The transport network considerations for 5G in CMCC
PTN Backhaul: More than 2M 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

Access ring, 10G; Aggregation and Core ring, 100G

Bandwidth plan for single S111 eNodeB

- Access Layer: 80 Mbps
- Aggregation Layer: 60 Mbps
- Core Layer: 40 Mbps

Latency requirements of 4G backhaul
- single direction of transport network: 10ms
- single equipment: 100us
- Test results in PTN field network: ~2ms
- single direction of transport network: ~50us
- single equipment: ~50us
- Test results in PTN field network: under ±500ns

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 ±100us
**5G new scenarios bring new challenges to transport network**

### 5G new scenarios
- **eMBB**
- **uRLLC**
- **mMTC**

### Networking architecture Changes
- **5G RAN**: CU/DU decouple
- **5G Core**: Cloud core network, UPF sink, MEC

### Service Requirement Changes
- **Bandwidth**: 320M -> 10Gbps/Single Station
- **Delay**: 10ms -> 1ms One-way Delay
- **Slicing**: For different service types and attributes
- **Sync**: 1.5us -> 400ns Time Sync.

### Infrastructure Requirement Changes
- **Fiber**: The density of the site is higher, which promotes the pressure of the terminal fiber.

### Machine Room
- More new equipments, higher requirements for room, power supply and heat dissipation.

The infrastructure, architecture, bandwidth, delay, synchronization and other requirements of 5G transmission network have changed greatly and need to be re-architected.
The Consideration of the network evolution

① follow the trend of IP-based network, and make full use of the advantages of Ethernet ecosystem chain to reduce costs in the optical and electrical layers.

② For large bandwidth and flexible forwarding demand, multi-layer resource collaboration is required, L0~L3 capability should be integrated at the same time.

③ For ultra low latency and vertical industries, soft and hard isolation chips are needed to support TDM and packet switching.
SPN (Slicing Packet Network) is a new transport technology profile, which include new protocols, new optical and new control.

Bandwidth $\uparrow$ 100 Times  |  Latency $\downarrow$ 100 Times  |  Per bit cost $\downarrow$ 10 Times

New Protocol
- Slicing Ethernet
  - Cost Effective (Opex)
  - Reliable
  - Flexible
- SR-TP

New Optical
- 50GE
- PAM4
- N*100GE
- DWDM

New Control
- SDN
- Orchestration
- Wireless and Core Network
- Centralized Control
- South and North Interface

Cost Effective (Capex)
SPN is a new generation transport network designed for 5G. It is a photoelectric fusion device. It can realize intelligent slice scheduling by SDN.

- **L2&L3**: The packet layer guarantees the flexible connection ability of the network and flexibly supports MPLS-TP, SR and other packet forwarding mechanisms.
- **L1**: The channel layer realizes lightweight TDM crossover, supports 66b based fixed length block TDM switching, and provides packet network hard slices.
- **L0**: Transport layer realizes Ethernet of optical interface, accesses PAM4 gray light module, and the DWDM network.

**Legend**:  
- Inheritance of PTN function  
- SPN New functions
SPN innovatively introduces SPN channel layer, integrates TDM and packet switching, and integrates L0 layer to L3 layer into a whole.
Transport Layer: Ethernet Optical Layer Interface Requirements

- **Fronthaul Requirements**: fiber direct drive, large core fiber, 25GE BIDI module
- **Middlehaul/Backhaul (small city)**: E2E gray Ethernet networking, 50GE PAM4*N
- **Middlehaul/Backhaul (large city)**: access with gray Ethernet, aggregation / core with DWDM

**Networking Scheme**

Single fiber bidirectional connection to reduce fiber consumption, maintain time synchronization and high performance delivery (to avoid errors introduced by asymmetric fiber length)

**Gray Ethernet module requirements**

- 1*λ
- 50GE (25G PAM4)
- 4*λ
- 200GE
- 8*λ
- 400GE

Distance:
- 2km
- 10km
- 40km

**Color Ethernet module requirements**

- **Coherent Ethernet Color Light Module**
  - 400G ZR
  - 200G ZR
  - 100G ZR

- **Distance**:
  - 80km
  - 120km
SPN as a 5G mobile oriented integrated transport network for metro application would raise reasonable requirements for its optical components.

