model the deterministic resources to form deterministic links. The routing layer computes deterministic routes based on the deterministic links to provide deterministic transport capabilities. The service layer maps flows to deterministic routes according to the specified traffic characteristics and performs traffic monitoring and shaping.

Deterministic Resource

Differentiated deterministic services require the networks to provide different deterministic capabilities. The resources related to deterministic capabilities are also differentiated. Deterministic resources refer to the resources that meet the deterministic indicators of a node and link processing (such as link bandwidth, queues, and scheduling algorithms). It is necessary to make unified modeling for heterogeneous deterministic resources to form unified deterministic links with different levels. A deterministic link can be a sub-network that provides deterministic transmission or a point-to-point (P2P) link. When the existing resources in a network are insufficient to meet the SLA requirements, a virtual network needs to be created.

Deterministic Route

Traditional routes only guarantee reachability and bandwidth. The paths change with the topology events. They cannot meet the deterministic requirements. To meet the requirements of different types and levels of deterministic services, it is necessary to create deterministic routes with different SLA levels based on the deterministic links.

Deterministic routes can be based on a strict or loose explicit path. The former is applicable to centralized scenarios with one or more controllers, and the latter is applicable to distributed scenarios without controllers. In the centralized scenario, one or several controllers may compute one or more paths with deterministic SLAs in advance according to the typical traffic specification (T-SPEC) based on the collected deterministic resources, or compute dynamically according to the T-SPEC as required by the services. It is suggested to generate two non-intersecting paths with very close delay to achieve 1+1 protection, and to perform replication on the ingress PE and elimination on the egress PE. In the distributed scenario, deterministic loose routes are computed through routing protocols. IGP is used to compute deterministic routes based on deterministic delay metric intra-domain, and BGP is used to compute deterministic routes based on accurate credit of delay/jitter across domains.

Deterministic QoS

Deterministic QoS includes delay and jitter determinism. The delay and jitter indicators can be considered together or separately. It is necessary to implement admission control and traffic policing at the ingress PE node based on the SLAs of deterministic service flows, and map the service flows to deterministic routes to achieve the final goal of deterministic QoS.

Deterministic QoS means that the end-to-end delay/jitter of flows with T-SPEC in the network will be strictly limited within a bounded range on the basis of deterministic resources and routes. As different service levels have different requirements for delay and jitter, the resources and routing mechanisms used for mapping service flows to deterministic routes are also different. For example, the extremely low delay and jitter can be guaranteed by L1 channel, so as to avoid the excessive intra-node delay contributed by too many hops of intermediate nodes at L3. Or in the customized virtual network, the bounded delay and jitter can be guaranteed by forwarding along the paths composed of links based on the ATS or CQF scheduling algorithm. Once the traffic is monitored and shaped on the ingress PE, the intermediate node does not need to maintain the QoS state; however, different scheduling algorithms have different shaping effects.

Conclusion

Deterministic 5G transport networks will gradually extend from LAN deterministic networks to MAN and WAN deterministic networks. The large-scale deterministic IP network architecture can meet the evolution requirements of this development trend for IP networks, and allows intelligent 5G IP networks to implement unified transport of emerging, differentiated and deterministic services in the future. ZTE TECHNOLOGIES

IP Autonomous Network Deployment

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In 2019, TM Forum proposed the concept of "autonomous networks (AN)", which aims to provide innovative ICT services with Zero-X (zero-wait, zero-touch, zero-trouble) experience based on fully automated life-cycle operations of self-configuration, self-healing and self-optimization, empowering digital transformation of operators. Over more than two years, the industry has reached a consensus on the concept with the launch of multiple relevant standard or research projects. In September 2021, the TM Forum White Paper on Self-Intelligent Network 3.0 was released, which advocates "building an automated and intelligent network". ZTE has also come up with its IP autonomous network solution based on years of innovative practices in the telecommunications field.

Overview of IP Network Intelligence System

Fig 1. shows the IP network intelligence system developed by ZTE. The bottom layer is the IP network layer, which needs the NE device to deliver the endogenous intelligence, such as self-awareness, self-configuration, self-recovery, and self-optimization.

The middle layer is the management and control system, and it is necessary to build an intra-domain intelligent closed-loop system. ZENIC ONE is ZTE's intelligent management and control system based on the cloud native platform. It contains awareness, control and intent engines, and combines the latest AI and big data technologies to generate a closed-loop system for sustainable learning.

The ZENIC ONE provides an intelligent and open API for the upper-layer system to support cross-domain global coordination and network application-based ecological closed loop.

Endogenous Intelligence of IP Network

Endogenous network intelligence allows real-time monitoring and analysis of IP NE data to best match software and hardware resources and conduct precise O&M for intelligent control. It delivers precise performance, status, and quality data for the upper-layer system, and allows flexible scheduling.

