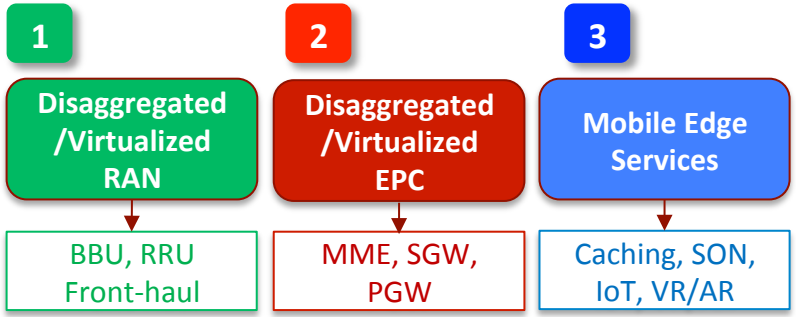
Mobile-CORD

Plans for 2H `2016

CORD
Central Office Re-architected as a Datacenter

M-CORD Focus Areas

Mobility Technology Trends



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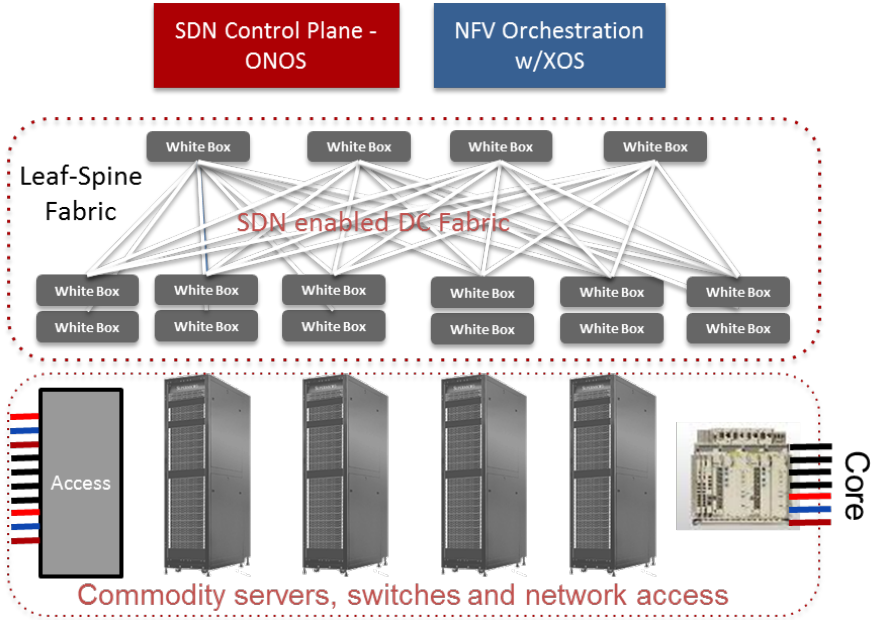
CORD



1 Disaggregated and Virtualized RAN

- **RAN Slicing**
  - Policy driven - Time, Location, UE category, Service, etc.
  - Resource management and isolation between slices
  - Front-haul slicing - based on simple tag such as VLAN
  - Support for Multi-RATs

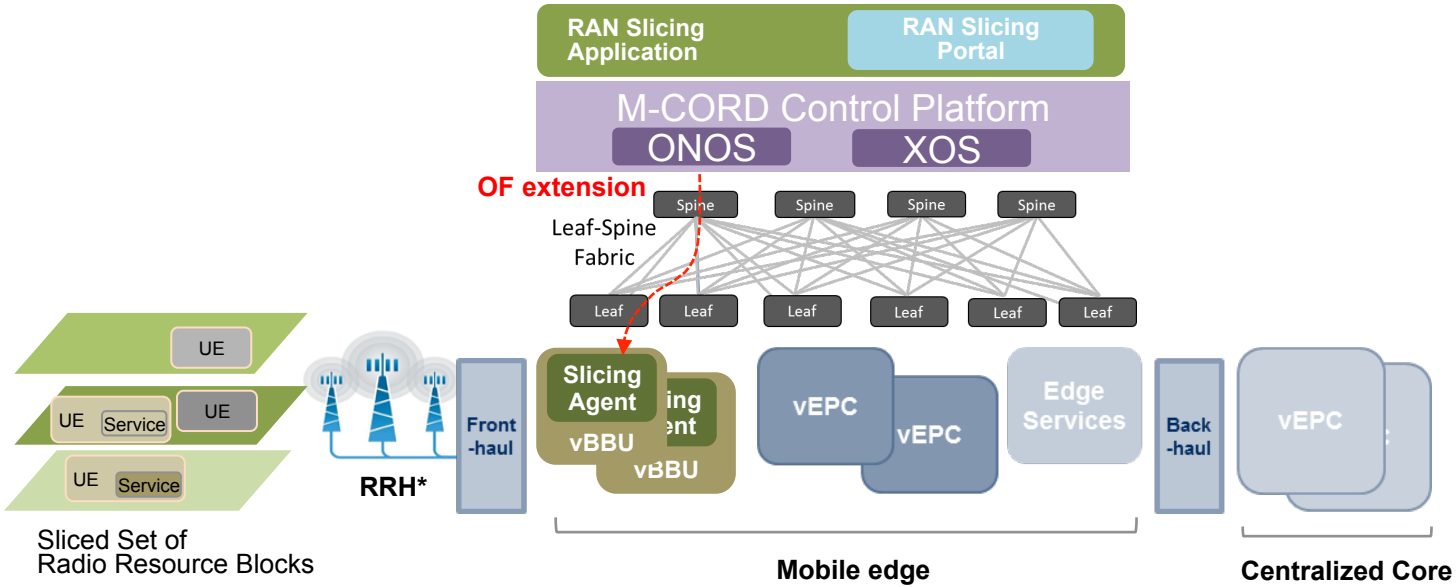
RAN + Core slicing should be coordinated

- **Observability and Analytics**
  - Integration with A-CORD
  - Real-time Smart Probes
  - Closed loop analytics apps
  - Example use cases: Open SON (self-organizing network), root cause analysis

- **Flexible Disaggregation – a stretch goal**
  - Vertical– Split architecture depending on front-haul and latency requirement
  - Horizontal– Control-plane / Data-plane

RAN Slicing: Implementation

- vBBU* assigns & manages radio resource blocks to different slices under the control of the slicing app
- ONOS slicing app talks to RAN agent/vBBU through proposed OF-extensions
- Slicing app or portal can take policies based on UE, time, location and/or services to create slices
- Service classification can be implemented by UE using tagging (e.g., network cookies)



