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ZTE TECHNOLOGIES

VIP Voice

VEON AdTech: Generating Growth for Local Businesses and Building a Better Protected World for Customers

Expert Views

Research on SPN 2.0 Technical Features and Application Solutions in Industry Scenarios

Special Topic:

Slicing Packet Network

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Cover Figure | *George Held, CEO of VEON AdTech, located in Uzbekistan*

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VEON AdTech

Generating Growth for Local Businesses and Building a Better Protected World for Customers

Reporter: Fu Yu

George Held

CEO of VEON AdTech, located in Uzbekistan

"VEON has developed an elegant way to deliver meaningful ads to the right consumers, at the right moments, on the right device," says George Held, CEO of VEON AdTech, who discusses how the company's digital marketing services empower local businesses and enhance user experience, at the ZTE 5G Summit & User Congress 2023 in Thailand. VEON, a global digital operator serving nearly 160 million customers in six dynamic markets, is addressing the growing digital advertising opportunity in its markets by establishing a dedicated AdTech company in April 2023, headquartered in Tashkent, Uzbekistan. VEON AdTech works with VEON's digital operators and supports the VEON Group in providing highly targeted digital marketing services based on machine-learning algorithms building on VEON companies' proximity to their customers.

Why Telco operator is looking into precision marketing services and why is VEON AdTech?

People who see ads want them to be relevant, customized, and based on customer insights. VEON has developed an elegant new way to deliver meaningful ads to the right consumers, at the right moments, on the right device. This improves the effectiveness of marketing communication, boosts the performance of local businesses, and reduces information overload.

Using detailed customer knowledge, combined with the application of advanced mathematical models on the enriched Telco data, VEON is empowering local businesses to flourish and local economies to grow.

In 2023, 2 billion ad impressions per month were served and 30 billion ad impressions per month were delivered through VEON AdTech services.

How VEON AdTech is approaching this customer need?

In order to enhance performance of local businesses, VEON AdTech combines Telco-data-based customer insights and advanced mathematical models. Today, VEON manages 31 petabytes of customer data. 28 TB of data is loaded daily, and 2.7 million data messages per second are streamed in real-time.

Using anonymized traffic data, VEON AdTech is enabling local businesses to communicate with their customers in the most efficient and accurate format through precision marketing instruments:

- VEON AdTech enables local entrepreneurs to attract new customers through highly targeted communication. All customer communications are highly customized and targeted to the "segment of one".
- Customer communications are delivered not only through the global advertisers (META, Google, Telegram, and TikTok), but most importantly through locally relevant channels (VEON's own applications, local websites) and SMS.
- VEON provides local businesses with the ability to measure the effectiveness of their communication campaigns in real time. No more "spray and pray" and waste of advertisement budgets.

This is paramount for local economies, and especially for small businesses, for whom VEON AdTech is often the most effective advertising channel utilizing state-of-the-art technologies.

How does your innovation streamline, simplify or enhance the user experience?

VEON AdTech's geo-analytics uses big data from anonymized traffic to optimize locations and opening hours for retailers. The service has been successfully used at Samarkand Darvoza, one of Uzbekistan's largest shopping centers.

The project showed that of the 18,000 people

who visit Samarkand Darvoza every day, the largest demographic group was men between 26 and 35, and the most popular visiting time was 9 pm. The anonymized data also revealed that 20% of people visited the shopping center only to go to the food court. According to Shokir Mirsaidov, Commercial Director of Samarkand Darvoza Shopping and Entertainment Centre, the geo-analytics provided valuable insights into its customers: "We wanted to understand the behavior, number and composition of people visiting our shopping visitors. The analysis we received gave us a clear understanding of the demographics of our customers, but also told us about the people who were not visiting."

VEON AdTech also enables advertisers to send personalized and targeted communication messages to potential customers, based on their interests and behavior. The service also protects consumers from informational pollution through accurate targeting of interests and with easy opt-outs. A countrywide pizza chain in Uzbekistan worked with VEON AdTech to target specific demographics for a precision marketing campaign. "The targeted communications not only brought about a 73% increase in app traffic, but also exceeded our expectations by driving a 58% boost in sales," stated Sergey Kim, Development Director of Dodo Pizza chain in Uzbekistan.

How do you ensure your service delivers in a secure and trustworthy manner?

VEON AdTech complies with international business standards to ensure consistency, security, and scalability. It follows the IAB standards and obeys the ICC marketing code.

VEON AdTech stores and manages customer data locally in data centers located in each country. The data centers are fully Tier 3 or Tier 4 certified, meet ISO 27001 Cyber Security requirements, and are managed by top local talent with Oracle, Microsoft, or VMWare certifications.

VEON AdTech respects stringent privacy policies and complies with local data privacy rules, requirements of local Central Banks and Ministries of Communication, and customer Terms and Conditions (T&C). Customers are fully informed about the T&C and can opt out of VEON communication at any time.

VEON AdTech also adheres to the highest ethical standards and ensures that only business scenarios that meet VEON's ethics standards are

14% Visitors came to the **new children's playground** on a weekday

20% Visitors are exclusively interested in the **food court**

18K The number of people who visit the **shopping center** per day

implemented in commercial operations.

To date, what results have you seen from the implementation of your services?

- Geo-analytics: By applying advanced mathematical models on people's movements, we help governments to plan city infrastructure and roads, bus routes and public events, and help local businesses to predict the best locations for their new stores and optimize delivery routes.
- Video analytics: Through the utilization of computer vision and AI, we are helping firefighters to identify and stop fires, ensure safety at the workplace, and enable efficient operations of the local businesses.
- Precision marketing (AdTech): By capitalizing on the proximity to the customers and detailed local knowledge, only in 2023, 2 billion ad impressions per month were served and 30 billion ad impressions per month were made available through VEON AdTech services.

All of this is executed on the customer data stored in the in-country Data Centers, ensuring full compliance with local data privacy rules, and managed by top local talent.

Through detailed customer knowledge, and by applying advanced mathematical models, we will empower local businesses to flourish and local economies to grow.

How is your product unique and truly innovative compared to other solutions on the market?

VEON AdTech leverages enriched VEON Telco Data and advanced mathematical models to offer valuable solutions to local businesses, improving their operational efficiencies and reducing informational pollution for the end-consumers.

VEON AdTech uses VEON's own local applications and websites (Telco Self-service, Television/media, Music, Healthcare, Fintech, etc) as the most relevant advertisement

publishing platforms for the end consumers. This is an integral part of VEON Digital Operator (DO1440) strategy and a key monetization channel. This is executed in addition to advertisements via META, Google, Telegram, and TikTok.

VEON AdTech adheres to stringent privacy policies and provides the highest level of protection to users, both from information overload and from unwanted communication. Users can easily and consistently opt out of VEON communication at any time.

VEON AdTech stores and manages customer data locally in each country of operation, ensuring full compliance with local data privacy rules.

VEON AdTech complies with major international standards, such as the IAB standards and the ICC marketing code.

What is your vision for sustainable future growth?

Fast growth of VEON AdTech is fueled by the knowledge, connection, and proximity it has to customers.

This is just the beginning.

Together, we are generating growth for local businesses, building a new value creation stream for mobile operators and a better protected world for customers. ZTE TECHNOLOGIES

Research on SPN 2.0 Technical Features and Application Solutions in Industry Scenarios

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The 14th Five-Year Plan marks a pivotal phase in China's digital and intelligent transformation. The 5G+ industrial Internet will drive innovation to develop new applications and ecosystems. Key sectors like power, transportation and railways will undergo gradual upgrades via private networks. The Ministry of Industry and Information Technology's Industry Internet Innovation and Development Action Plan (2021–2023) outlines strategies supporting the advancement of "5G+ industrial Internet" and deploying new technologies such as deterministic networks. To develop high-quality 5G+ industrial Internet and private networks, the focus includes upgrading enterprise intranets, integrating IT with OT networks, building secure campus networks, establishing external networks for enterprises with high-performance, high-reliability, high-flexibility and high-security network services, deploying new technologies such as cloud-network/computing-network convergence, deterministic networks, and IPv6 segment routing (SRv6), and promoting industrial access to high-quality external networks with a focus on data and network security.

In collaboration with the China Academy of Information and Communications Technology (CAICT) and leading device manufacturers, China Mobile actively drives technological innovation and industrial applications in the slicing packet network (SPN) field for various industrial scenarios. The practical implementation of application solutions is underway in sectors like power, transportation, coal mines, ports, healthcare, and industrial campuses. In January 2023, the Research Report on the Requirements and Application of SPN in Industrial Scenarios was approved during the plenary session of the Industrial Internet Industry Alliance.

Transport Demand Analysis in Typical Industry Scenarios

Network transport demands differ across various industry scenarios. For instance, in typical service scenarios like 5G+ industrial Internet and smart grids, Table 1 outlines variations in transport capabilities and index requirements for communication networks across eight service

scenarios (5G+ UHD video, 5G+ remote control, 5G+ cloud-based AGV, 5G+ machine vision, 5G+ drone, 5G+ cloud robot, 5G+ AR, and 5G+ VR) and smart grids.

To meet differentiated service requirements across different industries, the transport network needs to possess the following features:

- **Hard isolation slicing:** In the industrial sector, diverse scenarios including production control, collection/detection, and information monitoring, require end-to-end hard isolation slicing for effective management of mixed and complex traffic flows.
- **Carrier-class reliability:** Production services in the industrial Internet and smart grids require 99.999% or higher network reliability. This necessitates end-to-end high-reliability network protection and recovery mechanisms, and carrier-class O&M.
- **Deterministic transport:** For deterministic needs in scenarios like industrial control and monitoring, research is crucial for constructing end-to-end deterministic networks and innovating deterministic transport technology across wide-area heterogeneous networks.
- **Flexible access and scheduling:** In the industrial sector, service terminals and types vary widely, featuring diverse network interfaces, protocols, and communication demands. A key aspect of a transport network is to ensure extensive access, collaborative operation, and flexible, efficient scheduling and forwarding of heterogeneous terminals.
- **Versatile service perception:** In-depth service perception and the application of new ICT technologies strongly support the digital transformation and high-quality development of industrial users. Achieving deep integration with these technologies presents a major challenge for communication networks.
- **Intelligent control and O&M:** Intelligent, convenient and open network O&M greatly improves the operational efficiency and autonomy of various industrial Internet services. It reduces response time for new service deployment, enabling agile innovation in the industry.

Standardization and Technical Features of SPN 2.0

SPN 2.0 surpasses SPN 1.0 in multiservice transport, cloud-network convergence, network coverage, intelligent control and O&M, and low-carbon energy efficiency. With new frame structures and cross-connect technologies supporting N×10 Mbps fine granularity units (FGU), it expands 10GE small access SPN devices for private line access and industrial campus application. Moreover, it enhances the integrated transport of 5G+ vertical industries, enterprise private lines, and cloud-network/computing-network convergence

	5G+ industrial Internet								5G+ smart grids		
	Machine vision	Remote control	AGV	Ultra HD video	Drone	Cloud robot	AR	VR (partially immersed)	Differential protection	PMU	5G+MEC+slicing remote control
Latency	1~2 ms	2~5 ms	20 ms	<30 ms	≤3 ms (control)	10~100 ms	<10 ms	<30 ms	2~5 ms	5~10 ms	30~50 ms
Jitter	—	100 us	—	—	—	—	—	—	Two-way latency difference 200 us	—	—
Reliability	99.99%	99.999%	99.9999%	99.9%	99.99% (control)	99.9999%	99.999%	99.999%	99.999%	99.999%	99.9%
Committed bandwidth	Uplink: >50M	Downlink: ≤2M	10 Mbps~ 1 Gbps	12~40 Mbps	4 Mbps/ channel	>10 Mbps	>50 Mbps (uplink)	>100 Mbps	≤2M	≤2M	≤2M
Synchronization time-frequency	—	—	—	—	—	—	—	—	10 us-level timing	1 us-level timing	—

Table 1. Transport capabilities and index requirements for communication networks across various industry scenarios.

services.

Starting in mid-2019, China Mobile explored SPN fine-granularity technology for 5G+ industries and enterprise private lines. It adopted the N×10 Mbps-based FGU solution, releasing the *Technical White Paper on SPN FGU* in June 2021. By the second half of 2021, enterprise standards were completed. In June 2022, SPN 2.0 technical white paper and private line products were launched, and comprehensive evaluation of multi-vendor SPN 2.0 equipment is ongoing. China's Ministry of Industry and Information Technology (MIIT) has officially published three SPN industry standards: YD/T 3826-2021, YD/T 3974-2021, and YD/T 4172-2022. Additionally, three industry standards, including *Test Methods for SPN Equipment,* have been submitted for approval. Research is ongoing for six industry standards, such as *Technical Requirements for Fine-Granularity Transport of SPN* and *Technical Requirements for Interworking of SPN.*

As a key technology in the SPN slicing channel layer, metro transport network (MTN) has systematic international standards in ITU-T. By January 2023, five international standard recommendations (MTN architecture G.8310, MTN interface G.8312, MTN equipment function G.8321, MTN linear protection G.8331, MTN network management and control G.8350) and one technical report of network evolution G.sup.69 had been released. The MTN synchronization standard was completed in 2023. At the September 2022 ITU-T SG15 plenary session, Chinese members successfully obtained approval for the G.fgMTN standard, indicating international recognition for the core architecture and key technologies of the MTN extension fine-granularity sub-channel.

Research on SPN 2.0 Application Solutions in Industrial Scenarios

Analysis of SPN 2.0 Applications in Industry Scenarios

The industrial Internet includes two network application scenarios: industrial intranet and industrial external network. The industrial intranet connects the data of production, control and other enterprise sectors, managing daily operations through OT and IT networks. The industrial external network provides highly reliable, low-latency connections for remote production control. Telecom operators in China must evolve into integrated service providers supporting the industrial Internet. Their networks should not only prioritize reliable security, carrier-class high reliability and deterministic transport, but also

ensure ubiquitous access, flexible networking, visual and intelligent control, and SLA guarantee.

SPN 2.0 primarily serves industrial external networks in industrial Internet applications. It can also be applied to specific industrial intranet scenarios, like coal, ports, and industrial campuses, as required. The small access SPN 2.0 device functions as the egress gateway for industrial intranets, facilitating effective connections to industrial external networks. This includes integrated transport with multi-service security isolation, end-to-end network slice interworking and scheduling, and service capability exposure for different industry slices.

