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China Mobile

5G Transport Network Requirements, Architecture and Key Technologies

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Outline

- Requirements Analysis on 5G Transport Network
- Overview of Slicing Packet Network (SPN)
  - Architecture
  - Key technologies
- Proposals and suggestion

Overview of China Mobile Transport Network

Basic Network Capability

Mobile

Mobile Subscribers 910 M

-4G Subscribers 605 M

4G Base Station 1.5 M

4G carrier sectors >5 M

Residential

Residential subscriber 95.74M

- GPON FTTH 76%

Households coverage 355 M

Infrastructure

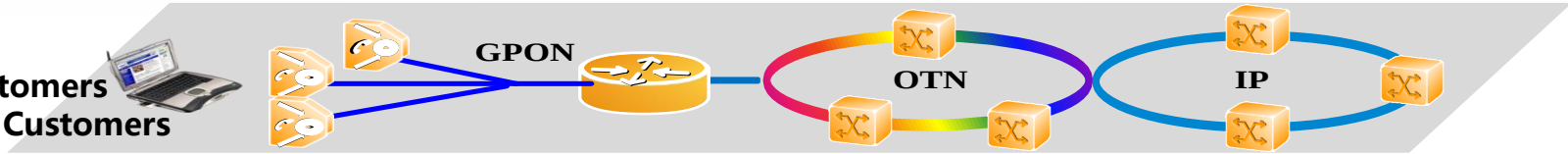
Fiber: 360M Fiber-Core-KM

-100 million fiber-core-km per year in 2016 and 2017

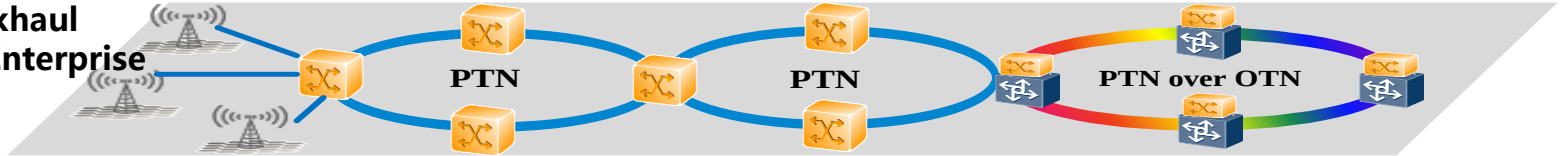
- 30% of the world's total

100G OTU: 30k in 2017

✓Family customers
✓Enterprise Customers

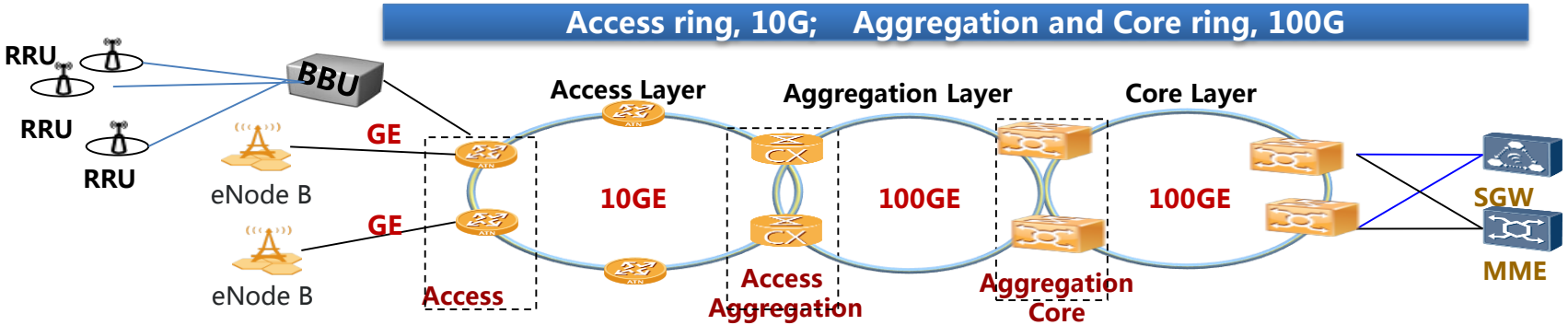


✓3G/4G backhaul
✓High-end Enterprise Customers



China Mobile Transport Network for 4G

- **PTN Backhaul:** 1.5M PTN nodes for Macro cell, Micro Cell and Pico cell; L3 in core layer for X2 and S1 Flex
- **GPON backhaul:** integrated Pico and femto Cell
- **Fronthaul:** ~5RRUs/BBU, is mainly based on fiber direct connection



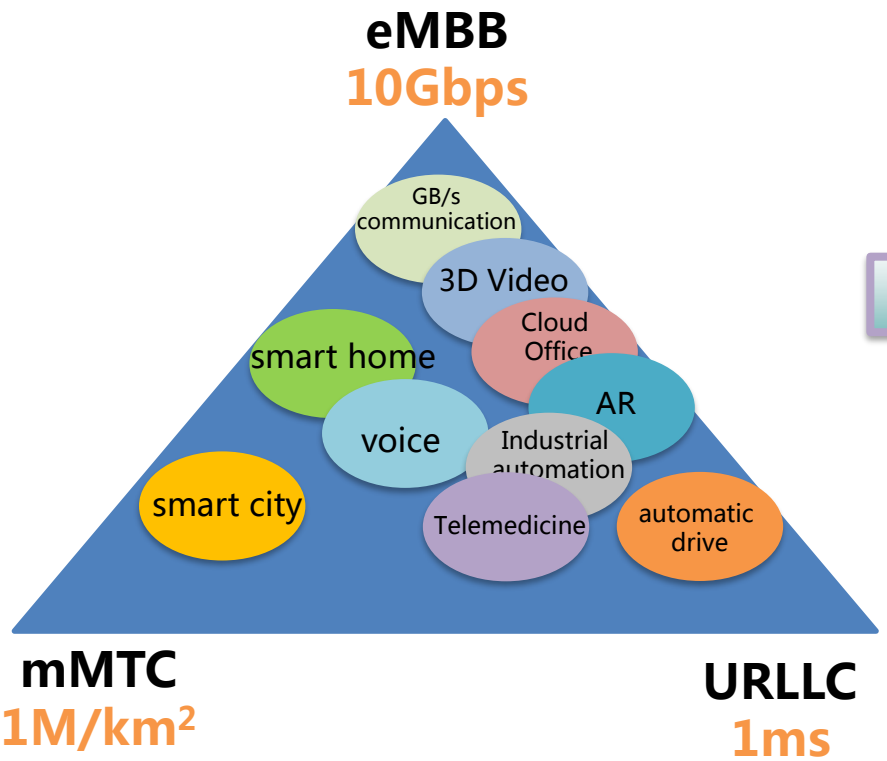
Bandwidth plan for single S111 eNodeB	Access Layer	Aggregation Layer	Core Layer
	80 Mbps	60Mbps	40Mbps