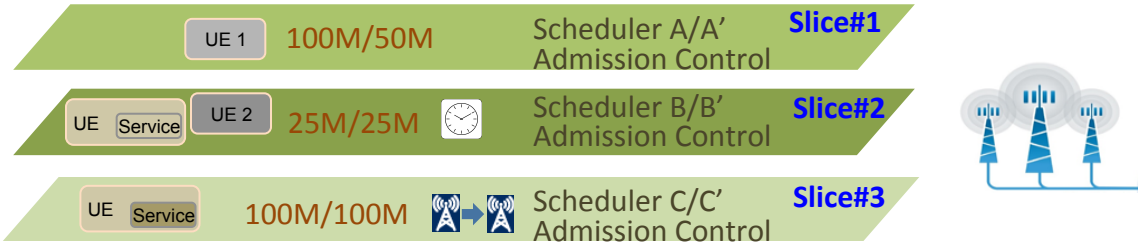
BBU ≈ Central Unit, RRH ≈ Remote Unit

1 RAN Slicing: PoC

PoC

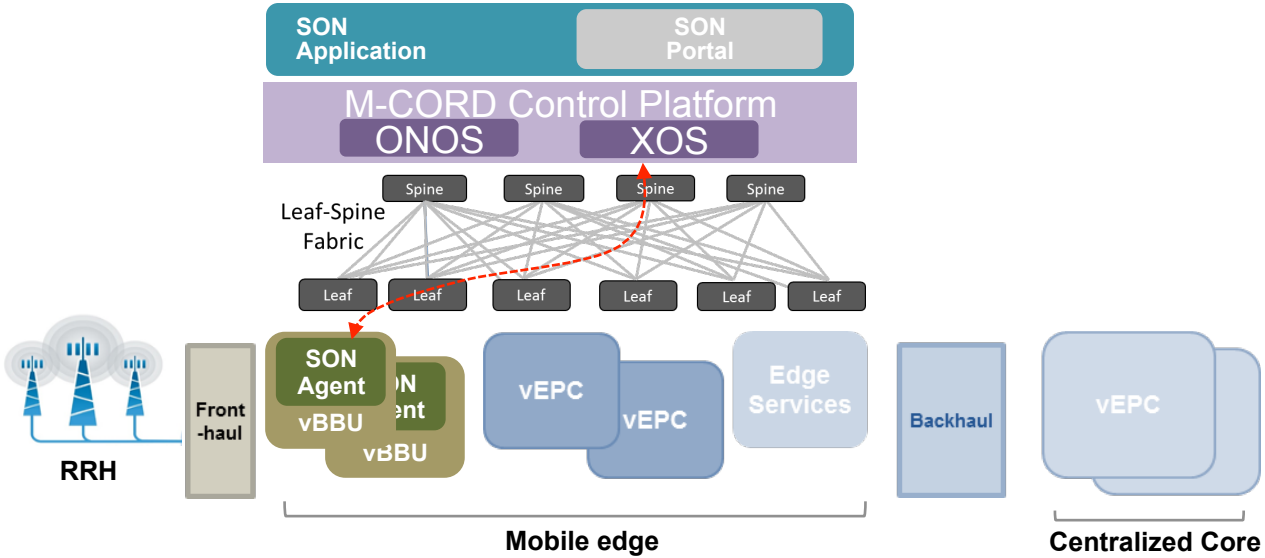
Different UEs and Services experience different QoS based on the slice policy

- Senario1: UE based slicing
  - VIP UE 1 belongs to slice#1 and served with reserved 100Mbps/50Mbps for DL/UL
  - Normal UE 2 belongs to slice#2 and served with limited speed of 25M/25M for DL/DL during peak time, 5-7 pm
- Scenario2: Application based slicing
  - When a UE, whose price plan is basic, uses s video streaming application, the (UE) flow is assigned to slice#2 with limited bandwidth
  - When the same UE uses m-Health application, the (UE) flow is assigned to slice#3 and can be served with high bandwidth and with slow triggered handover control



Observability and Analytics: Implementation

- Integration with A-CORD
- SON as a A-CORD service
  - Closed loop control with ‘measurement and action’
  - Measurement examples: power level, CQI (Channel Quality Indicator)
  - Action examples: adjust power, instantiate a new BBU (that is a new cell for more capacity)

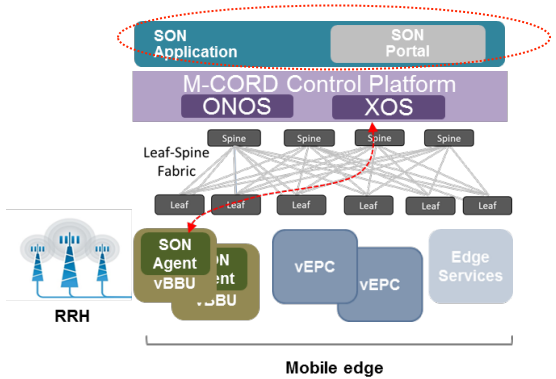


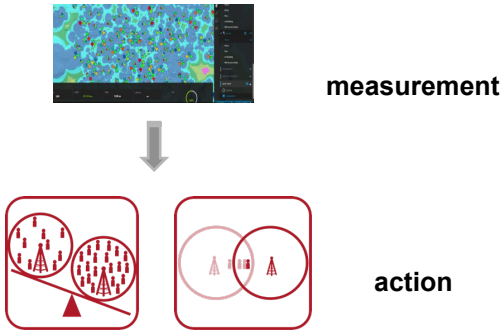
1 Observability and Analytics: PoC

PoC

SON application collects RAN information and triggers management actions through M-CORD platform

- Emulate congestion in one cell, SON recognizes this situation
- Take actions such as:
  - Load balance among existing cells and optimize performance for UEs
  - Instantiate a new vBBU on-demand (a new cell) and load-balance





2 Disaggregated and Virtualized EPC

- **Core Slicing**
  - Flexible allocation of VMs of EPC components and Service functions to slices
  - Slicing includes both control-plane and data-plane
  - Isolation, QoS, customized security per slices

  ※ Coordinated with RAN slicing (E2E slicing)

- **Observability and Analytics**
  - Integration with A-CORD
  - Observe – Slice utilization, EPC VMs resource utilization
  - Closed Loop Analytics Apps
  - Example Use Cases: active testing, dynamic resource allocation for slices

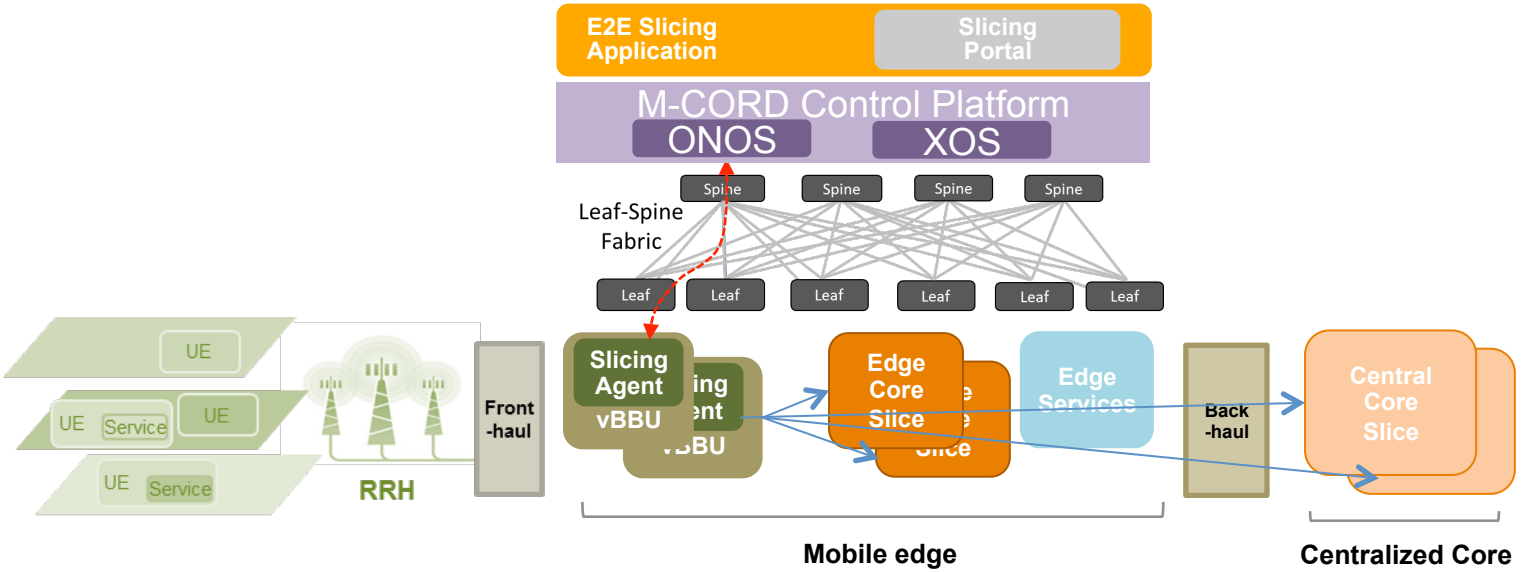
- **Connectionless**
  - Non-GTP based data forwarding model
  - Initial focus on static IoT devices, potential future support for mobility