SPN 2.0 features soft, hard, and hierarchical network slicing using N5 Gbps and M10 Mbps MTN channels. It provides deterministic transport similar to SDH VC-4/VC-12 TDM hard isolation and soft isolation with N5 Gbps MTN interfaces. This enables high-security isolation, highly reliable unified transport, and differentiated SLA guarantees for various industrial Internet services such as production control, information management and Internet access (Fig. 1). It ensures comprehensive competitiveness in current transport network technology with independent and controllable key technologies and a promising long-term development prospect.

SPN 2.0 Applications in 5G+ Smart Grids and Private Power Networks

The 5G-based virtual private network in the power industry offers ultra-low latency, massive connections, and ultra-high bandwidth. It enables end-to-end hard and soft slicing, ensuring various levels of security isolation for services across different power grid areas. This facilitates applications like 5G+MEC+slice for remote control, differential protection, DTU, distributed energy, and intelligent preventive maintenance, addressing communication challenges at the smart grid's endpoints.

5G power distribution network services, categorized into control and collection, vary in security levels. This includes differential protection with low delay/jitter and high reliability, power distribution automation requiring high synchronization precision, and large-bandwidth video conferencing. SPN power industry wireless slices use PRB reservation. Transport SPN is deployed through 5 Gbps coarse-grained or 10 Mbps fine-grained MTN slices, and UPF takes the form of ToB UPF. The main electric power station and ToB UPF employ VPN enterprise customer slices and 100 Mbps VPN private lines, ensuring assured bandwidth delivery (Table 2).

China Southern Power Grid has planned to deploy

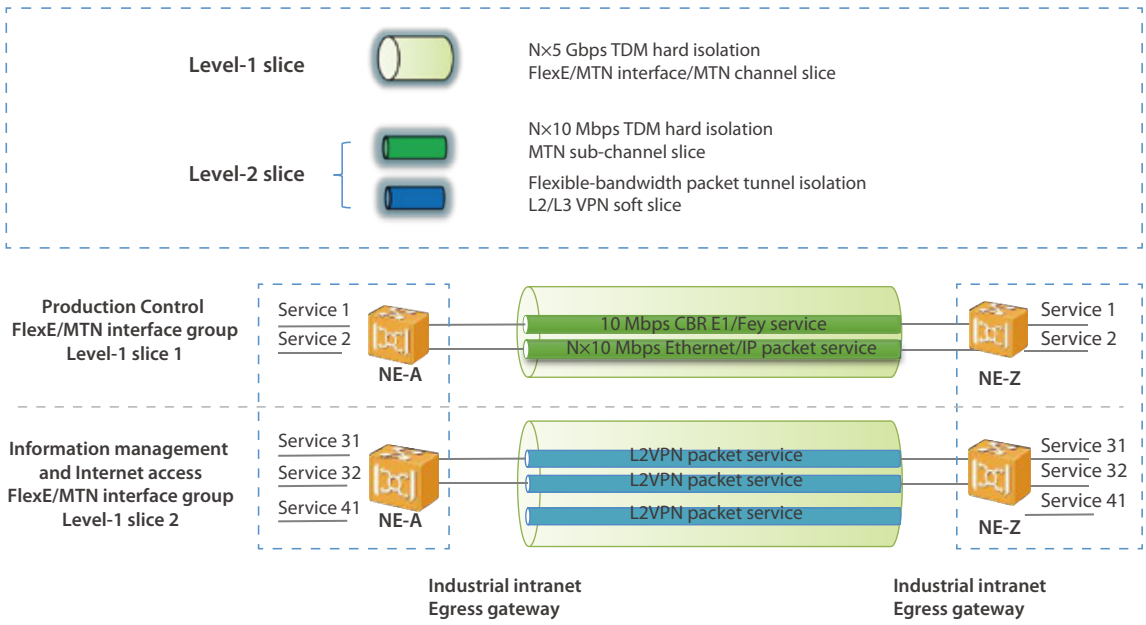

Fig. 1. Applications of SPN 2.0 hierarchical network slicing in industrial scenarios.

Table 2. Implementation of 5G+ smart grid network slicing.

Slice Name	Quantity	Slice Type	Description
Wireless sub-slice	2	Slice 1: PRB reservation Slice 2: Default slice	Slice 1: Select one site for RB reservation; RB recommendation: 1%
Transport sub-slice	2	Slice 1: MTN channel slice Slice 2: Default slice (packet VPN)	Slice 1: Use MTN channel hard slice; 5 Gbps coarse-grained slice in the early stage, and N×10 Mbps fine-grained slice after introducing SPN 2.0
Core network sub-slice	2	Slice 1: Share the ToB UPF of regional branches of China Mobile Slice 2: Default slice	Slice 1: Use the existing ToB UPF of regional branches of China Mobile
5G CPE	2	Ordinary terminal access	

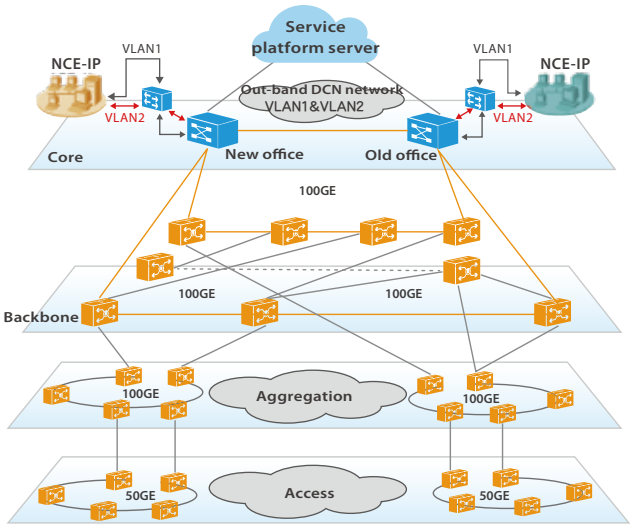

Fig. 2. A new SPN-based power communication network.

a new SPN-based power communication network since 2021 for transporting voice/video LAN, integrated data network, and 2M private line services. The solution supports large-bandwidth networking, hard slicing isolation, intelligent O&M, and 10 Mbps FGU, as illustrated in Fig. 2.

Application Prospects

SPN, a new-generation transport network technology jointly developed by Chinese operators, research institutions, and network device vendors, is a leading model in China for transport network standard innovation. Recognized by ITU-T, SPN has achieved a large-scale deployment of over 340,000 nodes on China Mobile's 5G transport network, marking substantial industrial progress.

SPN 2.0, with innovative TDM and packet statistics multiplexing, offers deterministic low latency, multi-granularity cross-connection, hierarchical slicing, and flexible intelligent perception. It is widely applied in typical industrial scenarios such as smart grid, smart transportation, smart mine, smart port, smart healthcare and smart manufacturing, and is emerging as a benchmark for the new-generation integrated service transport network. ZTE TECHNOLOGIES

SPN 2.0 Private Line: Creating Digital Intelligence Future

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Li Han

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In the evolving information industry, the surging demand for private lines, ranging from high-speed to low-speed TDM lines, necessitates a versatile solution. The industry's digital transformation mandates networks to deliver ultra-high-quality services, reduce costs, and enhance efficiency. SPN private lines, with flexible slicing options, cater to diverse service forms, meeting not only bandwidth and quality requirements but also addressing the comprehensive needs of industries. SPN ensures efficient bandwidth utilization, providing deterministic performance for TDM lines and large packet bandwidth. Moreover, enhanced management and control plane capabilities, coupled with intelligence, enable fast provisioning and visual performance, better meeting customer demands.

Development of SPN Technology

URLLC, eMBB and mMTC are key 5G application scenarios, with slicing and edge computing emerging as native technological features. In response to these new features, China Mobile introduces the concept of "lossless + efficient and flexible" transport, and partners with the domestic industry to build a new-generation transport network architecture known as slicing packet network (SPN).

SPN integrates TDM and packet networks, supports L0 to L3 capabilities, and offers advantages such as large bandwidth, low latency, network slicing, flexible connection, high-precision synchronization, and unified management and control. It minimizes network investments by reusing the Ethernet industry chain and achieves ultra-large bandwidth, addressing the issue of end-to-end efficient and lossless hard isolation transmission tailored to large 5 Gbps granularities. The SPN device using MTN channel cross-connection excels in performance with a single-node forwarding latency as low as 2.784 μs and ±5 ns time synchronization precision. Its slice isolation capability demonstrates minimal jitter (0.277 μs) before and after network congestion, which almost has no effect on the service. China Mobile has successfully deployed 400,000 SPN devices for 5G network backhaul since 2019, showcasing reliable and efficient operation.

In the thriving landscape of 5G vertical industries, government and enterprise services, and computing networks, SPN has transitioned into the SPN 2.0 era. This evolution brings increased slice granularity, enhanced service perception, flexible connection, ubiquitous access, intelligent O&M, and energy-saving technologies. A key aspect of SPN 2.0 is the introduction of SPN fine granularity unit (FGU). This innovation primarily addresses the demands for isolation, security, and reliability in fine-grained service transport in typical scenarios like government private lines, financial private

lines, and large enterprise private lines.

The SPN FGU technology refines the granularity of hard slices from 5 Gbps to 10 Mbps. Its features and capabilities include:

- **Fine-grained bandwidth to meet the bandwidth needs of diverse services:** Bandwidth granularity is 10 Mbps, enabling flexible N×10 Mbps bandwidth allocation. Fine-grained channels exclusively use deterministic timeslots to provide strict TDM features. The timeslots of the egress and ingress ports on any node of a channel are allocated and fixed in advance at the management and control layer.
- **Low latency and low jitter:** Through TDM timeslot cross-connection, fine-grained services ensure deterministic low latency by avoiding the perception of packet messages. These services exclusively utilize timeslot resources in TDM channels, resulting in jitter far less than 1 μs.
- **Independent and complete OAM capabilities provided by each fine-grained channel:** OAM blocks are inserted into each fine-grained channel to provide connectivity detection, and fault and performance monitoring. This ensures protection switching within 50 ms.
- **Hitless online channel bandwidth adjustment:** The bandwidth of fine-grained hard pipes can be increased or reduced during normal service transport. This facilitates flexible bandwidth and timeslot allocation.

With the evolution to SPN 2.0, continuous enhancements have been made to meet the needs of fine-grained slicing for diverse services and provide flexibility and intelligence.

Emerging Requirements for Private Lines

As industries undergo in-depth digital transformation, private lines show new demands and development trends.

The first demand is for integrated network transport accessing diverse services via private lines and networks. For instance, in the energy industry, typical services like power distribution automation, data network dispatching, power consumption collection, data communication network, video services, primary network relay protection channel, and Wi-Fi6 inspection robots have varied requirements in terms of latency, reliability, rate, and connection density. Therefore, it is necessary to utilize network resources to achieve unified transport of differentiated services on the same network.

The second demand is for deterministic networks, especially for control and transaction services in areas such as financial services, where low and deterministic latency, high reliability, and security are crucial. Despite not requiring high service bandwidth, financial services demand stringent network security.

The third demand is for ubiquitous access and fast provisioning capabilities. As industry networks evolve towards cloud and flat architectures, the surge in edge nodes and cross-area/cross-city service connections intensifies the complexity in network connections. Edge access may integrate wireless and wired access, so it is necessary to meet ubiquitous access and rapid provisioning needs of these numerous edge nodes.

The fourth demand is for end-to-end services rather than pipe services, emphasizing comprehensive customer services, like visual indicators and fast troubleshooting. Visual indicators rely on precise monitoring of network SLAs and can be displayed on customer-oriented application interfaces.

These new demands propel advancement and innovation in private line technology.

Features and Advantages of SPN Private Lines

The technical features and advantages of SPN effectively meet the private line market's development demands. SPN can offers access to TDM hard slices while supporting high-bandwidth access of packet soft slices. This allows a single SPN network to offer integrated access for various customer services. Additionally, for highly demanding control services, SPN 10 Mbps fine-grained hard slices can be directly used to provide independent TDM channels, isolating physical timeslots from other services. China Mobile's SPN networks have extensive coverage in China, boasting over 400,000 SPN devices and the capability of ubiquitous access. The intelligent O&M capability of SPN has seen continuous improvement, with inband OAM supporting service-flow-level accurate performance monitoring. The standard northbound interfaces of the

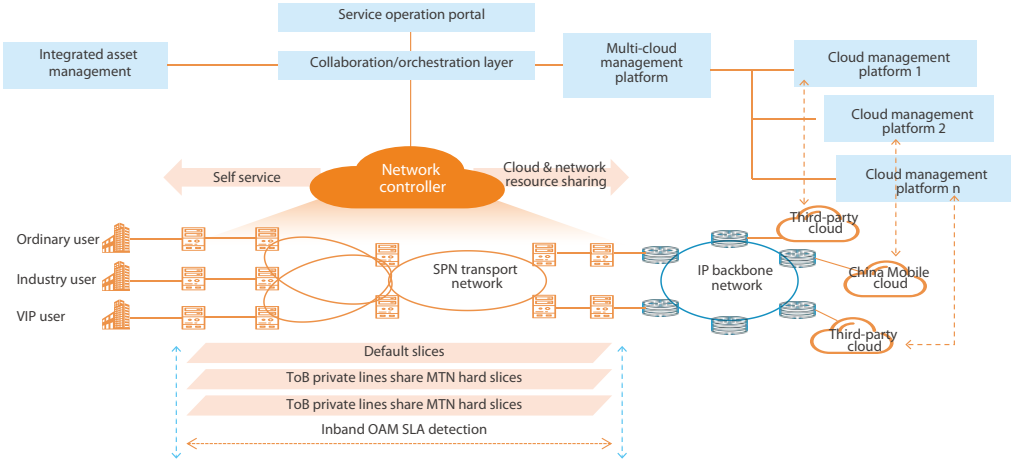

Fig. 1. Network architecture of an SPN private line.

SDN-based centralized management and control system enable data entry to the orchestration system and upper-layer customer systems. Fig. 1 illustrates the network architecture of an SPN private line.

China Mobile has launched three SPN private line products based on SPN features: basic SPN private line, advanced SPN private line, and customized industry SPN private network. The basic version focuses on slice sharing, ubiquitous access, and fast provisioning. Industry users can share MTN slices, with isolation through VPN for users within the same MTN slice. The advanced version provides fine-grained MTN slices for single-user dedication with ultra-high determinacy. Customized industry SPN private networks meet specific customer requirements, allowing the selection of hard or soft slices, and are physically isolated from other user slices.

For enhanced adaptation to edge access in SPN private lines, smaller SPN devices are developed in addition to metro SPN devices. These smaller devices feature reduced configurations and costs, with enhanced integrated access capabilities tailored for edge coverage. They offer small switching capacity, compact size, AC power supply, and low power consumption to meet the requirements in edge scenarios. Interconnected through NNIs, small SPN devices and metro SPN devices provide end-to-end Ethernet fine-grained hard slices and slice-based hitless bandwidth adjustment for high-value user demands. Small SPN devices must provide standard southbound interfaces and unified management and control capabilities to facilitate orchestration and control.