Awareness

The IP network needs to support the real-time awareness. The NE monitors its own software/hardware and the operational status, workload, and alarms of the services in real time, and offers data support for local or network-level closed-loop decision making. ZTE improves the NE awareness from the following aspects:

- Upgrade the out-of-band detection to the in-band one, and make IP traffic visible and measurable. IP IOAM can test the service quality of the IP network more accurately, and cut the number of detection packets in the network to improve the accuracy and efficiency of network awareness.
- Increase the granularity of network

awareness with the data collection intervals improved from 30 seconds to 10 seconds, and then 1 second.
- Intelligentize network awareness. In the precise awareness scenario, AI is introduced to enable self-learning and self-adaption of granularity for awareness. This technology can minimize the amount of data collected by the network, and ensure the awareness of tiny network status changes while improving the overall efficiency.

Self-Configuration

ZTE improves the automatic deployment of the IP network from the following aspects:
- Open NE capability by supporting such interface protocols as NETCONF, PCEP, BGP SR Policy and BGP-FS.
- Support NE configuration rollback to improve the fault tolerance of automatic NE deployment. If the configuration fails to be delivered, it will automatically roll back. The running configuration can be rolled back to a set rollback point.
- Allow NE to support VPN and tunnel combined configurations and automated service deployment and optimization.

Self-Recovery

ZTE has made the following improvements in the intelligent diagnosis and recovery of faults:
- Make redundancy protection for key components, and support millisecond-level hardware switchover.
- Support fast detection of BFD link faults and provide a 50 ms detection mechanism for active/standby service switching so that the NE can switch services quickly and recover services automatically.
- Enable TI-LFA FRR to achieve fast traffic recovery.
- Support configuration of service escape paths. When the end-to-end service path fails, services can be quickly recovered by escaping to the protection path.

Self-Optimization

IP network self-optimization evolves from manual to intelligent and proactive optimization. ZTE has made the following improvements:
- Adjust device power.
- Support automatic fan speed adjustments. The temperature of NE boards and racks is monitored for self-judgment and

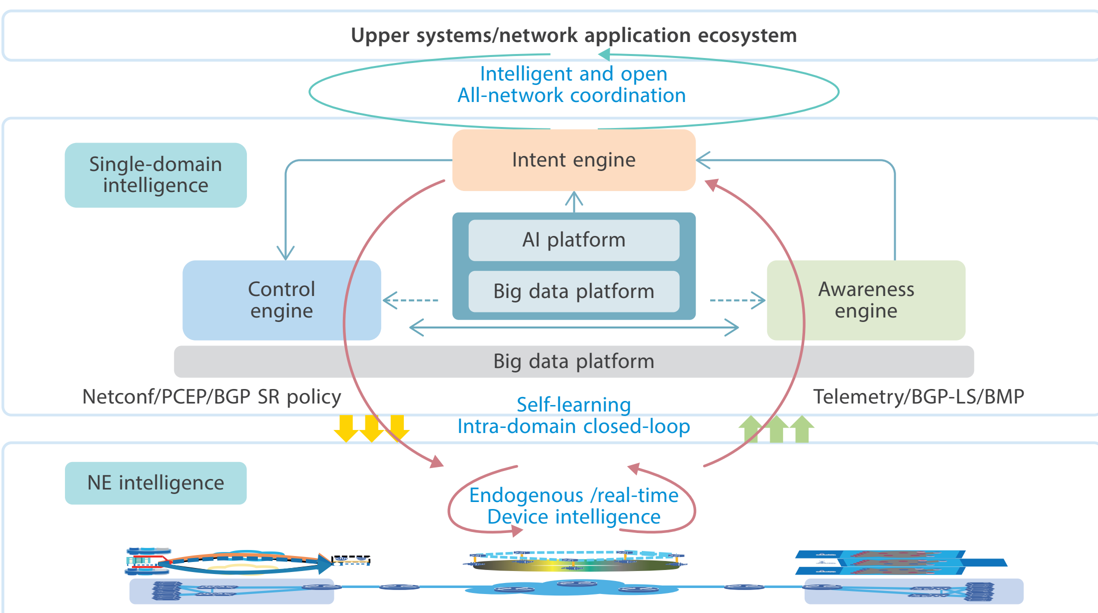


Fig. 1. IP network intelligence system.

