CORD: Central Office Re-architected as a Datacenter

Open Networking Lab and ONOS Partnership

ONOS/CORD Community

ON.LAB

SERVICE PROVIDER
PARTNERS

VENDOR
PARTNERS

COLLABORATORS

VOLUNTEERS

- ON.Lab provides architecture shepherding and core engineering with focus
- Leading service providers make ONOS & SDN/NFV solutions relevant to them
- Leading vendors help make ONOS and SDN/NFV solutions real: ready for deployment
- Collaborating organizations help grow the community and grow the impact

Agenda

- CORD Overview – Guru Parulkar, ON.Lab/Stanford
- M-CORD Overview –Tom Tofigh, ON.Lab/AT&T

CORD Aims to Deliver to Service Providers

Economies of a datacenter

Infrastructure built with a few commodity building blocks using open source software and white boxes

Agility of a cloud provider

Software platforms that enable rapid creation of new services

Telco Central Offices
Have to be Reinvented

Large number of COs

Evolved over 40-50 years

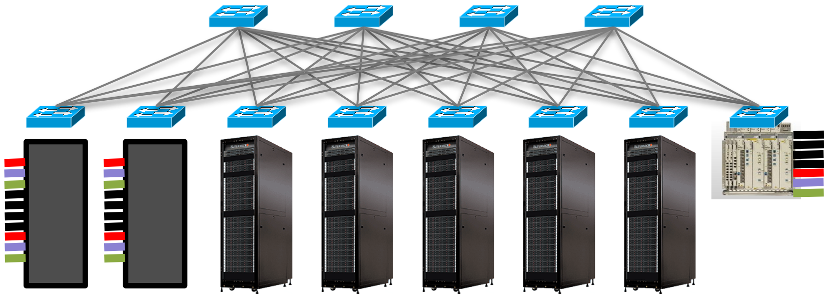
300+ Types of equipment
Huge source of CAPEX/OPEX

- Large number of complex facilities
  - AT&T alone operates 4-5k Central Offices
  - Each serves 10-100k residential, enterprise & mobile customers
- Evolved piecemeal over the past 40-50 years
  - Source of huge CAPEX/OPEX costs
  - Difficult to introduce new services
- Especially when compared to OTT cloud providers!

CORD = SDN x NFV x Cloud

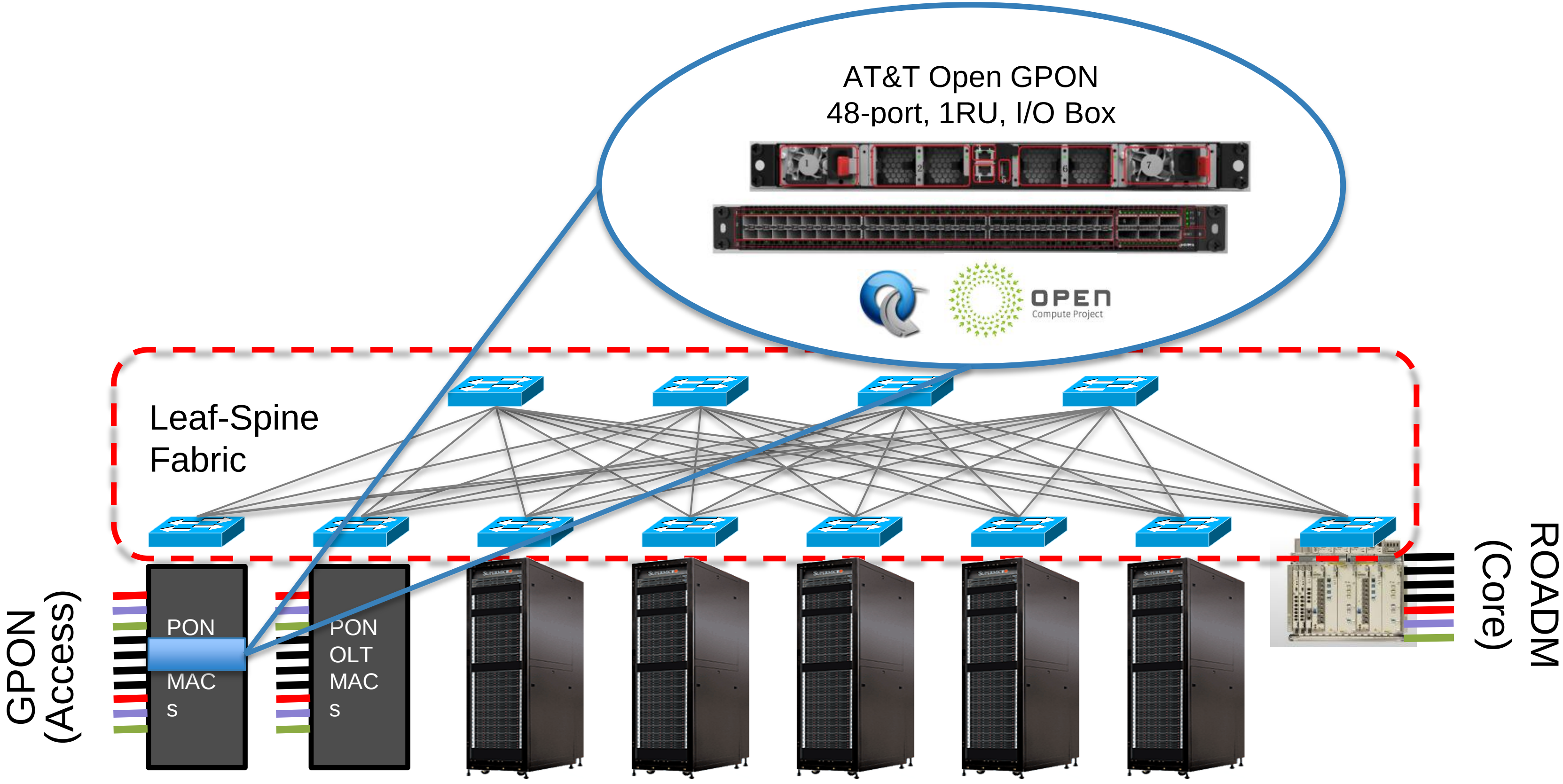
SDN
NFV
Cloud

Open Source Platforms:
ONOS + OpenStack + XOS +
VNFs



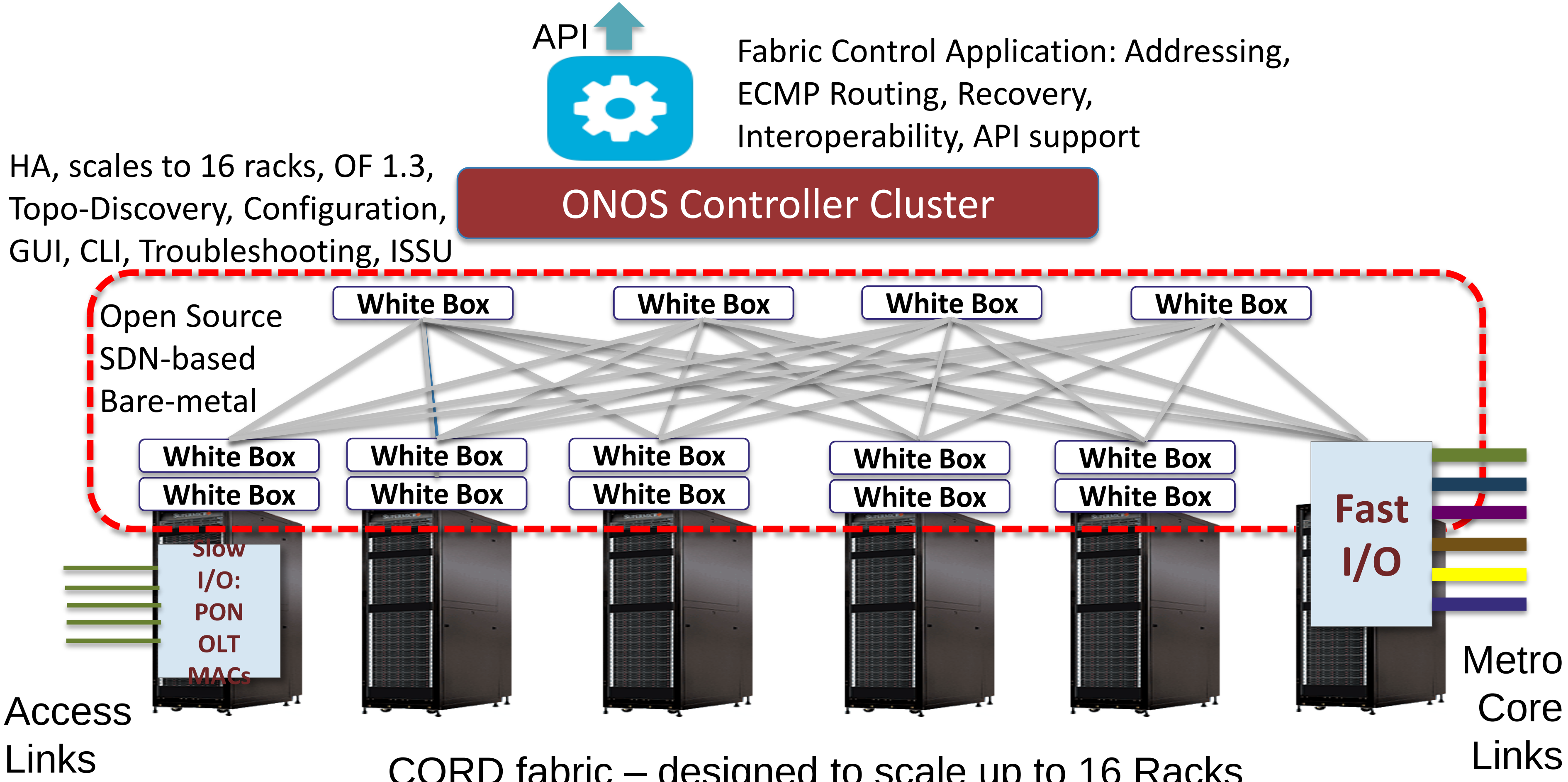
Commodity Hardware
+
Open Source Software

CORD – Hardware Architecture



Commodity Servers, Storage, Switches, and I/O

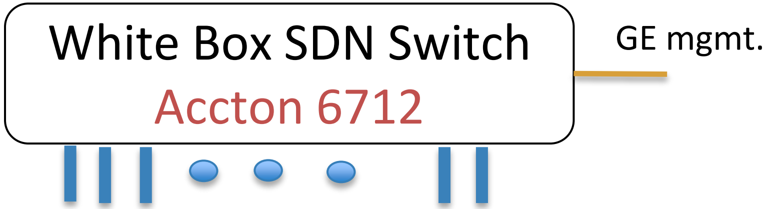
Open-Source Multi-Purpose Leaf-Spine Fabric