Latency requirements of 4G backhaul	single direction of transport network: 10ms single equipment : 100us	**Test results in PTN field network**	single direction of transport network: ~2ms single equipment : ~50us
Time Sync requirements of 4G backhaul	time servers are only deployed in metro end-to-end Sync precision : ±1.5us	**Test results in PTN field network**	end-to-end Sync precision : under ± 500ns

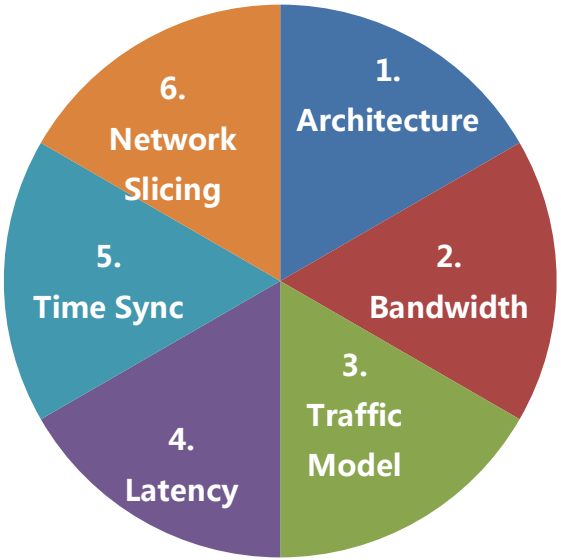
New Challenges for 5G Transport Network

New usage scenarios for 5G drive new transport network.

Families of usage scenarios for 5G



New transport network requirements



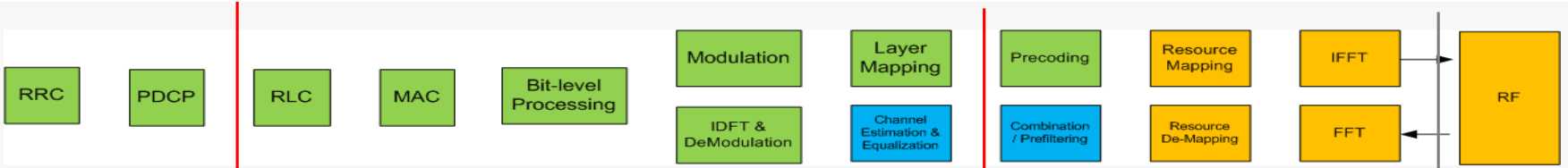
As well as the traditional transport requirements, such as:

- 50-ms Protection Switching
- End-to-end OAM

1. Architecture Change of 5G RAN

■ **Change in architecture : function split of 3GPP 5G RAN defines CU and DU two-stages architecture**

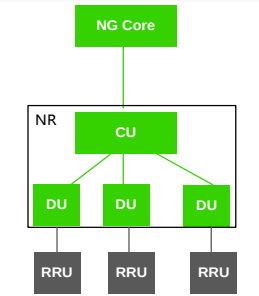
CU： non-real-time processing, centralized deployment, general hardware	DU： HARQ process , high real-time digital signal processing, radio interface oriented, spectral efficiency	RRU： eCPRI, bandwidth aggregation, not related to the number of antennas, related to tranffic load



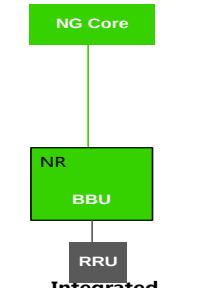
■ **CU/DU are logical elements. Both centralized C-RAN (CU/DU separated) and gNB (CU/DU integrated) may be widely introduced. The Mid-haul and backhaul are overlapped and need unified transport technology .**

Split Architecture of CU/DU

- CU is placed at county center or aggregation point, save telecom room number and cost，latency between CU and DU should be under 3ms
- Each DU is connected with 1~10 physical stations



Split Architecture of CU/DU



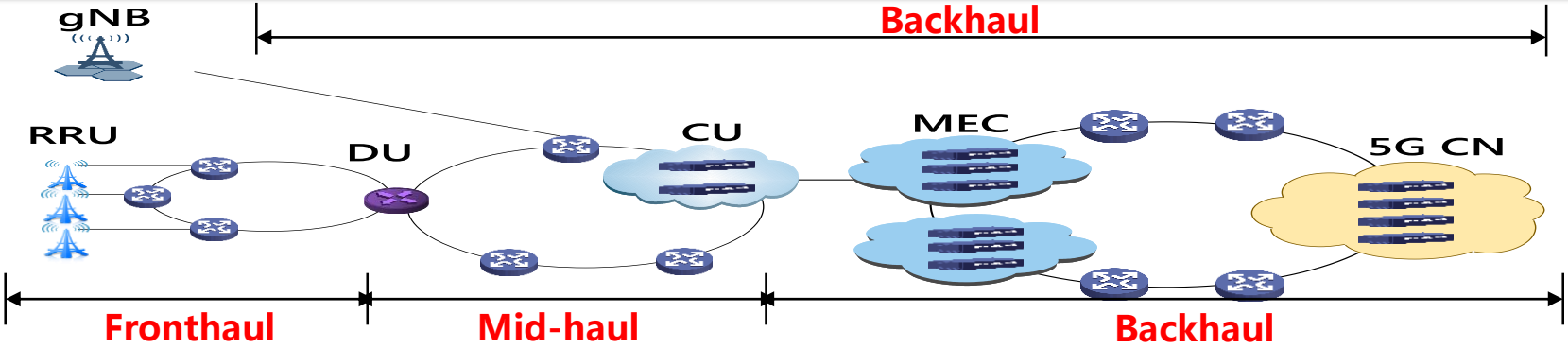
Integrated Architecture of CU/DU

Integrated Architecture of CU/DU

- Same with 4G metrocell deployment，CU and DU deploy at the same position
- Each gNB is connected with 3~6 RRU