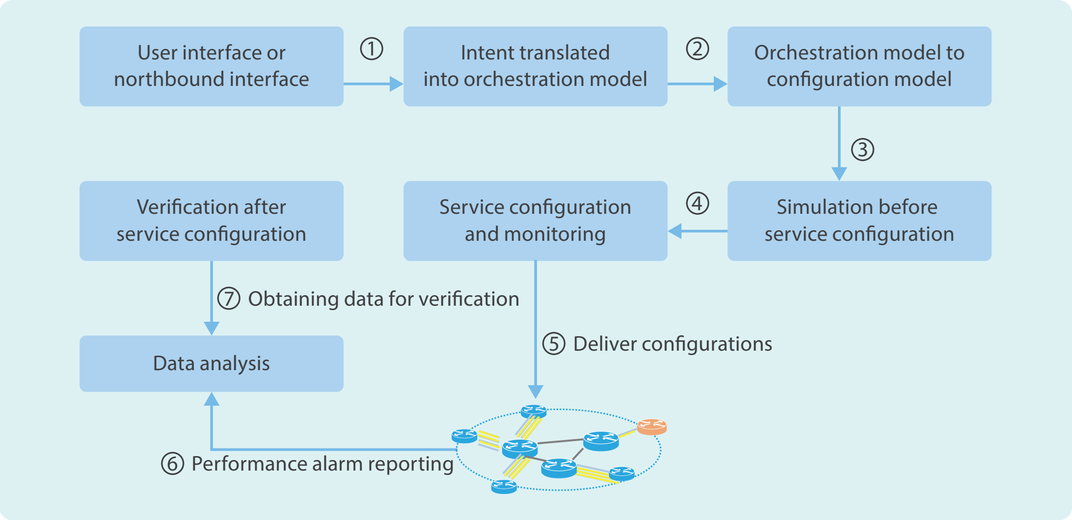


Fig. 2. Service provisioning flow.

decision-making.

- Dynamic sleep based on component load. When the component load is low, the system automatically determines whether to sleep the components to save energy.

Intelligent Management and Control System

In the current IP network O&M, service O&M and network troubleshooting are the most common scenarios. Service O&M automation and network troubleshooting intelligence can be enhanced to achieve autonomy within the IP network management and control domain.

Automatic Service O&M

Automatic Service O&M can be divided into two phases: deployment of automatic service provisioning and service maintenance and optimization.

The major problem in IP network service provisioning is low intelligence, which affects the service resource allocation speed. Moreover, service parameters are complicated and may be incorrectly configured.

In the IP network service provisioning (Fig. 2), the ZTE ZENIC ONE system automatically generates a service template according to the user's service requirements. The service is configured based on the service template. After the simulation succeeds, the system automatically sends the configuration to the device for service configuration verification.

It can be seen that the user only needs to pay attention to customer service requirements rather than professional network knowledge. The number of parameters that need to be concerned is greatly reduced.

When it comes to service maintenance and optimization, the ZENIC ONE system offers service self-healing and self-maintenance capabilities. The service awareness module can collect the service data in the network, and analyze the service operation information. If not as intended, the system optimizes services and modifies service configuration.

As network scale and traffic rise, service operation and protection routes will be unable to reach their optimal status. It is then necessary to optimize service routes and parameters, adjust service intents, design and simulate services again, and deliver optimized configurations.

On the other hand, as network services change, unbalanced network traffic has an increasing impact on the quality of the entire network, which needs to be detected and automatically optimized. The ZENIC ONE system can automatically monitor network traffic, analyze historical traffic and adjust network service bandwidth.

Intelligent Network Troubleshooting

There is great difficulty in identifying potential faults. Massive alarms overwhelm the monitoring system, and the network structure and service distribution are complicated. These make it hard to locate the root cause and solve the fault, and affect the O&M efficiency. To solve these problems, the ZENIC ONE has improved the intelligence in network monitoring and troubleshooting.

The management and control system divides network troubleshooting into three phases: fault identification, fault delimiting and locating, and fault handling and verification.

Fault identification relies on the intelligent sensing capability of the network to collect network status data and fault data from devices and the built-in intelligent analysis system to identify faults and potential troubles. It includes:

- Remote collection and big data analysis.
- Multidimensional fault analysis and tracing to quickly identify the root cause of a fault.
- Train data to create a fault model base.

Intelligent fault delimiting and locating is at the core of network troubleshooting. It supports precise scenario-based delimiting and locating, and can analyze and locate a specific fault within five minutes. If the detection module involves information exchanges associated with the device data, the fault can also be located within 15 minutes. The fault delimiting and locating support the following features:

- Hierarchical detection and fast fault delimiting.
- Automatic and visualized fault locating.
- Flexible policy as required by the users.

Fault handling and verification is the key of automatic closed-loop network troubleshooting, and allows automatic creation of systematic troubleshooting solutions. It includes:

- Automatically recommend multiple solutions and handling suggestions.
- Improve the level of fault repair automation.

The ZENIC ONE also supports simulation analysis suggested by network troubleshooting. Through simulating scenario-based network faults, it can find potential network troubles, and give a risk response plan before failure takes place.

Intelligent and Open IP Networks

The end-to-end intelligence of inter-domain services requires splitting the upper-layer system into different management and control systems. The open API of an intra-domain system is invoked to use the system intelligence. The upper-layer system performs end-to-end integrated analysis for intelligent O&M of cross-domain services.

The ZENIC ONE management and control system provides the upper layer system with intelligent and open capabilities of IP network and service data, supports northbound interfaces based on REST, SFTP, Socket, and SNMP protocols, and allows intelligent capabilities like service path provisioning, VPN service delivery, alarm, performance and resource obtaining, and notifications.