CORD fabric – designed to scale up to 16 Racks

Open Hardware & Software Stacks

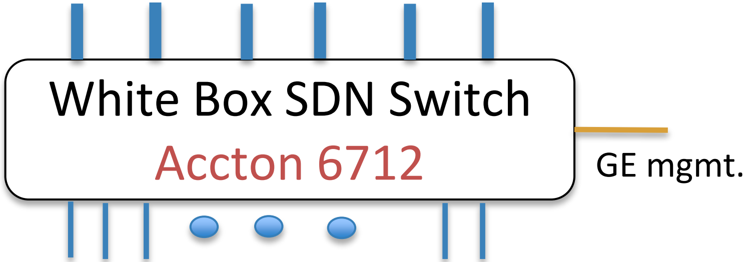
Spine Switch



32 x 40G ports downlink to leaf switches
40G QSFP+/DAC

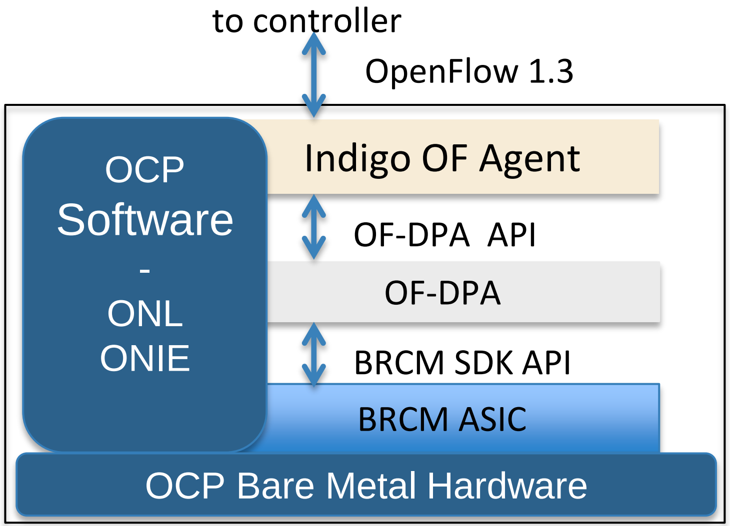
Leaf Switch

8 x 40G ports uplink to different spine switches
ECMP across all uplink ports



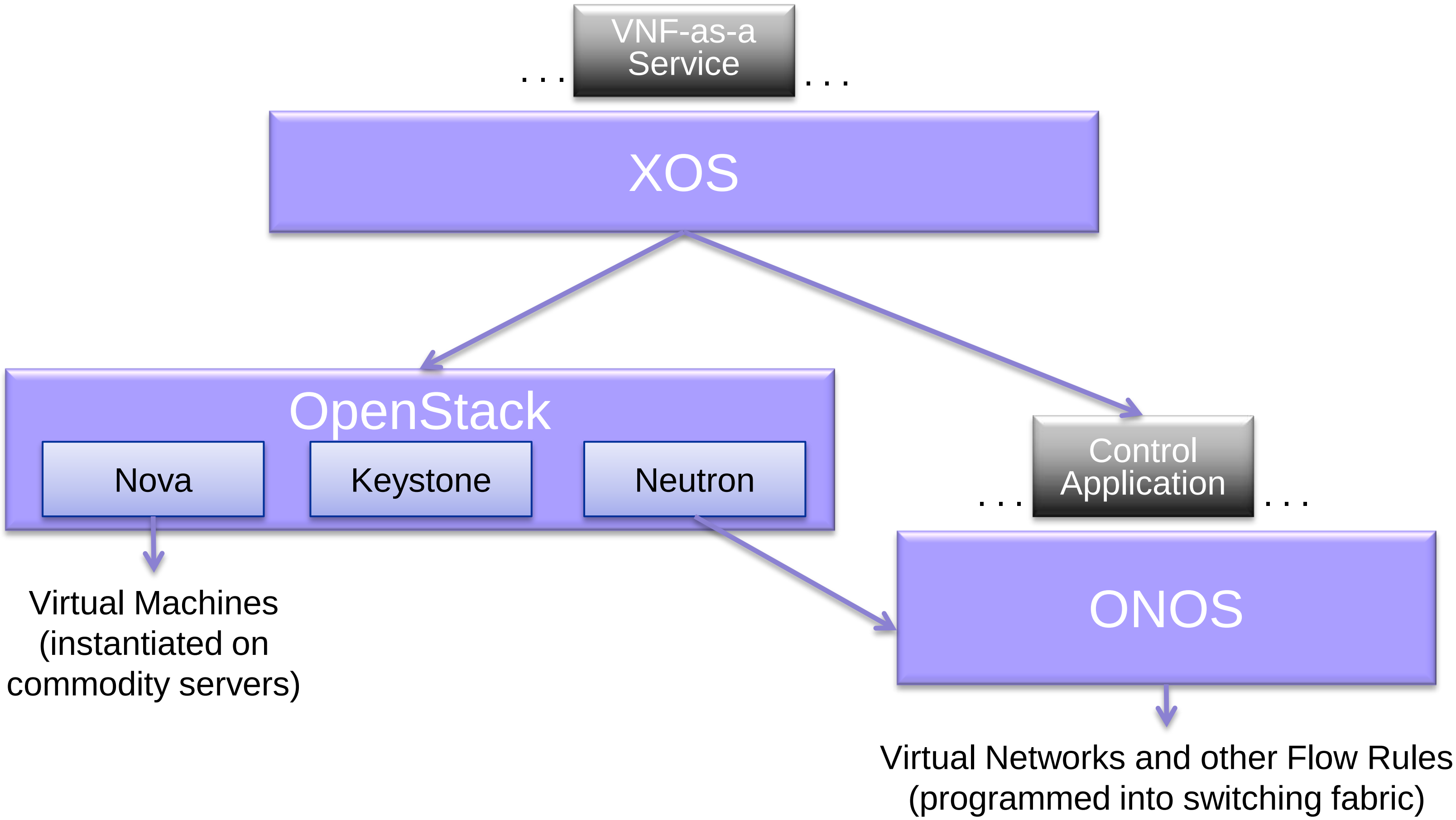
24 x 40G ports downlink to servers
via 4 X 10G breakout DAC

Leaf/Spine Switch Software Stack

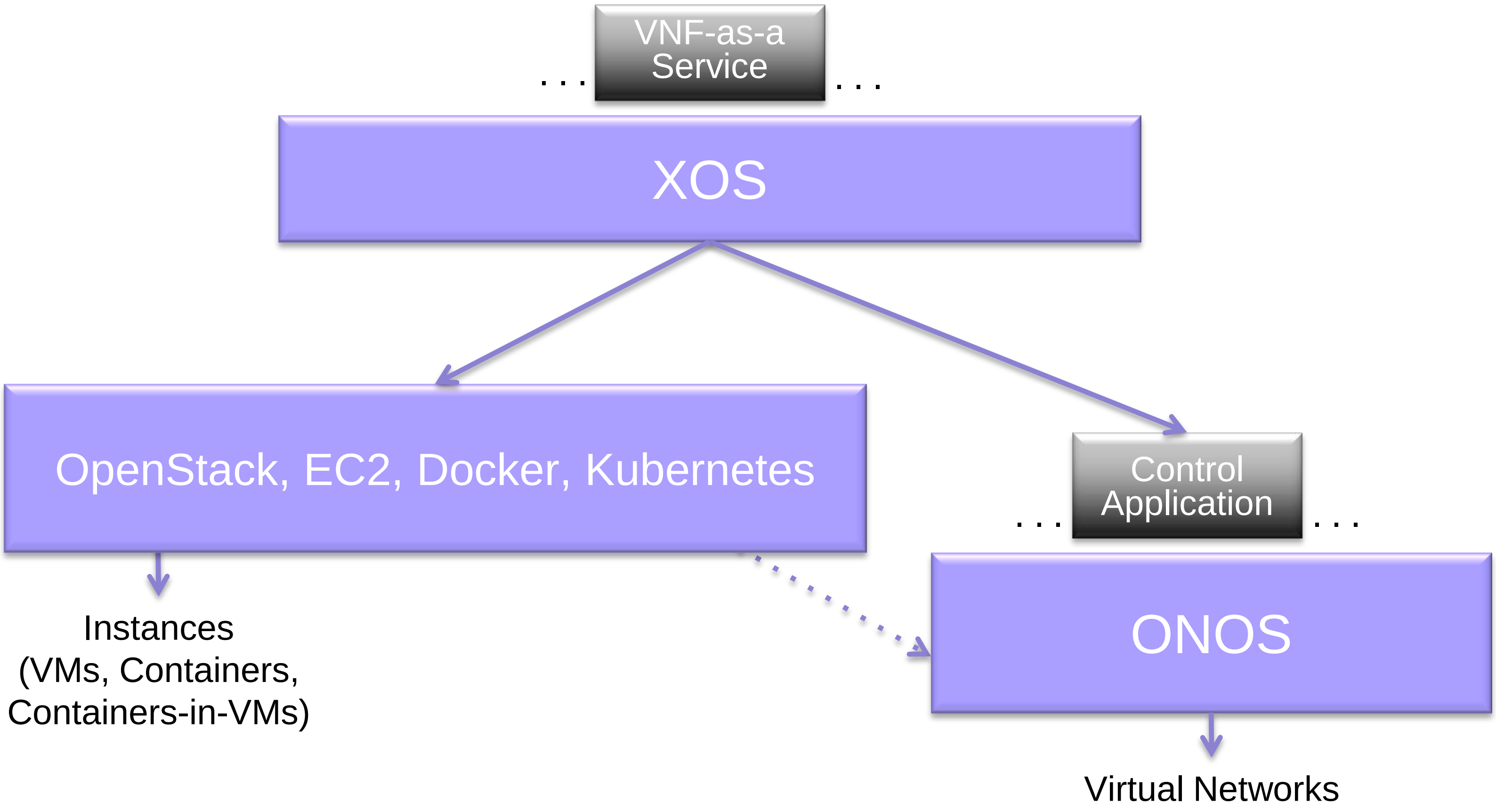


OCP: Open Compute Project
ONL: Open Network Linux
ONIE: Open Network Install Environment
BRCM: Broadcom Merchant Silicon ASICs
OF-DPA: OpenFlow Datapath Abstraction