  ※ Connectionless model also include RAN side

- **Seek and integrate Open EPC building blocks**

Core Slicing: Implementation

- Dynamic assignment of EPC resources (e.g. MME, SGW-C, PGW-C, SGW-D, PGW-D…) to slices
- Resources can be dedicated or shared between slices
- vBBU gets slice information from slicing app to select appropriate core slice for incoming packets



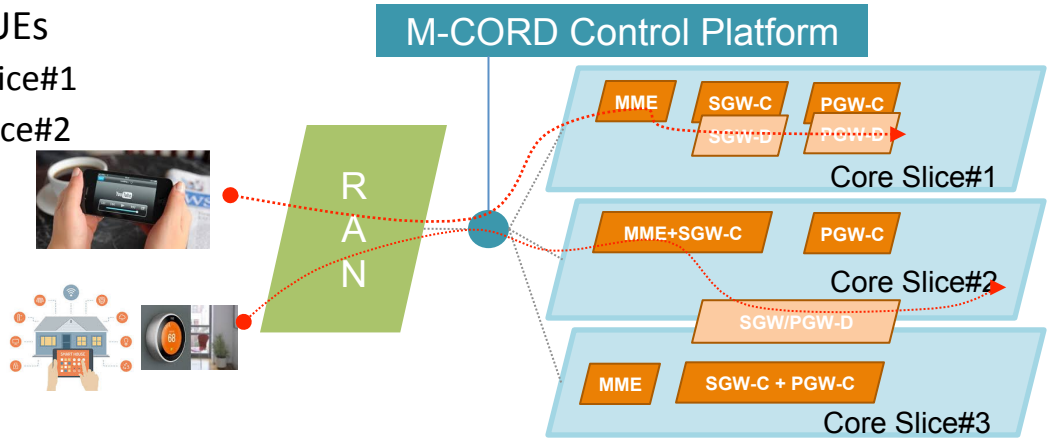
2 Core Slicing: PoC

PoC

Show setting up slices with flexible combinations of EPC VMs
The slicing app directs UE traffic flow from RAN to desired core slices

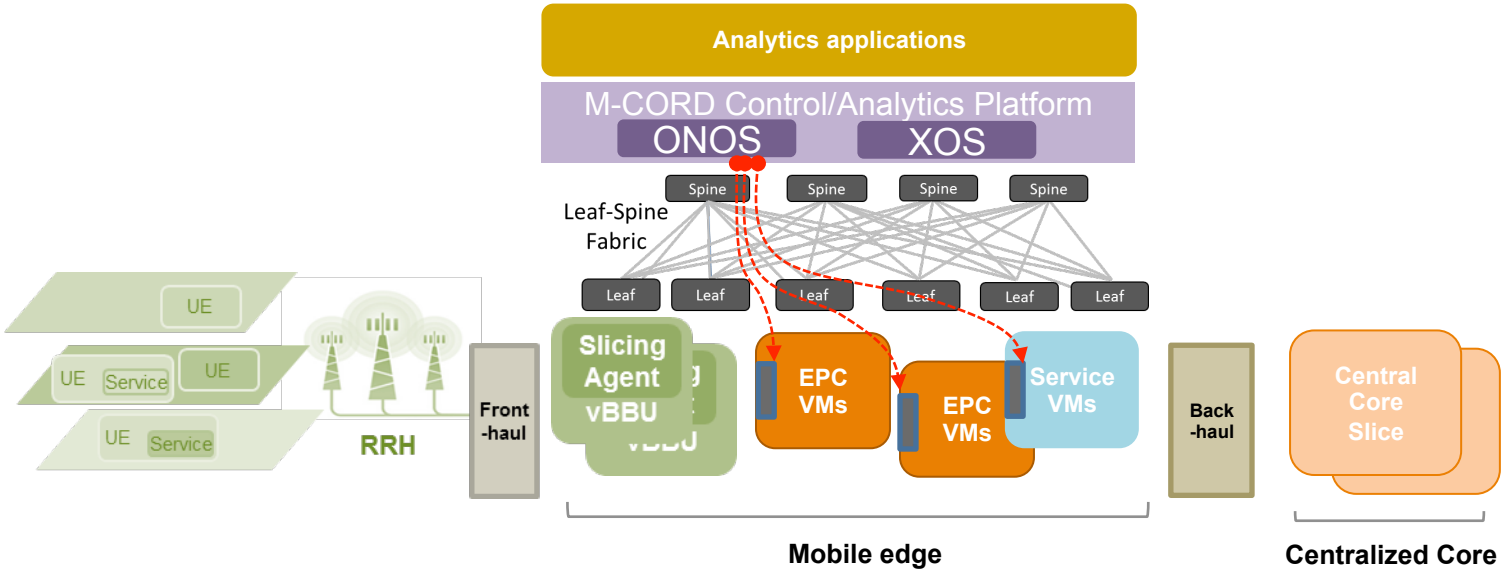
- Set up core slices
  - Slice#1: dedicated MME, SGW-C/D, PGW-C/D – suitable for huge data traffic
  - Slice#2: MME + SGW-C, PGW-C and SGW/PGW-D* shared with slice#3 – suitable for low traffic with low mobility
  - Slice#3: MME, SGW-C + PGW-C and SGW/PGW-D* shared with slice#2 – suitable for low traffic with low mobility

    ※ Sharing of Data plane need more discussion but can have practical use cases
- Core slice assignment for different UEs
  - UE①, heavy video user, is assigned to slice#1
  - UE②, home IoT device, is assigned to slice#2



2 Observability and Analytics: Implementation

- Integration with A-CORD
  - Monitoring as a Service, Active Test as a Service
- Implement programmable Smart Probe in EPC VMs
  - Measure/Identify examples: inter arrival time of data and signaling traffic, jitter, etc.
  - Control: instantiate new SGW-C, SGW-D, PGW-C, PGW-D when needed
- Through header based classification and DPI, enable application based slicing

