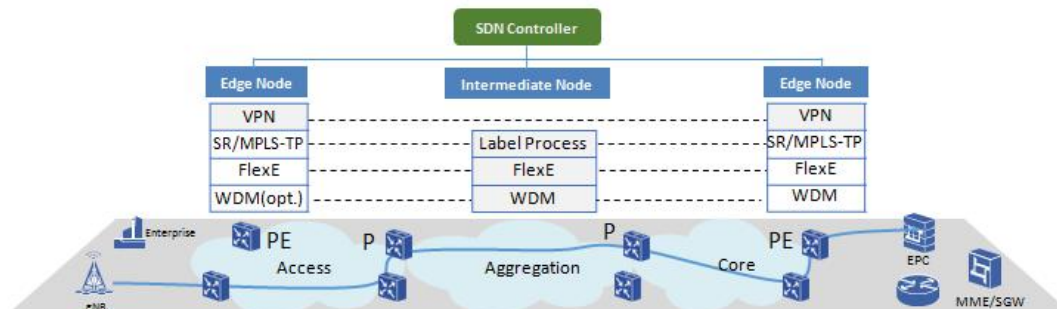


Innovative 5G Transport Solution – Flexhaul

5G is a real multi-scenario integrated network and an important foundation for future “Internet of Everything” (IoT). It supports digital economic transformation of vertical industry. 5G poses higher requirements for bandwidth, latency, flexible connection, reliability and open SDN capability of transport network, which causes huge challenges to transport network architecture and technology and drives continuous transport network technology upgrade and innovation.

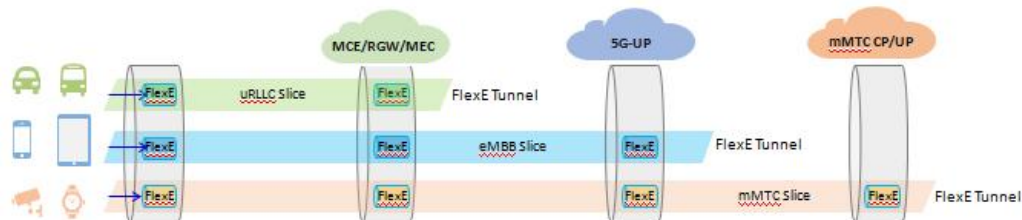
5G transport networks still have telecom network requirements for end-to-end (E2E) service, physical isolation of traffic, low latency and network protection besides large bandwidth technology. To address transport requirements of 5G networks, ZTE innovatively proposes the Flexhaul solution. Flexhaul is a new-generation E2E network solution oriented to 5G transport and provides an entire SDN-based technology system from L3 to L0. The architecture is as shown in the figure below. The Flexhaul solution supports L2/L3VPN services at L3, SR/MPLS technology at L2 and FlexE technology at L1. It also makes innovative extension based on standard FlexE technology. It creates E2E FlexE Tunnels at L1 to provide L1 switching, OAM and protection. It supports DWDM technology at L0, providing good network expandability and ensuring smooth evolution in the future.



The Flexhaul solution provides a unified E2E transport solution for 5G fronthaul, midhaul and backhaul services and supports flexible deployment according to network requirements. It supports IP+optical flat network architecture and implements multi-wavelength and multi-bandwidth binding based on FlexE over DWDM, which flexibly expands network capacity and highly increases bandwidth expandability. Meanwhile, this solution omits OTN framing but uses integrated topical transmission subrack to simplify equipment layers at the aggregation and core layer, reducing the network construction costs and simplifying operation, administration and maintenance (OAM).

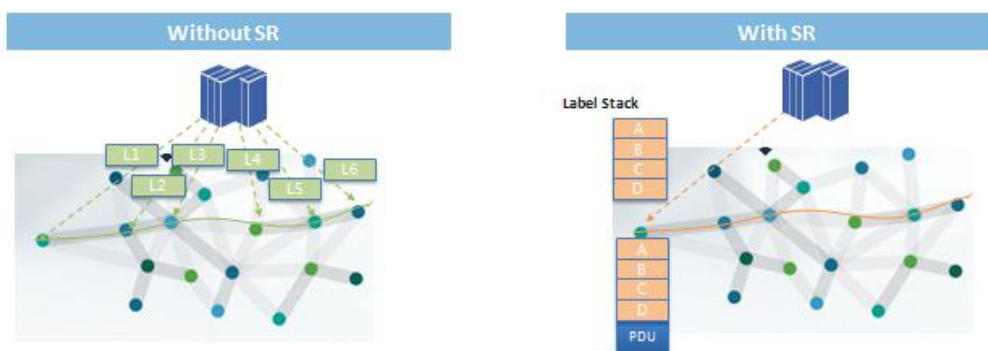
The solution employs innovative FlexE Tunnel technology to expand the FlexE from interface level to network level, and provides FlexE Tunnel-based network slicing to meet the requirements of 5G uRLLC service for low latency and high reliability. As shown in the figure below, Flexhaul can slice network resources (including bandwidth, latency processing function, CPU and VPN) to several virtual E2E networks based on FlexE