Private line technologies have enhanced forwarding layer capabilities and are advancing end-to-end intelligent services. Key improvements include enhancing the intelligent management system, automating interfaces for customer service integration, and timely display of private line commissioning, operation status, and fault locating on customer interfaces. Collaboration among intelligent systems at network equipment, management and control, and platform levels is essential. Collecting comprehensive historical and current data enables efficient control, analysis, prediction of risks, and enhanced user experience. As intelligent management and control capabilities advance, the efficiency of network OAM and private line services will see continuous enhancement in the future.

Conclusion

As a 5G mobile backhaul network innovation, SPN efficiently caters to 5G commercialization needs. Amid the digital transformation of industries, private lines seek integrated network transport, deterministic latency, ubiquitous access, fast provisioning, and end-to-end intelligent services. SPN 2.0, centered around fine-granularity hard slicing, addresses these market demands. China Mobile offers a range of SPN private line products including basic SPN private line, advanced SPN private line, and customized industry SPN private network, to support the transport of diverse private line services and create China's digital intelligence future. ZTE TECHNOLOGIES

SPN 2.0: Empowering Various Industries

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Liu Aihua

Senior System Architect, ZTE

In June 2022, China Mobile, along with partners including ZTE, released the slicing packet network (SPN) 2.0 White Paper, marking the beginning of the SPN 2.0 era. The SPN 1.0 technology has been widely used by China Mobile and other operators for carrying 5G backhaul services and has been increasingly adopted by vertical industries such as subway, mine, and expressway. With the gradual deployment of China Mobile's metro private line services on SPN networks and the growing transport demands of China Mobile's metro computing power networks, SPN technology is evolving towards integrated service transport.

SPN 2.0 aims to build an integrated transport platform that integrates TDM and packet multiplexing technology for metropolitan area networks and industry private networks. It focuses on high-value slicing private lines, slicing private networks that empower industrial digitalization and new computing-network convergence services. To support high-value slicing private lines, SPN 2.0 has introduced the 10M fine-granularity unit (FGU) technology, which achieves or even surpasses the quality of MSTP private lines. Miniaturized SPN devices have been also introduced to provide fine-granularity access and increase SPN coverage. To meet the needs of slicing private networks empowering industrial digitalization, SPN 2.0 provides both soft and hard isolation, along with deterministic reliable communication, through the deep integration of TDM and packet technologies. In terms of the evolution of computing power networks, SPN 2.0 proposes transport SRv6 (T-SRv6) and native AI technologies to support new service transport.

High-Value Slicing Private Lines

The SPN 2.0 private line technology, centered on the metro transport network (MTN)/FGU slice channels, provides hard isolation, multi-service transport, inband OAM-based quality perception, as well as various network protection and self-service functions. This technology meets the demands of fixed private lines, 5G private lines, and cross-provincial backbone end-to-end private lines with miniaturized SPN devices.

At present, ZTE has deployed SPN private lines to carry enterprise customer private line services for China Mobile across a number of provinces. ZTE has cooperated with China Mobile on enterprise standard formulation, prototype R&D, and pilot tests of miniaturized SPN devices, thereby expanding the coverage capabilities of SPN private lines. In addition, leveraging the construction of provincial and

SPN 2.0

national SPN backbone networks, ZTE is committed to enhancing the end-to-end fine-granularity private line technologies for cross-domain SPN networks to achieve full private line coverage throughout the entire network. The FGU-based SPN 2.0 private line transport solution is shown in Fig. 1.

Private Networks Empowering Industrial Digitalization

With the development of new infrastructure like 5G, industrial private networks have evolved from single-service private networks to integrated service private networks and virtual private networks. At present, the demands for private networks driving industrial digital transformation mainly include highly reliable and secure communication in the production field, broadband connection for production aid, interconnection of cloud-based applications, and manageable & controllable networks.

Traditional SDH/OTN technologies provide highly reliable and secure communication but lack sufficient packet transport capability. Ethernet/IP technologies excel in L2/L3 cloud-based interconnection but lack the capability of hard isolation crucial for highly reliable communication. SPN, which deeply integrates packet and TDM, addresses the key demands of new industrial private networks by incorporating hard isolation and high reliability into the packet architecture.

SPN offers diverse slicing capabilities. FGU-based hard isolation slicing meets the low latency and low jitter requirements of production services, and delivers carrier-class OAM and protection. MTN-based hard isolation slicing provides high packet bandwidths to meet the requirements of production aid services. Packet-based soft isolation slicing supports complete L3 connection capabilities and high-precision inband OAM to meet the interconnection requirements of cloud-based applications. Furthermore, SPN includes the transmission network management function, supports integrated SDN management and control, and features the intelligent management and control capability to ensure a controllable and manageable network.

Currently, SPN products have been commercially deployed in private networks within subway, mine, and expressway industries. China Southern Power Grid and State Grid are using SPN to carry integrated power services, while China's National Railway Administration is considering SPN as the major

access transport technology for building the 5G-R next-generation railway integrated transport network.

Evolution of Computing-Network Convergence Services

The development of China Mobile's computing power network technologies has spurred the demand for SRv6 technology evolution in metro SPN. ZTE and China Mobile has proposed the T-SRv6 solution based on the characteristics of SPN networks. T-SRv6 accurately binds SRv6 services with the SPN slicing channels by extending the programmable END.BXC function of SRv6. This solution combines standard SRv6 technology with transport slicing technology, creating an SRv6 solution with transport features aligned with the requirements of new computing power networks such as hard isolation, zero packet loss, deterministic latency, and high-quality differentiated slicing services. Through the implementation of the T-SRv6 solution, SPN 2.0 offers the open slicing capability, agile end-to-end SRv6 interconnection, high quality, differentiated service, and programmable features. The T-SRv6 solution is illustrated in Fig. 2.

ZTE has completed the R&D of the key END.BXC function extension of T-SRv6 based on the standard SRv6 programmable architecture. At the same time, ZTE and China Mobile have also submitted a draft at the IETF SPRING working group. The pilot tests of the phase-1 T-SRv6 transport solution were successfully completed in the existing network of China Mobile in September 2022.

Native Computing Power and AI

In addition to the evolution of computing-network convergence services, SPN 2.0 also focuses on utilizing native computing power and AI capabilities to improve the intelligence and adaptability of SPN. As a deployment form of hyper edge computing (HEC), the built-in lightweight AI computing power of SPN 2.0 has been successfully piloted to provide computing and network convergence services for ToB industry applications. In September 2022, China Mobile and ZTE jointly completed the first pilot of the Cloud SPN computing-network convergence solution in Changzhou, Jiangsu province. This pilot facilitated the upgrade from the traditional quality inspection to the AI-enabled one in industrial manufacturing and will be promoted in the future.

In terms of SPN 2.0 management and control with AI, the industry has set the autonomous level improvement goal, providing a continuously evolving intelligent SPN management and control solution. In 2022, ZTE and China Mobile Liaoning jointly launched

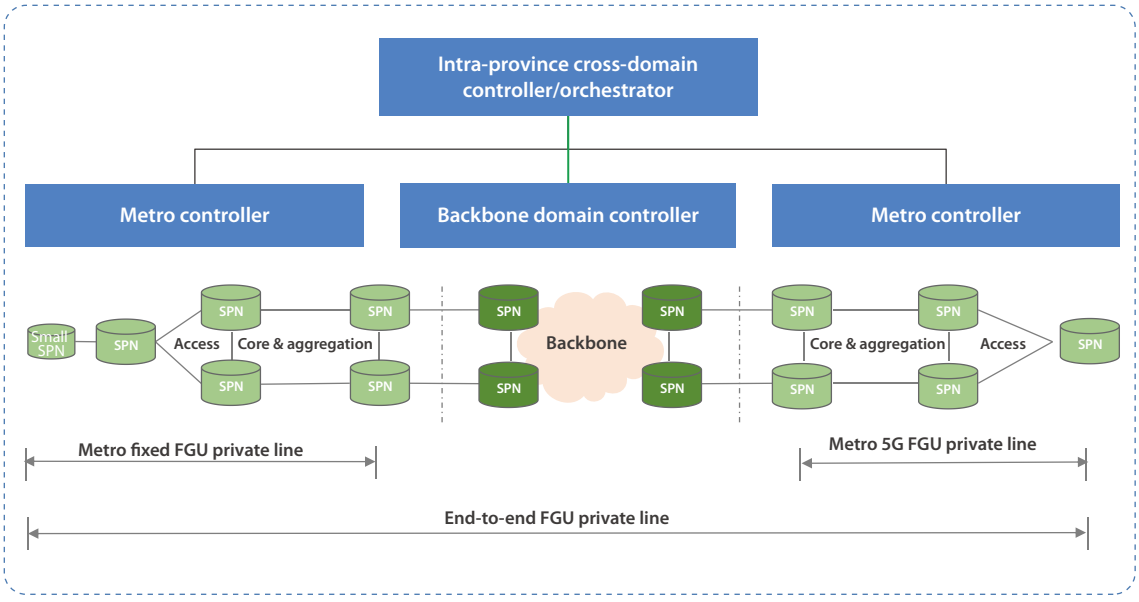

Fig. 1. SPN 2.0 FGU-based SPN private line transport solution.

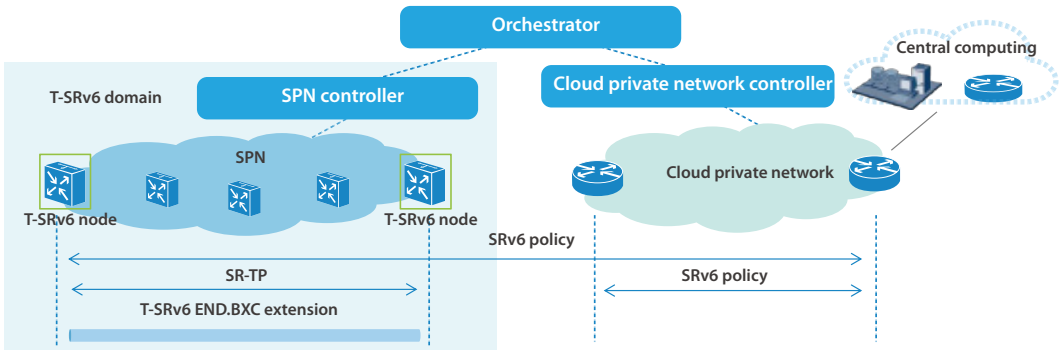

Fig. 2. SPN 2.0 T-SRv6 transport solution.

an intelligent closed-loop system solution for service quality assurance, and successfully verified this solution on ZTE's existing intelligent management and control system, ZENIC ONE (UME). This solution changes manual and passive O&M to automatic and active O&M in some scenarios, increasing network maintenance efficiency and service security, reducing customer complaint rates, and improving customer satisfaction.

Moreover, the industry has begun to harness the power of native AI in SPN devices to create an intelligent energy-saving solution. AI is used to adapt to the tidal traffic patterns of the existing network, collect network data in real time and analyze service load changes. Multi-layer energy-saving solutions have been developed at the chip, module, board, and network levels to achieve intelligent power saving while strictly guaranteeing the transmission performance of the transport network. This innovative intelligent energy-saving solution has been piloted and tested in China Mobile's existing network in 2022. Preliminary verification results indicate an energy-saving effect of 15%.

SPN 2.0 Technology Progress

SPN technology has been applied on a large scale in China, with smooth progress in both domestic and international standardization efforts. The standard on SPN 1.0 was released by China Communications Standards Association (CCSA) in 2021, while the ITU-T MTN standards, including G.8310, G.8312, G.8321, G.8331, and G.8350, were all released by September 2022. Currently, CCSA is in the process of releasing standards for SPN 2.0 FGU. The enterprise standards for miniaturized SPN and computing-network SPN of China Mobile have basically been formulated. Additionally, ITU-T has approved FGU as a new work item. Complemented by the drafts of IETF series standards, SPN 2.0 is expected to further enrich the SPN standards system.

With the application of SPN products in the industrial sector, the Alliance of Industrial Internet in China has released a research report that summarizes SPN's application in industrial scenarios. The 5G transport group of IMT-2020(5G) Promotion Group's 2022 research report on 5G-R transport technology and network management & control solution has identified SPN as the most preferred technology. In 2022, the SPN 2.0 solution was awarded the "Most Innovative Network Slicing Case" at the Network X held by Informa in Netherlands, highlighting the global recognition of SPN technology. As the SPN 2.0 technologies and solutions continue to be adopted by operators and integrated into industrial private networks, SPN technology is poised to enter a new stage of development, empowering various industries and shaping an intelligent digital future. ZTE TECHNOLOGIES

SPN Private Line Technology and Its Applications

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Private lines are an important service provided by telecommunications operators. However, traditional private lines face several challenges. These lines often come with a long provisioning period, failing to meet the enterprise's agile provisioning and e-commerce requirements, lack transparency in network service quality, and are often outdated, leading to slow fault handling. Furthermore, the presence of various network standards results in high overall network construction and maintenance costs. Performance factors such as bandwidth and latency are in urgent need of improvement. The gradual phasing out of SDH equipment necessitates the replenishment of hard slicing network capabilities. New services such as 5G ToB private lines and enterprise-to-cloud have brought about new demands, including network security and programmability features.

In June 2022, China Mobile unveiled the slicing packet network (SPN) private line solution to address the aforementioned issues. This offering provides a cost-effective solution for industry sectors, featuring high isolation, flexible bandwidth, deterministic latency, network visibility, and intelligent operation & maintenance. Additionally, it supports multi-purpose use, reducing costs and improving efficiency, thus meeting the differentiated, higher requirements posed by digital transformation for private line services.

Overview of SPN Private Line Solution

China Mobile's SPN private line solution comprises three products: the basic SPN private line, the premium SPN private line, and the customized SPN private network, as shown in Fig. 1.

The main features of the basic SPN private line include shared slices, ubiquitous access, and rapid provisioning. Services are carried on industry-specific private line slices, which are hard-isolated from the larger public network slices dedicated to ToC services. Soft isolation between private line services is implemented through a VPN network. Standard functions include multiple protection mechanisms and SLA visibility, while optional functions include provisioning progress visibility and topology visualization.

The premium SPN private line features fine granularity and high isolation. Services are carried through fine-granularity interfaces or channels, and isolation between services is achieved through fine-granularity hard slices. This meets the requirements for service isolation, deterministic latency, and security. Additionally, functions such as rerouting and network manageability, controllability, and visibility can be provided.