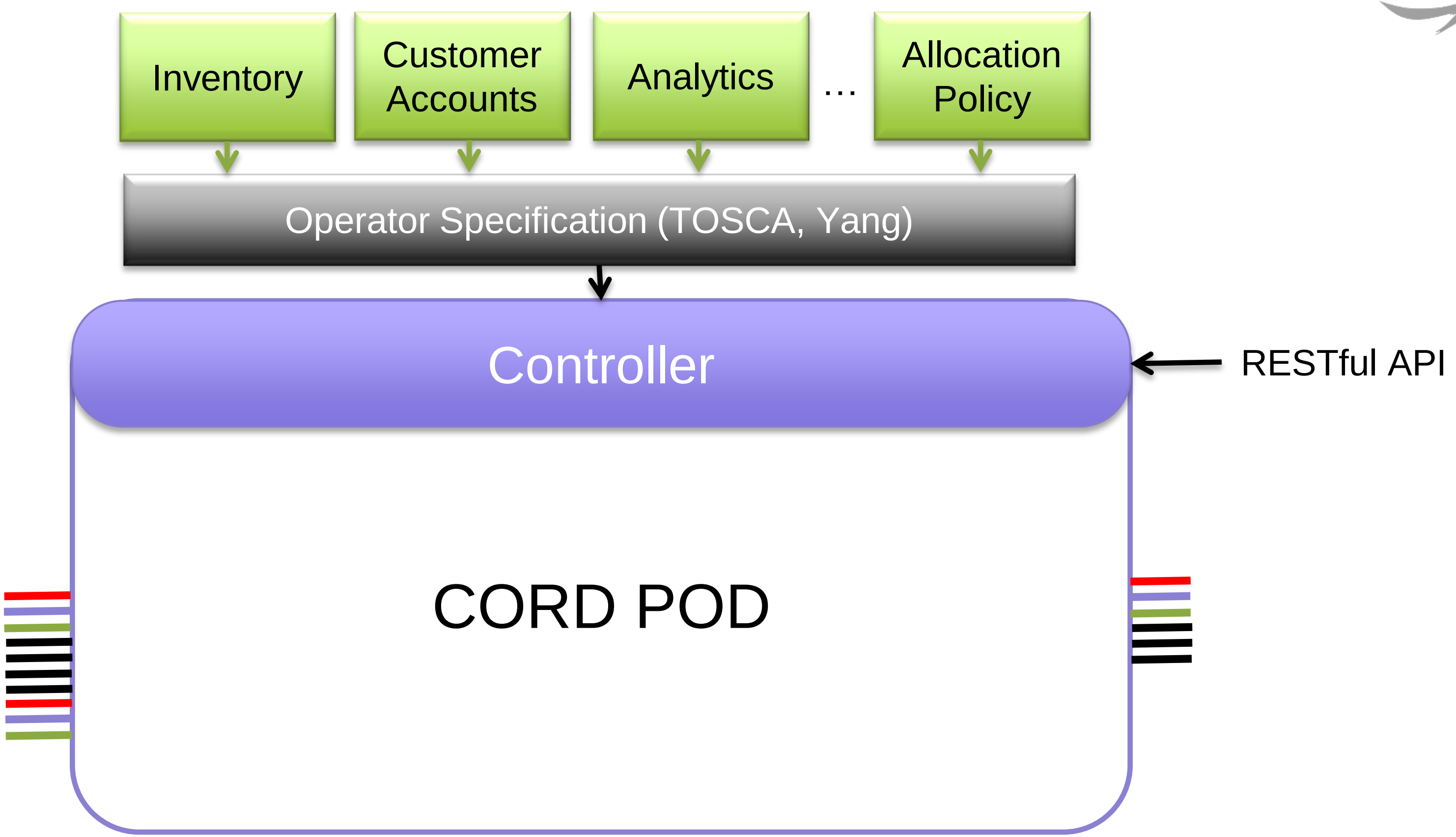
CORD – Software Stack



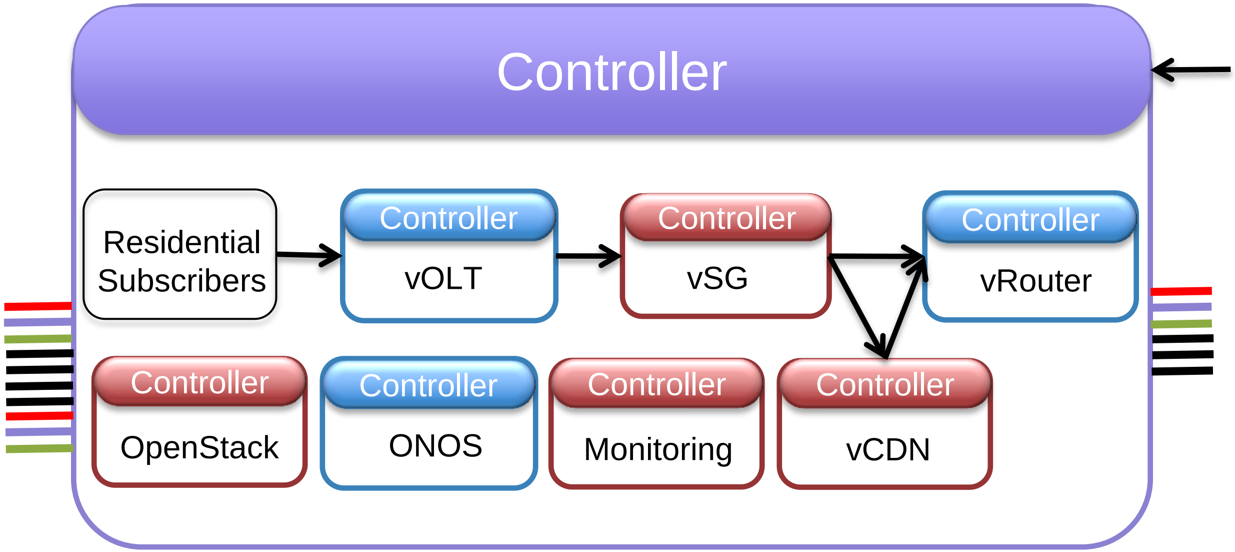
CORD – Software Stack



CORD – External View



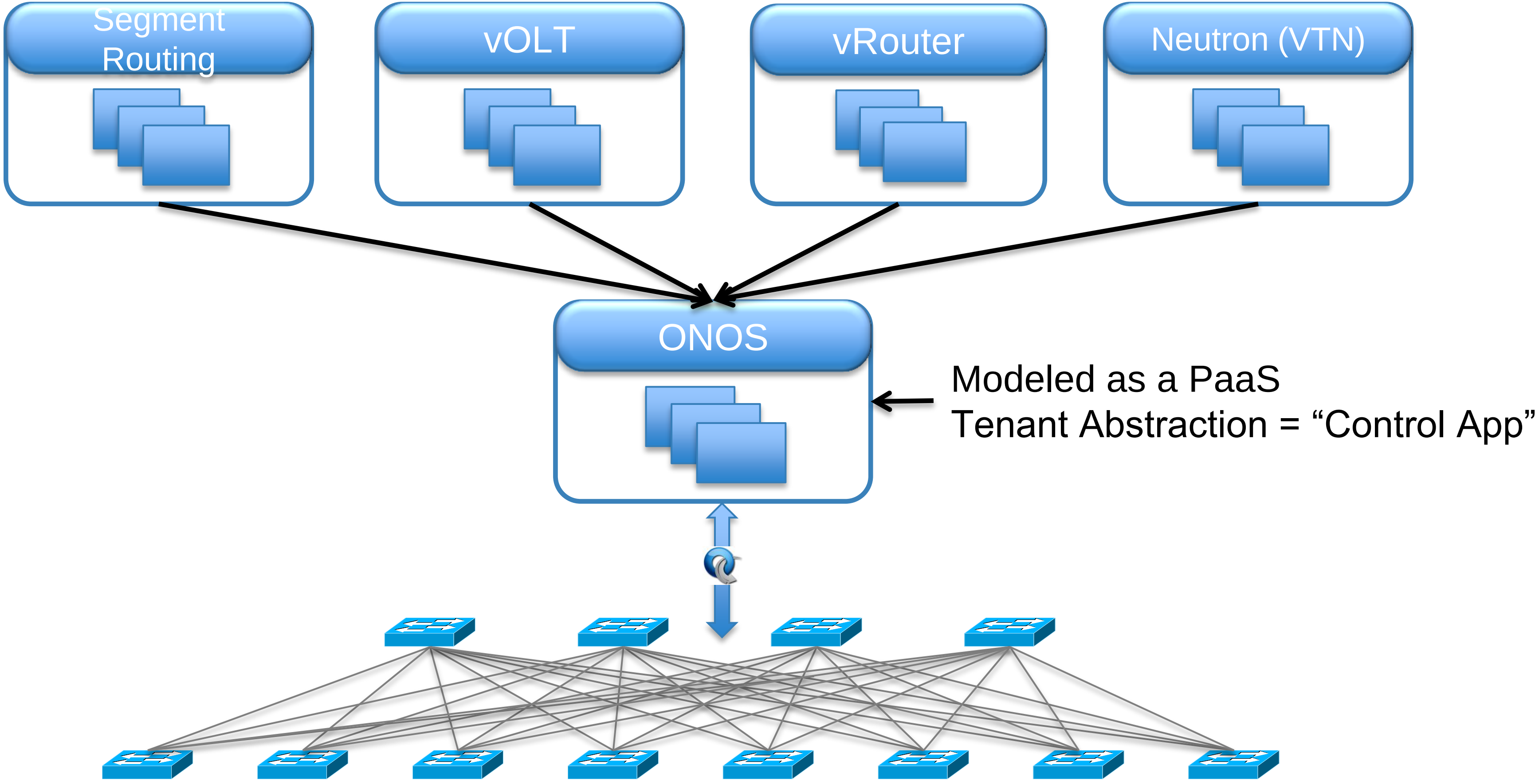
CORD – Internal View



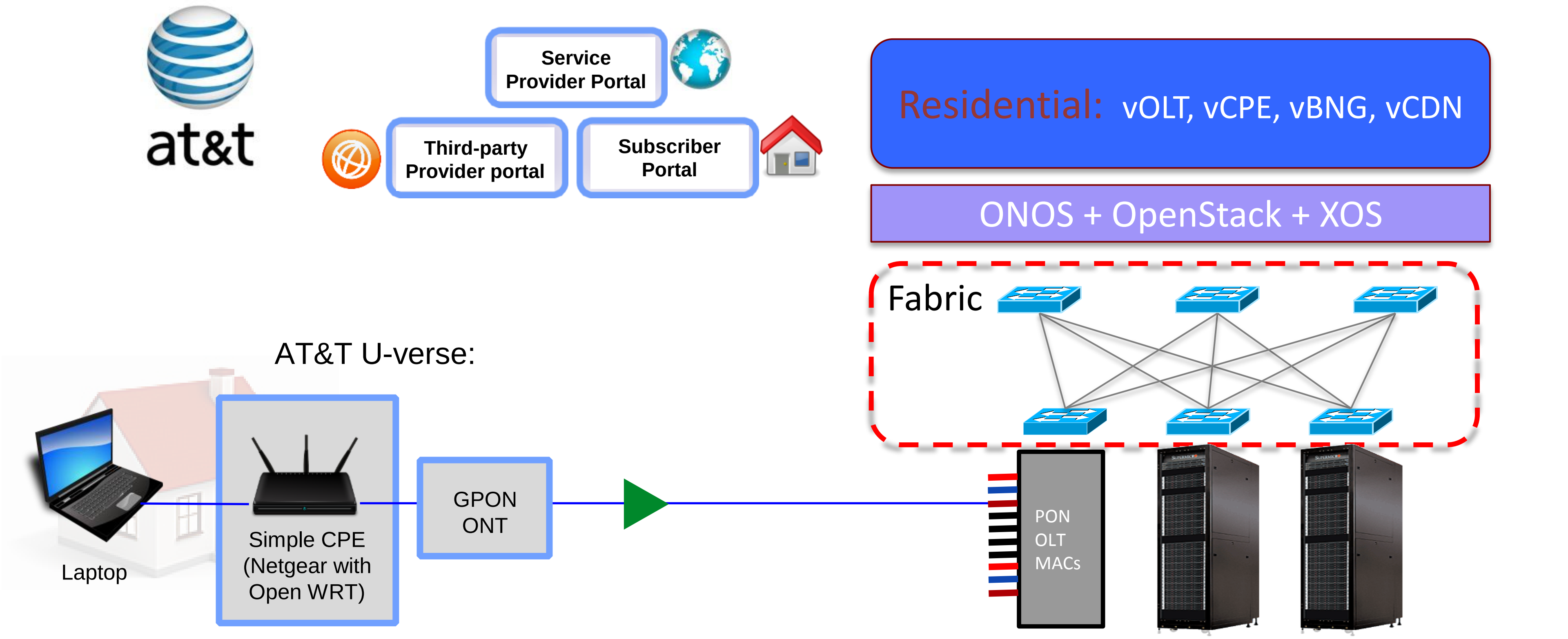
Service Graph
Resource Policy
Scaling Policy
Customer Policy

Everything-as-a-Service (XaaS) / Micro-Services Architecture

CORD – Control Plane Services



CORD Residential POC at ONS, June 2015



Commodity Servers, Storage, Switches, and I/O

Details at http://onosproject.org/resources/

CORD – Reference Implementation

Hardware Blueprint ← **CORD POD** → **Open Source Software**

*An open virtualized service delivery **platform** that provides cloud economies and agility.*

From FTTH-as-a-Service to Software-as-a-Service.

Hardware Blueprint

Bill of Materials
- OCP Servers
- OCP Switches
- Access Devices

Assembly Instructions
- …

Testing Infrastructure
- …

Open Source Software

Core Components
- OpenStack
- ONOS
- XOS
- OCP

Access Services
- vOLT
- vSG
- vRouter
- …

Other Services
- Monitoring
- …

Open CORD Reference Implementations

Hardware Blueprint

List of Goods, Assembly and Test Instructions

Server Racks

Access & Fabric Racks

White Boxes

Open Source Software Distributions

Residential OLT Services

Mobile Services (later)

Enterprise Services (later)

Common Services

SW Infrastructure: ONOS, OpenStack, XOS

Embedded OS: Switch, OLT, BBU

CORD Work in Progress

- Residential (GPON) CORD
  - Lab trial end of 2015
  - Field trial end of Q1, 2016
- Generalization of CORD
  - Mobile CORD: mobile subscribers and apps
  - Enterprise CORD: enterprise subscribers and apps
- Deliver open reference implementation of CORD
  - To allow the industry to build on it