Summary

ZTE has been committed to exploring the evolution of network intelligence and automation and solving various challenges faced by traditional networks through innovative solutions. By practicing the self-intelligent network concept and introducing the latest technical solutions, ZTE will continuously increase network O&M efficiency and resource utilization, and improve the intelligence and sustainability of IP networks. ZTE TECHNOLOGIES

Analysis and Discussion on Energy Efficiency of Large-Capacity Network Elements

Zhu Xiaolong

Chief Engineer of BN Product Planning, ZTE

With the cross-domain development of ICT technology in the past two decades, IP network has gradually become the key infrastructure for people's life and work as well as social and economic development. The bandwidth of the IP network has increased hundreds of times. The router, an network element (NE) in the IP network, is facing huge challenges in power supply and heat dissipation deployment, energy saving and emission reduction as its platform capability has evolved from 2.5G/slot to 1T+/slot and its power consumption has increased from 2 kW to 20 kW.

In this paper, the energy efficiency of large-capacity NEs is analyzed and discussed from the aspects of power consumption structure, energy-saving methods and technologies, and the benefits and deployment.

Power Consumption Structure

From the perspective of power consumption, the structure of a router consists of three subsystems: function subsystem, heat dissipation subsystem, and power subsystem (Fig. 1). The function subsystem is the main body of the router, responsible for service processing like receiving/transmitting of optical signals, and data packet forwarding. It consumes a lot of electricity, while generating a large amount of heat. The heat dissipation subsystem is an important part of the router, responsible for dissipating the heat generated inside the device to ensure that the components of the function subsystem operate properly, which consumes a large amount of electricity during this process.

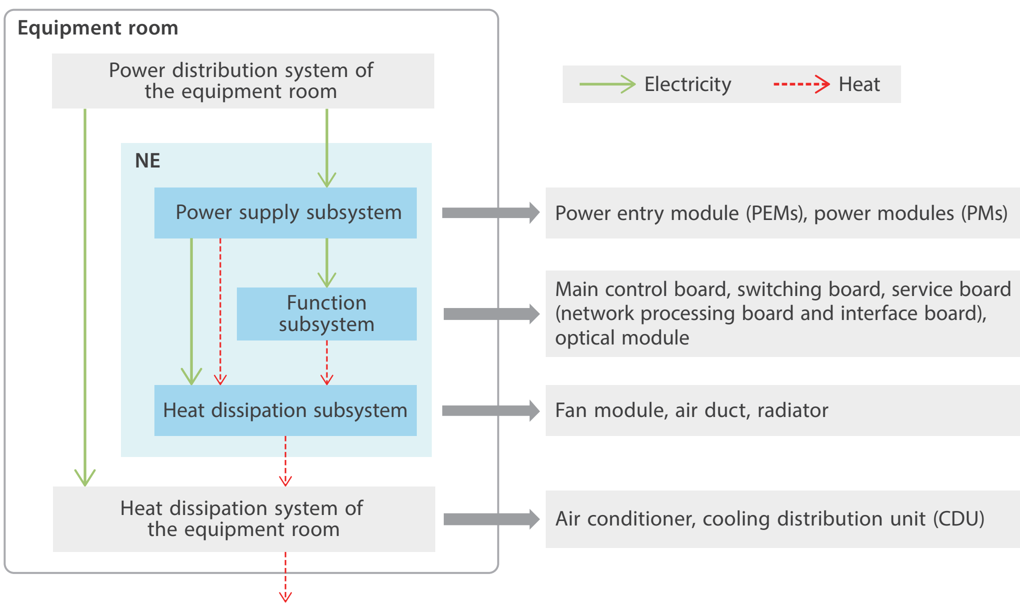


Fig. 1. NE structure.

The power subsystem is connected with external power distribution systems, converts the input power supplies, and provides power for both the function subsystem and the heat dissipation subsystem. It consumes some electricity. In addition to the heat dissipation subsystem of the router, the heat dissipation system of the equipment room also needs to consume a large amount of electricity to dissipate the heat generated by the router into the outdoor air.

The actual power consumption of the router may vary with the implementation solution, operating environment, service deployment, and traffic load, and its power consumption structure may also be different. Fig. 2 shows the power consumption structure of ZTE's large-capacity equipment with full hardware configuration and full load at normal and high temperature respectively. The power consumption of service boards in the function subsystem accounts for about 60–70%, and is 15% higher at high temperature than at normal temperature. The power consumption of the heat dissipation system accounts for about 15–25%, and is 125% higher at high temperature than at normal temperature.

For the equipment with the same thermal density and heat, the energy efficiency ratio (EER) of the heat dissipation system in the equipment room varies greatly with the air distribution and heat dissipation technologies. To dissipate the heat of 10 kW, the power consumption of the air-conditioning system in a traditional equipment room is at least 5 kW, while the power consumption of liquid-cooled CDU is not more than 500W.

Energy Saving Methods and Technologies

The energy saving methods and technologies are discussed from the function subsystem, heat dissipation subsystem, and power supply subsystem of the equipment according to the analysis on its power consumption structure.