1. Architecture Impact of 5G Transport Network

- Unified transport technology is necessary for fronthaul, mid-haul and backhaul network
- Mid-haul and backhual have the same requirements , Slicing and L3 functions are needed
- Fronthaul can use fiber connection or use channelized network solution with DWDM system



Fronthaul : RRU-DU

- eCPRI interface，IQ signal is effective sampled and packetized，do not recommend to use statistical multiplexing
- Point-to-point, 1~10km
- High latency requirement(related to HARQ): transmission latency ~100us
- No need to introduce electrical Switching

Mid-haul : DU-CU

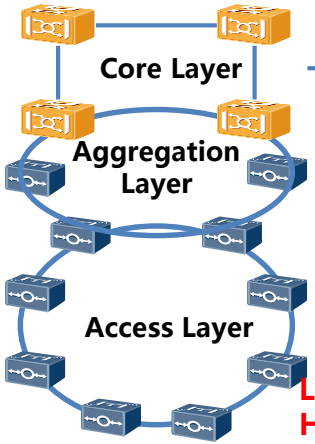
- Bandwidth of Mid-haul is around that of backhaul. Statistical multiplexing can be used.
- under 40km~80km, Point-to-point or Point to Multi-point
- One CU is for 300~500 physical stations
- Normal latency requirement(related to signaling control): under 1ms

Backhaul : CU-Core network

- Statistical multiplexing
- Multi-Point-to-multi-point
- Distance：under 200km
- Latency is related to services, Requirement is less than 10ms

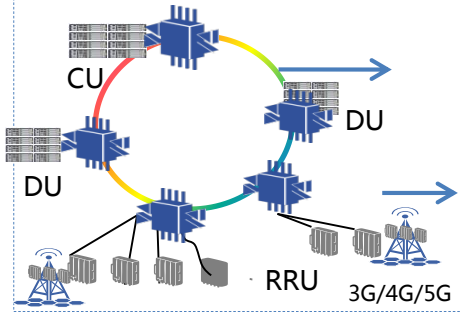
2. Bandwidth Estimation of 5G Transport Network

5G bandwidth estimation



	Ring network capacity	
	LF station	LF+HF station
Core Layer →	117.315G	632.61G
Aggregation Layer →	78.22G	421.74G
Access Layer →	26.07G	140.58G

LF station: average bandwidth ~3G
HF station: average bandwidth ~10G



Mid-haul : ~10G

Fronthaul : 3 RRU each station , ~ 75G

Backhaul :

- ✧ Line side bandwidth of core layer and aggregation layer: 100G~600G。
- ✧ Client side interface of access Layer: 10GE/25GE , network interface bandwidth is more than 25G 。

Mid-haul :

- ✧ The bandwidth of mid-haul is around that of backhaul

Mid-haul and Backhaul have the similar requirements, which can share one network technology , Access ring can use gray 50GE , Aggregation and Core layer use DWDM with 100G /200G λ

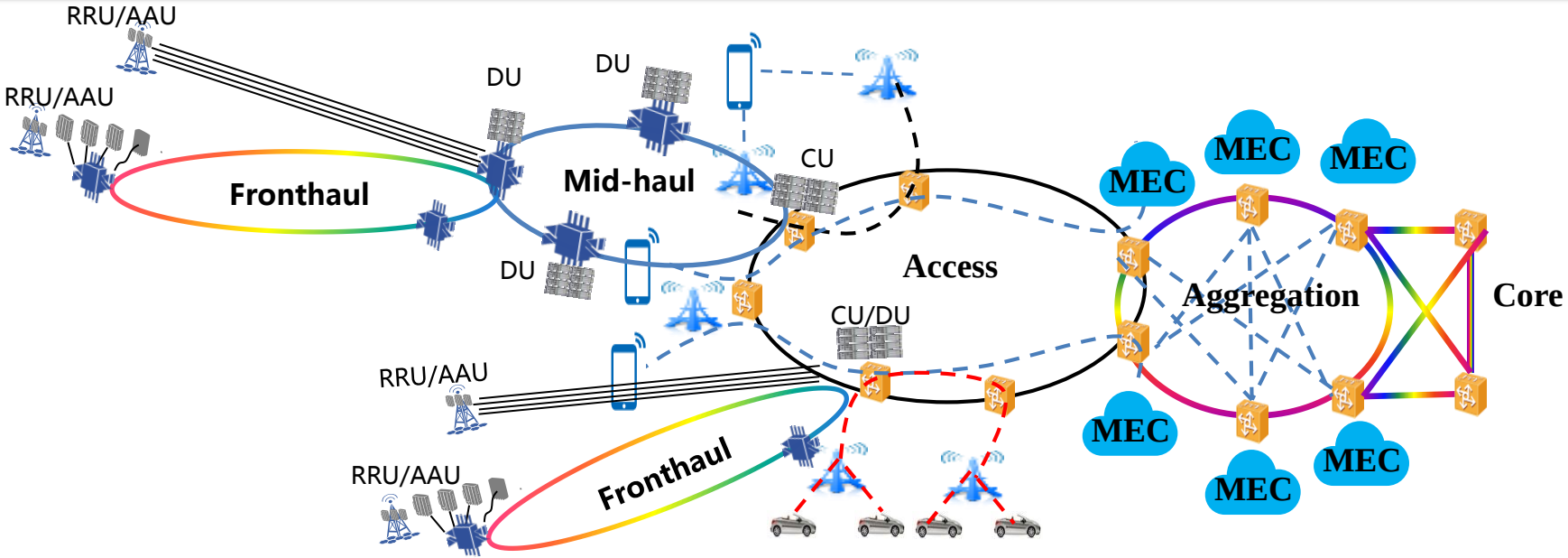
Fronthaul :

- ✧ eCPRI bandwidth for single RRU: under 25G (100MHz)

Fronthaul has the different requirements from Mid-haul and backhaul, which should be based on simple optical technology.