Tunnel. The network slices are logically isolated in the forwarding plane, control plane and management plane to adapt to various types of services and satisfy different user requirements. At the same time, protection switching based on FlexE tunnel technology can be finished within 1ms, elevating carrier-class protection to industrial control level. FlexE tunnel technology is used for uRLLC service, solving the problems of too large service granularity and low transport efficiency of wavelength pass-through solution and too high latency and no physical isolation of soft slicing technology.



In addition, it provides E2E 5G slicing solution by combination of wireless and core network slicing to meet the multi-scenario and multi-tenant requirements of 5G vertical industry.

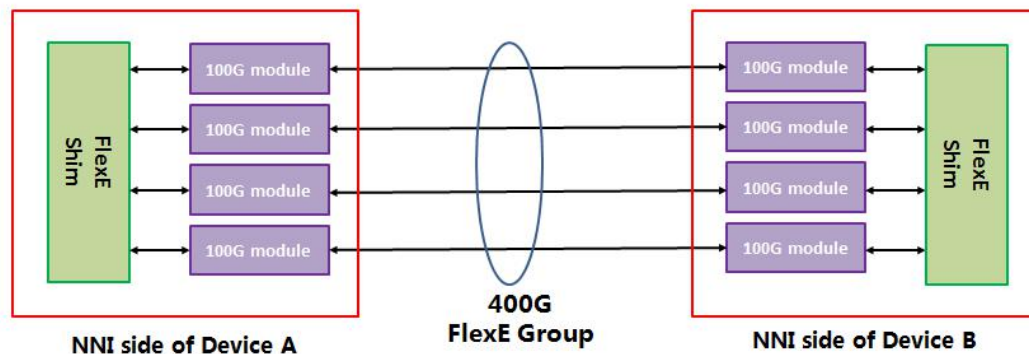
To address the ubiquitous connection requirements brought by cloudification of 5G core networks and base stations, the Flexhaul solution adopts Source Route (SR) technology as well as intelligent traffic engineering of SDN and employs the deployment of a centralized controller and a distributed control plane. The controller computes E2E SR paths, and generates complete labels stacks and forwards them to the devices to establish the SR tunnel. The intermediate nodes only need to maintain topology information but do not need to maintain connection states, solving the expandability problem of MPLS network. Besides, SR technology enables E2E path establishment by merely operating source nodes, highly improving service deployment efficiency. The distributed routing protocol implements basic network topology collection, SR label forwarding table generation and FRR local protection. The distributed control plane has the advantages of self learning, self adaptation and self healing. The centralized controller has the advantages of global resource optimization, centralized scheduling and policy control. The combination of the two can make the most of the advantages of SR.



Below is a detailed analysis of the innovative technology of 5G Flexhaul transport solution

– FlexE Tunnel.

Optical Interconnection Forum (OIF) set up a Flex Ethernet research team in January 2011, released the draft in July 2015, released Version 1.0 of FlexE (OIF-FLEXE-01.0) in March 2016, and now is drafting the Version 2.0. FlexE technology decouples the service rate from the physical channel rate. The physical interface rate is not necessarily equal to the customer service rate. It can be another flexible rate (for example, the customer service rate is 400GE, but the physical channel (PHY) rate is 100GE or another rate). Customer services are not necessarily transmitted on a physical channel, but on a virtual logical channel formed by multiple physical channels bound together. After the service rate is decoupled from the PHY rate, customer service rates are diversified and PHY rates become multiple different rates independent of each other. Therefore, the bandwidth of large-bandwidth customer services can achieve gradual evolution of 25G->50G->100G->200G->400G->xT by port binding and time slot cross-connect technology using standard 25GE/100GE interfaces, solving the problem of high-speed physical channels being not cost-effective.