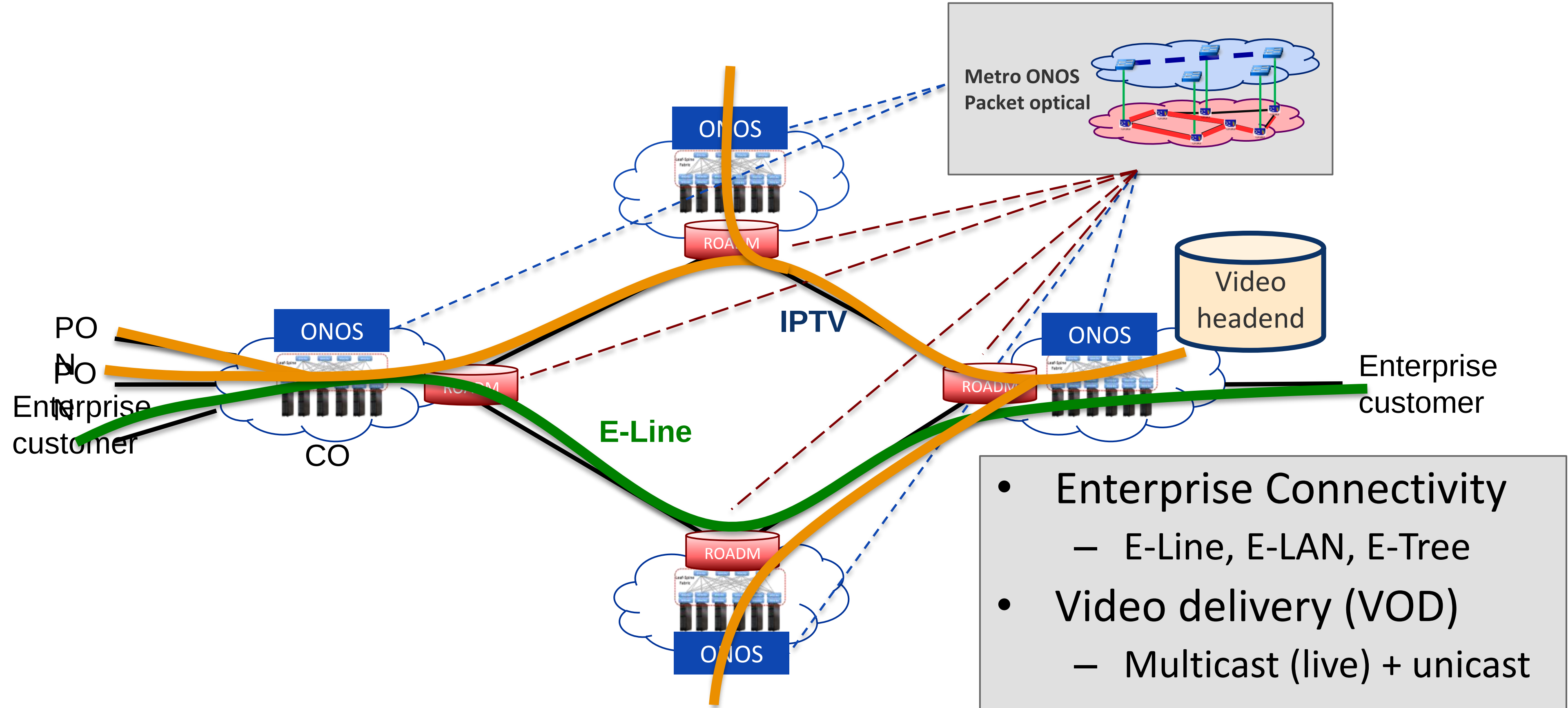
Enable service providers to turn on CORD POD in a day!

E-CORD: Objectives

Demonstrate CORD can support enterprise customers and services

1. Demonstrate converged packet optical control in metro
   - Based on ROADM technology
   - Tied in with CORD architecture
2. Demonstrate relevant enterprise metro services
   - Metro Ethernet Forum (MEF): L2VPN services including network on demand
   - Video multicast and video on demand
   - Self-serve portal

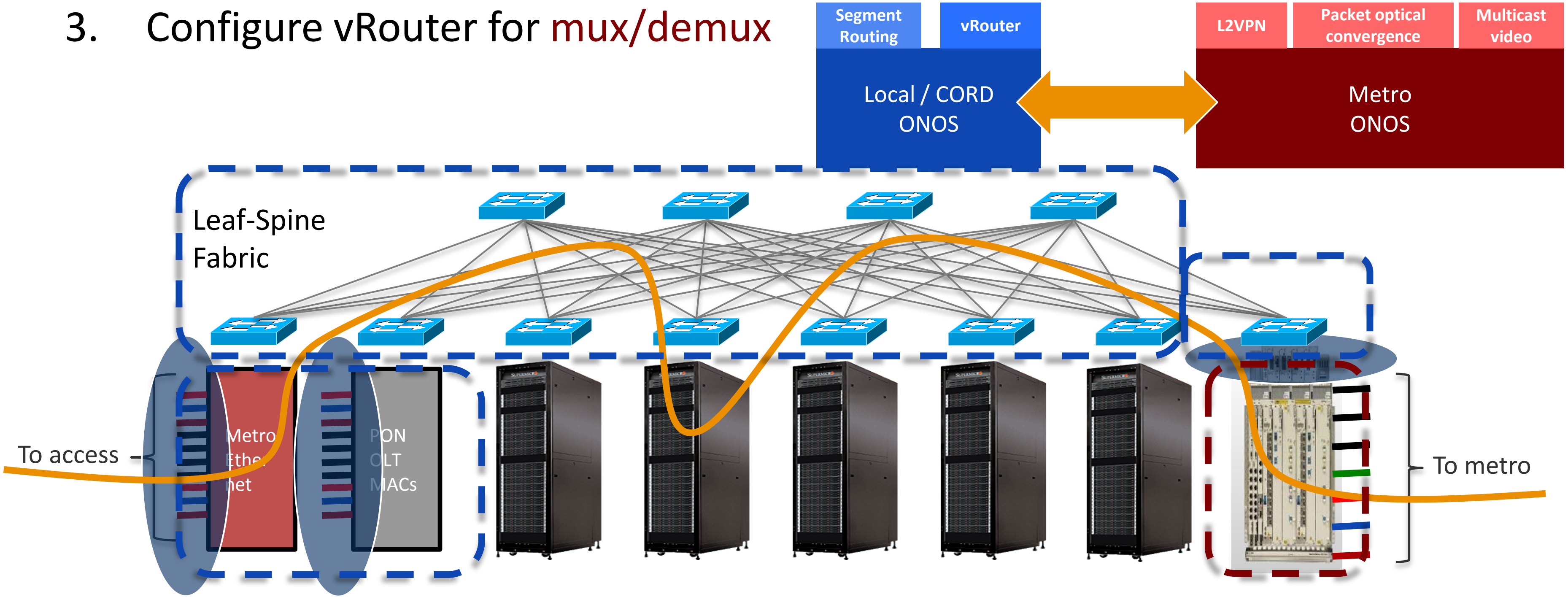
E-CORD POC: Support Enterprise Customers



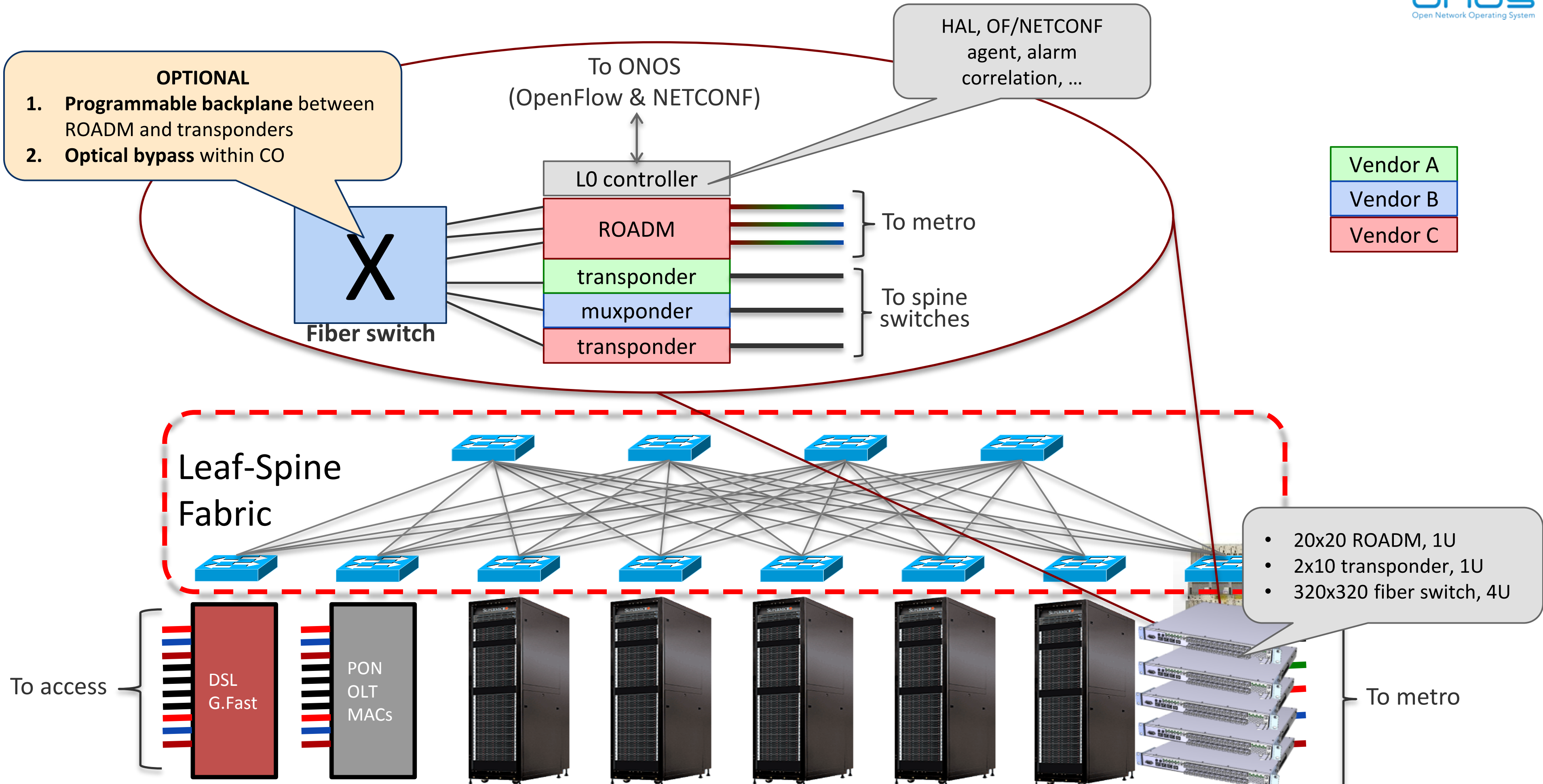
- Enterprise Connectivity
  - E-Line, E-LAN, E-Tree
- Video delivery (VOD)
  - Multicast (live) + unicast

Implementation Details: Inter-ONOS API

1. Represent CORD fabric as big switch
2. Instruct CORD to setup connectivity between big switch ports
   – Pseudo-wire policy for segment routing
3. Configure vRouter for mux/demux



Disaggregated ROADM



M-CORD: Support Mobile Customers and Services

CORD Generalization

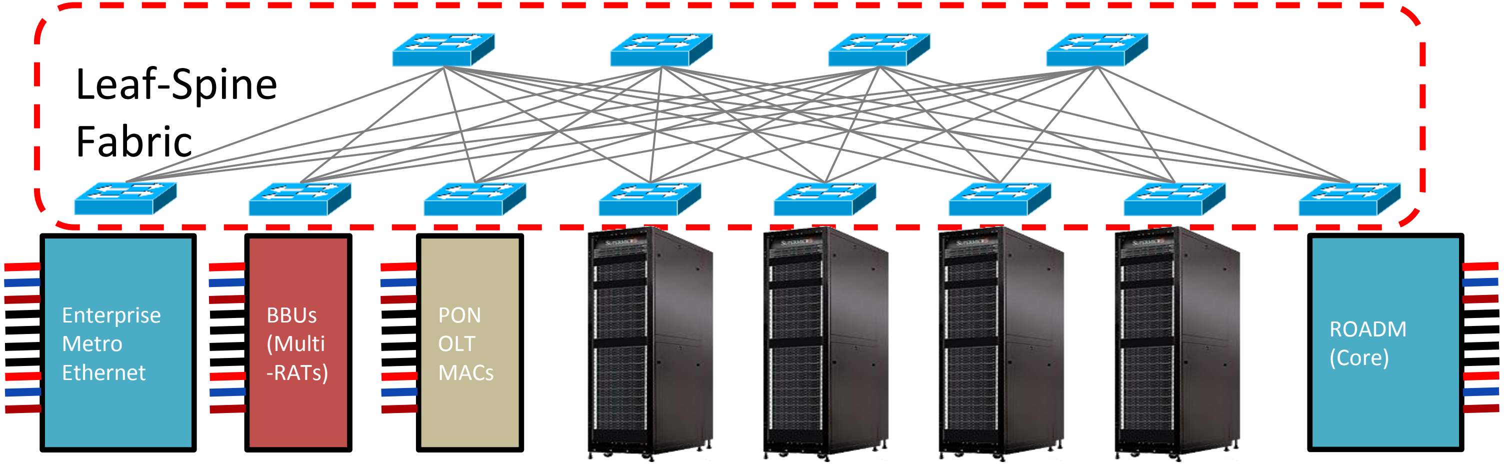
Residential
Residential Software Stack vOLT, vSG, vRouter, vCDN

Enterprise
Enterprise Software Stack: VPN, VOD, vCDN, ...