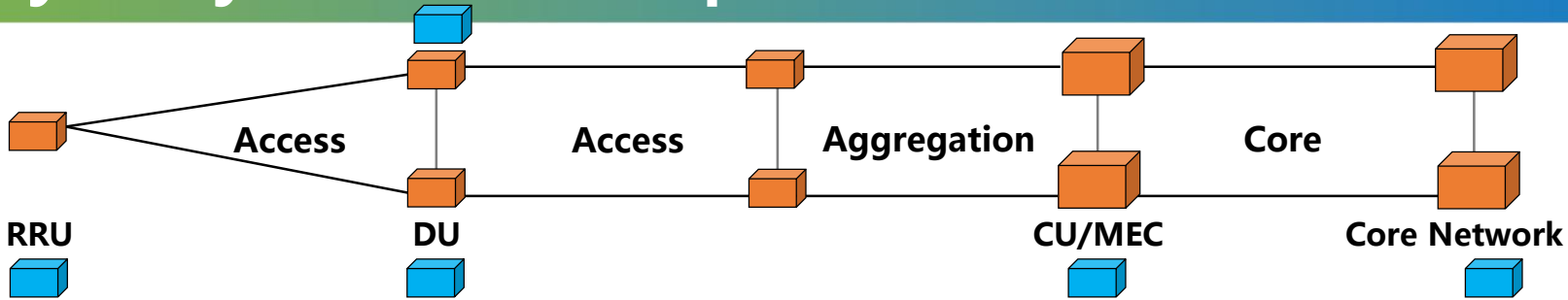
3. Traffic Model of 5G Transport Network

- Increasing traffic load, more flexible flow direction and more complicated traffic scheduling are required
  - ✓ The traffic flow between clouded MEC is increasing dramatically
  - ✓ eX2 traffic among base stations are increased
  - ✓ URLLC service with ultra-low latency requirement should be satisfied



Local mesh network may be applied in aggregation even access layer of 5G transport network. L3 function of metro network should move to aggregation even access Layer。

4. Latency analysis of 5G Transport Network



Network	Transport	Fronthaul	Middlehaul+Backhaul
	Latency	<100us	<0.5ms	service requires
	Distance	1~10Km	5~50Km	20~300Km
	Hops	~8hops	~15hops	~5hops
Services	uRLLC eV2X	1ms	eV2X<1ms, end to end fronthaul+backhaul <1ms
	eMBB VR/AR	5ms~40ms	

Latency requirements: Pizza box 1us; Chassis Box 10us;
Test result of prototypes from Huawei/ZTE/Fiberhome: Pizza box ~1us; Chassis Box ~10us;