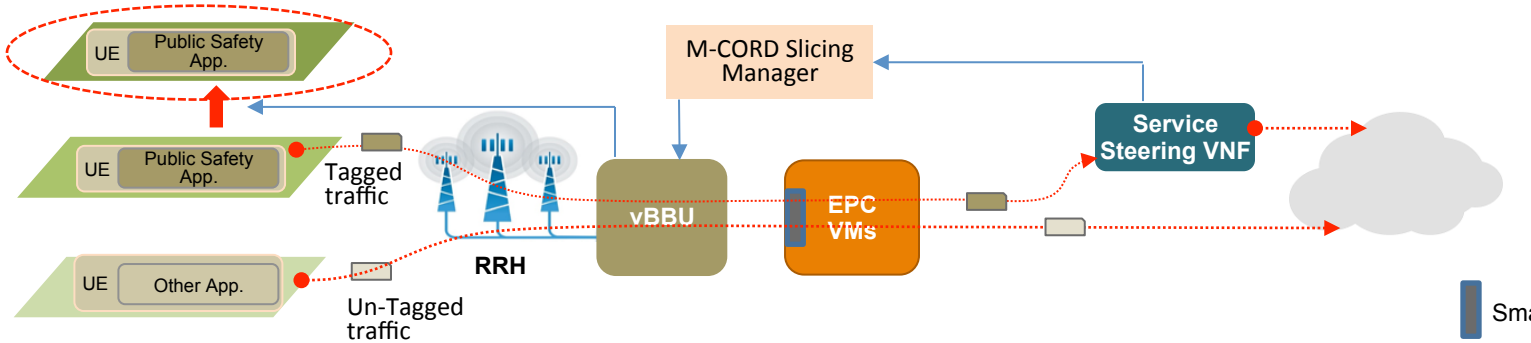


2 Observability and Analytics: PoC

PoC

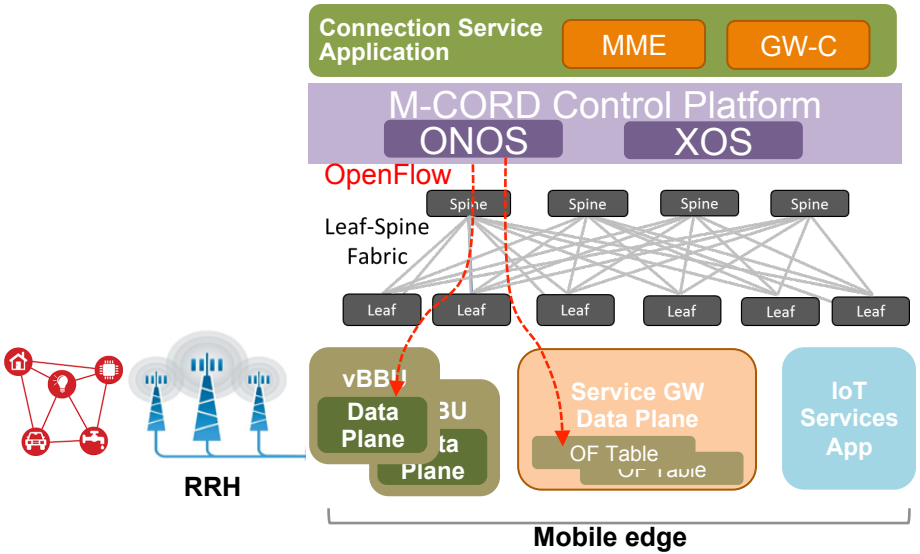
Show traffic analysis agent can do QoE analysis in a slice
Show service based Core slicing

- Test agent analyzes QoE & QoS in a slice and trigger new PGW-D VM to handle increased traffic when needed
- Through packet inspection feature at 'Smart Probe', enable application based RAN slicing
  - Smart Probe classifies type of application and adds tag to each packet
  - Service Steering VNF asks RAN slicing upon detecting this tags
  - RAN slicing agent move the UE to different slice and support higher bandwidth
  - Examples : m-Health application, public safety application



2 Connectionless: Implementation

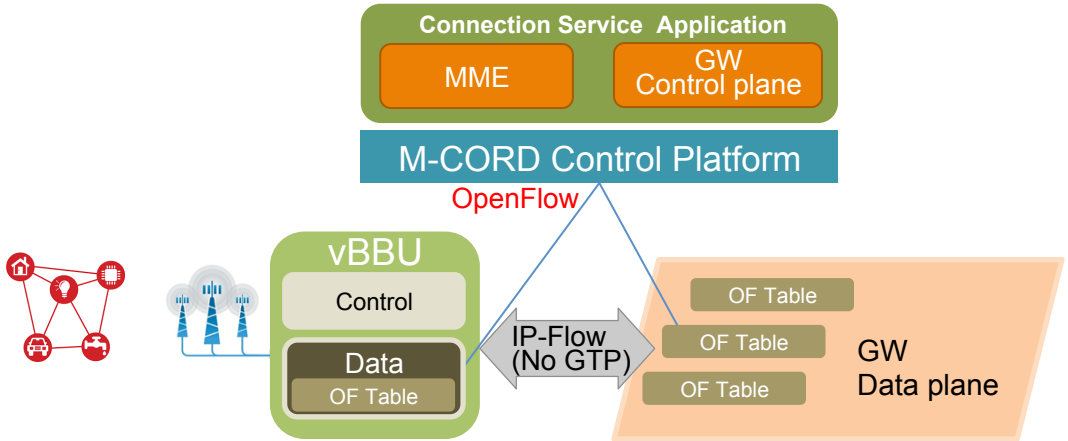
- Disaggregated eNB/SGW/PGW functionalities to enable a centralized application to manage new (non-GTP) data plane
- vBBU data plane and service gateway data plane are controlled by ONOS and apps
- Get rid of GTP tunnels, replace with OF rules in data path element in a proactive way



2 Connectionless: PoC

PoC **Static and cellular IoT Devices are serviced by Non-GTP based network.**

- Show there is no MME, SGW, PGW
  - Instead, includes SDN controllable Service GW Data plane and Service application
- Cellular static IoT devices are connected to and served by the new network
  - Emulate hundreds or thousands of IoT device traffic
  - Show OF table set up inside vBBU and GW data plane



3 Mobile Edge Services

- **CDN**
- **AR/VR**
- **Public safety**
- **m-Health**

- Take advantages of
  - Proximity (Mobile Edge)
  - RAN/Core slicing
  - Resource management
  - Tagging mechanism
  - Service steering

3 Implementation and PoC

Backup / TBD

CDN

- Support serving locally cached CDN content for better QoE
- Support CDN data traffic demand by scaling EPC components
- Utilize Slicing to provide policy-based QoE

PoC PoC benefits of EPC scaling for CDN application

AR/VR

- Support customized Augmented Reality and/or Virtual Reality services in a targeted area
- Utilize Slicing to meet the high throughput requirement
- Examples : AR Gaming, VR museum
  - Solution partners are TBD

PoC PoC AR/VR applications with enhanced QoE

Public Safety

- Utilize Slicing to support for 'xpose', an app for public safety combined with streaming and enable
  - Free cellular access in case of "panic" mode
  - SLA and QoS for non-panic mode
- Implement steering mechanism to forward the emergency traffic to the appropriate destination (such as police, fire station)

PoC Provide free xpose service for panic mode
Forward fire event to the fire station

m-Health

- Utilize RAN Slicing to support priority by dedicating resources for critical m-Health application
- Examples : Remote medical treatment app.
  - Solution partner is TBD