4G
Mobility Software Stack over Multiple RATs

5G
Mobility Stack over Multiple RATs

ONOS (Virtualization, Slicing) + OpenStack (Multi Domain) + XOS



Commodity Servers, Storage, Switches, and I/O

M-CORD Objectives and Challenges

- Realize CORD benefits for mobile customers and services
  - Data center economics and cloud agility
- Mobile Networks have their own challenges and opportunities
  - Fastest growing in terms of customers/devices (IOT), traffic, services
  - New requirements:
  - New technologies and solutions: Soft RAN, E-SON, 5G, ….
  - The technologies are not readily available in commodity hardware and open source

Mobile Edge: A Few Possibilities

Adopt mobile network designs more akin to modern data centers

- Scale up the mobile resources to specific functions:
- Distribute micro data center (Mobile Edge Cloud) to realize value proposition
  - Augment Reality
  - Lower Latency translates to lower battery life for UEs
  - Combines mobile & cloud with real times cognitive engines
  - Lawful interception
  - Conscious robots
  - Analytics @ the edge, Intelligent Video Analytics
  - Real time Control (IOT, Mhealth)
  - Real time city wide rapid face recognition
  - Direct video through transcoding & firewall functions

- Higher Spectral Efficiencies , Flexible partitioning of RAN
- Elastic traffic Management
- Optimal HW-SW Partitioning, RF Tuners

M-CORD: Two Pronged Approach

1. Mobile Edge (Backend)

Bring service functionality of mobile core to the edge

- L4-L7 Service chaining at the edge
- Cache @ Mobile Edge
- Distributed EPC & Services @ Mobile Edge
- Localized service customization
- Eliminate signaling and data inefficiencies
- Support for edge applications (IOT, smart cities, Mhealth)

Shorter term with existing technologies
POC in Q1, 2016
Followed by Trials

2. Frontend

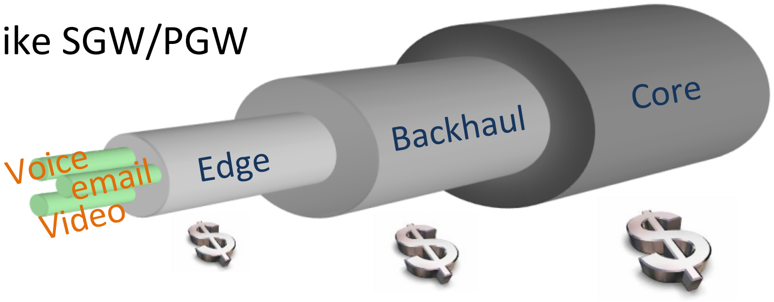
Realize Value of Soft RAN (Sachin Katti)

- Data plane programmability & increased flexibility
- Increased radio resource optimization
- Increased RAN performance

Longer Term
Conceptual POC in Q1, 2016
POC and Trials to follow

Mobile Edge Problem Statement

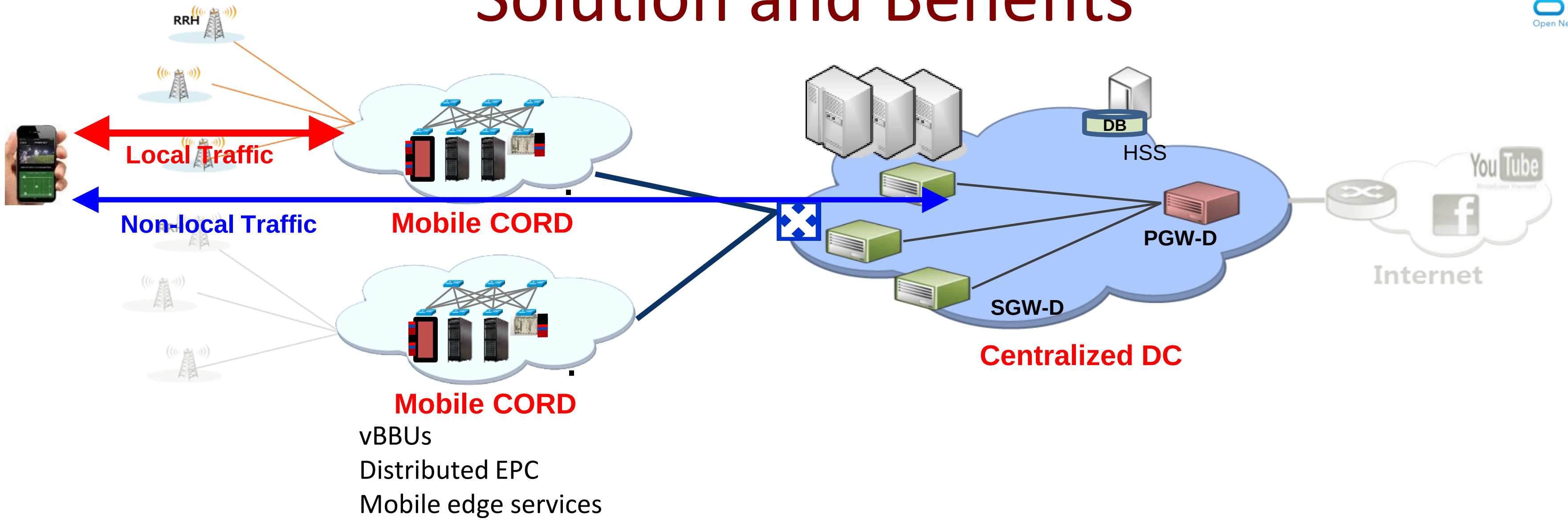
- **All traffics are gathered to the center of mobile core, which cause**
  - load on backhaul, backbone transport and core systems like SGW/PGW
  - waste of network resources from operators' perspective
  - deterioration on QoE from users' perspective



- **Operators overprovision their infrastructure to cope with unpredictable peak traffic**
  - It is inefficient to have surplus capacity everywhere to handle peak traffic
  - Deploying new infrastructure takes long time to cope with ever increasing peak traffic
  - Traffic surge varies with time and location

Current architecture makes it too hard for an operator to achieve efficiency, agility and scalability that are so essential to cope with rapid growth and dynamic characteristics of mobile traffic

Solution and Benefits



- **On-demand provisioning**

Virtualized infrastructure and services (e.g. vBBUs, Caching, EPC functions) can be deployed on demand

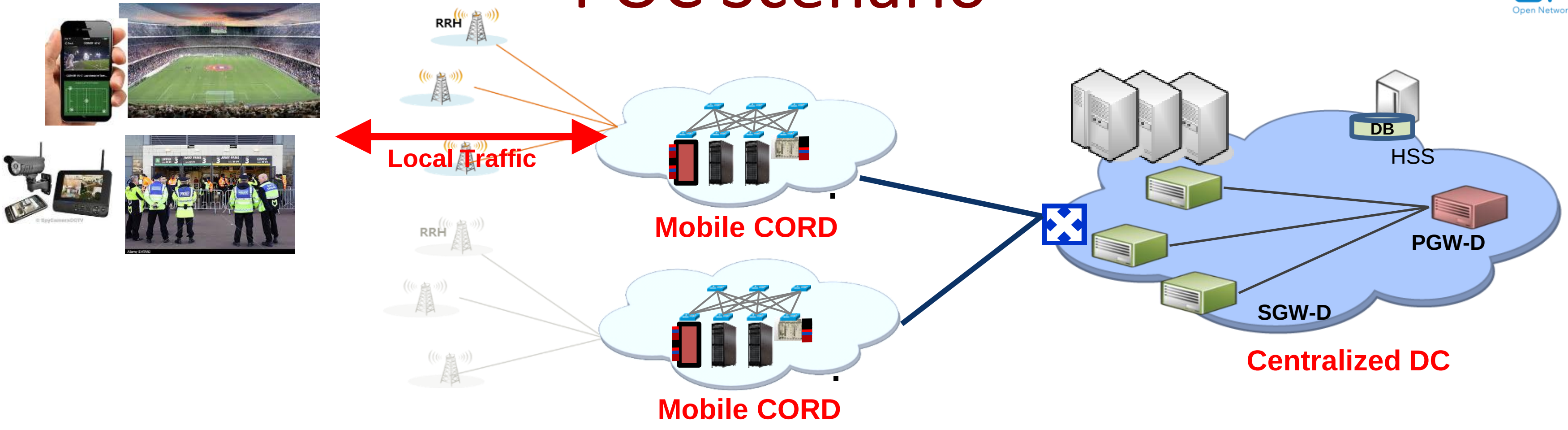
Benefits: Avoid inefficient provisioning of infrastructure & support agile action for dynamic traffic requests

- **Services at mobile edge**

Certain contents can be served from the mobile edge without the inefficiency of traversing mobile core

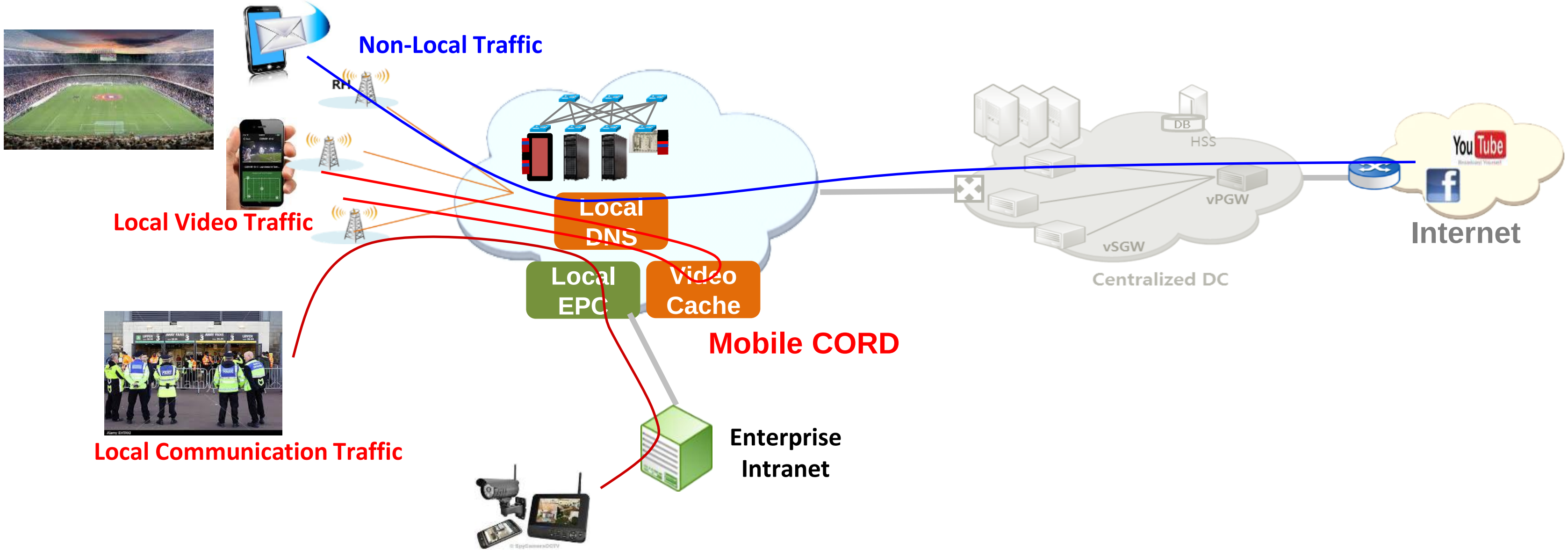
Benefits: Decrease burden on backhaul and mobile core; and increase QoE of users, Network slicing, MVNO, new

POC Scenario



- **Local video streaming service at mobile edge**
  - On-demand provisioning of vBBUs at cell sites near big sport match
  - On-demand provisioning of video caching application(VM) for local video caching service
  - Functions like DNS and DPI also need to be deployed locally for traffic classification
  - Other traffic of spectators is treated same as before; traverse from and to the Centralized Core
- **Local communications hosted by distributed EPC**
  - Virtualized EPC can also be deployed to host local and internal communications
    - Communication between security staffs
    - Remote monitoring of Security CAM