5. Time Sync Requirement of 5G Transport Network

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4G Sync

TD-LTE: ±1.5us

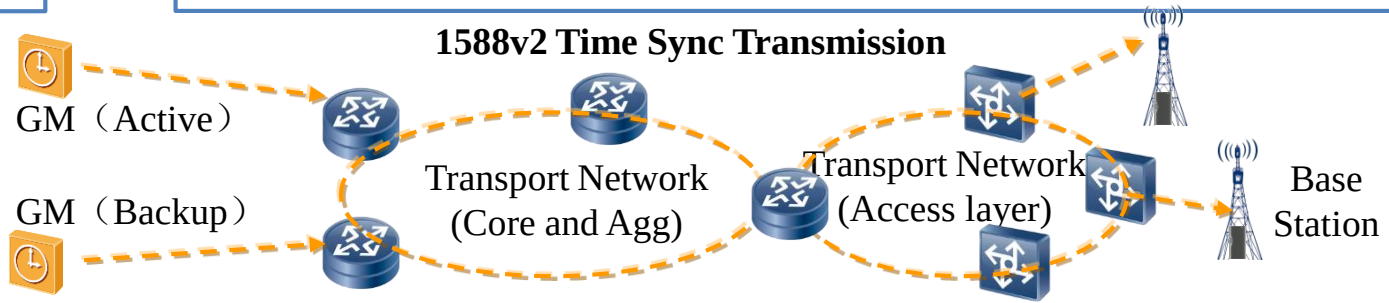
5G Sync

A. **Basic radio interfaces (Whole Network)**: Ultra-short Frames，about ±390ns

B. **Cooperations among stations (Local)**: CoorapCA, CoMP etc., about ±130ns

C. **5G new services (Local)**: Base station positioning etc. about ±10ns

Sync Model



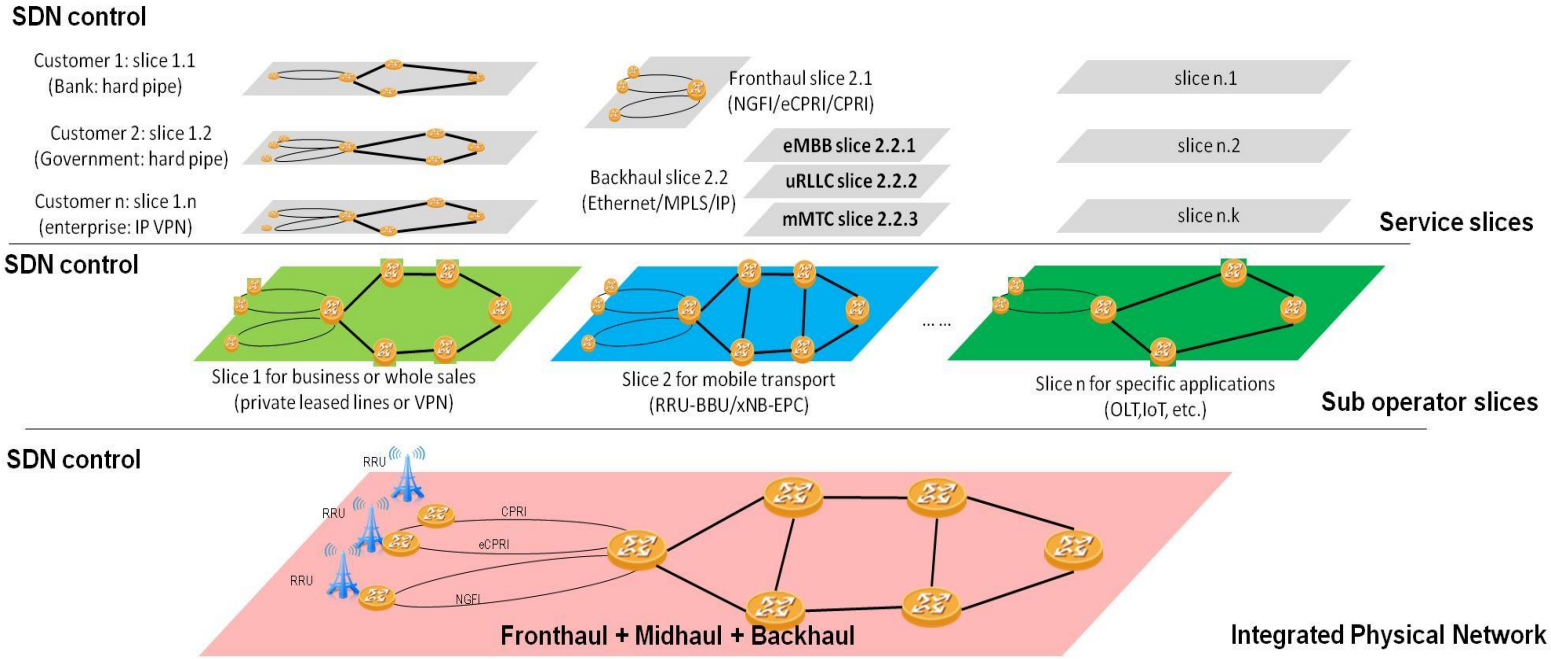
Network budget

	PRTC	Transmission Network	Base Station
4G	250ns	1000ns（including holdover），30ns per hop，>20 hops	250ns
5G	50ns	Tracing 100ns, holdover 100ns，5ns per hop，>20 hops	50ns

- Fronthaul, mid-haul, and backhaul should support time sync functions. End-to-end budget could be +/-200ns without holdover
- The multi-lane interface need be supported and BiDi modules should be used in front haul and access layer of backhaul
- Compared with 4G, innovative time source and time transmission technologies are required to improve time sync precision.

6. Slicing requirement of 5G Transport Network

- **Network slicing as a Service (NSaaS)**: integrated transport network as a common resource and infrastructure should be able to be sliced as different logical network slices.
- **Hard and soft isolation :** the slices based on TDM and the slices based on Packet should be supported. The VPN or H-QoS can not meet the both requirements for Hard and Soft isolation.
- **Nested slicing:** in one dedicated slice, the new slicing can be created



Summary

- 5G has many new requirements on transport network, such as architecture, bandwidth, traffic model, slicing, latency, and time synchronization.
- 5G transport needs revolution: New technology, New chips, New Boxes

Packet Layer	Link Layer	Time Synchronization	Control/Management
➢ L3 to the edge need carrier grade L3 ➢ SR-TP(Segment Routing-Transport Profile): connection-oriented L3	➢ New functions: ● Link aggregation ● Channelization ● TDM/Packet convergence switching ➢ New interface: FlexE ➢ Latency optimized	➢ ±1.5us -> ±200ns (without holdover)	➢ Flexible and smart control/management: SDN

5G requires new transport network !

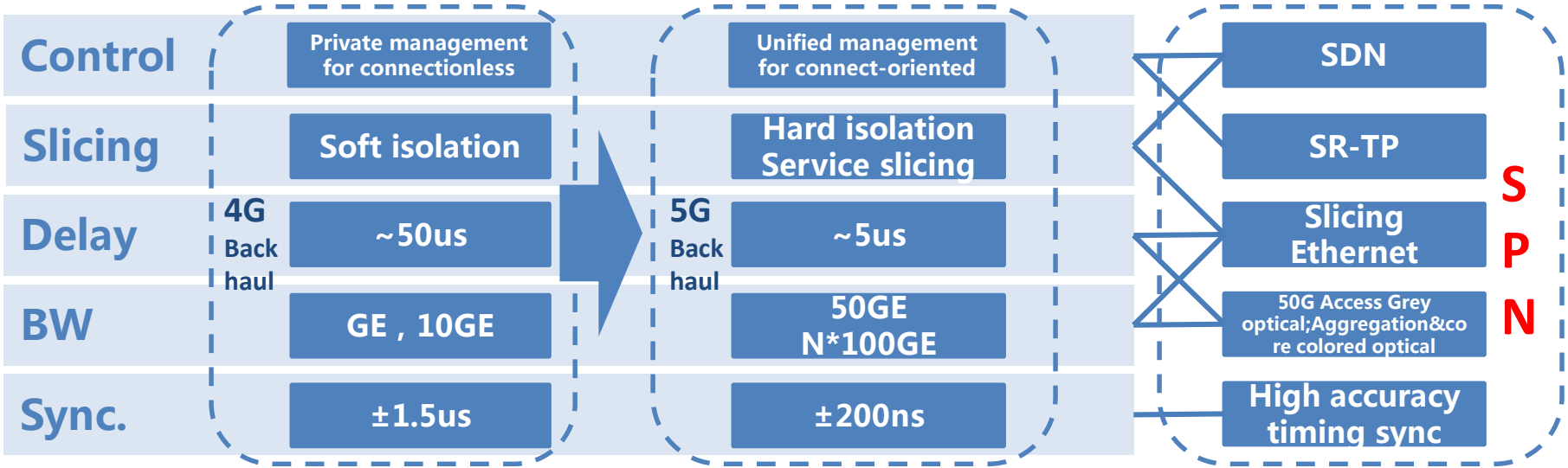
Outline

- Requirements Analysis on 5G Transport Network
- Overview of Slicing Packet Network (SPN)
  - Architecture
  - Key technologies
- Proposals and suggestion