Function Subsystem

The function subsystem is the main body of equipment power consumption. The actual consumption is determined by hardware design solution, component operating status, and component traffic load. Therefore, the power consumption of the function subsystem can be reduced from the following aspects:

- **Hardware design solution:** With the continuous increase of IP network bandwidth, the capacity of the equipment platform has doubled almost every 2–3 years in the past decade. The chips with higher integration, more advanced manufacturing process and larger capacity are used to reduce the number of chips on a single board and lower the chip-level power consumption per unit capacity and the power consumption of inter-chip communication. This can effectively slow down the growth trend of overall power consumption and reduce EER.
- **Component operating status:** When the equipment is deployed, many board components are installed. Generally there are some components that are not officially enabled but are powered on and consume energy. Therefore, if the power-on/power-off function of service board components is supported and controled as required, the actual power consumption of the function subsystem can be effectively reduced. To ensure high system reliability, key components like main control boards and switching boards are generally not powered off.
- **Component traffic load:** The actual power

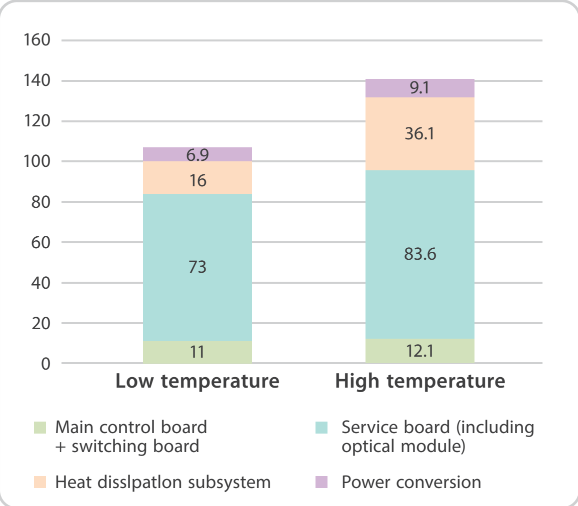


Fig. 2. Power consumption structure of large-capacity equipment.

consumption of board components is affected by traffic load. The more complex the services, the higher the traffic load, and the higher the chip power consumption. The core chips have been able to automatically adjust power consumption in real time according to load changes. On this basis, energy saving can be considered from two levels. At the chip level, a large-capacity forwarding plane chip usually consists of different function units. Theoretically, some function units of the chip can be turned off based on the actual service type, traffic load, and interface enabled to save more energy. This method requires the support of chip-level features and intelligent software analysis and control features. In actual deployment, there is uncertainty about the impact of the function units that the chip turns off on actual services as well as the time and mode of restarting the function units. At the network level, generally there are a large number of parallel links for IP network node interconnection. When the traffic load is low, some of these links can be shut down to save energy. If the disabled links correspond to one interface board or service board, the corresponding board can be powered off to maximize energy saving. When the traffic load increases, the disabled links or the powered-off board needs to be restored. If the parallel links are members of the LAG interface, the NE itself can perform intelligent analysis and restoration. If the parallel links are members of route load sharing, the centralized controller is required to implement network-level analysis and management.

Heat Dissipation Subsystem

The power consumption of the heat dissipation subsystem mainly comes from the rotation of fans. The fans consume more electricity as its rotational speed increases. The fan speed is also related to chip temperature, system air duct, radiator, and fan efficiency. Therefore, the power consumption of the heat dissipation subsystem can be reduced from the following aspects:

- **Advanced air duct design:** At the system level, independent air ducts are designed in different areas, and front-to-back I-type or Z-type air ducts are employed to shorten the air duct path. At the component level, the chip layout is optimized to reduce wind resistance of the path.
- **Advanced radiators and fans:** Advanced heat conduction technologies such as phase change radiators and efficient thermal conduction interface materials are used to improve the efficiency of heat transfer from the chip to the air. Energy-efficient fans are used to consume less electricity and emit more heat.
- **Intelligent fan speed control:** Real-time precise closed-loop monitoring of chip temperature and fan speed is realized, and the chip temperature is controlled within the optimal operating temperature range with the lowest fan power consumption.
- **Liquid cooling technology:** The cold plate is used to dissipate heat for key chips with high heat density on the component, and the heat is transferred from the equipment to the CDU through the liquid-cooled media in the pipeline connecting the cold plate and the CDU. The CDU exchanges heat to the water cooling system of the air conditioner in the equipment room, and releases it into the outdoor air.

Power Subsystem

The power consumption of the power subsystem is reflected in the power conversion efficiency. The higher the power conversion efficiency, the lower the power consumption of the power subsystem. The power conversion efficiency is related to the number of power modules and power load. When the power load is low, the power conversion efficiency is relatively low.