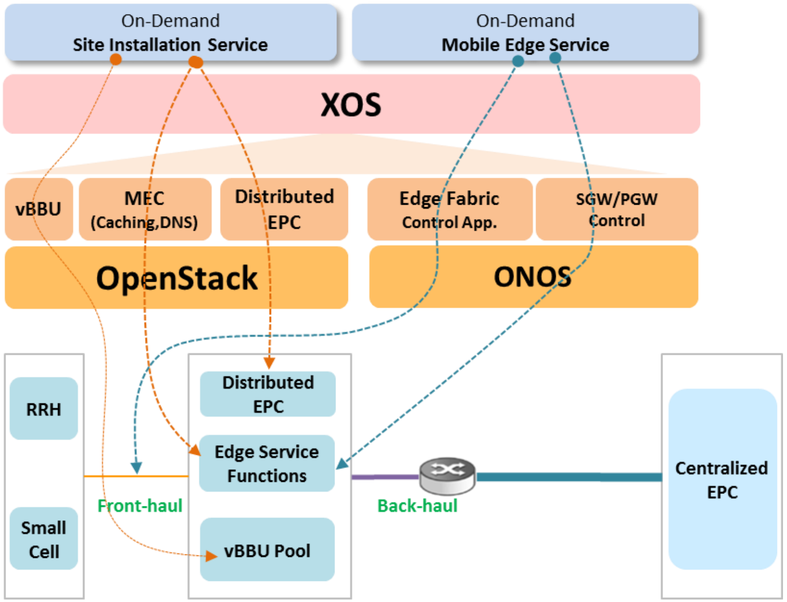
POC Scenario – Packet Flow



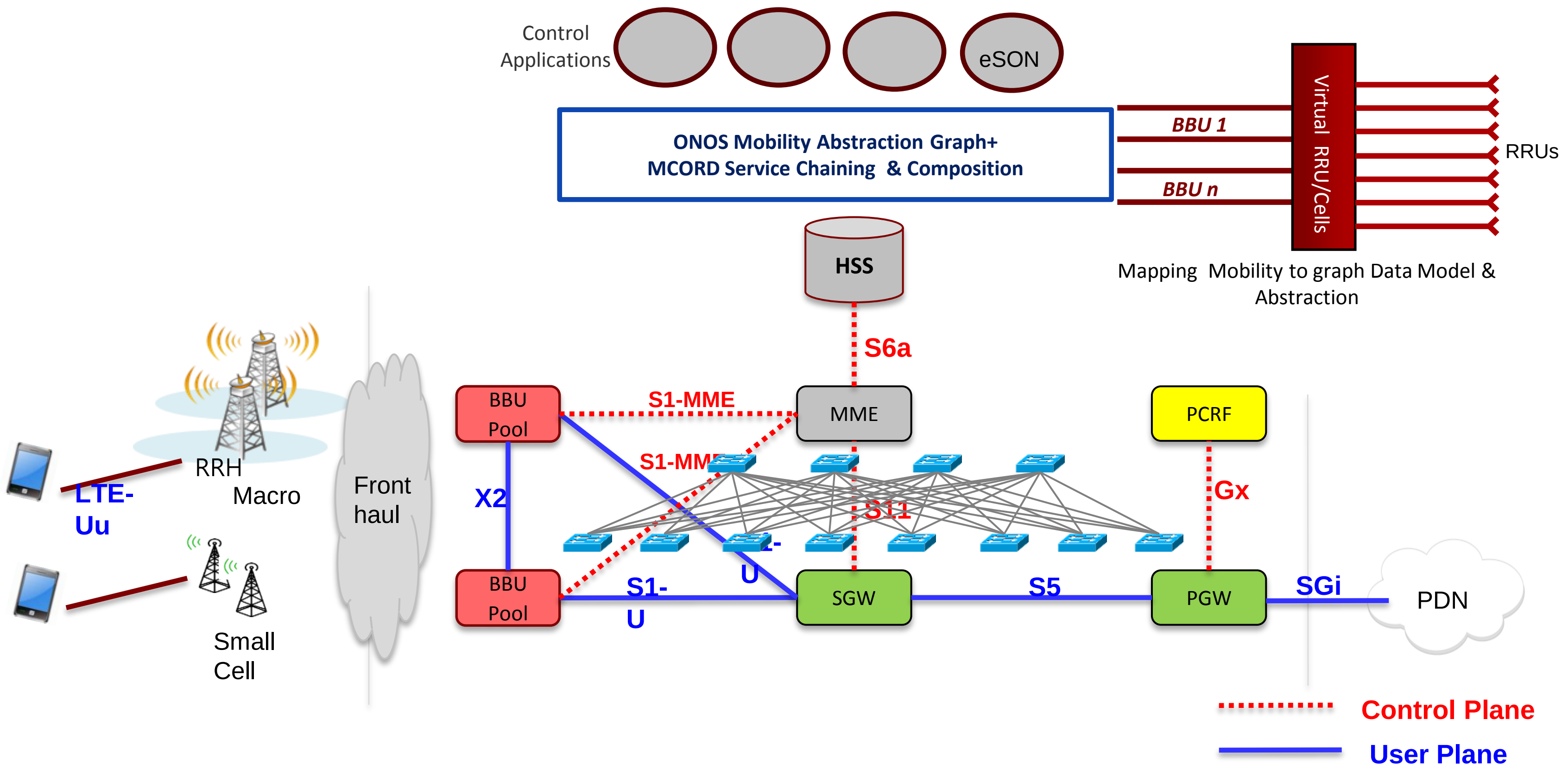
- Non-local traffic like web and email traverse to central core same as before
- Local video traffic is served by local cache
- Traffic of **Local communication** or **Intranet** is diverted to local network via local EPC

POC Implementation: Mobile Edge Software Stack

- **XOS**
  - Manage/orchestrate services provided by OpenStack and ONOS
- **OpenStack**
  - Provision VMs and virtual networks
- **ONOS**
  - Manage switching fabric
  - Connectivity among virtual network functions
    'video traffic' to local edge service servers and distributed EPC
    and other traffic to centralized EPC
- **Control Applications**
  - Video content caching
  - DNS
  - DPI
  - MME, PCRF
  - eSON

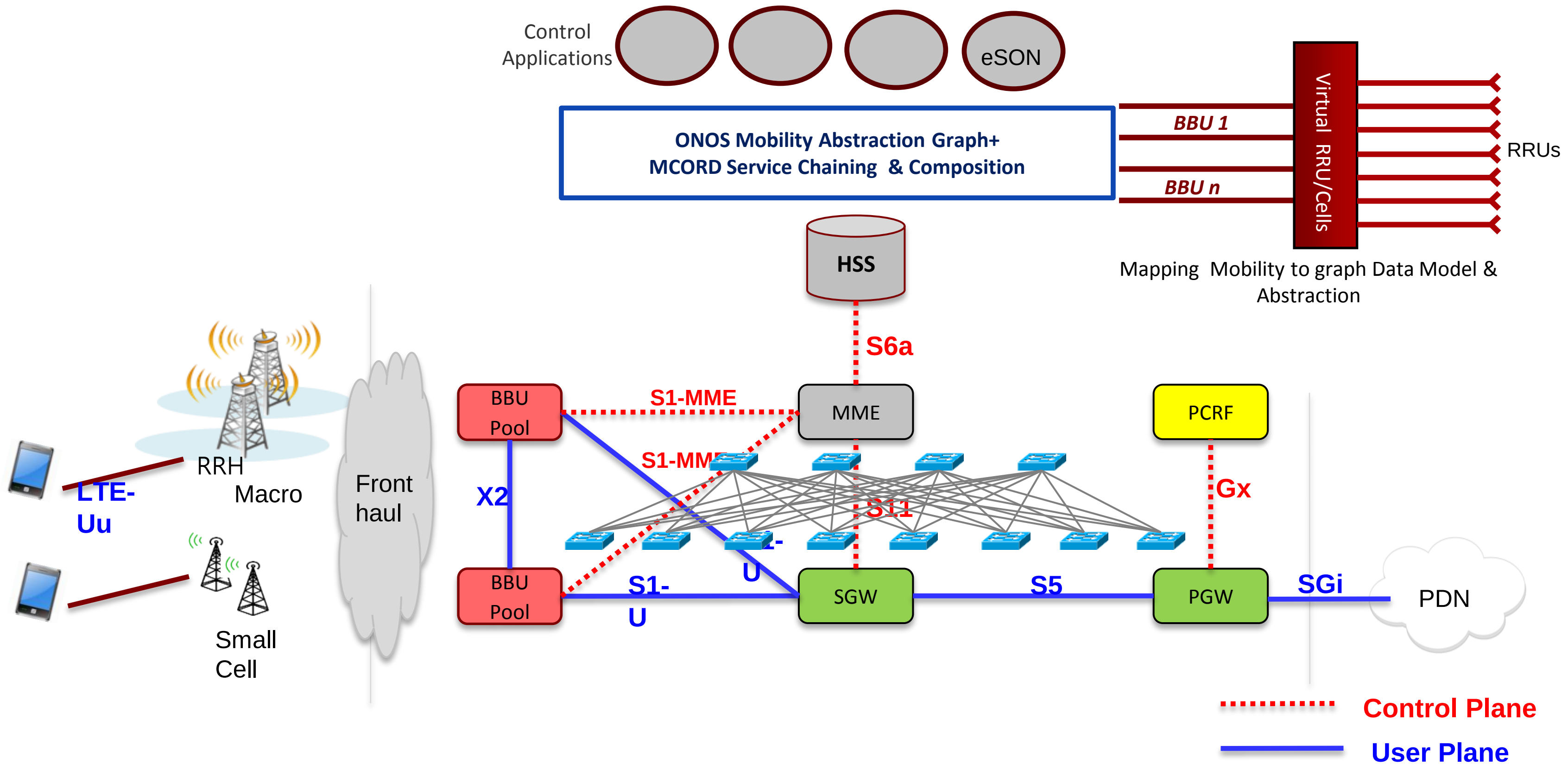


Mobile Edge: Data Path



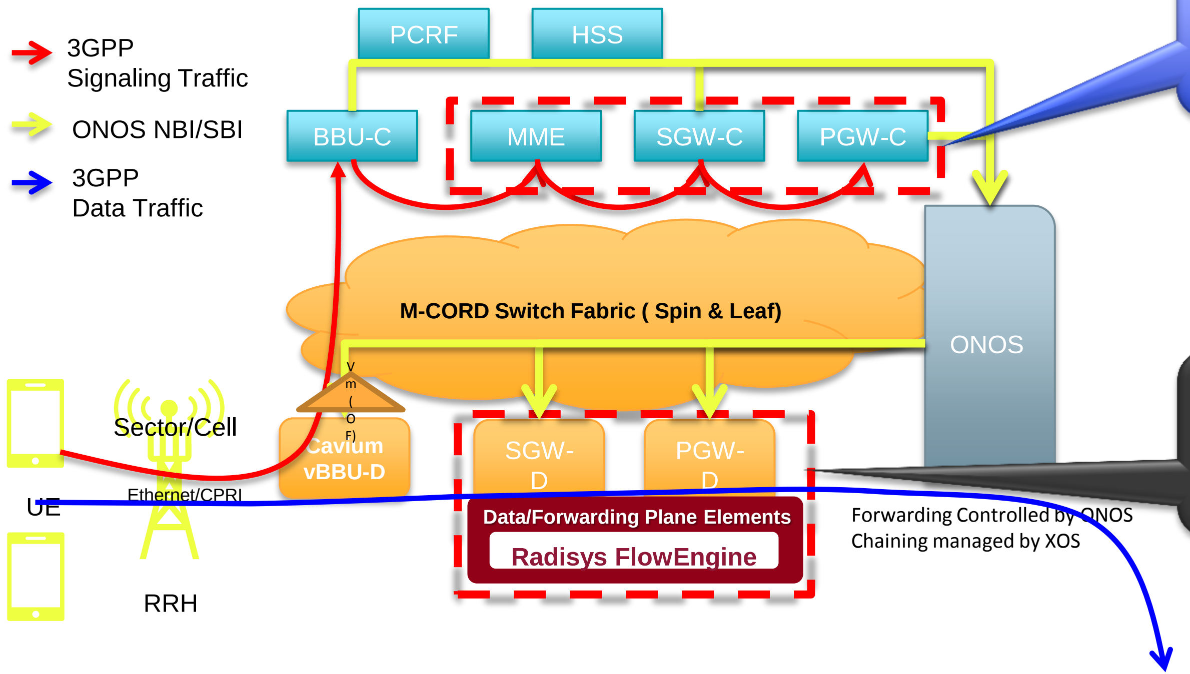
Mobile Edge: Control Path

Mobile Edge: CORD Control Path



Mobile Edge Implementation Details

Main Components of Segmented Gateway PoC



Control Path Component

- MME functions
- Signaling and control plane of serving and packet gateway.