Slicing Packet Network(SPN) meets 5G requirements

SPN (Slicing Packet Network) : A hierarchy that merge TDM and packet

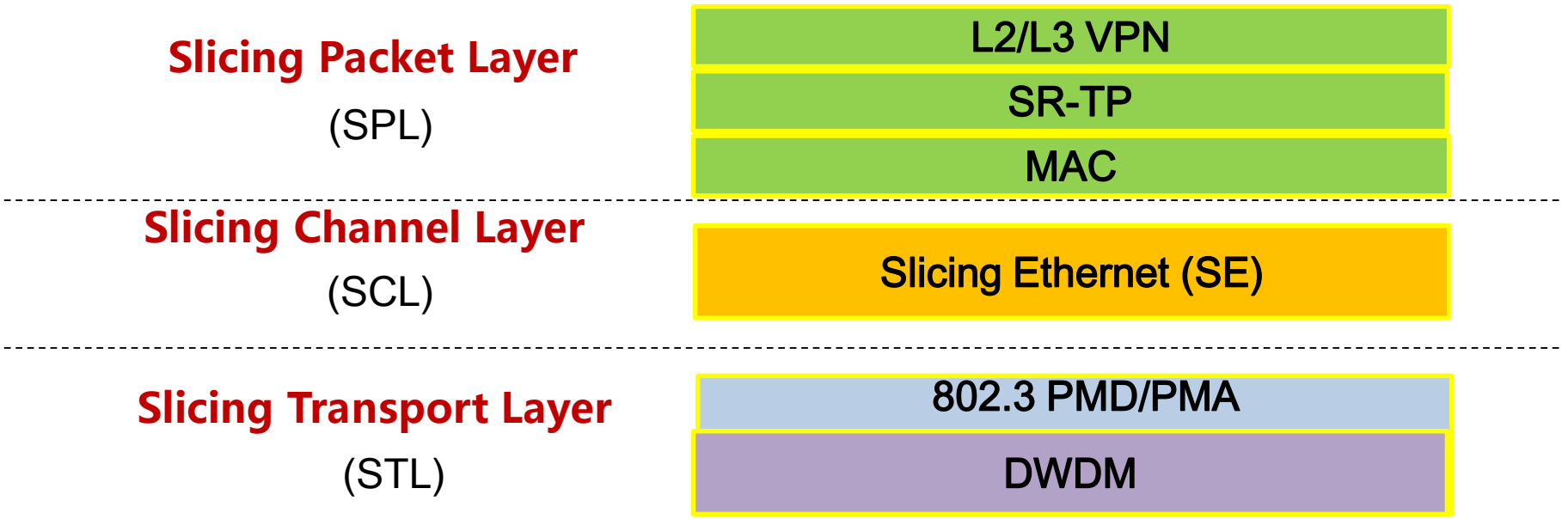
- forwarding plane: "Segment Routing transport profile" over "Slicing Ethernet" over "DWDM"
- control plane: SDN



Architecture of SPN network

■ **SPN (Slicing Packet Network):New generation E2E network system, based on Slicing Ethernet and segment routing transport profile(SR-TP), combine with DWDM and ROADM**

- SPL (Slicing Packet Layer) ： Packet forwarding and routing, Segment Routing and MPLS-TP will be supported
- SCL (Slicing Channel Layer) ：Slicing Ethernet support 66b block cross connection and E2E channel layer OAM
- STL (Slicing Transport Layer) ：compatible with Ethernet Phy and support DWDM.

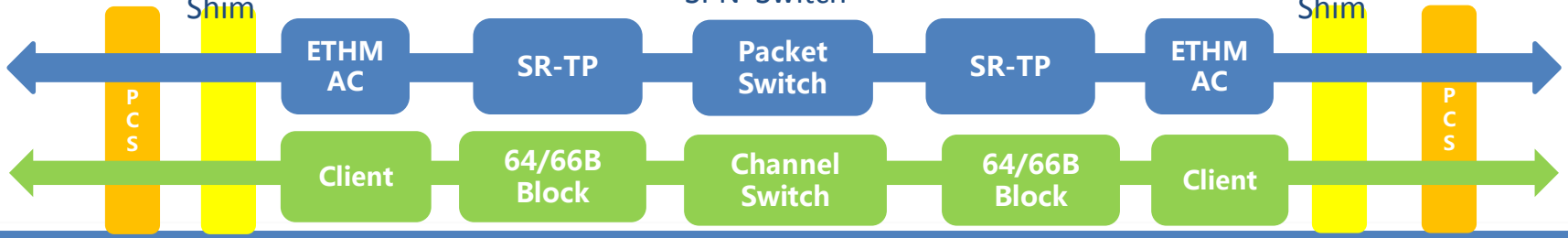


New requirements for SPN Chip Series

Much higher demands on the chips-**Switching Capacity , Latency , MAC Quantity , Exchange Mode , Label Layers, Power Consumption**

Switching Capacity		Latency		MAC Quantity		Exchange Mode	Label Layers	Power Consumption
Access	Aggregation /Core	Access	Aggregation /Core	Access	Aggregation /Core			
40G	640G 4.8T	50 us	100 us	16	64 128	MPLS-TP	>3	1
320G	6.4T 12.8T	1us	10us	>64	>512 >1K	SR-TP SE-TP	>10	70%

4G 5G



Working on the R&D schedule with **Huawei, ZTE, Fiberhome, Nokia, Ericsson, Broadcom, Microsemi** and so on.

Outline

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Summary

5G transport network is facing requirement on re-architecture.

- SPN for mid-haul and backhaul
- Optics for fronthaul:
  - ☐ Fiber direct connection
  - ☐ Passive WDM
  - ☐ Simplified SPN/OTN

Key technologies for 5G transport network

- New Architecture and Control:
  - ☐ SR-TP over Slicing Packet over DWDM
  - ☐ SDN
- New link layer:
  - ☐ End-to-end slicing
  - ☐ Link aggregation
  - ☐ Channelization
- New packet layer:
  - ☐ SR-TP
  - ☐ Carrier grade L3

Suggestions on the SPN Standardization

Suggestions: ITU-T SG15 lead the standardization of SPN and work together with other SDOs to setup the overall SPN standards .

- SG15 Q12/11/10: SPN Architecture, atomic functional mode and OAM
- SG15 Q9: SCL SNC protection.
- SG15 Q13: The New Sync technologies
- SG15 Q14: SCL and overall SPN management aspect.
- SG15 Q6: Optical Aspect support Ethernet interface signal over WDM, especially for Ethernet PHY data rate at 50Gbps.

- Functions of Segment Routing for transport network should be considered.

Thanks !