Operators require full configuration of power modules for large-capacity NEs, while the number of power modules for large-capacity NEs is usually designed based on extreme conditions such as long-term evolution and high temperature conditions. As a result, the

Subsystem	Energy saving technologies	Benefits	Deployment considerations
Function subsystem	High integration, advanced manufacturing process, large-capacity chips	Significant reduction in EER per device Platform capacity: 400G->800G->1.6T->3.2T EER: 2.5W/G->1.5W/G->0.8W/G->0.4W/G	Purchase the equipment with higher platform capability according to service development requirements, equipment room conditions and budget
	Disable idle service boards	0.4–0.8 kW saved per service board	Consider the deployment based on network planning, component redundancy and maintainability
	Disable idle interface boards	20–40W saved per interface board	
	Disable idle optical modules	3–5W saved per interface	
	Dynamically adjust chip power consumption according to traffic load	0–250W saved per service board	Inherent features of equipment
	Intelligently disable some functions or interface units of the chip	Uncertain	Consider the deployment based on support of equipment, network and service risks, energy saving benefits and maintainability
	Intelligently disable light-load interfaces or corresponding boards	0.4–0.8 kW saved per service board 20–40W saved per interface board 3–5W saved per interface	
Heat dissipation subsystem	Advanced air duct design, energy-efficient fans, phase change radiator, high-efficiency thermal conduction interface material	Improving energy efficiency	Use equipment with higher platform capability according to service development requirements, equipment room conditions and budget
	Intelligent fan speed adjustment	0–5 kW saved per device	Default operating mode
	Liquid cooling	4–10 kW saved per device + equipment room	Consider the deployment based on maturity of liquid cooling technology, heat dissipation requirements, equipment room conditions and reliability risks
Function subsystem	High-efficiency power supply	Improving power conversion efficiency	Inherent features of equipment
	Dynamically adjust the number of operating power modules according to the load	0.2–1 kW saved per device	Consider the deployment based on support of equipment, network and service risks, energy saving benefits and maintainability

Table 1. Recommendations on energy-saving benefits and deployment.

actual power load of the equipment may be relatively low, and the power conversion efficiency is not optimal. According to the actual power load of the equipment or the power load of the function subsystem in full configuration, appropriate redundant power modules can be added to turn off idle power modules. This helps to improve the power conversion efficiency, thereby reducing the power consumption of the power subsystem.

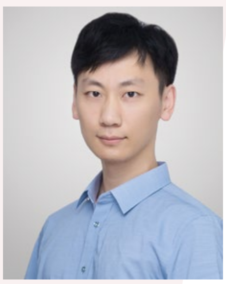
Benefits and Deployment

The benefits of energy efficiency vary greatly with different energy-saving technologies, and there are also differences in technology maturity and deployment risks, as shown in Table 1. It is recommended that operators deploy appropriate energy-efficient technologies based on their own conditions.

Conclusion

ZTE has fully employed the self-developed chips with high integration, advanced manufacturing process and large switching and forwarding capacity in the function subsystem of its large-capacity IP NE, which can support component-level power-on/power-off. In the heat dissipation subsystem, it has used independent front-to-back I-type or Z-type air ducts in different areas, and has also adopted advanced thermal conduction technologies and energy-efficient fans to support intelligent fan speed adjustment and liquid cooling technology. The anhydrous liquid cooling system has been trialed on the operator’s network, which can effectively reduce the noise and power efficiency usage (PUE) of the equipment room. Self-developed high-efficiency power modules have been used in the power subsystem, with a power conversion efficiency of up to 95%. ZTE has adopted advanced and mature energy-saving technologies in its large-capacity IP NEs, which will help operators reduce the power consumption of their equipment and auxiliary facilities and contribute to the green development of human beings. ZTE TECHNOLOGIES

Telekom Malaysia Builds 5G Transport Network



Wang Shuyu

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Significance of TM's NGN Project

With the 5G wave sweeping the world, Malaysia started large-scale 5G network deployment in 2021. Telekom Malaysia (TM), the largest wireline operator in Malaysia, aimed to build a new generation of SDN-based transport network that could meet 5G service needs in the next 10 years by replacing existing old networks. The new transport network will become the infrastructure for carrying 5G services and providing excellent interconnection and interworking capability in Malaysia. To achieve the goals, TM initiated a biding for its next-generation network (NGN) project in early 2020, which put higher requirements for technical solutions, network planning and equipment vendors.

In recent years, based on its in-house core chipset technologies and fast delivery of customized functions, ZTE has rapidly enhanced the competitiveness of its IP products, continuously won contracts from mainstream telecom operators worldwide, and steadily increased its market share. ZTE created a professional team to fully prepare for network planning, design and testing, so TM chose ZTE to help with its NGN project. With its enhanced product performance and fast delivery of flexible customization, ZTE has established a deep cooperation with TM, helping TM seize market opportunities in the 5G era and better serve the 5G deployment in Malaysia.

TM Builds Intelligent and Reliable 5G Transport Network with High-Performance Products

TM officially launched its NGN IP CORE network in October 2021. The NG CORE and HSE devices provided by ZTE were successfully deployed on the network (Fig. 1), marking the first important milestone in the completion of TM's NGN project.