The customized SPN private network offers integrated network services tailored to specific industries such as medical, education, and power. Different service levels can be provided within a private network slice as required, with the slice being externally hard-isolated from other slices.

The SPN private line provides customers with an exclusive slice network, including soft slices, hard slices, and end-to-end channels. It fulfills high-bandwidth, high-burst service transport requirements while also addressing low-latency, low-jitter service demands. Additionally, it offers multiple layers of protection through mechanisms like rerouting and escape routing, along with various network self-service options.

SPN Private Line Technology

To establish a precise, integrated, intelligent, and low-carbon next-generation service transport network, SPN technology continually evolves to cater to various scenarios, including 5G transport, industry sectors, and government and enterprise networks. The rich customization capabilities of the SPN private line is built upon several key SPN technologies.

Hard-Isolated Channel

The SPN architecture innovatively introduces slicing Ethernet technology, which extends Ethernet slicing capabilities based on the native Ethernet kernel. It is fully compatible with current Ethernet networks while eliminating the need for packets to go through caching and table lookup at L2/L3. SPN also supports FlexE interfaces and slicing Ethernet cross-connect (SE-XC) channel technologies. This enables Ethernet physical layer networking, which provides deterministic low latency and hard pipe isolation, primarily used for basic slicing in 5G granularity.

Inheriting SPN's efficient Ethernet kernel, SPN fine granularity unit (FGU) technology incorporates fine-granularity slicing into the SPN architecture through a hierarchical design, providing end-to-end fine-granularity hard pipes at the FGU sublayer. The FGU uses a TDM mechanism similar to SDH to achieve strict hard isolation between different services. By defining a fixed frame structure, this technology further divides the 5 Gbps time slot at the SPN channel layer, with a minimum granularity of 10 Mbps. SPN FGU technology constructs efficient, lossless, bandwidth-flexible, and reliable end-to-end channels and transport modes to meet differentiated transport requirements (e.g., low bandwidth, high isolation, and high security) in scenarios like 5G–for-industry-sector applications and private lines.

Network Quality Perception

Leveraging inband operations, administration, and maintenance (OAM), SPN offers end-to-end inband and real-time monitoring capabilities, facilitating direct measurement of service packets. This enables real-time awareness of the SLA for each service and packet. With second-level telemetry data collection, unified control, computation, and visualization capabilities, it provides real-time visibility into network quality, active monitoring and rapid fault location.

ZTE's inband OAM functionality supports a vast number of concurrent instances, self-learning of traffic control, and scenario-focused priority assurance, enhancing network quality perception capabilities of the SPN for carrying diverse services.

Multiple Network Protection Mechanisms

Within the SPN architecture, there exists both a centralized control plane for the management and control system and a distributed control plane for devices, providing multiple network protection mechanisms. The SPN provides basic linear protection modes, such as segment routing-transport profile (SR-TP) 1:1 protection, and also VPN fast reroute (FRR) node protection. These network protection mechanisms greatly improve the reliability and security of the SPN. Take the SR-TP tunnel as an example. If both

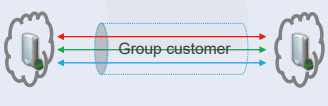
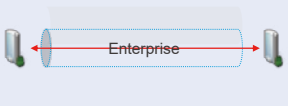
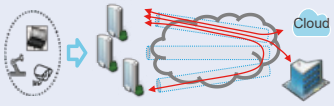
	Basic SPN private line	Premium SPN private line	Customized SPN private network
Product category	Network upgrade over traditional private line	Tenant-/service-level dedicated line	Big-customer-level private network
Network solution			

Fig. 1. SPN private line products.

working and protection paths in 1:1 protection fail, the SPN provides a rerouting protection solution. Furthermore, if a connection between the management and control system and a network device is interrupted, the distributed control plane for network devices may activate an escape route protection mechanism via segment routing-best effort (SR-BE) tunnel using the IGP protocol.

Ubiquitous Coverage Capability

The SPN is a unified transport network that carries 5G backhaul, government and enterprise private lines, and enterprise-to-cloud services. With more than 400,000 SPN devices already deployed, its coverage area exceeds that of the optical transport network (OTN) and the IP metropolitan area network (MAN), but still smaller than that of the packet transport network (PTN). Give the importance of the last kilometer in rapid service provisioning, operators need a network capable of ubiquitous coverage. The deployment of indoor distribution devices and small cells brings the SPN network closer to the edge, enhancing its coverage capability to some extent.

Moreover, the deployment of SPN CPEs will greatly contribute to achieving ubiquitous coverage. SPN CPEs support FGU over a 10 GE interface, extending Nx10 Mbps hard pipes to office desks of the customer, facilitating end-to-end SPN slicing. With reduced capacity, they consume less power, enabling access for ToB services. Their 1U height and smaller size increase deployment flexibility. Additionally, SPN CPEs can network with MAN devices end-to-end through a network-to-network interface (NNI), reducing deployment difficulty. They also incorporate computing power for real-time data collection and analysis, enhancing data security by keeping data within the campus.

Self-Service Capability

ZTE's cloud native platform includes three engines (intent, control and perception) and two sub-platforms (big data and AI). The SPN management and control system is built on this platform, integrates network resources based on NE capabilities, and provides multiple self-service capabilities for customers.

- **SLA visibility capability:** Real-time service indicators of the network, such as traffic, latency, jitter, and packet loss, can be exposed to third parties. Government and enterprise customers can develop web and app portal interfaces to display SLA indicators in real time.
- **Transparent provisioning capability:** The service provisioning progress is visible so that customers can track the the provisioning status in detail.
- **Private network connection topology:** The SPN management and control system provides a slice view showing the connections between the headquarters and branches of the industrial customer, along with slice view-based management and maintenance functions.
- **Online bandwidth adjustment:** Based on dynamic bandwidth requirements, enterprise customers can submit bandwidth increase or decrease orders online, which are then delivered to the network through the service orchestration and control system. Network devices support lossless bandwidth adjustment.

SPN Private Line Technology Trials

The development of the SPN private line has gone through many stages. In 2020, function-level demonstrations were conducted, showcasing large-granularity slicing, agile network provisioning, and multiple network protection mechanisms. In 2021, trial commercial deployments started for functions such as small-granularity private lines and inband OAM with an aim to carry services for government and enterprise customers like electric power companies. In 2022, China Mobile launched a major SPN private line initiative, conducting live trials to validate the end-to-end transport of group customer services through SPN slices and to promote this technology in the market.

The main items tested in the initiative were:

- **Service performance:** Evaluating end-to-end service performance in various scenarios, and comparing it with the current mode.
- **Networking solution:** Comparing the advantages and disadvantages of SPN networking solutions for various scenarios, along with their deployment, maintenance, management, and

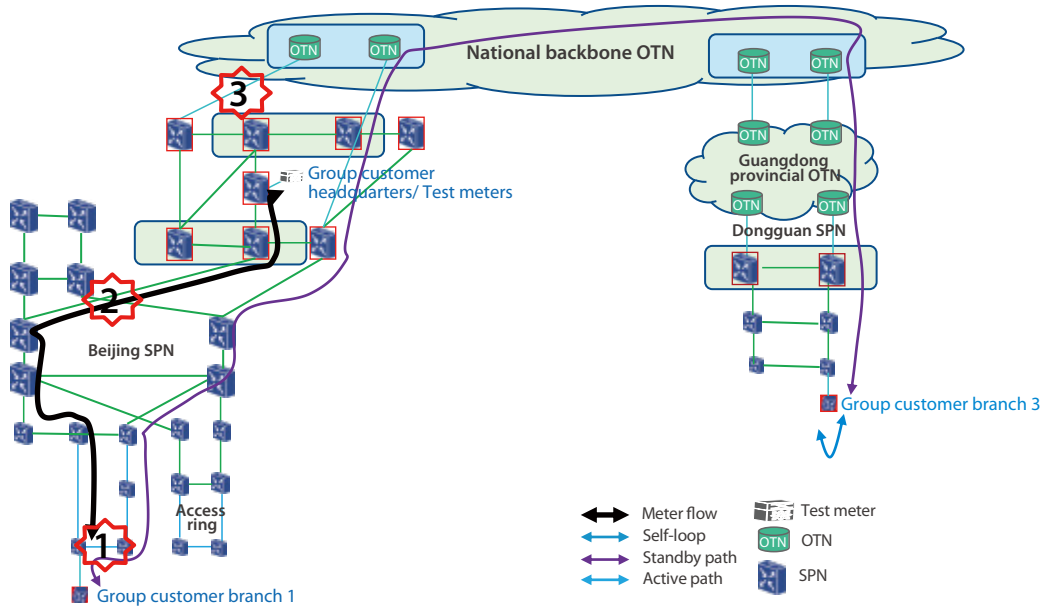


Fig. 2. Inter-province SPN private line test topology.

investment aspects. The networking solution for massive SPN deployment was also tested.

- **Maintenance management:** Examining key issues such as maintenance management modes of SPN services from different vendors.

This initiative comprised the inter-province and intra-province parts. ZTE participated in the Beijing-Guangdong inter-province same-vendor test, the Shanghai-Guangdong inter-province different-vendor test, as well as the intra-province same-vendor tests in Beijing and Guangdong. These tests fully validated various network protection switching functions including fine-granularity escape and interconnection protection, as well as functions like lossless bandwidth adjustment, service isolation, and network self-service. These tests also compared the SPN functions with those of PTN and OTN networks. Fig. 2 shows the inter-province private line test topology.

The test results demonstrated that the SPN could provide hard slicing with flexible granularity and facilitate lossless bandwidth adjustment. It could provide both hard and soft slicing simultaneously, along with multiple protection modes, such as rerouting and fine-granularity escape routes, to improve network security. The statistics of sent/received packets and latency obtained during inband OAM detection matched with those recorded by test meters, and network SLA indicators were effectively detected. The SPN's network agility and self-service capabilities were also verified, confirming the completeness of its functions.

At the same time, China Mobile launched a live trial of the SPN CPE. The SPN CPEs were expected to facilitate access for various types of customer services and meet the flexible networking requirements across different vendors. By connecting with the NNI of the MAN SPN, the SPN CPEs could provide end-to-end fine-granularity hard slicing, hierarchical fault location, channel-associated inband OAM performance monitoring, L2/L3-to-edge multi-service access capability, and lossless bandwidth adjustment.

ZTE is committed to collaborating with the industry chain to utilize the technological advantages of the SPN to empower a multitude of industry sectors. Across networks in provinces including Shanxi, Shaanxi and Jilin, the SPN has already been extensively used to carry private line services for group customers. Industries like transportation and mining have begun significant commercial use of SPN technology. It is anticipated that in the near future, the SPN private line technology will see even wider adoption across many industries to create value for a vast array of users. ZTE TECHNOLOGIES

T-SRv6: SPN Computing Network Solution for Slicing Transport Network

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Computing networks, curcial for driving high-quality digital economy development, are highly favored by major telecom operators for their promising prospects. Building capabilities centered around computing power presents operators with vital opportunities for transformation and upgrading, as well as reconstructing industrial value ecosystems. Slicing packet network (SPN), a key component of computing networks, mainly provides flexible access to computing services for users. It also offers ubiquitous computing power scheduling for cloud-edge and edge-edge collaborations, catering to diverse computing connectivity needs across vertical industries. Additionally, SPN requires evolving capabilities in perception and routing within computing networks, meeting the needs that computing networks evolve to computing-network integration.

Currently, computing services in computing networks are primarily deployed in provincial/regional data centers. Accessing computing resources from the metro SPN network necessitates coordinated scheduling across multiple networks, including the metro SPN network and provincial/inter-provincial backbones (such as China Mobile's cloud private network), reach the data center. Therefore, SPN needs to support SRv6 capabilities to achieve interoperability with cloud private networks, providing users with end-to-end service provisioning and O&M capabilities for one-hop SRv6-to-cloud connectivity. As a transport network, SPN needs to consider the following factors in its evolution to support SRv6:

- **Inheriting transport service features:** When accessing computing services on the SPN network, the computing connection must have transport features, such as bidirectional same path, bidirectional delay symmetry, carrier-class protection switching, and hard slice isolation capabilities.
- **Encapsulation efficiency and forwarding performance:** The SPN network should minimize additional SRv6 encapsulation overhead and associated forwarding performance degradation.
- **Complexity in upgrading the existing network:** The SPN network should smoothly evolve to support SRv6 capabilities, avoiding intricate reconstruction and minimizing impact on existing services.

T-SRv6 Solution Overview

ZTE innovatively proposes the transport-segment routing IPv6 (T-SRv6) solution, tailored to the diverse requirements of computing services and the current state of the SPN network, for implementing the SRv6 technology.

T-SRv6, integrating transport network features, deploys nodes at the SPN network edge, enabling complete T-SRv6 capability without upgrading internal nodes. With minimal upgrades or additions to edge nodes, the entire network achieves end-to-end SRv6 one-hop cloud computing connectivity from metropolitan to provincial backbone.

Fig. 1 shows the T-SRv6 solution architecture,

employing a hierarchical management and control architecture and service model due to the distinct domains of the metro SPN and intra-province/inter-province backbone. The cross-domain orchestrator identifies domain border nodes and links. Each domain's SPN/cloud private network controller computes and configures the forwarding path, and reports the binding SID (BSID) indicating the intra-domain path to the orchestrator. The orchestrator orchestrates the BSID into an end-to-end SRv6 policy path. Since the intra-domain forwarding path indicated by the BSID is configured by each domain controller and remains invisible to external networks, SRv6 programmable technology is used to associate the BSID with SR-TP or MTN channel within the domain. In this way, the SPN network can achieve SRv6 capability only at border nodes while maintaining existing SR-TP or MTN channel forwarding mechanisms within the domain, thus creating an SPN SRv6 solution with transport features.

Key T-SRv6 Features

The T-SRv6 solution supports flexible and programmable capabilities defined by the standard SRv6 solution. It can interoperate with networks like the intra-province/inter-province cloud private networks of China Mobile, exclusively supporting the standard SRv6 solution. Moreover, it combines SRv6 and transport network technologies, constituting an SRv6 solution with transport network features. Compared with the standard SRv6 solution, T-SRv6 stands out with key features such as flexible slicing, efficient forwarding, bidirectional same path, and agile deployment.