- **50Gbps PAM4 Grey Optical**
  SPN access/metro aggregation would heavy drive the volume of IEEE 50GE/100GE/200GE grey optical, e.g. would provide broad market potential for the new 50Gbps PAM4 grey optical (n Lanes)

- **Single fiber Bi-Directional**
  Would prevent optical signal delay asymmetry for supporting SPN high accuracy synchronization.

- **Coherent Colored Optical**
  SPN metro aggregation/core is a key application scenario for 100/200/400G per lambda High speed/BW coherent optical at about 80~200km, e.g. 400G ZR

- **Silicon photonics**
  SPN is also a key application scenario for silicon photonics due to low power consumption, high density and economic efficiency considerations

SPN provide broad market potential for the new generation optical industry for the next 5+ years.
FlexE and DWDM enable flexible expansion and segmentation of bandwidth

- **Feature 1:** Sub-interface
  - Client
  - 64/66b
  - FlexE
  - Interface

- **Feature 2:** Channelized isolation
  - 5G---->n*5G
  - Client
  - 64/66b
  - FlexE
  - Interface

- **Feature 2:** Interface Bonding
  - 100GE--->100GE+
  - 100GE
  - FlexE
  - DWDM

- **FlexE supports bandwidth that exceeds the physical interface rate through multiple interface bonding**
- **FlexE+DWDM** not only provides single-fiber large-bandwidth capability, but also combines DWDM channels to flexibly increase bandwidth on demand
- **FlexE supports sub-interface channelization with n*5G bandwidth to achieve network slicing**
Path Layer: Slicing Channel Layer (SCL) overview

- **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.

### Diagram

- **802.3/FlexE**
- **SPN Channel Layer**
- **802.3/FlexE**

**Diagram Elements**

- **SPN Channel**
- **SE-XC**
- **SCO (SPN Channel Overhead Processor)**
- **Service pass through**
- **Service up/down**
**Path Layer:** the cross connection and OAM

**New Switch:** based on 66bit Slot which is the basic block of original Ethernet

**New OAM:** Using the IDEL block slot as the OAM message block slot and provide OTN like OAM
Packet Layer: SR-MPLS Solution

- **SR-TE** provide the simple E2E L3 VPN solution without complicated protocol such as RSVP and LDP. **SR-BE** provide the simple solution for flexible connection.
- Current SR solution need carrier-grade service guarantee with E2E OAM, we introduced the path segment and binding label to build Segment Routing Transport Profile (SR-TP).

**SR-TE (adjacency label)**

**SR-BE (Node label)**

**Path segment for Connection oriented OAM**

**Binding label to support more hops**
**SR-TP:** On the basis of SR-TE, we add a layer of Path SID to guarantee the path of SR can be monitoring.

**Path Segment:** Path segment for Connection oriented OAM

**Packet layer:** Path Segment solution

**Path SID Distributed:** The destination nodes distribute the Path SID to the source node.
**Time Sync: enhanced sync requirement**

### 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

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**1588v2 Time Sync Transmission**

<table>
<thead>
<tr>
<th>Network budget</th>
<th>PRTC</th>
<th>Transmission Network</th>
<th>Base Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G</td>
<td>250ns</td>
<td>1000ns (including holdover), 30ns per hop, &gt;20 hops</td>
<td>250ns</td>
</tr>
<tr>
<td>5G</td>
<td>50ns</td>
<td>Tracing 100ns, 5ns per hop, &gt;20 hops</td>
<td>50ns</td>
</tr>
</tbody>
</table>

- Fronthaul, mid-haul, and backhaul should support time sync functions. **End-to-end budget could be +/-200ns without holdover**
- The multi-lane interface need to 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.
Control Layer: SPN Control Plane Solution

- **Functional Requirements**: SPN enhances service dynamic capabilities through SDN centralized control plane.
- **Design Ideas**: “Integration of management and control, centralized control supplemented by distributed control”

With the combination of IS-IS, BGP-LS and PCEP protocols, SPN realizes real-time closed-loop control of service paths.
SPN Network Slicing: With the management and control plane integration, SPN implements logical abstraction of physical resources, achieving "one physical network and multiple networking architectures".