5G Requires New Transport Network

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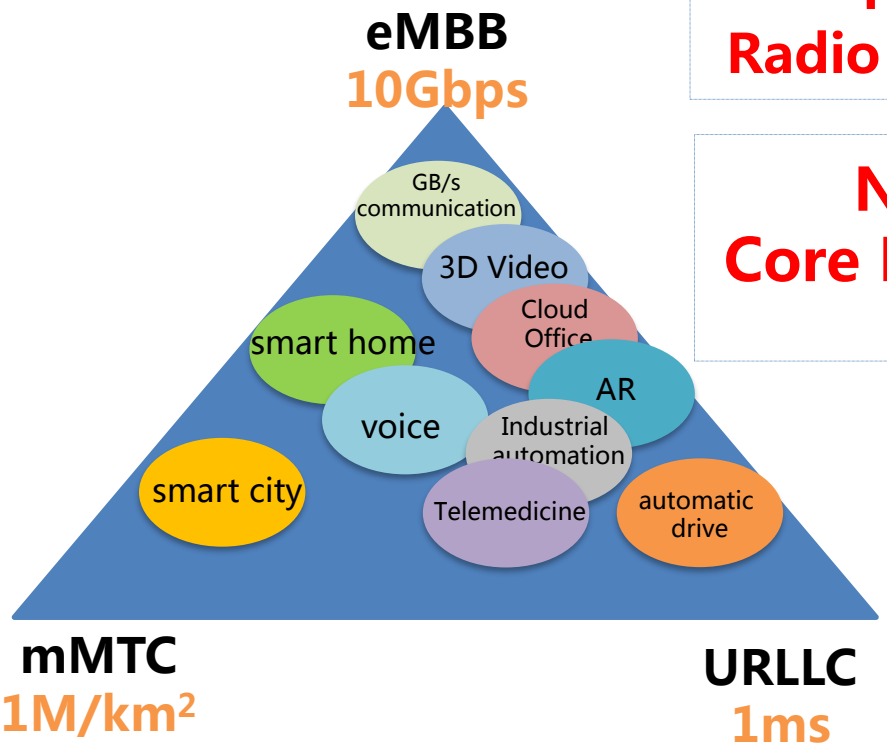
Families of usage scenarios for 5G



New Radio Interface

Low frequency for wide area coverage

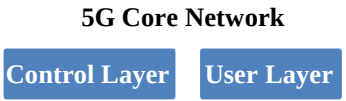
High frequency for Hotspot coverage

New Core Network

Service-oriented Architecture

C/U Separation

Network Slicing



New Transport Network

5G requires new transport network !

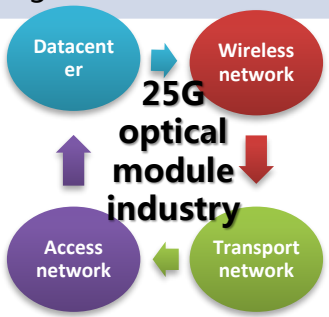
25G Optical module application will be the trend

Datacenter, wireless, access and transport network have common requirement on 25G optical module which will be the next hot-spot in industry.

Temperature range	Industrial Grade (-40~85 °C)	Commerial Grade (0~70°C)
Application scenario	RRU-BBU, Outdoor station	Datacenter, PON, DU-SPN
Requirement estimate	Ten million grade	Ten million grade

50G(SFP56): 100m
Grade: Million

50G PAM4: ~20km
Grade: Ten million



25GE(industrial grade) : <1km
Grade: Ten million

50G PAM4 10km/40km
Grade: Ten million

- **Datacenter, wireless, transport and PON network application scenario are complex but have common requirement, will need to drive the industrial development together.**
- DC inter-connect and RRU can share one kind of 25G DML optical module, DC inter-connect can use commercial grade, RRU use industrial grade.
- Transport and 50G PON network need 50G PAM4 single wave-length optical interface with 10KM or 40KM long range support, they will also need to drive the low-cost 25G EML and long-range 25G DML optical module development.
- Now the estimate price is about $300, new technology need to be used to lower the cost. The price need to be $50 at first application price and $30 at second stage.

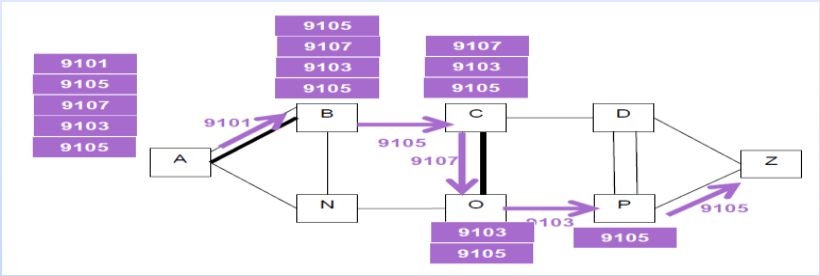
Slicing Packet Layer (SPL) technology

■ **Slicing Packet Layer (SCL) provide per packet forwarding and routing process**

➢ **SR-TP : Segment Routing Transport Profile** , transport network applications based on MPLS segment routing, achieving service and network decoupling, supporting both connection-oriented and non-connection-oriented services

➢ **SDN Based L3VPN** : IP routing technology based on SDN with centralized control , achieving service on demand

SR-TP Technology

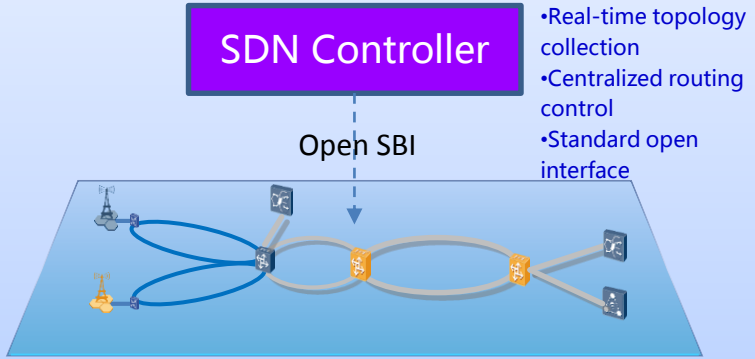


■ **Based on Segment Routing, add "bidirectional SR-TP tunnel" and "connection-oriented OAM" features into transport network applications :**

① **service and network decoupled,** service establishment only operate on the edge node, the network does not perceive, and seamless convergence with SDN centralized control.

② **Providing "connection-oriented" and "no connection" pipeline,** to meet the flexible connection of the 5G cloud network requirement.