Flexible Slicing to Meet Diverse Computing Connectivity Needs Across Industries

The SPN network supports metro transport network (MTN)-based slicing technology, offering soft-isolated high-reliability SR-TP connections and flexible SR BE connections in a shared slice, or hard-isolated MTN channel connections in an exclusive slice. With SRv6's programmable capability, it can bind SRv6 to SR-TP tunnel in the SPN network using the Endpoint bound to an SR-MPLS policy (End.BM) defined by RFC 8986, providing a soft-isolated slice channel with statistical multiplexing and QoS bandwidth guarantee to the computing network. In addition, the T-SRv6 solution extends the standard SRv6 solution by defining the endpoint bound to a cross-connect channel (End.BXC) function to bind SRv6 to MTN channel hard isolation slice channels in the SRv6 network, providing lossless and deterministic hard isolation connections to the computing network. This approach enables end-to-end SRv6 binding to different types of slicing channels within the SPN network, meeting the differentiated SLA

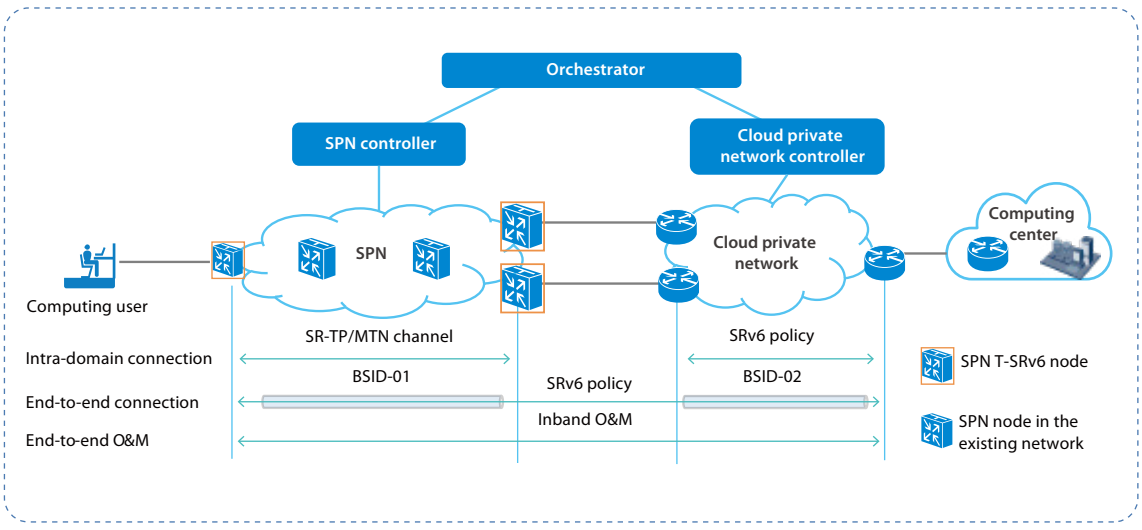

Fig. 1. Architecture of the T-SRv6 solution.

requirements of various industry applications.

Efficient Forwarding to Give Full Play to Existing Network Capabilities

Due to its hierarchical architecture, cross-domain SRv6 uses two types of packet encapsulation: end-to-end SRv6 and intra-domain encapsulation. In the T-SRv6 solution, end-to-end SRv6 employs general SRH encapsulation for interworking with heterogeneous networks. Within the SPN domain, T-SRv6 uses SR-TP label stack or MTN frame encapsulation. Given the SPN's strict constraint paths, SR-TP encapsulation involves a 4-bytes constraint label at each hop, enhancing encapsulation efficiency through label stripping during forwarding. In contrast, hop-by-hop SRv6 encapsulation includes a 16-byte constraint label along with an additional 48 bytes for IPv6 header and SRH header encapsulation. Therefore, hop-by-hop SRv6 exhibits significantly lower encapsulation efficiency compared to the T-SRv6 solution. Although G-SRv6 utilizes the header compression technology to reduce per-hop constraint encapsulation to 4 bytes like T-SRv6, its encapsulation efficiency remains relatively low due to IPv6 header and SRH encapsulation overhead. Fig. 2 compares encapsulation efficiency in different packet lengths, using a 10-layer constraint label as a reference.

Enhanced encapsulation efficiency not only boosts effective bandwidth utilization but also improves forwarding performance. This avoids performance degradation caused by the need for internal chip processing when encapsulated bytes exceed the processing capacity of the device chip.

Bidirectional Same Path to Meet Application Needs of Delay-Symmetric Industry

In the T-SRv6 solution, transport network technology features are reserved in the SPN network. The forwarding paths of SR-TP and MTN channel are bidirectionally the same. Moreover, the protection mechanism implements bidirectional protection switching through the APS protocol to ensure that the forwarding paths are bidirectionally the same after the switching. This approach offers natural advantages for certain industrial applications, like grid differential protection signals, which demand bidirectional delay symmetry.

Agile Deployment for Rapid Computing Service Provision

In the T-SRv6 solution, only edge nodes in the SPN network need to support T-SRv6 capability, with no need to upgrade forwarding nodes. In a typical cloud service activation scenario, the SPN network simply adds a pair of termination devices connected to the

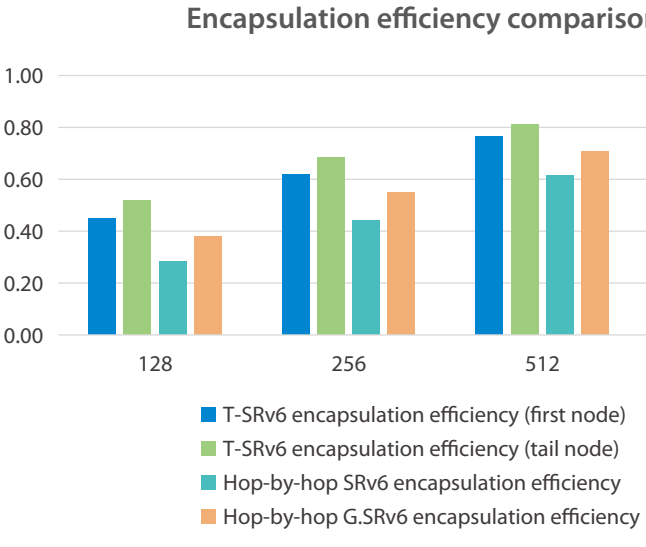

Fig. 2. Encapsulation efficiency comparison between T-SRv6 and hop-by-hop SRv6/G-SR6.

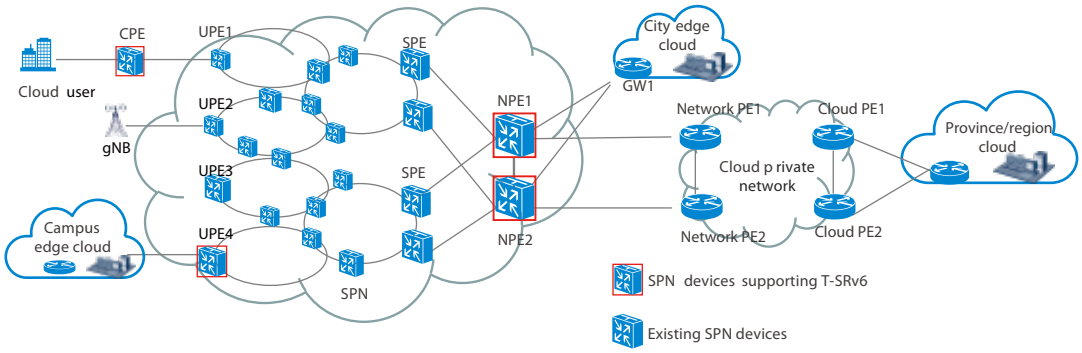

Fig. 3. Agile T-SRv6 deployment solution.

cloud private network, or upgrades existing termination devices in the SPN core layer. At the same time, SPN CPE supporting T-SRv6 capability is deployed on the client side of the cloud service. Other network devices remain unchanged. This enables end-to-end SRv6 one-hop connectivity to the cloud, facilitating rapid provisioning of computing connection services (Fig. 3).

Continuous Evolution to Meet Full Lifecycle Needs of Computing Networks

In the future, computing networks will evolve to computing-network integration, requiring devices connected to computing resources (such as edge cloud) in the computing network to possess computing perception and reporting capabilities. These devices must also support computing routes and implement route search and forwarding based on the computing power. The choice of forwarding method for nodes within the network does not affect the functionality and applications of the computing network. By upgrading SPN network edge nodes, the T-SRv6 solution can meet the future requirements of computing-network integration for computing scheduling.

SRv6 Trial on Existing SPN Network

To achieve the vision of "ubiquitous network, computing power, and intelligence", China Mobile has actively researched computing network technologies. In the SPN network domain, China Mobile Research Institute formulated the Technical Specification for SPN Computing Network Perception Equipment in the first half of 2022. In August 2022, in collaboration with ZTE, China Mobile trialed the T-SRv6 solution on its existing SPN network in Guangdong. This marks the first SPN SRv6 trial with existing network services in China, verifying the agile SRv6 deployment capability on the SPN network and its ability to open flexible slice channels through programmable technology.

To further verify end-to-end interoperability between the SPN T-SRv6 solution and the cloud private network, China Mobile and ZTE jointly conducted cross-domain SRv6 interoperability tests integrating SPN with the cloud private network in Zhejiang Provence. Utilizing an orchestrator, they orchestrated cross-network services between SPN and the cloud private network, confirming the end-to-end SRv6 one-hop cloud service provisioning capability of SPN T-SRv6 and the cloud private network.

The successful T-SRv6 trial on China Mobile's existing SPN network verifies the feasibility and advancement of the SPN T-SRv6 solution, making a significant step towards its commercial use. ZTE TECHNOLOGIES

SPN: Empowering 5G Virtual Private Networks for Electric Power Industry

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As climate change intensifies, more countries and regions are adopting plans to peak carbon emissions and achieve carbon neutrality. Concrete actions to reduce greenhouse gas emissions and promote a low-carbon economy are being taken. At the 2020 United Nations General Assembly, the Chinese government put forward its "30-60" target , aiming to peak carbon emissions by 2030 and achieve carbon neutrality by 2060. To reach this target, China will focus on building a clean, low-carbon, secure, and efficient energy system. This includes controlling fossil energy consumption, improving energy efficiency, implementing renewable energy substitution, and undertaking structural reforms in the electric power sector. The goal is to construct a new power system centered around new energy sources. The introduction of 5G virtual private networks (VPNs) in the electric power industry will facilitate the creation of an energy Internet, supporting power grid companies and energy enterprises in transitioning to the new power system and advancing dual carbon goals.

Requirements and Background of 5G VPN for Electric Power Industry

5G services for the electric power industry fall into two main categories: control and collection. Based on power security requirements, they can be further categorized into four zones: production control zones (Security Subzones I and II), and management information zones (Security Subzones III and IV). Each zone carries distinct services with varying security needs. For example, Security Subzone I demands low communication latency (less than 12 ms end-to-end) and high reliability for differential protection services. Although fiber communication is heavily relied upon, the power distribution network span a vast area with numerous scattered communication terminal points. High synchronization accuracy is crucial for power distribution automation service in Security Subzone I and high-bandwidth video conferencing in Security Subzone II. Automatic relay protection equipment monitors distribution network lines and devices to quickly locate and isolate faults. For electric power video surveillance, especially HD monitoring, ultra-large bandwidth is needed. For example, deploying multiple 4K cameras at places like substations and high-voltage towers allows comprehensive multi-angle inspection.

According to security requirements of power services, physical isolation separates power grid services from other B2B/B2C services. Production control zones are physically separated from management information zones, with logical isolation within each zone. Traditional power networks rely on the overlaying of multiple transport schemes including synchronous digital hierarchy (SDH), optical transport network (OTN), and power line carriers. This results in high deployment costs, inability to guarantee service requirements, and lack of centralized control.

VPN Solution for Electric Power Service Transport

The emergence of 5G VPN slicing technology allows services from different power network zones to be transported through multiple logical networks overlaid on a single physical network.

When planning network slicing to meet various service requirements, dedicated and resource-exclusive network slices are created for production control zone services, utilizing resource block (RB) reservation and 5G QoS identifier (5QI) priority scheduling at the wireless side, metro transport network (MTN) slicing at the transport side, and a dedicated user plane function (UPF) for core network isolation. Management information zone services are logically separated from other B2B services and public-network services through 5QI priority scheduling, VPN isolation, and industry-network UPF sharing. See Table 1 for the implementation scheme.

Considering the requirements of electric power services for fined-grained bandwidth and hard isolation, we can deploy fine granularity units (FGUs) supporting a minimum of 10M bandwidth, based on the 5G bandwidth slicing specification of the MTN1.0 standard, to carry control/protection-class high-security services (Fig. 1).

Services in Security Subzones III and IV can share a VPN and be carried by a group-customer hard slice in the existing network, while services in Security Subzones I and II can be carried by a dedicated VPN through FGU slices that can flexibly allocate N×10M bandwidth. In shared large-network hard slicing, slice services are scheduled based on priority. Whether a slice service uses a dedicated VPN or shares one with others depends mainly on IP address conflicts and the necessity for independent management, operation and maintenance.

According to listed service requirements and transport slice characteristics, the VPN can be designed as follows: For services in production control zones (Security Subzones I and II), MTN hard slices (including fine-grained slices) are hard-isolated from management information zones (Security Subzones III and IV time slots). For services in Security Subzones I and II, an L3 VPN using SR tunnel of the MTN client channel or an L2 VPN using MPLS tunnel of an MTN subclient can be created. Depending on network conditions, they may also utilize a soft-isolated VPN on the MTN hard-slice channel. Services in management information zones (Security Subzones III and IV) can be transported via soft-isolated VPN on an MTN hard slice.

Practices of 5G VPN with State Grid Jiangsu

In August 2022, China Mobile Nanjing Branch, in collaboration with ZTE and State Grid Jiangsu, successfully tested and validated power production control services such as differential protection and

Table 1. 5G VPN slicing scheme.