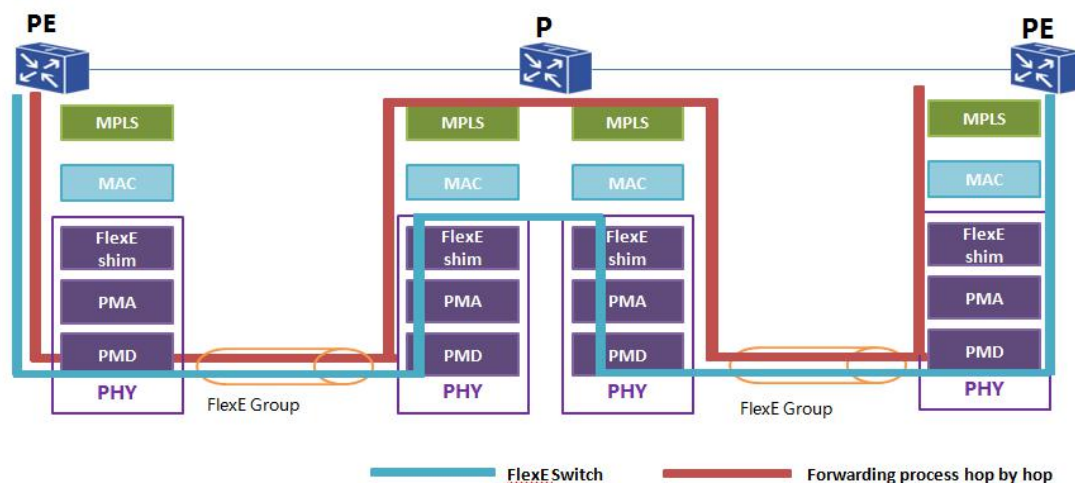


FlexE technology is developed to solve the large bandwidth transmission problem at the beginning. The standardization team mainly considered point-to-point application scenarios, so the current standard FlexE technology is a physical interface technology lack of consideration about networking application, E2E transport and service protection. ZTE carried out a series of technical expansion and perfection work based on existing FlexE technology standards. Besides providing large bandwidth expansion technology, ZTE proposed the industry's first FlexE-based revolutionary technology – FlexE Tunnel. FlexE tunnel is an ultra-low-lantency, physically isolated and highly reliable E2E pipe. It is established at the FlexE channel layer and can be flexibly adjusted according to the customer's bandwidth requirements. FlexE Tunnel expands FlexE from a point-to-point interface technology to an E2E networking technology by FlexE time slot switching, OAM expansion and ultra-fast protection switching technology, providing an important technology support for E2E 5G transport solution. ZTE's E2E FlexE Tunnel solution provides operators with the following advantages:

■ **Equipment-level ultra-low-latency forwarding technology**

FlexE technology implements service flow forwarding based on physical layer using time slot cross-connect technology. The service flow forwarding procedure is completed almost

in real time without the need to resolve user packets on intermediate nodes. The single-hop forwarding latency is less than 0.5us, laying the foundation for ultra-low-latency service transport.