PoC PoC an m-Health app. running with stable QoS under congestion situation

M-CORD Lite

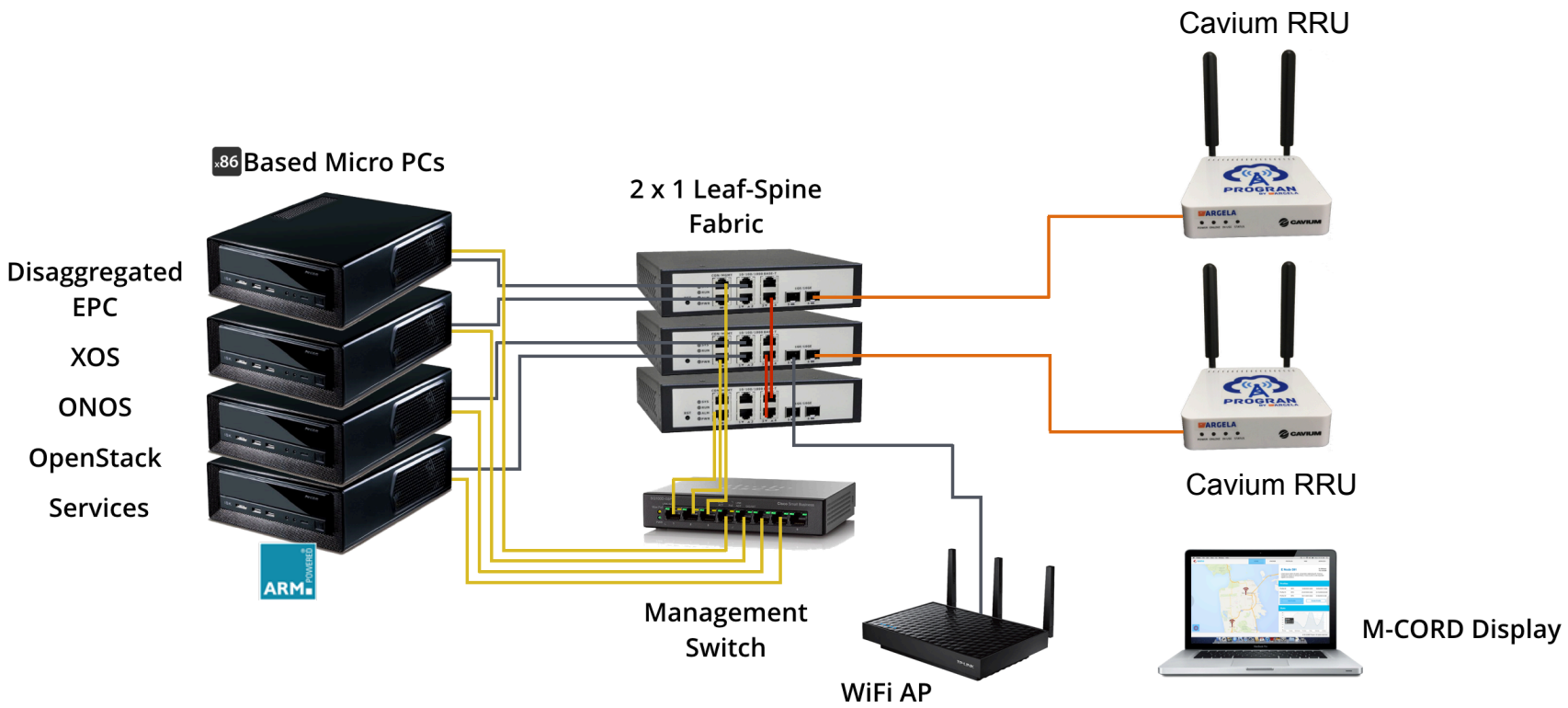
Goals, Functionalities, Packaging

- **Goals**
  - Build a portable, inexpensive, & easy to replicate M-CORD for development, experimentation, demonstration
  - To enable experimental deployments in support of acceleration of 5G
- **Functionalities**

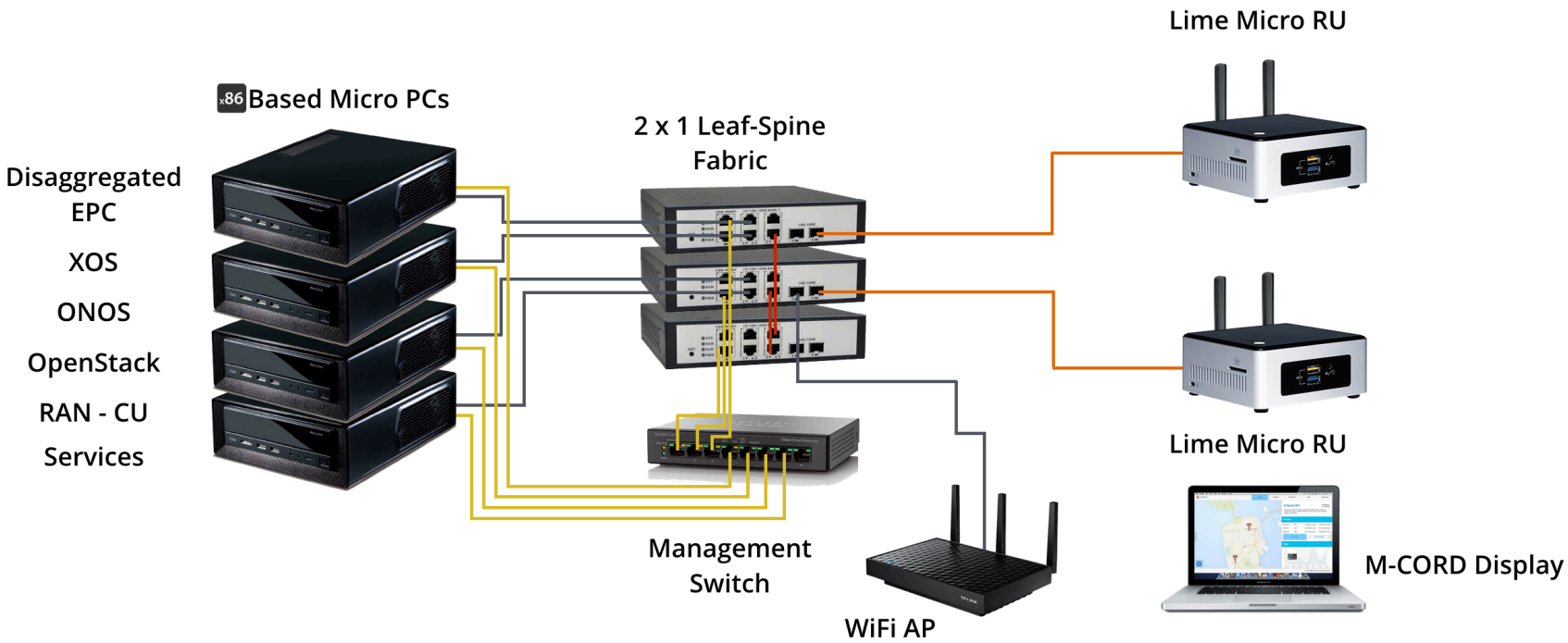
• Disaggregated, virtualized, sliceable RAN • Disaggregated, virtualized, sliceable EPC • Mobile Edge Applications	+	• ONOS, XOS, Openstack/Docker • OpenFlow enabled networking

- **Packaging and Form factors**
  - No more than quarter racks or desktop environment
  - Run on standard power
  - Appropriate for office environment
  - Desirable cost 10k – 20k
  - Should support 16-32 UEs

Solution Candidate (1)



Solution Candidate (2)