Service Type	Scheme			
	Wireless	Transport	Core network	Slice and data network name (DNN)
Production control zone services	RB reservation + 5QI priority scheduling	FlexE or MTN slice isolation + VPN isolation	Provincial or prefectural dedicated UPF	Allocate dedicated S-NSSAI for Security Subzones I and II, and dedicated DNNs as needed for their services
Management information zone services	5QI priority scheduling	VPN isolation	UPF shared by provincial or prefectural industry networks	Allocate dedicated S-NSSAI for Security Subzones III and IV, and dedicated DNNs as needed for their services

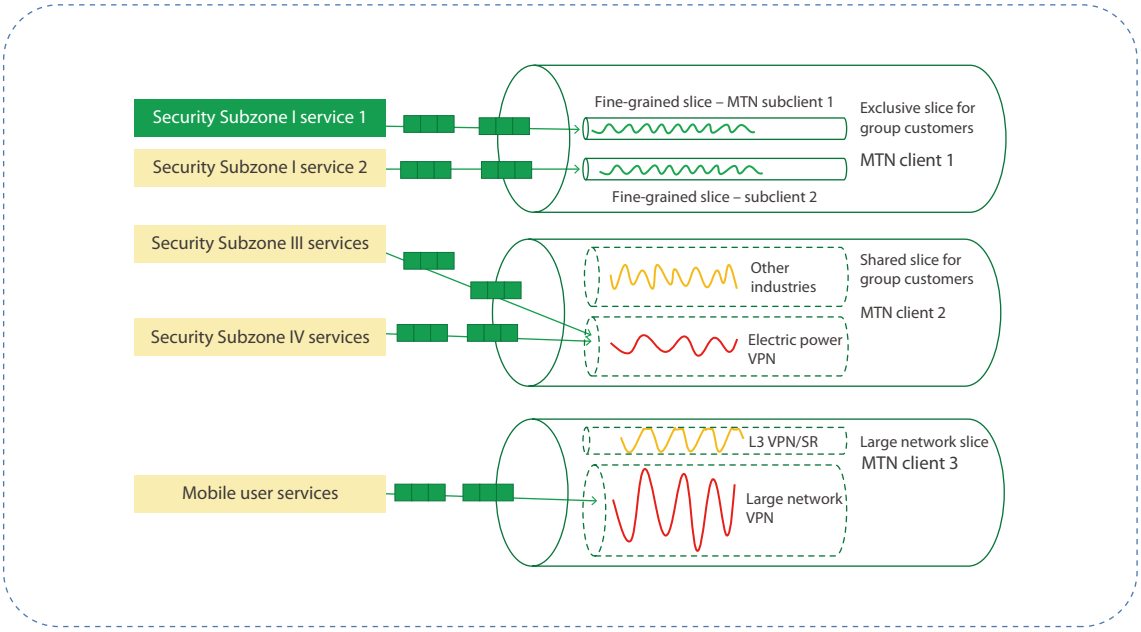

Fig. 1. Recommendation for using SPN slices to carry electric power services.

power distribution automation. This environment encompassed a 5G wireless network, core network, and transport network in Jiangbei New District, Nanjing City, China.

In this test, the core network used a dedicated UPF to carry power services, while the SPN transport network employed ZTE's ZXCTN6700 core aggregation device and ZXCTN6180H access layer device. Results show that SPN fine-grained slices isolate power control and protection services securely. Unlike shared slices for group customers, fine-grained slices remain unaffected by congested flows and have hard isolation capabilities of SDH. With hard slices deployed at a minimum granularity of 10 Mbps, bandwidth requirements for power services can be met, allowing the 5G VPN to achieve 9 ms end-to-end average latency, zero packet loss, over 99.999% reliability, and synchronous timing accuracy error of less than 500 ns (meeting the 1 μs requirement of power services). The SPN FGU establishes a secure and efficient communication management channel with deterministic latency and jitter for power services, laying a solid foundation for SPN network to transport power services and achieve widespread commercial use in the power industry. ZTE TECHNOLOGIES

Analysis on 5G-R Transport Technology

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Background

China State Railway Group issued the "National Railway Planning Outline for Transportation Powerhouse in New Era" in 2020, outlining the direction for advancing railway communication technologies. The outline emphasizes tasks such as developing independent and advanced technological equipment systems, improving the technological level of infrastructure equipment, and empowering smart development through new infrastructure.

To implement China's decisions on deploying 5G networks and other new infrastructure, the Group has set the goal of building a dedicated 5G mobile communication system for railway (5G-R). This large-scale 5G private network will support railway production and operations. As IP-based railway services grow, objectives for intelligent network operation, resource management, system maintenance, and service applications become clearer. New requirements have been raised for the next-generation railway transport network technology, including secure and reliable 5G-R communication for transportation-related production services, 5G-R slice isolation, transport of multiple existing services, and manageable railway private networks.

To enhance 5G-R construction, the primary focus of the current transport network is selecting a suitable transport solution based on 5G-R's key requirements and the development evaluation of railway multi-service transport. In the 2022 5G-R transport solution research project led by China Railway Signal & Communication Corp Ltd (CRSC), the IMT-2020 5G transport promotion group thoroughly analyzed SPN, IPRAN, and M-OTN solutions. The current SPN, based on new international standardized technical solutions with deep integration of TDM and packet technologies, holds relative advantages and is expected to become the primary choice for 5G-R access backhaul and integrated railway transport.

SPN 1.0 has been widely adopted by operators and is evolving to 2.0 for multi-service transport. Featuring fine-granularity 10M FGU hard-isolation slicing with 10GE interfaces, E1/STM-1 CBR multi-service transports, mature coarse-granularity MTN hard-isolation slicing, high-precision inband OAM performance measurement, and manageable transport, it can transport 5G-R and traditional railway communications services from L1 to L3, while ensuring high-isolation, high-reliability, and manageable transport of existing SDH services.

Major Challenges

Operators have put 5G into large-scale commercial use. 5G-R, as the private network technology for railways, faces differentiated demands for railway production and operation. The primary challenges include:

- **L3 networking with transport features:** 5G-R inherits the transport network features of GSM-R and introduces flexible L3 networking in addition to bandwidth requirements of the existing SDH/MSTP transport network. It maintains SDH/MSTP hard isolation, high reliability, manageability and controllability, along with other transport features like L3 bidirectional connection, comprehensive traffic planning, complete OAM and protection, addressing the

> From the perspective of overall 5G-R construction objectives, SPN 2.0 technical standards and products align well with its transport construction requirements, offering advantages in technical capabilities. Currently, China State Railway Group is conducting a range of 5G-R verification tests, with ZTE SPN actively cooperating.

quality needs of the railway private network.

- **Secure isolation and reliable transport:** The 5G-R system needs to support railway production services such as dispatch communication and train control. Moreover, it involves operational support services such as video monitoring, line inspection, and other railway applications, all requiring secure and reliable transport equivalent to or even higher than traditional SDH/MSTP. TDM hard isolation is provided between production operations, operational support services, and other applications.
- **Large-scale private network management and control:** The nationwide large-scale 5G-R private network has higher requirements for network planning, construction, maintenance, and optimization. All network services are manageable and controllable, with enhanced management and control capabilities of the transport NM facilitating fast service deployment, stable operation, easy troubleshooting, and intelligent O&M. Therefore, using the integrated management and control architecture to inherit and continually evolve the management and control capabilities of existing SDH/MSTP is reasonable.

Technology Analysis

During the 5G network design phase, the white paper "5G Transport Network Architecture and Technology Solution" released by the IMT-2020 5G transport promotion group in 2018, evaluates three 5G transport technologies (SPN, IPRAN 2.0, and M-OTN) and analyzes three transport solutions. These solutions reflect the ongoing convergence and advancement of transport and packet technologies, differing in the layer and depth of transport and

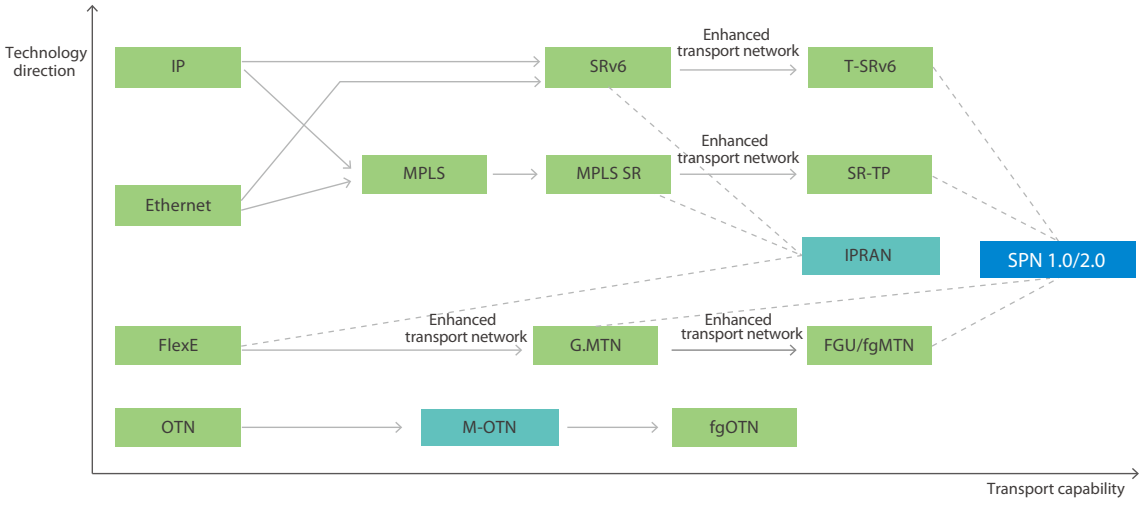

Fig. 1. Development of the transport technology route.

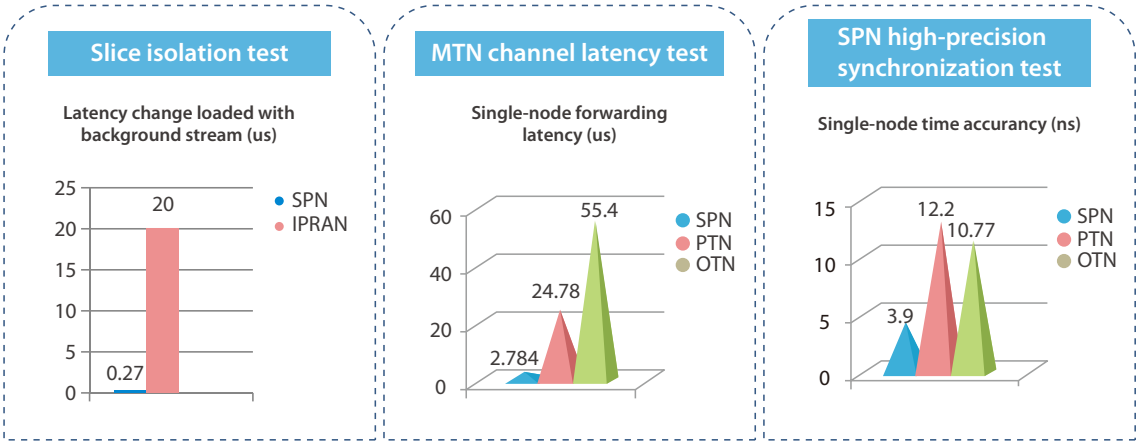

Fig. 2. Key performance index testing for three transport technologies.

packet convergence. Figure 1 outlines the development of the transport technology route.

These three transport technologies vary in their support for 5G-R transport.

- M-OTN still employs dedicated OTN interfaces and offers TDM hard isolation slicing, but lacks 5G backhaul applications and L3 networking.
- IPRAN 2.0 supports L3 networking but lacks sufficient enhanced capabilities in the transport network, including TDM hard isolation and various manageable and controllable features.
- SPN boasts both TDM hard isolation and L3 networking capabilities. It has carried 5G services on a large scale, offering rich manageable and controllable features.

Operators have also carried out performance comparison tests for three transport technologies in addition to technology analysis. The test data analysis shows that SPN leads in key performance indexes that support 5G and integrated service transport (Fig. 2).

The IMT-2020 5G Transport Promotion Group's research report on 5G-R transport solutions shows that among the three options, SPN has superior technical satisfaction. In the recent 5G-R technical selection test, ZTE's SPN successfully completed all test requirements.

The ITU-T has released international standards for SPN 1.0 and completed the establishment of formulation of G.fgMTN standards for SPN 2.0 FGU. Over 400,000 SPN devices are deployed in existing networks and are increasingly used in production private networks like power, subway, high-speed rail, and mining. Mature 5G-R transport industry chains are now available.

Considering the primary challenges outlined for 5G-R transport network and the current development roadmap of transport network technologies, adopting an SPN-based 5G-R solution offers the following advantages:

- Building an end-to-end 5G-R backhaul L3 network with SPN, enabling soft/hard-isolation slicing for 5G services, and achieving manageable and controllable private network services.
- Supporting E1/STM-1 CBR transport through SPN TDM hard isolation channels, enabling the comprehensive transmission of both 5G-R and railway production services.
- Utilizing SPN's standard independence and industry chain advantages to construct a next-generation integrated service access and transport platform for railways, supporting the overall strategy of becoming a 5G-R transportation powerhouse.

From the perspective of overall 5G-R construction objectives, SPN 2.0 technical standards and products align well with its transport construction requirements, offering advantages in technical capabilities. Currently, China State Railway Group is conducting a range of 5G-R verification tests, with ZTE SPN actively cooperating. ZTE has prioritized meeting the 5G-R transport requirements with SPN 2.0 in product planning and R&D, contributing to the development of smart railways. ZTE TECHNOLOGIES

Application of SPN Ethernet Ring Network in Smart Mine

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Application Background and Requirements

The successive proposals of digital transformation strategies like Industry 4.0, Industrial Internet, and "Made in China 2025", along with the rapid development of new-generation information technologies such as the Internet of Things, big data, cloud computing, and 5G, have propelled China's mining industry towards intelligence. With China's rich coal resources and limited oil and gas reserves, the coal industry plays a pivotal role in the country's economic development. To promote integrated development of intelligent technologies and coal mining, eight departments including the National Development and Reform Commission, Energy Administration, and Coal Supervision Bureau jointly issued the "Guiding Opinions on Accelerating the Intelligent Development of Coal Mines" in March 2020. These opinions aim to ensure that by 2035, all types of coal mines will achieve intelligence, facilitating the creation of safe, efficient, and environmentally friendly coal mines supported by intelligent perception, decision-making, and automated execution.

Intelligence in coal mining is the cornerstone technology for enhancing the coal industry's quality development. It is of great significance to boost the safety standards in coal mines and ensure a steady coal supply. Communication network infrastructure is integral to coal mine intelligence. Mines require diverse communication services, each with unique network requirements. Traditional mines generally deploy multiple physical fiber optic ring networks to meet the communication needs of various application systems.

In mines, dozens of application systems exist, spanning security, location, communication, video, and industrial control systems. The Energy Bureau has outlined basic requirements for application systems of coal enterprise informatization, each service system demanding specific quality assurances:

- The 5G system for mobile devices and personnel, above and under the mine, has comprehensive transmission requirements for large bandwidth, low latency, and extensive connectivity. Safety production monitoring networks must be independently constructed per policy mandates.
- Remote control of the comprehensive mining plane requires low latency and jitter.
- Various HD videos and VR/AR inspections require high bandwidth.
- Various underground sensor systems require extensive connectivity.

