Future Broadband Network Virtualization – Cloud Central Office
• Challenges of current rigid network and transformation towards Cloud-centric network
• The High-level Cloud CO architecture
• Huawei’s understanding on Cloud CO components
  • “PNF network” abstraction, slicing and centralized control for multi-access, multi-tenancy and e2e underlay network
  • VNF/VNFC diversity and use cases
  • Overlay networking and I/O technologies in NFVI
  • Domain abstraction, autonomy and assurance
  • Open Ecosystem
• Huawei Vision
• Summary
Challenges of Service Provider

- Linear growth of CAPEX&OPEX with expansion of network
- Slow response for service requirements and long TTM for new services
- Low utilization and efficiency of network resources

Root Causes

- Coupling between Service and Network
- Invisible & complaint-driven user experience mgmt.
- Skill dependent troubleshooting
- Device-centric & Manual Operations with fragmented networks

Invisible & complaint-driven user experience mgmt.

Coupling between Service and Network

Small CO (~thousands)
- CSG

Medium CO (~Hundreds)
- RSG
- PE
- BNG

Large CO (~dozens)
- IMS
- EPC
- CR

Hyper-scale Cloud

Internet

Access

Metro

BackBone
Network & Service Decoupling Brings Huge Benefits to OTT

- **3000 devices / person** in Hyper-scale DC
- **~ 4 hours** OTT New Service Provisioning
- CAPEX 10%↑ Traffic Double Growth

- **~ 100 Devices / person** in Telco-S network
- **~ 28 weeks** Private Line Service Provisioning
- CAPEX 60%↑ Traffic Double Growth

### Data Center Network
- Web
- Service
- VM

### Metro Network
- Service Functions
- Transport Functions
- B2C
- B2H
- B2B

**VS**

- Network & Service Decoupling, network is service agnostic
- Spine/Leaf Arch., elastic scale out, any to any non-blocking
- Simplified protocols, reduce O&M experience requirements
- Automatic service provisioning, O&M visualization

- Network & Service coupling into dedicated HW, difficult to scale out
- Network change with service, difficult to scale up independently
- 30+ protocols, high experience requirement
- Low efficiency by Manual O&M, 80% fault via configuration errors
Physical infrastructure close to users is the operator’s greatest advantage and assets

More and more services need delay and bandwidth guarantee to enhance their experience and quality

Building an open telecom cloud based on CO is the biggest opportunity for operators

Telecom Cloud first considers network services, and then opens up and builds a telecommunication cloud IAAS. What are the characteristics of such a telecom cloud? What kind of architecture and design considerations are needed?
CloudCO Architecture

End-to-End Service Orchestration /OSS/BSS/Portals (Assurance, ... ) (#)

CloudCO North Bound API(s)

CloudCO Domain Orchestrator

Domain Orchestrator

VNF SDN Mgmt & Ctrl

VNF SDN Mgmt & Ctrl

DC SDN Mgmt & Ctrl

NFVO

EMS (#)

PNF SDN Mgmt & Ctrl

PNF

VNF

NFVI

VIM

VNF

NFVI Network

SDN Management & Control

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CloudCO -- PNF Network

End-to-End Service Orchestration /OSS/BSS/Portals (Assurance, ... ) (#)
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VNF

VNFM

NFVI

Virtual Compute

Virtual Storage

Virtual Network

Virtualization Layer

Compute

Storage

Network

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Focus on PNF SDN “network automation”,
No only devices within CO
Broadband Access Abstraction enabling NaaD (Network as a Device) and OPEX reduction

Access Network Evolution Challenges:

• Management Complexity
  ✓ Multi-Access media: DSL, PON, Active ETH, HFC etc.
  ✓ Multi-Access devices: DPU, ONU, OLT, CMC, CMTS/CCAP, CPE, Access Router, and etc.