SPN Physical Network View

SPN Controller

SPN Network Slice Presenting

L1: TDM

L2 VPN

L3 VPN

- Large bandwidth
- General reliability
- Non-sensitive to delay
- High reliability
- Sensitive to delay

Slice subnet control
uRLLC
mMTC

Software isolation

Hardware isolation

ONAP

wireless VNFC

SDN-O

Core NetworkV NFC

Slicing control: Centralized Controller Achieving Network Slicing
Considerations on SPN Equipment

- Packet Switching and Slicing Ethernet cross connect (Required) should be supported and mutually 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.

**UNI**: 
- Eth
- FlexE
- TDM

**NNI**: 
- FlexE/EthPHY
- Grey or Colored

**SPN Electrical Layer**

**SPN Optical Layer**

**Slicing Packet Switching**

**Slicing Ethernet Cross Connect**

**ROADM (Optional)**
Lab test on the SPTN

Lab Test have been done in China Mobile lab, and the test result is very good.

### Single Vendor Test

<table>
<thead>
<tr>
<th>Slot Switch</th>
<th>phy isolation</th>
<th>Latency (Min)</th>
<th>Jitter</th>
<th>OAM</th>
<th>Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box</td>
<td>Support</td>
<td>P (~0.5us) PE (~1.0us)</td>
<td>~10ns</td>
<td>Support</td>
<td>~1ms</td>
</tr>
<tr>
<td>Chassis</td>
<td>Support</td>
<td>P (~2us) PE (~10us, with L2/L3 enabled)</td>
<td>~250ns</td>
<td>Support</td>
<td>~1ms</td>
</tr>
</tbody>
</table>

### Multi-vendors Interoperation Test

<table>
<thead>
<tr>
<th>Slot Switch</th>
<th>NNI interface</th>
<th>latency</th>
<th>Jitter</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE-P-PE</td>
<td>100G</td>
<td>4.48/4.485 us</td>
<td>0.003/0.003 us</td>
</tr>
<tr>
<td>PE-P-PE (with L2/L3 enabled)</td>
<td>100G</td>
<td>18.4/18.5 us</td>
<td>0.2/0.2 us</td>
</tr>
</tbody>
</table>
Suggestions: ITU-T SG15 lead the standardization of SPN and work together with other SDOs to setup the overall SPN standards.

- SG15 Q11: G.mtn defining the interface, Frame format and OAM, New work item have been setup last week in Geneva.
- SG15 Q9: SCL SNC protection.
- SG15 Q12: SPN Architecture
- 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.

ITU-T SG15 has create the new work item for SPN to define the path layer and section layer of SPN and it plans to set up a series of standard to define SPN further.
Key processes of the SPN industry

- 5G Transport project initiation
- Specify the SPN technical system
- Multi-Vendor SPN Lab test
- ITU-T SPN standard initiation
- SPN White Paper Release
- SPN Field test with 5G wireless

Maturity of SPN Industry

SPN Industry Chain

- Equipments
- Chips
- Test instruments
5G transport network is facing requirement on re-architecture.

- The unified transport solution for fronthaul, mid-haul and backhaul makes the network maintenance easier and more efficient.

Key technologies for 5G transport network

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

Lab Tests and field trials verification

- Lab tests results show that the SPN can meet the 5G requirements
- SPN Field trials is running in CMCC field network
Thanks