Each application system has multiple service connection points. The main station system may be located above the coal mine or within certain caverns inside it. Industrial control systems entail stringent safety requirements. The Energy Bureau clearly specifies that the network security of intelligent industrial control systems in fully mechanized mining operations should be at level two or above, with comprehensive consideration for data security in each application subsystem. Traditionally, meeing diverse service requirements involves separate system construction, leading to high costs and complex maintenance.

SPN Ethernet Ring Network Solution

To address the issues of high costs and complex

maintenance brought about by the traditional siloed construction of mining communication networks, ZTE has proposed a solution: building a backbone transport network in mining areas to carry production services both above and under the mine. This involves constructing a physical ring network using metro transport network (MTN) hard slicing isolation technology, which provides multiple logical ring networks. These networks ensure service quality for various intelligent mining subsystems, offering low latency, low jitter, high reliability, high security, and good scalability in transmitting data across complex coal mine environments through ring networking (Fig. 1).

A pair of slicing packet network (SPN) convergence devices are used for core convergence, with SPN access devices above the mine and SPN CPEs under the mine. A 100G ring network or a 50G ring network is used above and under the mine respectively to form a transmission self-healing protection ring, intersecting at active and standby centers with a bandwidth of at least 100 Gbps. The active and standby convergence nodes meet or exceed 2.0 level-3 information security standards, offering unified service interfaces for connection with data centers or office networks. Leveraging SPN's low-delay feature, ring delay in the mining area is less than 1 ms, with multiple protection technologies like node protection, link protection, and active/standby redundancy, ensuring a highly reliable and intelligent mine backbone transmission system.

To meet data transmission and service requirements for each service subsystem, the 100G SPN Ethernet ring network is divided into five slices: network per site, industrial video, integrated monitoring, industrial control, and 5G transmission (Fig. 2). These slice subsystems employ virtual routing forwarding (VRF) to isolate services, ensuring hardware isolation for different service types and software isolation for identical service types. This approach guarantees reliable service transmission while facilitating classified service management and access for different service terminals. L2VPN over MPLS-TP tunnels or L3VPN over SR-TP tunnels can be selected based on service requirements and features to carry services. SPN convergence devices at both ends operate in hot or cold standby mode, with one end connected to a server for node protection. Within each slice, multiple PWs from the SPN access device at one end to the SPN convergence device at the same end can share the same tunnel, with tunnel protection configured. Network-side HQoS configuration is adjustable as required.

Refer to Table 1 for bandwidth configuration and slice allocation details for service systems. The industrial video slice is allocated 30 Gbps bandwidth, the 5G transmission slice has 20 Gbps, and the remaining three slices each have 10 Gbps. Additionally, 20 Gbps bandwidth is reserved, allowing for flexible allocation and adjustment of slice bandwidth as needed.

This solution leverages 5G transport technology,

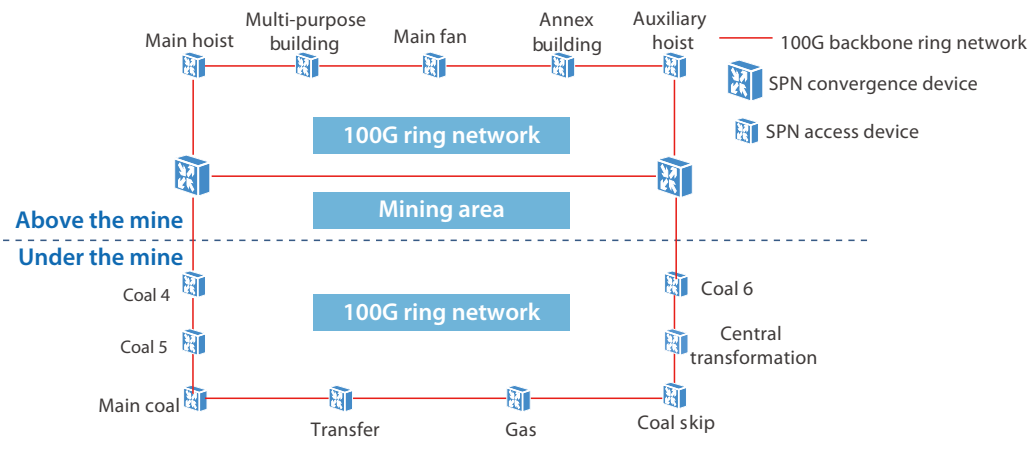

Fig. 1. Deployment architecture of SPN Ethernet ring network.

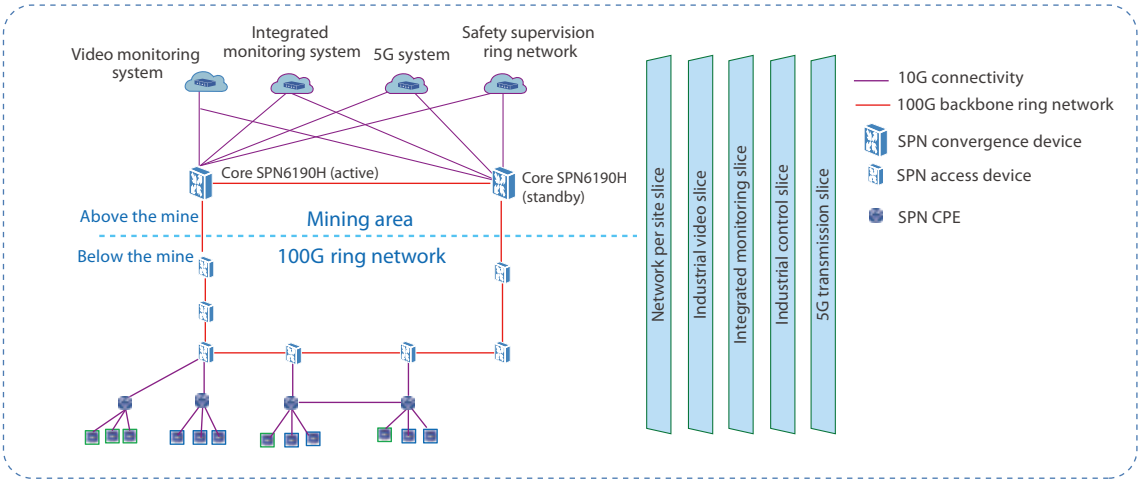

Fig. 2. SPN Ethernet ring network solution.

Slice	Service systems	Parameters
5G (or fine-grained slice)	5G transmission slice	20%
Network per site slice	Emergency broadcast system, personnel positioning system, information release system, and wireless communication system	10%
Video surveillance (30G slice)	Industrial video system	30%
Integrated monitoring (10G slice)	Information release system, KJ-628 mine hydrology monitoring and early warning system, ZWX8 mine distributed optical fiber temperature measurement system, beam tube monitoring system, roof disaster monitoring system, rock burst monitoring system, dust disaster monitoring system, and geological safety system	10%
Industrial control (or fine-grained slice)	18 industrial control application subsystems, including the tunneling control system, intelligent mining surface system, and main coal flow transportation system	10%
Reserved slices	To be allocated based on traffic expansion	20%

Table 1. Bandwidth configuration and slice allocation details for service systems.

especially hard slicing isolation, to significantly reduce network construction costs and simplify O&M, laying a solid foundation for intelligent mining development. It offers the following benefits:

- **Super-large bandwidth:** The all-optical backbone ring network can smoothly expand to 100GE bandwidth, meeting service development needs for the next decade.
- **One integrated network:** Utilizes one fiber, one set of equipment, and one integrated network for industrial, video, and 5G multi-network integration.
- **Security isolation:** The FlexE technology supports end-to-end hard service isolation, meeting differentiated service quality requirements.
- **Independence:** China's new-generation international 5G transport standard has completed extensive commercial verification.

Practical Implementation

ZTE cooperated with Changzhou Institute of China Coal to build an industry-leading 100G SPN Ethernet slice ring network for Shaanxi Coal and Chemical Industry Group's Xizhuo coal mine in November 2022. This network provides integrated service transmission for both aboveground and underground production in smart mines. ZTE SPN devices use the MTN hard slicing isolation technology to provide a physical ring network for mining operations, with multiple logical rings catering to various intelligent mine subsystem services.

The successful application of SPN technology in the B2B field will lay a reliable foundation for the development of intelligent mines at the Xizhuo coal mine, accelerating the digital transformation towards 5G+ intelligent mining. ZTE TECHNOLOGIES

SPN Empowers Changsha Rail Transit to Build a Premium Intelligent Metro

In June 2022, Changsha Metro Line 6 commenced initial operation, featuring ZTE's SPN equipment for its dedicated transport system adopts, marking the debut of the first private SPN transport network for rail transit in China.

The metro's communication network is essential for guaranteeing the smooth operation of the metro system. It encompasses complex communication services, including traditional services such as train control, scheduling communication, video imaging, detection and monitoring, as well as emerging services such as massive sensor data transmission and unmanned driving. These services vary in bandwidth and latency requirements, with train-related services demanding higher levels of security and reliability.

The conventional MSTP network, with a maximum bandwidth of 10 Gbps on the line side, cannot meet the rapidly growing bandwidth demand of metros and the convergence requirements of various service types. To address the specific technical requirements of Changsha Metro Line 6 for transport network deployment, ZTE has introduced an end-to-end SPN transport solution. Unlike traditional transport solutions, the SPN solution integrates TDM and packet switching, supports super-large bandwidth, and incorporates hard slicing and soft slicing to provide communication guarantees for both dedicated communications and the intelligent operation of metros.

Hierarchical Large and Small Granularity Hard Slicing Technology

The introduction of fine granularity unit (FGU) technology in Changsha Metro Line 6 marked its commercial debut in the existing rail transit networks. By utilizing its hard isolation and low latency features similar to SDH, production services with a bandwidth of approximately 100 Mbps—such as wireless communication systems and communication power monitoring—are carried over independent FGU channels to ensure physical isolation under the hard pipeline and meet the low latency transmission requirements of these services. For services with a bandwidth of 1000 Mbps or above—such as the video surveillance system, passenger information system, office automation system, and automatic ticketing system, FlexE large-granularity slices with a bandwidth of n×5G are employed. This enables efficient and rational allocation of bandwidth resources. In the metro service deployment, each line-side 100GE is divided into six large-granularity n×5G bandwidth channels, with one large-granularity channel further divided into four small-granularity channels to accommodate the requirements of different service channels.

Nested Slicing Based on Hard Slicing and Soft Slicing

The integration of hard slicing and soft slicing ensures the isolation of different types of metro services while improving the utilization of hard

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slicing bandwidth. As depicted in Fig. 1, 10 Gbps hard slice channels are allocated to metro video surveillance services within a total bandwidth of 100GE, ensuring complete isolation from other service channels. A PW/tunnel-based VPN (a basic soft slicing mode) is used to carry the video surveillance service from each station. At each station, a switching module facilitates convergence between the local PW/tunnel and those of other stations. These converged services are carried over the hard slice channel. Different service models such as virtual private wire service (VPWS) and virtual private LAN service (VPLS) can be deployed, maximizing bandwidth utilization of hard slice channels through statistical multiplexing technologies such as VPN.

Compared to the Ethernet over SDH (EOS) convergence function of traditional MSTP, which typically offers a backplane bandwidth of about 2.5 Gbps, SPN equipment can provide n×5G bandwidth to hard slicing services, with the maximum bandwidth reaching the line bandwidth. In addition, the convergence ratio of the virtual concatenation group (VCG) on the backplane of EOS is generally no greater than 48, posing constraints on networking applications. However, the soft slicing of SPN equipment, based on VPN technology, supports a significant number of PWs and tunnels, extending to the K level, fully meeting the application scenarios involving multiple service types and a large number of sites and services.

Super-Large Bandwidth

A 100GE ring is deployed on the line side of the network to provide metro subsystems with redundant, reconfigurable, and flexible channels for information transmission and switching. Utilizing large-bandwidth elastic packet pipes, metro security check information can be collected in real time and processed centrally, facilitating simultaneous checking of both human bodies and objects. This approach improves the efficiency and accuracy of inspection and backtracking processes. Moreover, the SPN-based FlexE link bundling function binds two physical channels of 100GE interface to create a logical channel with large bandwidth. This enables high-rate services to be transmitted through low-rate physical ports and facilitates the smooth upgrade of line-side bandwidth to 200GE.

Looking ahead, a unified smart platform for metro development and operation will be built. The transport system will carry services such as smart O&M, smart travel, smart station, smart factory, smart driving, smart scheduling, and smart operation. The availability of 200GE ultra-large bandwidth on the line side will provide sufficient channel capacity for the development of this smart platform.

Supporting E1 CBR

In metros, the E1 service usually serves as an important production service, such as the dispatching telephone service, which has high requirements for service security, reliability, and delay indicators. SPN can carry E1 services at a constant bit rate (CBR). Client services are encapsulated into 10 Mbps small-granularity hard channels in the form of 66B blocks, without packet processing. This solves the soft isolation problem of the original PWE3 mode, ensuring not only service bandwidth and bit error performance but also providing delay performance similar to SDH. Through end-to-end FGU channels, E1 CBR ensures the hard isolation of E1 services on the entire path, meeting the high security and reliability requirements of metro production services.

Complete Network Protection Modes

The SPN device offers network-level hierarchical protection capabilities, supporting carrier-class fast protection switching with service switchover time of less than 50 ms. Additionally, it supports controller-based rerouting to achieve permanent 1+1 protection similar to that of ASON.

Furthermore, SPN equipment supports VPN FRR/IP FRR protection on the customer service sublayer to provide redundancy protection to PE nodes. It also supports link aggregation group (LAG) protection to enhance bandwidth and link reliability. On the network transmission sublayer, SPN supports linear protection, dual-homing protection, ring network protection, and SR-BE protection in any topology. On the slicing channel layer, it supports MTN path 1 +1 protection function, with service protection switching time reduced to several milliseconds. The rerouting and slicing channel protection capabilities of SPN provide superior functions and performance

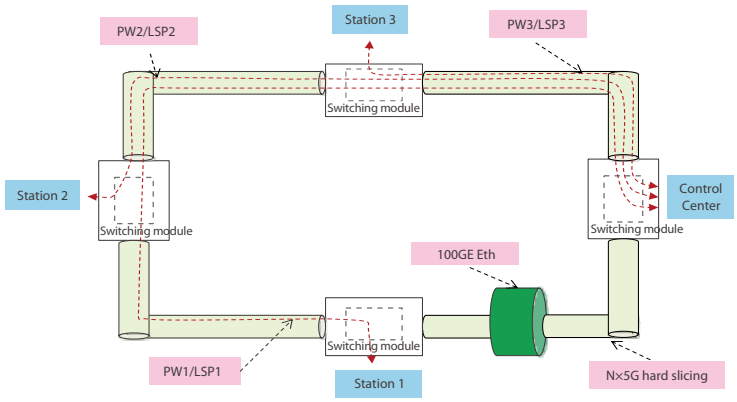

Fig. 1. The video surveillance service carried by the combination of SPN hard slicing and soft slicing.

compared to SDH and MSTP technologies, ensuring the high security and reliability of rail transit services.