M-CORD in Portable Rack

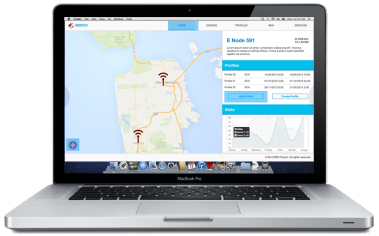
OpenFlow Switch

vBBU

Mobile Edge Applications

Disaggregated EPC

XOS, ONOS, OpenStack



M-CORD Display

M-CORD Implementation Options

	M-CORD Lite		M-CORD Rack	
TYPE	**with Cavium**	**with Intel**	**Portable Rack (6/8U)**	**Carrier Grade full rack**
CONNECTIVITY	1 OpenFlow Switch	1 OpenFlow Switch	3 COTS, Leaf & Spine switches	Carrier Grad, Leaf & Spine
# OF SERVERS	3 x86 + 1 ARM	4 x 86	4 x86 + 1 ARM	5 x86 + 1 ARM
CPU	16-core Intel, 4 core ARM	16-core Intel	24-core Intel, 48 core ARM	24-core Intel, 48 core ARM
RAN	Cavium vBBU + RRH	Intel vBBU + USRP RRH(or Lime)	Cavium vBBU + RRH or Intel vBBU + USRP RRH(or Lime)	
EPC	Quortus	?	Netcracker, Radisys, Quortus vEPC	Netcracker, Radisys, vEPC
UE CAPACITY	16 UEs per RRH	?	16 UEs per RRH	16 UEs per RRH
# OF eNBs	Small	Small	Medium	Large
Power consumption	150 W X 5 = 750 W	150 W X 5 = 750 W	1000 W * 8 = 8 KW	~14-20 kW
Weight	6 x 5 = 30 lbs	6 x 5 = 30 lbs	~300 lbs	
Size	(3.8”*5) 19” x 8.7” x 12.9”	(3.8”*5) 19” x 8.7” x 12.9”	17.3’’ x 25.6’’ x 37.7’’ (6U Box)	14~18U
Features	Virtualization, Disaggregation, Slicing	Virtualization, Disaggregation, Connectionless, Slicing (?)	Virtualization, Disaggregation, Slicing, Multi-RAT	Virtualization, Disaggregation, Slicing, Multi-RAT
Apps.	Streaming, IoT, AR/VR	IoT, Streaming, AR/VR	IoT, Streaming, AR/VR	IoT, Streaming, AR/VR
Approximate Cost	10-20 K	10-20 K	~40 K	

Software on M-CORD Lite Platform

- Consensus on M-CORD Lite platform - Align with CORD
- Acquire H/W → Assemble → Test
- Create the Software Stacks (Standard CORD Stack + RAN + EPC)

	Components providers	Services	Timeline
Plan 1	Cavium, Argela, Quortus	Example ONS Services	1st PoC in Oct.
Plan 2	Radisys, Intel, Argela,	Example ONS Services	TBD

Summary

- **Disaggregated/Virtualized RAN**
  - RAN Slicing
  - Observability and Analytics
  - Flexible Disaggregation
- **Disaggregated/Virtualized EPC**
  - Core Slicing
  - Observability and Analytics
  - Connectionless
- **Mobile Edge Services**
  - CDN
  - AR/VR
  - Public Safety
  - m-Health
- **M-CORD Lite** - Agile development, experimentation, PoCnstration

E2E Network Slicing

E2E Network Analytics

Backups

Mobile-CORD

Explore 5G

ONOS/CORD Partnership

http://opencord.org/

CORD
Central Office Re-architected as a Datacenter

M-CORD Drivers = Operator Challenges

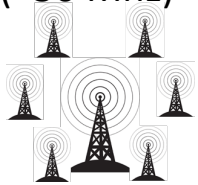
In the last 5 years

100,000%

Increase in Wireless Data Traffic

$50 Billion

Spectrum investment (~50 Mhz)



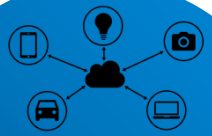
$5 Billion

LTE System investment (RAN, EPC)

FREE WiFi

Alternative "shared" access

(WiFi, LAA, LTE-U)



New and very diverse devices with IoT

Vendor Lock-in Interfaces

Slowing revenue growth

M-CORD Drivers: Proprietary to Open

State of the infrastructure: Built with closed proprietary boxes

- Inefficient utilization including sub-optimal use of precious radio resources
- Inability to customize for various customers
- Slow in creating innovative services
- Cannot support industry-specific IoT scenarios

Mobile infrastructure needs re-architecting

About M-CORD

- **Mobile CO Re-architected as DC**
  - Economics of DC
    - ✓ Infrastructure mainly built with commodity H/W and white-boxes
  - Agility of a Cloud provider
    - ✓ Software platform that enable rapid creation of new services

- **Mobile Edge**
  - Provide services at the edge of network to leverage the Benefits of;
    - ✓ Proximity to Users
    - ✓ Reduced latency, Reduced backhaul load
    - ✓ Utilizing information related to Radio Resource

- **Micro-services**
  - Provide services and infrastructure well suited for the targeted enterprise;
    - ✓ Lightweight platform on-demand
    - ✓ Independency and autonomous control in accordance with centralized orchestration
    - ✓ Enterprise specific SLA

M-CORD Guiding concepts

- SDN/NFV
- Open source
- Open interfaces (RAN/Core)
- Open platforms
- Commodity hardware
- Programmability
- Observability
- Service assurance, Performance
- Coexistence with existing infrastructure

Capabilities to be Explored on M-CORD

✓ Enhance resource utilization

- Real-time resource management
- Exploit multiple Radio Access Technologies
- Real-time analytics framework

✓ Provide customized services and better QoE to customers

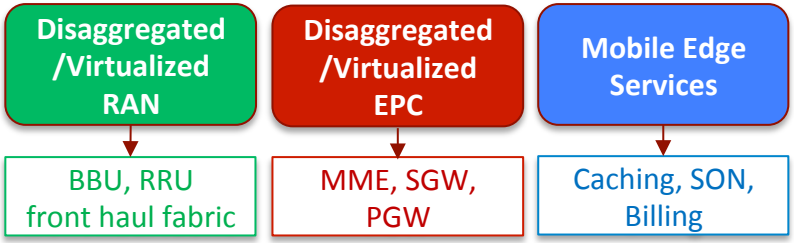
- Customized service composition
- Differentiated QoE based on service requirements: latency and throughput
- Enable use cases: IOT, smart cities, hospital, education, industrial M2M apps

✓ Agile and cost-efficient deployment

- On-demand deployment
- Virtualized /disaggregated RAN and EPC
- Commodity H/W and open source

QoE: Quality of Experience, **RAN**: Radio Access Network, **EPC**: Evolved Packet Core