Data Path Component

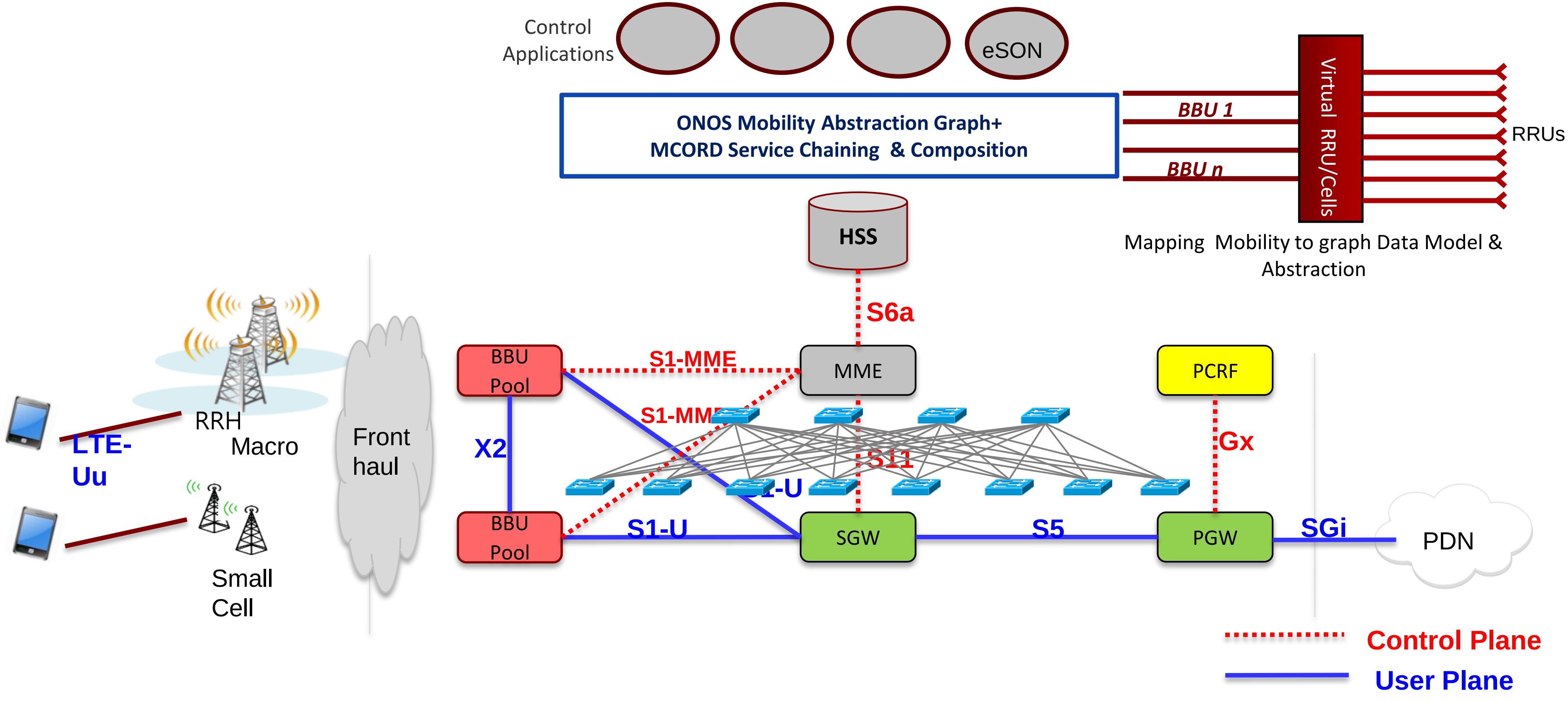
- Serving Packet gateway data path function.
- Packet gateway data path function.

Mobile Edge: Summary

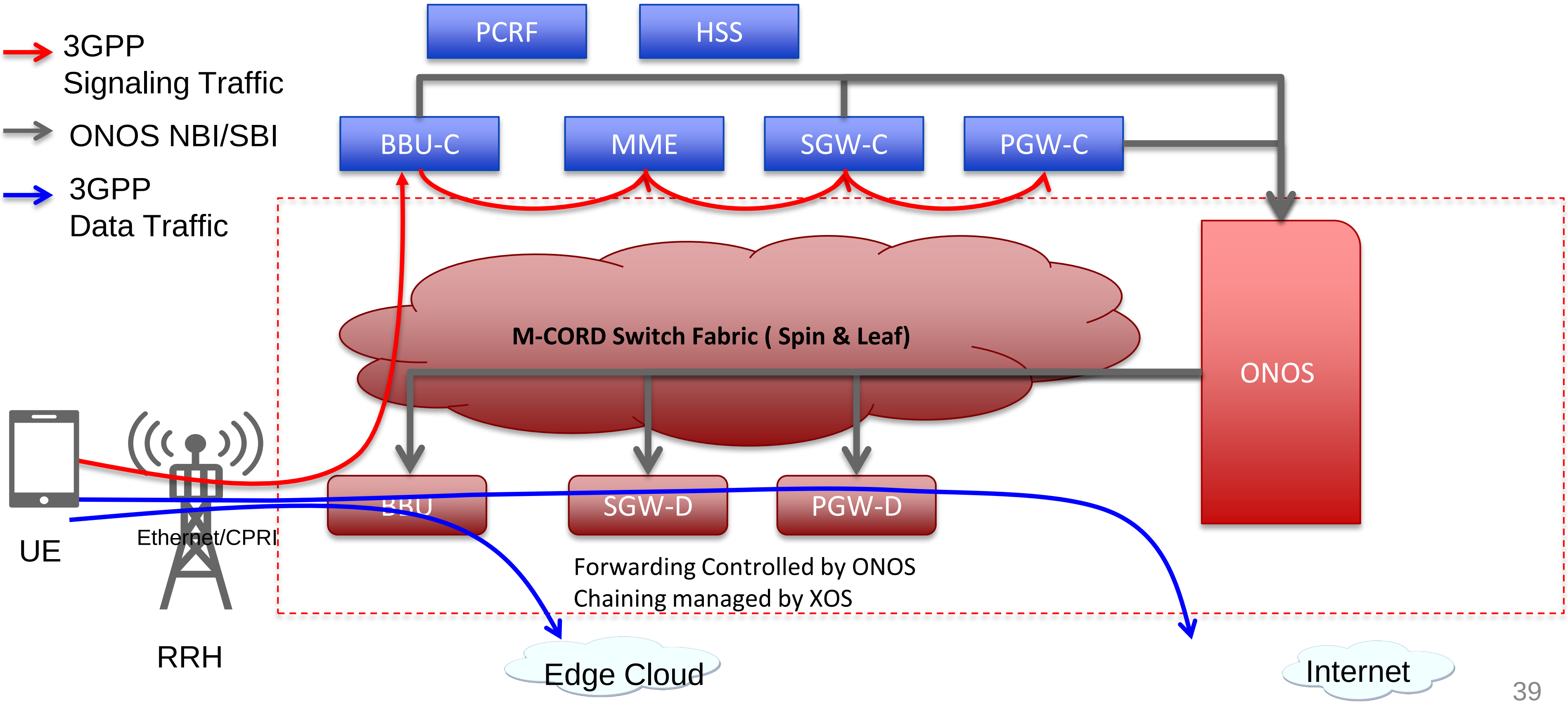
- POC at ONS in Mid March 2016
- Potential partners
  - Cavium (VBBU, Access)
  - NEC (Applications, Policy)
  - Radisys (Disaggregated PGWY)
  - Airhop (eSON application)
  - Ericcson (may be Central Core)
  - Aeroflex (Test and Integration)
- We will look for Applications to show benefits of Mobile Edge

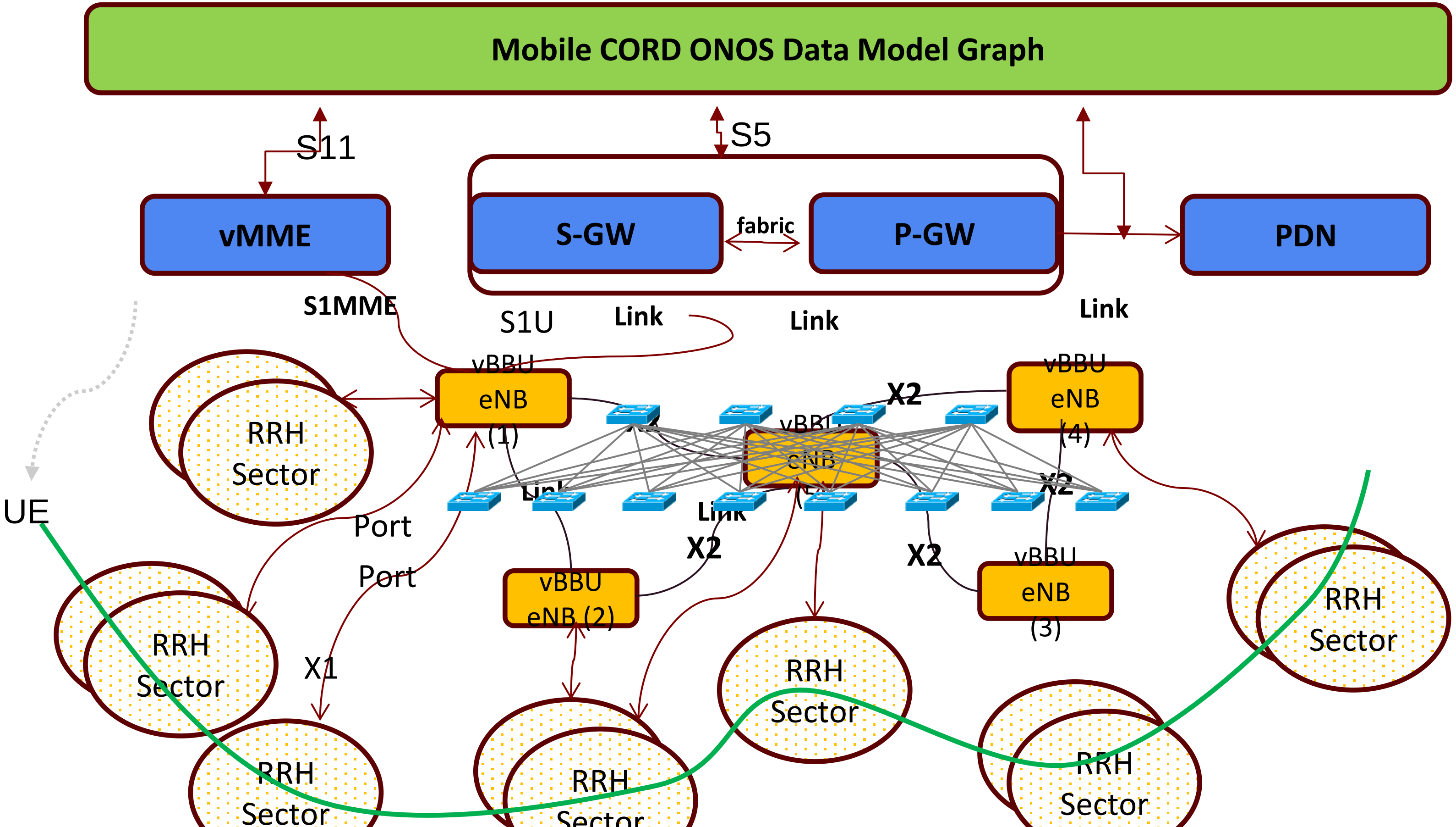
Mobile-CORD

Simpler Deployment; Lower OPEX



SDN(ONOS) Control for Mobile Network





Mobile CORD ONOS Data Model Graph
S11
S5
vMME
S-GW
fabric
P-GW
PDN
S1MME
S1U
Link
Link
Link
vBBU
eNB
(1)
vBBU
eNB
(4)
X2
X2
X2
X2
vBBU
eNB (2)
vBBU
eNB
(3)
Link
Port
Port
X1
UE
RRH
Sector
RRH
Sector
RRH
Sector
RRH
Sector
RRH
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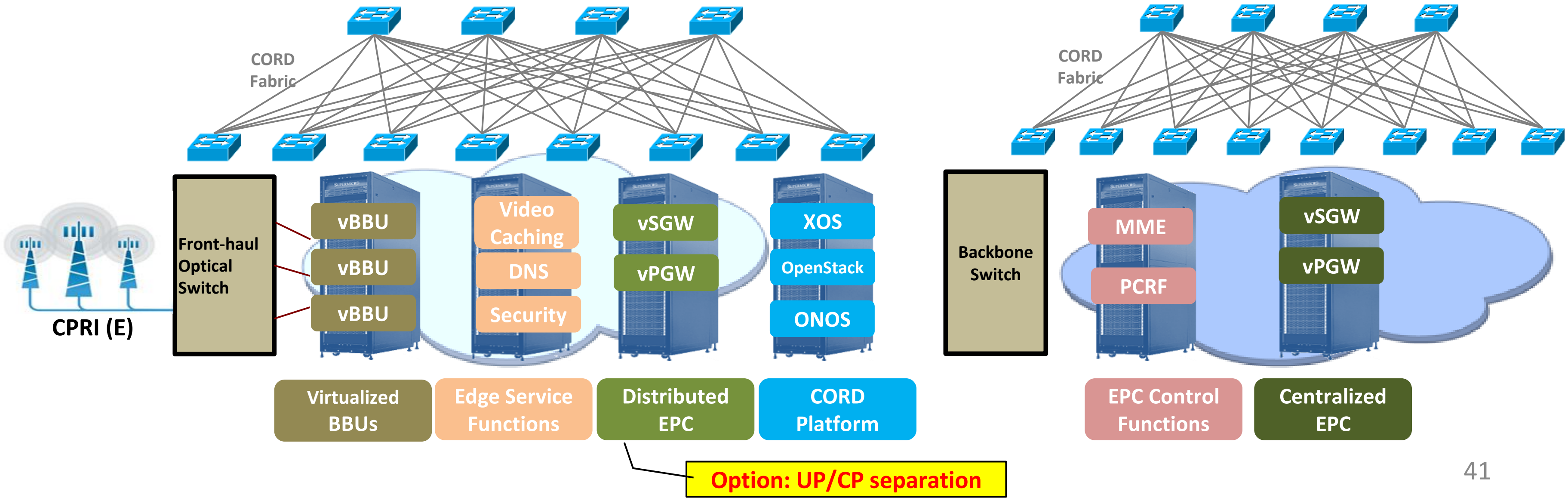
Sector