Ultra-High-Precision 1588 Time Synchronization

The SPN equipment supports synchronous Ethernet function for stable and reliable frequency synchronization, along with PTP function for ultra-high-precision time synchronization, providing necessary synchronization signals to the wireless subsystem of metros.

SPN's high-precision time synchronization includes ultra-high-precision clock sources and ultra-high-precision time transfer technologies. Time servers track satellites, enhancing performance from 100 ns to 30 ns. The ultra-high-precision time transfer technology improves the transmission time synchronization precision of SPN through optimized interface timestamp processing, evolution of the 1588 time synchronization protocol, and enhanced single-fiber bidirectional link symmetry. SPN can deliver ultra-high time precision of ±5 ns to each site, ensuring precise synchronization for various new metro services in the future.

Intelligent Management and Control

ZTE's new universal management engine (UME) system integrates network management, service control, and network analysis functions, serving as the core system that enables network resource pooling, network connection automation and optimization, and O&M automation. Through the UME system, the SPN network achieves centralized network management and control, unified network-wide policies, end-to-end network visualization, and intelligent O&M, thereby improving O&M efficiency.

Moreover, it implements unified management of resources across the entire network, offering real-time visualization and visual analysis of existing network resource information across multiple dimensions, including services, tunnel connections, capacity, and sites, enabling accurate identification of network resource bottlenecks. Based on SDN technology, the SPN network supports centralized path calculation, ensuring optimal route determination during service provisioning, and preventing rerouting failures caused by resource conflicts during service recovery.

Additionally, the SPN network supports one-click automatic and rapid deployment, an end-to-end service quality detection mechanism, intelligent communication fault diagnosis, and automatic optimization and adjustment of channel bandwidth, providing strong support for smart metro operation.

Since the launch of Changsha Metro Line 6, its communications system has been operating smoothly, with all service performance indicators meeting the strict requirements of the intelligent rail transit system for transport networks. This serves as an important reference for future large-scale commercial deployment. ZTE remains committed to offering comprehensive technical support for the operation of the Changsha Metro communications transmission network, and strives to establish a premium rail transit network. ZTE TECHNOLOGIES

Guangdong Mobile Embraces SPN Dynamic Energy Solution for Green Transport

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Amid global warming, the Chinese government aims to achieve carbon peak by 2030 and carbon neutrality by 2060, as outlined in the 2021 State Council Government Work Report. China Mobile has diligently implemented this directive by upgrading its "Green Action Plan" to the "C^2 Three Capabilities—Carbon Peak and Carbon Neutrality Action Plan" in 2021, setting clear energy conservation and carbon reduction goals. By the end of the 14th Five-Year Plan, comprehensive energy consumption and carbon emissions per unit of total telecom services are projected to decline by over 20% compared to the 13th Five-Year Plan.

The energy consumption proportion of China Mobile's transport network ranges from 5% to 10%. There are obvious tidal effects and periodical traffic variations, but power consumption of network devices does not vary with service loads, leading to substantial wasted energy. To address these challenges, China Mobile Guangdong (Guangdong Mobile for short) and ZTE initiated AI energy-saving research and development for SPN in April 2021, successfully piloting the application in the existing Shaoguan network in May 2022.

SPN AI Dynamic Energy Saving Solution

The existing SPN experiences noticeable tidal effects and periodic traffic fluctuations over time. The innovative AI dynamic energy-saving solution collects real-time network data, analyzes and predicts changes in service load, and devises energy-saving schemes at chip, module, board, and network levels, ensuring intelligent power conservation while maintaining strict transmission performance.

Utilizing big data technologies and AI algorithms, the solution analyzes SPN traffic, predicts service trends, and implements precise energy-saving policies. It also incorporates various security protection mechanisms and energy-saving exit strategies according to network device and service operation statuses, thereby ensuring network and service security.

Traffic Data Analysis: Determining Mainstream Scenarios

Based on half-year traffic data, scenarios are categorized into base station and private line traffic

models by service type, high/low-traffic by traffic scale, regular/irregular-traffic areas by traffic features, and short/long-cycle scenarios by traffic changes.

Traffic Trend Prediction and Energy Saving Policy Selection

Combining multi-model weights with the operational status of each period, long-term trend prediction adopts Prophet and LSTM algorithms to predict the next period's traffic trend, generating periodic prediction baselines and determining maximum and minimum traffic prediction ranges.

The short-term early warning algorithm utilizes ARIMA and exponential regression algorithms to predict real-time traffic, assess trends, and make energy-saving decisions such as chip/module/board sleep based on real-time traffic trends. It evaluates the long-term trend model and dynamically adjusts it according to real-time traffic data.

Energy Saving Safety Mechanism

In sandbox mode, the energy-saving algorithm simulates operation, evaluates its impact on devices and services, and calculates energy-saving effects.

Multi-Layer Protection Mechanism

Given the fundamental role of the SPN in the communication network, ensuring network security is crucial. The energy-saving solution integrates a multi-layer security protection mechanism spanning from NE to network.

On the NE side, multiple regression algorithms are used for weighted analysis and prediction of network traffic to generate trend prediction models, build energy consumption prediction baselines, and calculate secure and reliable energy-saving spaces based on the traffic model. Moreover, the power consumption distribution inside the equipment is controlled according to its structural thermodynamic model. Combined with the design of ZTE's in-house core chips, different components such as chips, fans, modules and boards within the equipment are adjusted to execute energy-saving policies in a secure and reliable environment.

On the network side, to deal with prevalent scenarios in transport networks like protection switching or traffic migration, the controller analyzes traffic relationships between NEs, calculates the protection path of each NE in real time, predicts potential traffic migration, and avoids burst step impacts that a single NE cannot predict. This approach establishes an energy-saving policy on the network layer, ensuring energy efficiency under stringent performance conditions.

Energy Saving Exit Mechanism

To ensure uninterrupted service operation, the system incorporates three energy-saving exit mechanisms: when real-time traffic exceeds the preset threshold, a specific alarm is triggered, and the energy-saving mode is manually deactivated.

Verification in Guangdong Mobile's Existing Network

The AI energy-saving solution was discussed multiple times by Guangdong Mobile and ZTE, underwent numerous lab verifications, and was deployed and tested extensively in China Mobile Shaoguan in May 2022.

- **Energy efficiency:** If dynamic energy saving is disabled, the existing network of Guangdong Mobile with 955 sets of ZXCTN 6700 is estimated to consume 16.5177 million kWh. Enabling dynamic energy saving saves 15.28%, approximately 2.5239 million kWh annually, equivalent to 2.0191 million RMB in electricity costs.
- **Security verification:** The devices enter energy-saving mode to test four scenarios: burst traffic, board plugging/unplugging, tunnel switchover, and forced shutdown. No alarms or packet loss occur in the system, achieving the expected result. The system has operated securely and stably for over six months, enduring tests during major events such as Dragon Boat Festival, shopping festivals, college entrance examinations, National Day, and Spring Festival.
- **Achievement promotion:** Building on successful trials in Guangdong, China Mobile has actively promoted the SPN dynamic energy-saving solution to other provinces in the country. It's now being applied in Heilongjiang, and will expand to Gansu, Guizhou, Zhejiang, Yunnan, and Fujian. Pilot projects and applications are expected to be completed across all provincial branches of China Mobile. ZTE TECHNOLOGIES

ZTE and Liaoning Mobile Jointly Build Intelligent Closed-Loop System for SPN Service Quality Guarantee

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In the 5G era, network architecture and service models become increasingly complex. The traditional O&M mode, relying on expert experience, suffers from low fault location efficiency and lengthy troubleshooting time, acting as a bottleneck for network O&M. Passive O&M, triggered by user complaints after service quality degradation or fault occurrence, severely affects user experience. To improve service quality in existing 5G SPN networks, boost user satisfaction, and drive automation, digitization, and intelligentization of network O&M, ZTE and China Mobile Liaoning (Liaoning Mobile for short) jointly proposed an intelligent closed-loop system solution (Fig. 1). Verification of this solution was conducted on ZTE's intelligent management and control system ZENIC ONE (UME) in the existing network.

This solution extends alarm compression and root cause analysis capabilities based on intelligent rule-orchestrated fault diagnosis. It also deploys group fault analysis and automatic service quality maintenance (intent maintenance) functions, enabling intelligent closed-loop management. This includes real-time service status perception, automatic delimitation and location during fault analysis, and minute-level service recovery in certain scenarios. With this solution, SPN fault location accuracy can reach 95%, and overall O&M efficiency can increase by over 35%, as service quality problems are identified more efficiently and precise solutions are provided. By transitioning from manual and passive O&M to automatic and active O&M in certain scenarios, network maintenance efficiency and service security are enhanced, customer complaint rates are reduced, and customer satisfaction is improved.

Intelligent Rule-Orchestrated Fault Diagnosis

Traditional manual fault analysis relies heavily on the experience of professional personnel, involving extensive tasks such as alarm filtering, correlation analysis, tool preparation, and locating, which are time-consuming. It is challenging to pass on O&M experience and train new personnel. ZTE proposes an intelligent fault diagnosis solution that centralizes and modularizes distributed diagnosis tools such as ping, IOAM, RCA, and configuration check. In different service scenarios, maintenance personnel can independently orchestrate these modular diagnosis rules, adding fixed solutions to the library. During fault location, the system automatically selects and executes a diagnosis solution based on the fault type. Currently, the system can locate faults in various services, including connection/disconnection, packet loss, and clock faults. This feature allows mature diagnosis rules to be rapidly fixed, making it convenient for O&M personnel to call the rules at any time. It addresses the bottleneck of low efficiency in O&M knowledge transfer and the long accumulation cycles for maintenance experience. Diagnostic time is shortened from hours to minutes, greatly improving fault location efficiency.

Group Fault Analysis: Automatic Fault Location

A group fault refers to a quality abnormality affecting multiple services or network objects simultaneously due to the same fault. These faults mainly occur at the aggregation and core layers of the network and are typically identified through customer complaints. When a group fault occurs, it can result in a decline in the service quality of

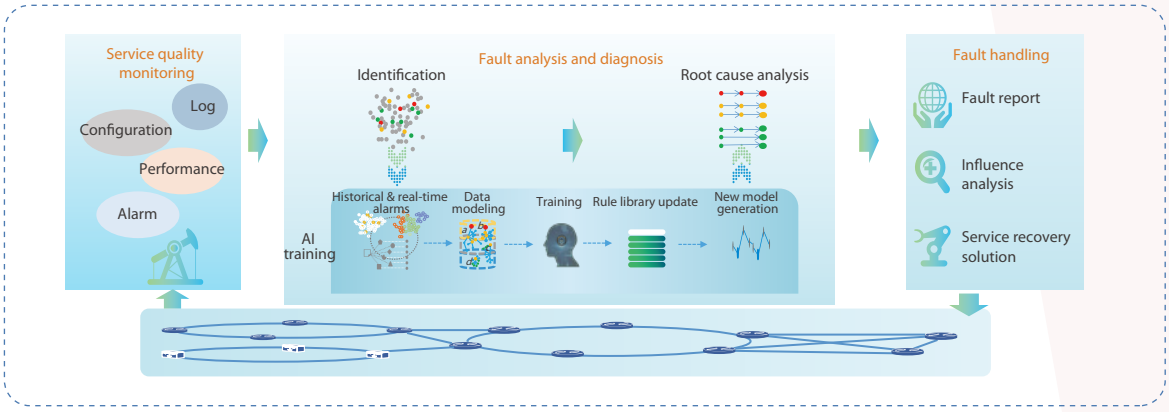

Fig. 1. Intelligent closed-loop system for SPN service quality guarantee.

multiple users, or even service interruption. Traditional restoration methods, relying on manual analysis and location, are time-consuming, inefficient, and significantly affect customer satisfaction. ZTE's group fault analysis tool integrates a closed-loop process encompassing service quality perception, fault commonality analysis, fault diagnosis, and fault restoration to rapidly locate group faults. Once a key service analysis task is initiated, the system monitors the quality of the service object in real time. When identifying abnormal service quality, the system comprehensively analyzes whether the fault is caused by a group fault based on current system alarm information. If identified as a group fault, the system starts a fault commonality analysis task to help O&M personnel quickly locate and resolve the fault. This functionality enables real-time network monitoring and group fault analysis within minutes, enhancing efficiency by over 90% and implementing proactive O&M in group fault scenarios.

Maintaining Service Intent: Supporting Committable SLA

The most direct factor affecting customer experience is the continual maintenance of SLA to meet user expectations, which is also a critical competitive advantage for operators. The service intent maintenance feature introduced by ZTE is aimed at fulfilling this important task.

ZENIC ONE (UME)'s service intent maintenance feature comprises three layers of closed-loop capabilities. The first layer is second-level service self-healing, where network-layer devices automatically trigger switching or rerouting of corresponding network objects upon identifying a service interruption, ensuring rapid resolution. The second layer, minute-level service restoration, kicks in when the network layer cannot implement second-level self-healing. The management and control system identifies service quality issues, locates and analyzes them, generates restoration policies, and automatically executes restoration commands within minutes. The third layer focuses on medium and long-term service optimization, predicting and analyzing service quality and traffic to preemptively address potential issues and optimize services.

At preset, the service intent maintenance function at the first two layers has been successfully implemented and verified on existing networks. This function facilitates self-perception and self-healing of service quality, reducing restoration time from hours to minutes compared to traditional manual O&M. It maintains services "permanently online", simplifies O&M, and enhances customer experience while meeting SLA requirements.

Liaoning Mobile and ZTE have made significant investments in network O&M to tackle challenges and overcome bottlenecks. The intelligent closed-loop guarantee system for SPN service quality, which integrates intelligent fault diagnosis, group fault analysis, and service intent maintenance functions, enhances O&M efficiency for Liaoning Mobile, shifting from passive to active O&M. Looking ahead, both parties will extend their cooperation to reinforce fault root cause analysis, implement a "one fault, one worksheet" approach, and simulate restoration solutions, thereby further enhancing O&M efficiency, expanding application scenarios, and leveraging intelligent precise O&M to achieve breakthroughs in network O&M. ZTE TECHNOLOGIES

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