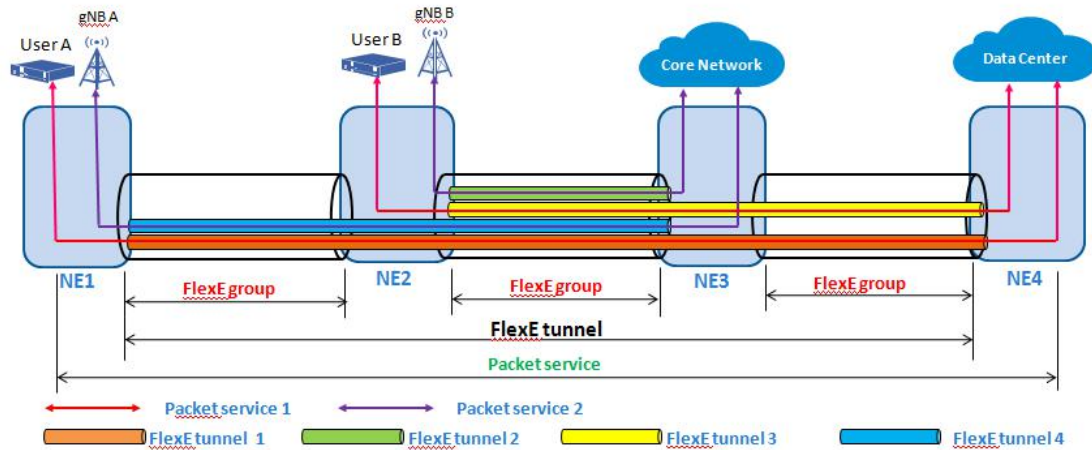


■ L1 E2E OAM and fast protection

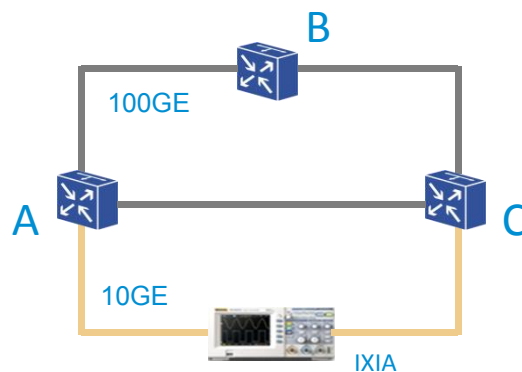
FlexE Tunnel also makes corresponding overhead expansion and implements E2E bit error detection and performance monitoring. FlexE Tunnel performs E2E OAM information monitoring. OAM information includes CC/CV, LM, DM, RDI, LB, LT, LCK, TST and APS. FlexE Tunnel provides protection function to improve the reliability of service transmission. When a customer service fails in one tunnel, it is quickly switched to another tunnel for transmission. The protection mode includes 1+1 and 1:1 protection. As protection switching of FlexE tunnel is implemented at the physical layer, the protection switching time is substantially reduced to less than 1ms.

■ Any rate slicing, physical isolation, E2E rigid pipe

Based on the features of FlexE sub-channel and the time slot cross-connect feature at the physical layer, cross-NE E2E FlexE Tunnel rigid pipes can be established on the transport network. The intermediate nodes do not need to resolve service packets, so as to implement strict physical layer service isolation. An example is as shown below. E2E FlexE Tunnel 1 is established for services between NE1 and NE4; the intermediates nodes NE2 and NE3 forward the services directly by physical layer cross-connect, so as to form a one-hop direct rigid pipe from NE1 to NE4.



At Mobile World Congress Shanghai (MWCS) 2017, ZTE carried out an on-site test about the key technology FlexE Tunnel, including service isolation, ultra-low-latency forwarding, E2E OAM and fast protection switching. In this test, three 5G Flexhaul pre-commercial transport devices – ZXCTN 609 are used and connected with the tester (data tester IXIA XM2); the devices are networked by 100GE links.



This test verifies that ZTE's revolutionary FlexE technology can provide:

- FlexE Tunnel service E2E isolation solution
- Less than 1ms service protections witching solution
- Less than 0.5us single-hop latency solution

ZTE believes that FlexE technology has innate advantages in ultra-low-latency forwarding and securely isolated network slicing and is the best choice for 5G transport and forwarding technology.

With the deepening research into 5G wireless standards, researches into 5G transport standards are being gradually carried out. Technologies and standards related to 5G transport involve a large number of standardization organizations, including ITU-T, IEEE and OIF. ZTE has been actively participated in the researches into 5G transport standards of the standardization organizations. At the plenary session of ITU-T SG15 held in Geneva Switzerland in June 2017, Chinese enterprises including China Mobile, ZTE and China Academy of Information and Communications Technology (CAICT) submitted a

number of proposals related to 5G transport. Participating experts considered transport networks supporting 5G requirements as a very important new subject. At the summary meeting on June 30, they formally approved the technological report of Transport network support of IMT-2020/5G (TRGS-TN5G) and the research plan of 5G transport standards. This marks a critical step of ITU-T in 5G transport standard research and great contributions made by Chinese enterprises in promoting 5G transport standard research. As the industry's first supplier providing complete 5G E2E products and solutions, ZTE has been actively promoting applications and trials of 5G transport solutions. ZTE together with China Mobile showcased the revolutionary advantages of FlexE series solutions to the public in 2017Q3, fully demonstrating the leading position of ZTE in 5G transport.

As a leader in the 5G era, ZTE will continue innovations in 5G transport technologies, solutions and devices to provide highly cost-effective and competitive solutions for operators. Leading 5G transport innovations, ZTE has been ready.