POC Implementation

- **BBU**: Servers hosting VMs of BBU function
- **Edge Service Functions**: Servers hosting VMs of service functions like DPI, DNS and Video caching
- **Distributed EPC**: virtualized EPC <u>(Decoupling of UP/CP is preferable)</u>
- **EPC Control nodes**: Control nodes of EPC (MME, PCRF)
- **Mobile CORD Platform:** Servers hosting control software stack: XOS, Open Stack and ONOS
- **Mobile CORD Fabric**: White-box switches networking mobile edge components

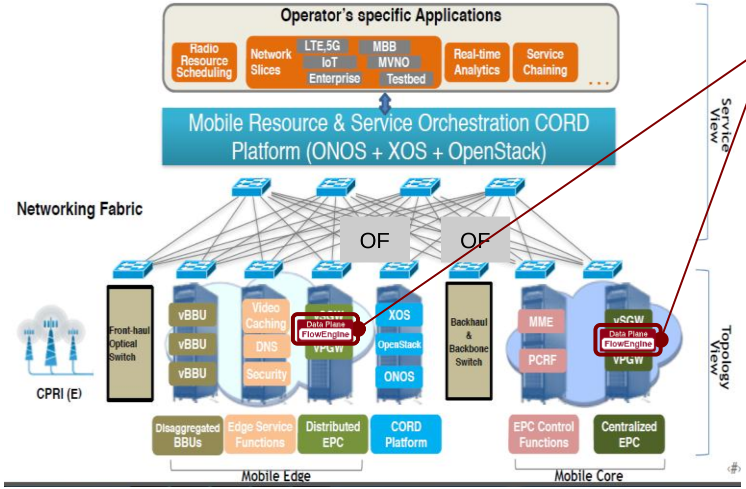


Back-ups

MCORD Mobile Edge POC

- High Level Overview: Segmented GW (Data Path Component)

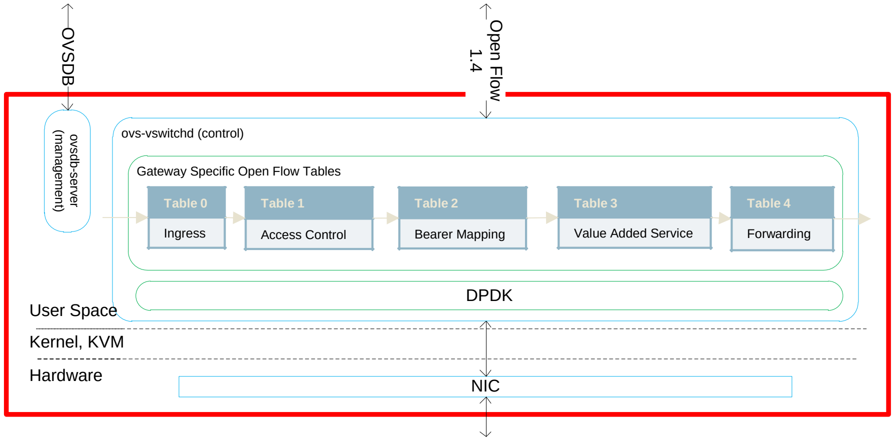
Main Components of Segmented Gateway PoC: Data Path Component



Component: Radisys FlowEngine providing data/forwarding components for PGW and SGW
Location: Distributed and Centralized EPC CORD Racks
Form Factor: x86 COTS server (*and EZchip NPU system for high scale/performance)

- **NOTE: Radisys FlowEngine also supports deployment as leaf switch.*

High Level Block Diagram: Software switch, OVS based architecture



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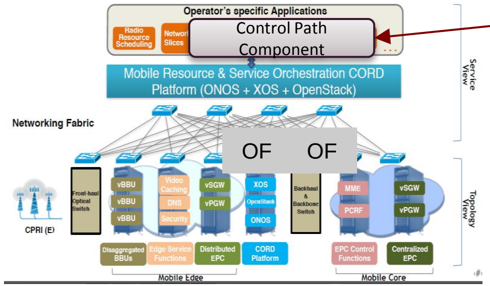


Location : Act as one of CORD application.

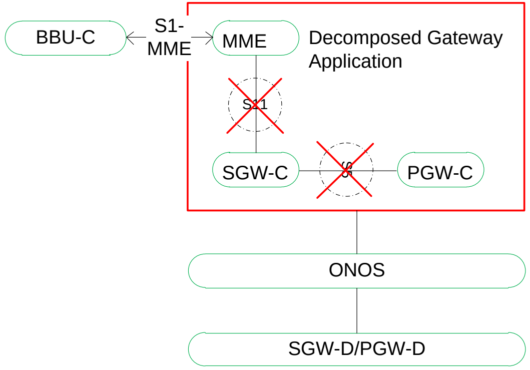
Function: Optimized, Colocated MME, SGW and PGW control plane function.

Use Case: Optimize LTE signaling overhead

Why: LTE core signaling (eNB -> MME, MME -> SGW) during idle to active (and vie versa) transition is not scalable for IoT deployments.

How: Make eNB to SGW bearer connection permanent, not to be teared down during UE idle state transition.

Additional use case: Connection less communication for IoT device, in case UE and eNB support it.
http://web2-clone.research.att.com/export/sites/att_labs/techdocs/TD_101553.pdf



- Optimize standard LTE interfaces S11, S1-C, S5-C and S8-C.
- During idle state transition SGW-C (and BBU-c) will not be asked to delete its S1-U bearer, SGW-D keeps the bearer information. OF **flow timeout mechanism can be used to tune when bearer gets deleted in SGW-D.**
  - (TBD) Interface with vBBU to keep GTP bearer intact during idle transition.
- When UE goes to active state and established RRC connection, no core signaling is needed to modify bearer in SGW-D.
- Form Factor: All of MME, SGW-C and PGW-C can be part of a VM with S11, S5-C/S8-C replaced by internal interface.

Implementation Summary

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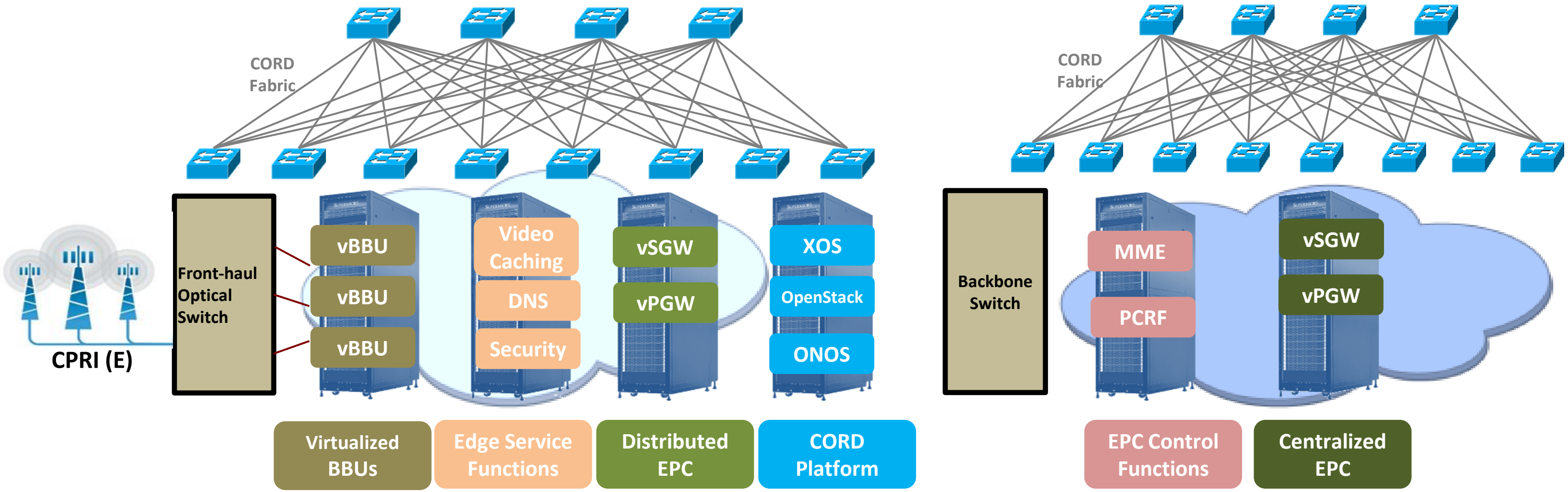
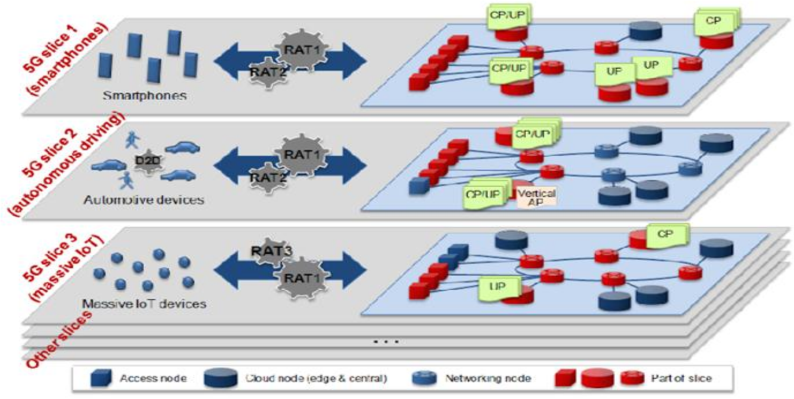


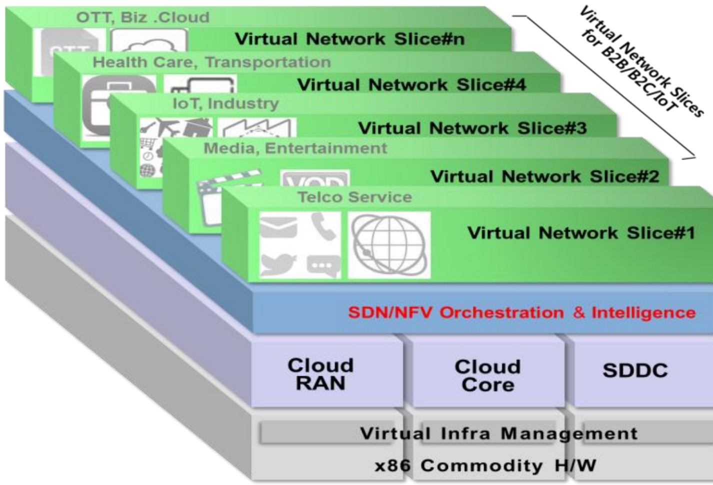
Network Slicing

- **Networks for the Customers' needs (SLA)**
  - Traditional: One network for all purpose with same architecture and configuration
  - Trend: **Network Slices to meet specific demands of customers and services (Network as a Service)**

[Concept References]



※ Reference: NGMN



※ Reference: SK Telecom

- **Key Enablers for Network Slicing**
  - Abstraction of network functions
  - Programmability of Networking
  - End to End Orchestration

NFV

SDN