• Migration Difficulty
  ✓ How to migration from VDSL->Vector->G.fast->FTTH

Proposed Solution:

• M & C plane centralized to SDAN controller through BAA without impacts on OSS
• Applications running on top of BAA: vAN, vCCAP, vCPE, vCDN, vQAM…
BAA enabling network slicing and new business model

<table>
<thead>
<tr>
<th>Current Wholesale</th>
<th>Network as a Service</th>
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<tbody>
<tr>
<td>Pipe wholesaling</td>
<td>Multi-tenancy with virtual network</td>
</tr>
<tr>
<td>Only BW different, but services similar</td>
<td>Self-defined services for different tenant’s network</td>
</tr>
<tr>
<td>Fixed network planning</td>
<td>Network planning on demand</td>
</tr>
</tbody>
</table>

Unbundling/Bit stream

Physical Deployment

SP’s logical network view

Wholesaler

Retailer

VNO1

VNO k

open API
SDN-PNF: Centralized Control E2E Underlay Network

- **Small CO (~thousands)**
  - CPE
  - ONT
  - CSG

- **Medium CO (~Hundreds)**
  - vPE
  - vBNG

- **Large CO (~dozens)**
  - vIMS
  - vEPC
  - SDN Controller

- **Virtual Overlay Network and Distributed IAAS**
- **Physical Underlay Network**

- **Metro and Backbone**

- **VLL**
- **L3VPN**
- **VPLS**
- **GRE**
- **BGP**
- **RSVP-TE**
- **LDP**

- **MPLS Solution**
- **SR/EVPN Solution**

- **Segment Routing**
  - Tunnel: RSVP-TE/LDP/GRE/L2TPv3/PPTP... -> SR
  - VPN: VLL/VPLS/L3VPN... -> EVPN

- **Pros**
  - >10 complex protocols
  - >6000 command line, manual O&M
  - >28 weeks provisioning period with section by section configuration
  - 10+ Protocols -> 2 Protocols
  - E2E **seamless automatic** provisioning & path optimization
  - Provisioning period week->hour
  - SRv6 for IPv6-oriented evolution
CloudCO -- VNF

End-to-End Service Orchestration /OSS/BSS/Portals (Assurance, ... ) (#)

CloudCO North Bound API(s)

CloudCO Domain Orchestrator

SDN Management & Control

EMS (#)

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CloudCO Domain
NFV has been adopted in Wireless CN first:

1. IMS and other network functions rely on high computing capability and is easy to transform from dedicated HW to software based-on COTS server.
2. Major VNF are deal with session, same as IT application and relatively easy stateless transformation, EPC is different.
4. High Ntwk layer location, and easy to get the scale effect.
5. Commercially available.
VNF@CloudCO Use Case-2B

Telco 2B services:

Main feature:
1. High ARPU
2. BW high per user but total BW is much less than residential
3. High QoS compared with residential

Challenge:
1. Provisioning too long (about 28 weeks)
2. Not cover all sites of enterprise by one Telco

Solution:
1. Deploy VPN-GW at CO/POP to provide VPN services, connect and coexist with underlay VPN such as MPLS
2. Virtualize VPN GW is FW VNF and totally different with IT appl:
   1) extremely high forwarding performance
   2) Pass-through traffic, SA and DA not in DC. VNF is not endpoint and require many routes outside DC
   3) Routing and Forwarding consistent and reliability
Huge Amount Subscribers, Ultra High Bandwidth, But Low ARPU

- **Centralized Control Plane @ Cloud**
  - Improve control plane performance & scalability, solve CP resource problem.
  - Sharing control plane resource with multiple UPS, improve efficiency.
  - Centralized service provision point to a single CP, simplify O&M.

- **High performance User Plane**
  - Ultra high bandwidth but low ARPU, Dedicated Hardware vs VNF.
  - Reuse existing BNG hardware, protect investment
How to raise ARPU of residential service

- **vRG**: Anchor Point for Residential Value Add Service
  - Enrich service for residential customers to increase ARPU
  - Traffic dispatch on service demand & policy to improve experience
  - Open environment for integrate 3rd party Application.
  - Centralized management, control and analysis to simplify O&M

- **Challenges**
  - Business: cost sensitive, trivial requirements, killer app?
  - Technical: 1000s containers within one server, lifecycle management & HA
VNF@CloudCO Use Case-More

- vCDN
- vSTB
- IOT
- 5G
- AR/VR
- V2X
- ...