TM's newly-built NGN network will carry a variety of services such as home broadband, voice, enterprise private line, wholesale, CDN,

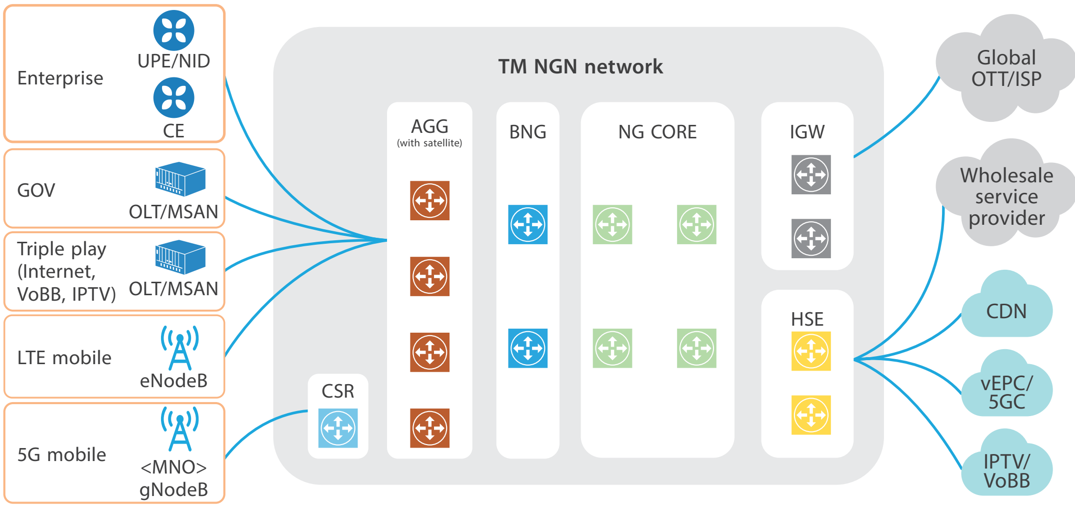

Fig. 1. TM's NGN network.

and wireless 4G/5G backhaul, and will become the only backbone bearer network for transmitting 5G mobile services in Malaysia.

In this NGN project, TM used ZTE's multi-service router ZXR10 M6000-S 2T/slot to build NG CORE, HSE and AGG sites. At the AGG site, the innovative satellite router solution with ZXR10 M6000-S and ZXCTN 6120 H-A were adopted to offer massive GE interfaces for large-scale access to fixed-line home broadband and enterprise private lines. ZTE also provided its ZXCTN 6100H series supporting Tbit access to construct CSR sites, offering flexible slices for 5G transport.

In terms of network design, ZTE helped TM implement interconnection of old and new planes for smooth service transition, gradually replace the old Metro-E network, and integrate with the existing IP CORE network, and finally build a large flexible intelligent transport network delivering all services. To improve the reliability and intelligent planning of links, TM employed ZTE's segment routing (SR) technology to deploy new network routing that could achieve fast route convergence, TE protection switching, flexible load sharing, and rapid response to link and node faults. ZTE's segment routing mapping server (SRMS) was also used to connect old and new network tunnels to guarantee the end-to-end tunnel transmission of existing services. Functions such as Netflow, BGP-FS, TWAMP-Light and Y.1731 were deployed as required for network transmission quality monitoring and security protection. The new network will put 5G services into operation in Malysia for the first time, meeting the complex needs of QoS, tunnel selection and bandwidth allocation in case of access by multiple wireless operators. Besides, the customized network slices based on DSCP can flexibly carry 5G services.

ZTE also supplied end-to-end 5G IP network products with full-stack SDN capability, which could be used with TM's SDN controller to quickly distribute services end to end, flexibly optimize network, and simplify O&M. This helped TM ensure differentiated SLA guarantee and maximize business profits.

Solid Foundation for 5G Project Launch

TM and ZTE project team conducted an in-depth study of the existing network and designed a network planning blueprint. ZTE also shared with TM its successful experience in SPN and IPRAN, and discussed the most suitable network deployment solution for carrying 5G services in Malaysia. Despite the inconvenience caused by the widely spread COVID-19 pandemic, the project teams of both sides overcame the difficulties and completed the meeting communications and on-site testing on time.

ZTE made in-depth analysis on service requirements of the existing network, and provided fast and flexible delivery of the customized functions. Finally, with its excellent product strength, ZTE successfully passed the tests and was highly recognized by TM. The successful completion of the NGN project has laid a solid foundation for TM to build a 5G networks on a larger scale in Malaysia. ZTE TECHNOLOGIES

Operators Set Clear Autonomous Network Goals, Progress in Exploration and Practice

5G-data-AI synergies spark intelligence to ease O&M challenges, spur digital transformation

Source: Mobile World Live

The emergence of 5G—one of key technologies in the Fourth Industrial Revolution—has spawned networks with digital, cloud-based and micro-service features. These networks foster a wide array of new services and spearhead digital transformation that fulfils diverse customer requirements for vertical industries in the new era.