M-CORD: Mobility Technology Trends + CORD



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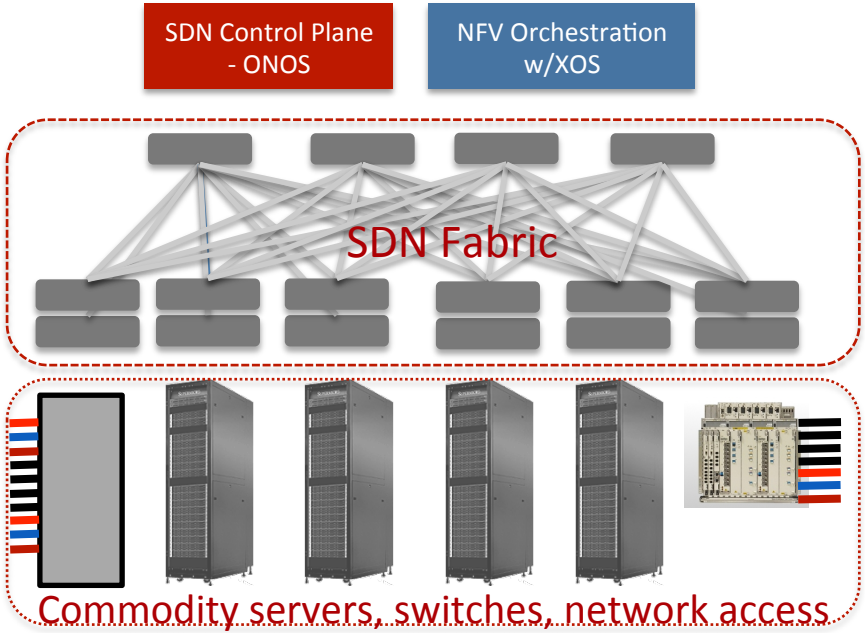
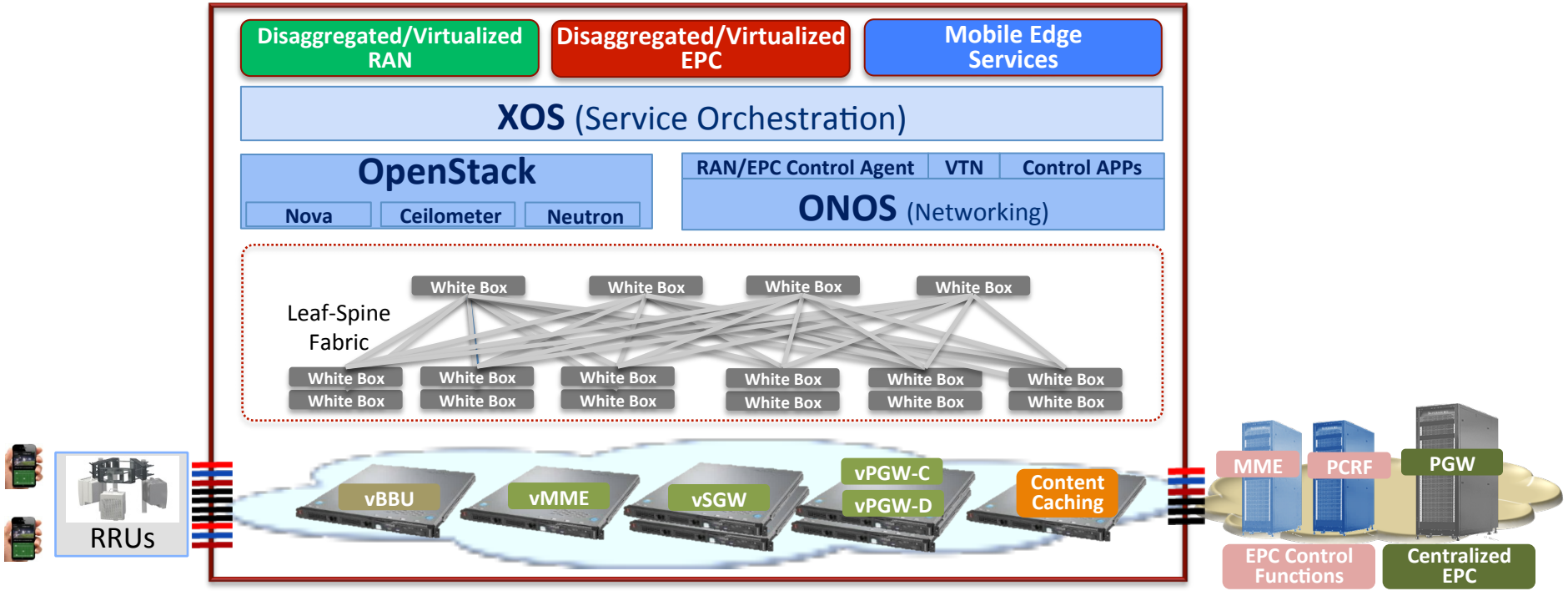


M-CORD: A Platform for 5G Exploration

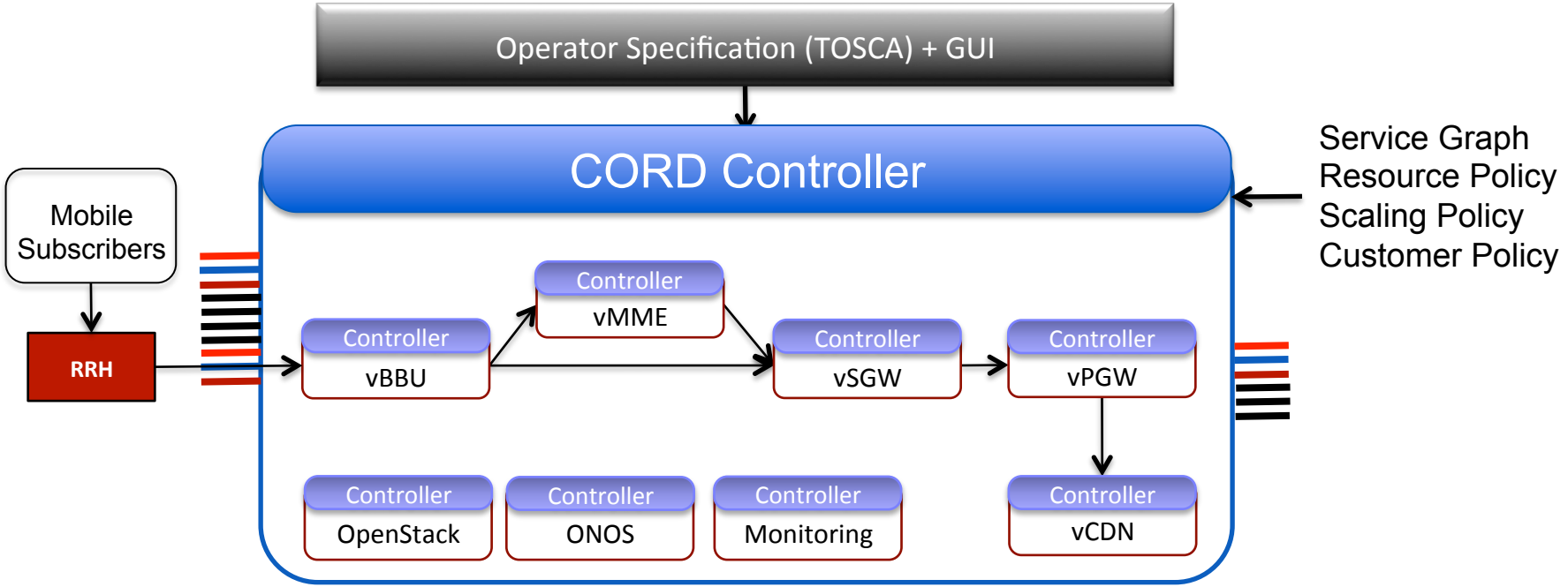
M-CORD Architecture Framework



[M-CORD mobile edge]