SDN based L3VPN



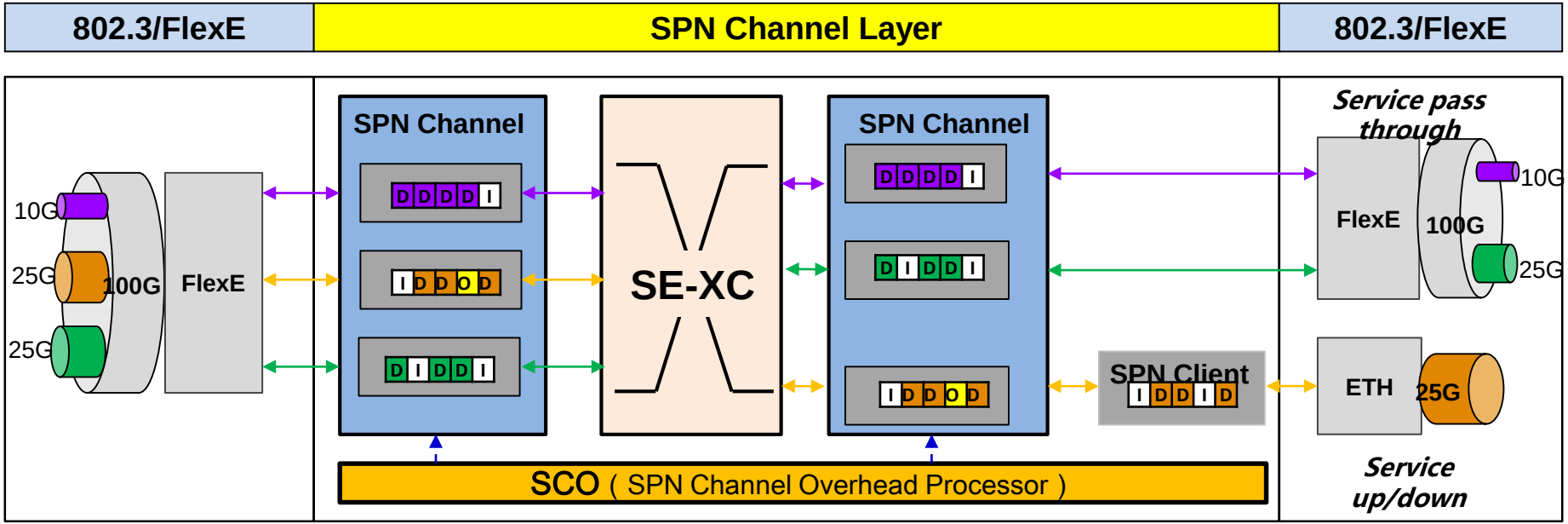
■ **Provide centralized routing control,** flexible programmable routing strategy capabilities, to achieve flexible business scheduling.

■ **Reduce the complexity of SPN forwarding devices** by using a moderate combination of route-centric policies and distributed protocols.

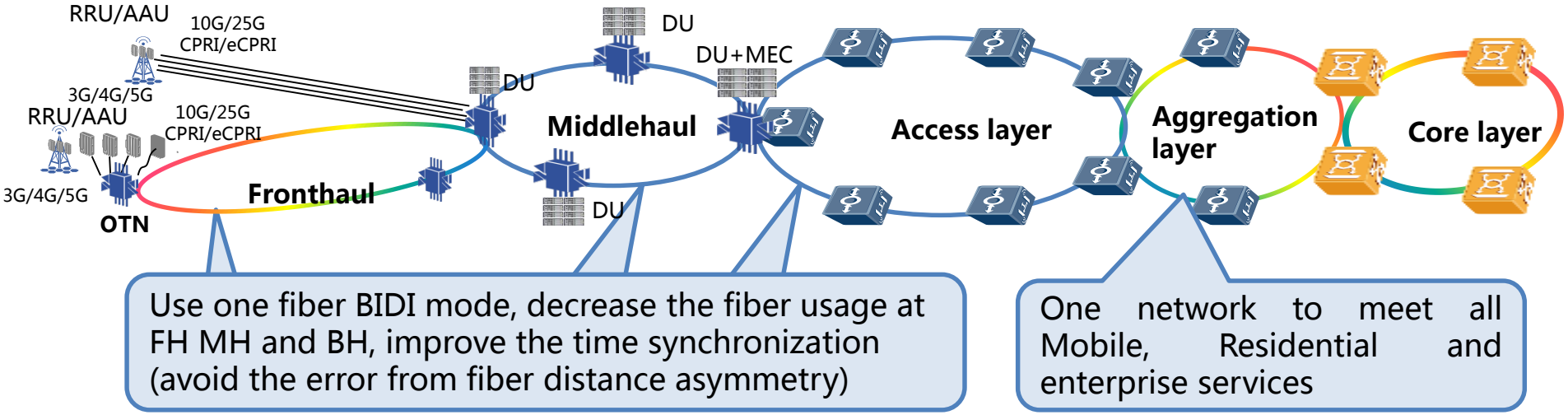
Slicing Channel Layer (SCL) technology

■ **Slicing Channel Layer (SCL)** Providing **low latency, hard-isolated** slice channels based on L1 for multi-service.

- **SC : SPN Channel** , based on the Ethernet 802.3 stream, the end-to-end slice channel L1 is implemented.
- **EXC : Ethernet Cross Connection** , 66bit block cross connection based on TDM slots
- **SCO : SPN Channel Overhead** , based on 802.3 code block expansion, replace IDLE code block, to achieve SPN Channel OAM function.



Slicing Transport Layer (STL) technology



- **Aggregation and core layer: Color Light to support DWDM;** Two possible solutions: Direct Detection modules and Coherent detection modules, **now 100G/200G coherent modules is mature but high cost .**
- **Access layer**: **Gray light to support 50G/100G:** 50GE PAM4 and 100GE PAM4 is possible solution.
- **Fronthaul network:** mainly use fiber direct connection, passive WDM at 4G; for 5G, multi-core fiber can be used; **SPN-Lite device (without L3 functions)** also can be used for multi-service, multi-interface convergence and fulfill the unified management on fronthaul, middlehaul and backhaul.

Considerations on Mid-haul and Backhaul Equipment

- **Packet Switching and Slicing Ethernet cross connect (Required) should be supported and mutual integrated.**
- **ROADM (Optional) , to achieve wavelength switching, save the optical module. It is recommended to use low-level crossover to support static configuration only ;**
- **Building block design: The electrical layer and the optical layer of the Equipment can be a flexible combination according to the application scenarios.**