CloudCO

NFVI

vGW  vBNG  vRG  ...

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VNF\VNFC Diversity

Differences in service features of VNF processing:
1. Management/control/signaling services:
The VNF acts as an Endpoint.
2. Traffic forwarding type service:
VNFs process pass-through traffic, forwarding will consume a lot of computing resource.

Different types of VNF/VNFC based on the service features:
1. VNF/VNFC processing management/control/signaling
2. VNF/VNFC processing traffic forwarding services
3. VNF/VNFC simultaneously processing both management/control/signaling and traffic forwarding services

Different types of VNF/VNFC have different requirements on NFVI
CloudCO – NFVI Network

End-to-End Service Orchestration /OSS/BSS/Portals (Assurance, ... ) (#)

CloudCO North Bound API(s)

CloudCO Domain Orchestrator

NFVI

- Compute
- Storage
- Network

Virtualization Layer

Virtualization

VIM

EMS (#)

PNF SDN Mngt & Ctrl

VNF SDN Mngt & Ctrl

DC SDN Mngt & Ctrl

NFVO

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Different I/O technologies for VNF/VNFCs

<table>
<thead>
<tr>
<th>Throughput</th>
<th>VM Mobility</th>
<th>Standardization</th>
<th>Route coupling</th>
<th>Applicable VNF/VNFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>vSwitch</td>
<td>Low(&lt;10Gbps)</td>
<td>High</td>
<td>High</td>
<td>Y</td>
</tr>
<tr>
<td>SR-IOV</td>
<td>High(10-100Gbps)</td>
<td>Low</td>
<td>High</td>
<td>N</td>
</tr>
<tr>
<td>SmartNIC</td>
<td>High(10-100Gbps)</td>
<td>High</td>
<td>Low</td>
<td>Y</td>
</tr>
</tbody>
</table>

- The same VNF is often composed of Endpoint-type, traffic-forwarding VNFC. NFVI must support both vSwitch and SR-IOV.
- The Smart NIC is the direction of the forwarding function offload in the future. It mainly offload vSwitch. Is it possible to offload VNF functions in the future?
NFVI Overlay Networking---VXLAN

vSwitch-based VXLAN networking:
1. Overlay and underlay (DCN network) completely decoupled, VNF / VNFC can be dynamically migrated (IP unchanged).
2. Suitable for Endpoint type VNF/VNFC: vSwitch only needs to handle the routing of VNF/VNFC.

TOR-based VXLAN networking:
1. Relatively higher performance than vSwitch, but coupled with DCN network, VNF/VNFC dynamic migration requires DCN network cooperation.
2. Suitable for Endpoint type VNF/VNFC: TOR only needs to handle the routing of VNF/VNFC.

VNF-based VXLAN networking:
1. The overlay is fully decoupled from the underlay (DCN network) forwarding, but the dynamic migration of VNF/VNFC requires publishing the VTEP address to the DCN network.
2. Suitable for forwarding VNF/VNFC for high forwarding performance.

Hybrid Mode:
- Applicable to different scenarios
- Unified SDN Controller Manages VXLAN Network
Deployment environment for VNF/VNFC : VM & Container

• Currently VNF/VNFC is mainly deployed based on VMs. VMs can meet the needs of most VNFs.
• Future VNF/VNFC will be deployed based on a mixed environment of VMs and Containers. Coexistence of VMs and Containers should be supported.
• Partial Endpoint type VNF may evolve to pure Container deployment
• NFVI VIM needs to support unified management of VMs and Containers
CloudCO – Domain Orchestration

End-to-End Service Orchestration /OSS/BSS/Portals (Assurance, ... ) (#)

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Domain Abstraction Reduce Integration Complexity

- **Multi-vendor Interoperability challenge**
- **Solution**:
  2. Model layering: decouple service model, network model and vendor specific model.