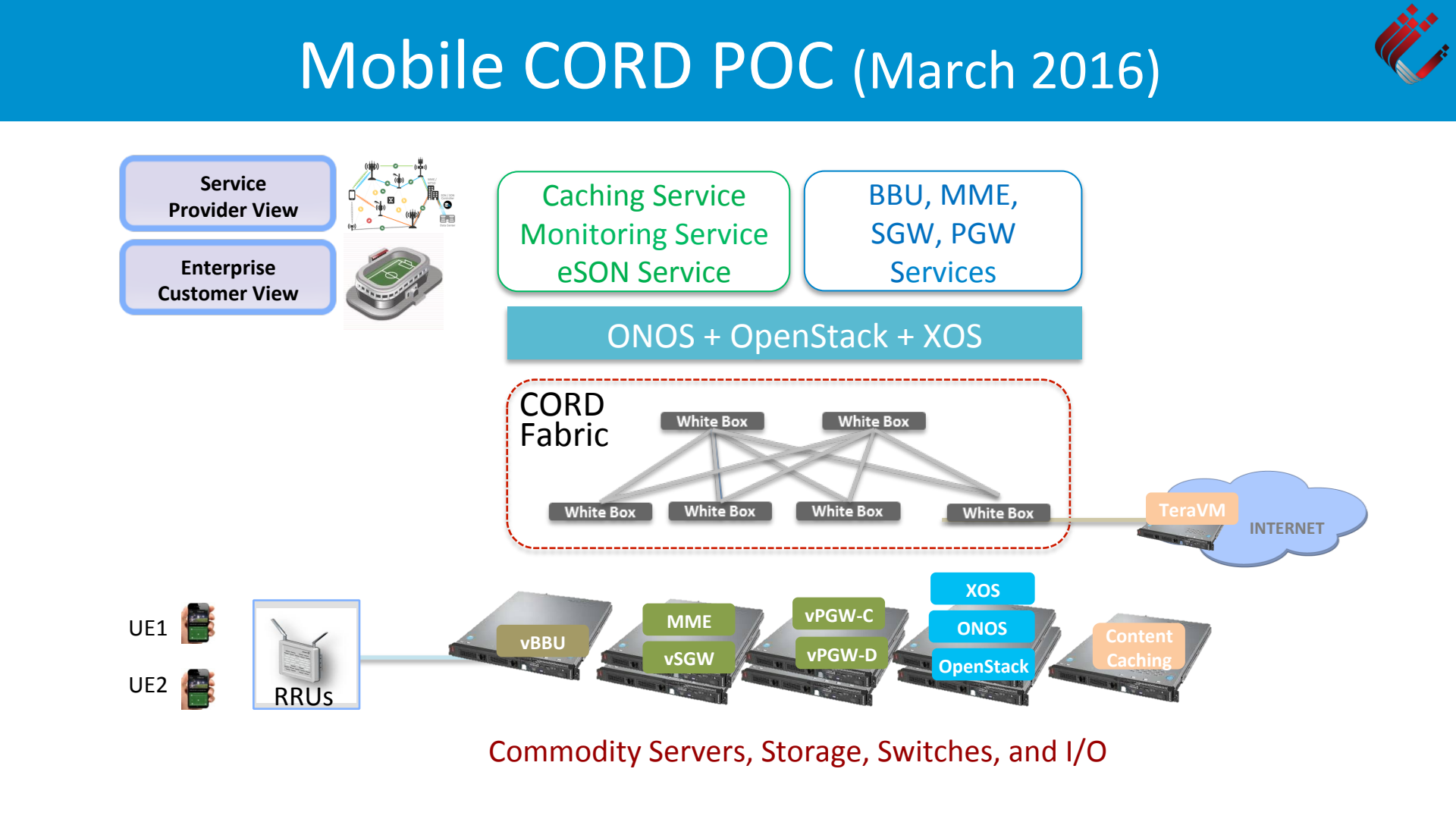
[Mobile Core]

M-CORD Software Architecture

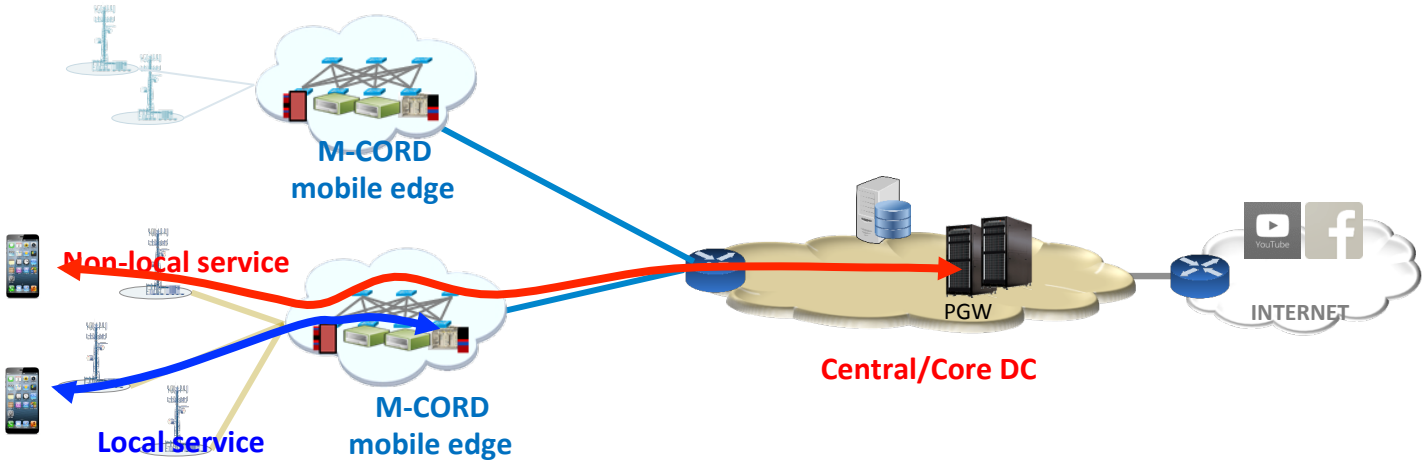


- *Mobility Functions modeled as XOS services*
- *Utilizes XOS service composition*

Mobile CORD POC (March 2016)



M-CORD Service example: Video from the Edge



- Local service : UE1 → vBBU → vSGW → local-PGW
- Non-local Service : UE2 → vBBU → vSGW → global-PGW

M-CORD PoC: Infrastructure & Collaborators

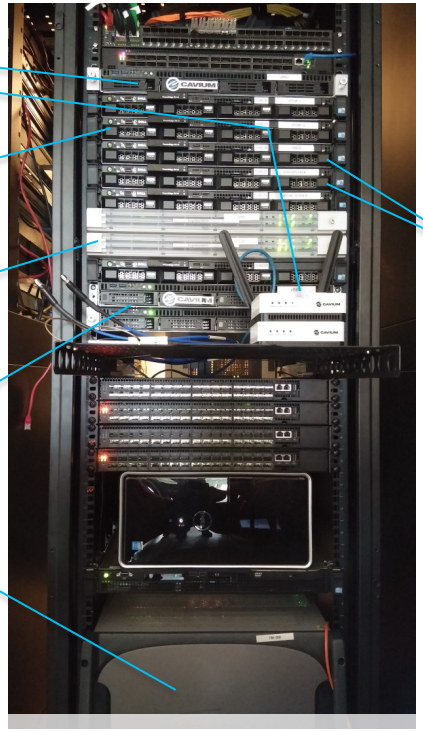
CAVIUM — vBBU RRU

radisys — vPGW-C vPGW-U

NEC Netcracker — vMME vSGW

airhop communications — eSON

COBHAM — UE, App Emulator



ON.LAB — ONOS XOS

[M-CORD POC Rack]

RRU: Remote Radio Unit, **(v-** : virtualized**)**, **vBBU**: Baseband Unit, **vMME:** Mobility Management Entity, **vSGW**: Serving Gateway, **vPGW-C/D**: PDN Gateway Control plane/Data plane, **SON**: Self Organizing Network