However, operators are facing great challenges in their efforts to transform. To overcome them, ZTE encourages operators to apply the principles of "Three Leads" when they embark on their digital transformation journey.

- The Business and Experience Lead enables experience-driven, closed-loop operations whilst operators explore optimal strategies for dynamic and optimal network utilisation and business development.
- The Open Lead drives collaborative transformation of business, network and data. The aim is to create synergy between the design state and the operations state.
- The Value Lead allows operators to focus on the high value scenarios which satisfy market demands and their customers' needs.

If the network was to be regarded as a human being, self-autonomy would lead to energised body parts with more agility and flexibility. However, without the central coordination using closed-loop insight based on experiencing the surrounding environment, the full benefits of automation cannot be unleashed to realise the goal of an autonomous network.

At ZTE, we believe that network intelligence utilising big data and artificial intelligence (AI) as the "Brain" for the network is the way forward for operators to meet the challenges of digital transformation and realise the ultimate goal of an autonomous network.

Today, autonomous networks are used in the whole process of network operations and maintenance (O&M), bringing essential business value and benefits to operators.

Overall, autonomous networks enable operators to enhance network agility in support of business dynamics in the following key areas:

- **Operations strategy improvement:** This supports operations strategy decision making with "experience insight", "business insight" and "value insight" to increase competitiveness in the market.
- **Collaborative product innovation:** This provides a unified business-enabling platform yielding high agility and reliability. The platform lays the foundation for operators to work closely with ecological partners so as to differentiate their products and services from competing ones.
- **Efficiency improvement, cost reduction and sustainable development:** The enabling platform makes it possible to manage 2C (to consumer), 2B (to business) and 2H (to home) operations and maintenance efficiently for sustained development across vertical industries.

After years of industry development and exploration, leading global operators have set the vision and goal of realizing autonomous networks in four key aspects, namely single domain autonomy, cross-domain collaboration, capability openness, and joint construction of the ecological environment.

ZTE actively participates in the systematic construction of

Zhang Wanchun, Senior Vice President of ZTE Corporation

"ZTE believes that a network embedded with native intelligence lays the core foundation while the service-driven, cross-domain intelligent "Brain" holds the key for the future."

autonomous networks and carries out comprehensive pilot projects and commercial trials of autonomous networks with global operators. Aligning with the operators' aspirations, ZTE has launched the uSmartNet cross-domain autonomous networks solution, which has a layered architecture and ubiquitous AI capability.

The envisioned architecture for autonomous networks encompasses native intelligence at the network elements (NE) layer, single-domain autonomy at the network layer, and cross-domain collaboration at the service layer.

In terms of the NE and network layers, ZTE focuses on the native intelligence of NE embedded with AI capabilities within the closed loop of single-domain resources. This achieves the objective of a network being "perceivable, operable, highly reliable and self-optimising". It also establishes intelligent foundation blocks for the unified management of cross-generation, cross-domain and cross-vendor operations on a single-domain operations maintenance centre (OMC) professional workbench.

In the cross-domain service layer, the uSmartNet solution contains the VMAX digital intelligent platform that utilises big data and AI technologies.

The solution focuses on cross-domain operations and provides end-to-end (E2E) analysis of voice and data services. It delivers a "unified view with global awareness as well as automation of intelligent closed-loop operations". uSmartNet also provides open data and AI via OpenAPI to support partners' eco-systems. Such openness frees operators to develop an ecological network with a high degree of autonomy.

At present, the uSmartNet autonomous networks solution has been deployed in a few operators' networks with applications in a number of areas.

Some of the deployments focus on customer experience management and service quality management. Some of the deployments focus on network resource management such as network alarm management, network performance optimisation through automated analysis, intelligent root cause mining as well as close loop automation. Still others focus on network optimisation automation.

One of the noteworthy use cases relates to the energy-saving feature of the uSmartNet solution for 5G. The capability makes it possible to dynamically switch on and off power based on localised and dynamic traffic demand while maintaining a high quality of customer experience.

Embedding ZTE uSmartNet into network operations also helps to raise the intelligence and automation level across domains. We believe that in our industry collaboration efforts over the coming years, we can work with global operators to achieve the ultimate goal of autonomous networking via a phased approach.

The ever-growing intelligence capabilities of uSmartNet will also enable collaboration across vertical industries. This will enable operators to explore untapped business opportunities and expand into new vertical and digital markets.

Bearing the vision of the ultimate autonomous digital network, ZTE believes that a network embedded with native intelligence lays the core foundation while the service-driven, cross-domain intelligent "Brain" holds the key for the future.

The networks of tomorrow will feature intelligent planes to support intent-based networking and enable operations utilising the latest technologies such as digital twins, federated learning and intelligent computing convergence. This will in turn lead to game-changing applications that make the universal benefits of intelligent autonomous networks a practical reality across industries. ZTE TECHNOLOGIES

To enable connectivity and trust everywhere