**Good Model layering eases CloudCO and OSS integration**

**Complexity hiding via CloudCO Domain abstraction**:
1. Simplify interoperability issue between CloudCO and OSS.
2. Unaware of domain product change or upgrade.
CloudCO – Assurance & Analyzer

End-to-End Service Orchestration /OSS/BSS/Portals (Assurance, ... ) (#)

CloudCO North Bound API(s)

CloudCO Domain Orchestrator

MCO Engine

NFVO

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Assurance & Analyzer
Challenge for Assurance of CloudCO Network

Root Cause Classification of Service Fault in DC

- Configuration Error of Network (43%)
- Bug of HW/SW (20%)
- Abnormal of IT Infrastructure (30%)
- Resource Exhaustion (7%)

Aware via traditional approaches: 30%
Unaware via traditional approaches: 70%

Issues of service & experience perspective

- Connectivity (70%): Interrupt of service
- Performance (20%): Bad experience of service
- Policy (10%): Abnormal service access

• Lack of data for fault cause analysis
  - Not coverage completely from chipset, device, network, IT infrastructure, flow and applications
  - Low sampling frequency, min -> ms;
  - Lack of historic data, >90% does not support fault playback

• Unaware of abnormal application and network status, majority faults are detected passively

• Lack of capability to correlate the issues between network and applications
• Capability to predictive resource exhaustion (<7%), bugs of HW/SW (<20%), configuration error (<43%)

- Data from some real typical medium DC (5300+ VM, 65 subnet)
- Average number of flow: 96,545,774/day, among them 3,543,230 (3.67%) are abnormal
Data Analyzer improve the assurance of Central CO

Imagine You Can Know Everything about Your Fabric Behavior

Data Analyzer

Fabric State Database
- Fabric real-time status and behavior model

Flow State Database
- App flow, real-time status, and behavior model

Chipset, Device, Path, and Flow

Context Data

Traditional

- Afterward event-driven

Polling-based, focus on device status
Static topology-based, focus on device links
App-oriented black box network, focus on management plane

Telemetry-based, focus on real-time fabric status
Dynamic path-based, focus on app flows
Transparent network, focus on actual forwarding plane

Data Analyzer

Real-time data-driven
Key Capability of Data Analyzer

Precise playback of historical faults and retrieval of ten billion data records within seconds

- Searches tens of billions of data records per second
- Processes millions of flows per second
- Visualizes the network in multiple dimensions for precise history review

Search

Verification

Correlation

Actual network quality assessment and proactive risk prediction

- Evaluates the network SLA based on true flows across the entire network
- Identifies and analyzes abnormal network flows

Mutual visibility between applications and networks, facilitating minute-level fault locating

- Associates apps with network paths to enable quick issue demarcation
- Evaluates network strategies through application dependency mapping (ADM)
Introducing Data Analyzer to close loop Central CO

Intent-driven Automation
Service Agility Improves 90%
- Intent-based APIs reduce complexity
- E2E Automation for Hybrid Network

Big-data based Analytics
60% Issue Predictable
- Real time network state awareness
- Algorithm-based issues/risks/threats detection for Predictive Maintenance
Open Ecosystem

Standard Organization

Network Architecture

Protocol & Model

Cloud CO

Co-operation

Open Source Community

Linux Foundation Networking Fund
Huawei Vision: IDN Bridges Business Intent and Networks

- Network-centric
- Fragmented
- Reactive
- Skill-dependent

- User-centric
- Closed-loop
- Predictive
- AI/Automation

Digital Twin

Intent Engine

Analytics Engine

Automation Engine

Intelligence Engine

Network-Cloud Engine

Intent-driven automation

Predictive maintenance

Real-time awareness

Network Infrastructure
Summary

- In Cloud-centric, 5G and IoT era, operators are facing challenges of current network and transformation towards Cloud-centric network.

- The Cloud CO architecture is the cornerstone of NG broadband network to enable network & service decoupling, SDN, NFV and cloud technologies in order to address multi-access, multi-tenant and fast service innovation, with various of flexible network modes.

- We present Huawei’s understandings, experiences and learnings from the executive projects in the scenarios of access, metro network, overlay VPN and NFVI. The details of network abstraction, slicing and centralized control, VNF/VNFC diversity and use cases, overlay networking and I/O technologies in NFVI, domain orchestration and enhanced assurance based on data analysis will be discussed.

- Open ecosystem and Huawei vision are shared.
Thank You.