Mobile CORD (M-CORD)

Open Reference Solution for 5G

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CORD™

Central Office Re-architected as a Datacenter

A brief history - SDN origins

2006 - Clean Slate Program - Stanford, Berkeley, NSF
First open source projects - Mininet, OVS ...
Beginnings of Software Defined Networking (SDN)
Created OpenFlow standard

2011 - Open Networking Foundation
      Non profit - advance SDN and OpenFlow for industry benefit
Open Networking Lab
      Non profit - Open Source network infrastructure development
            for public benefit

2014 - Open Network Operating System (ONOS) launched
2016 - Central Office Rearchitected as a Data Center (CORD) launched
Both are Linux Foundation Collaborative Projects

Partners

6 Leading service providers make solutions <u>relevant</u> to them

10 Leading vendors help make solutions <u>real</u> & <u>ready</u> for deployment

onosproject.org

ONOS® is building a better network.

The Open Network Operating System (ONOS) is a software defined networking (SDN) OS for service providers that has scalability, high availability, high performance and abstractions to make it easy to create apps and services. The platform is based on a solid architecture and has quickly matured to be feature rich and production ready. The community has grown to include over 50 partners and collaborators that contribute to all aspects of the project including interesting use cases such as CORD.

LEARN MORE ABOUT OUR MISSION

ONOS Project Collaborators

Collaborating organizations help <u>grow the community</u> and grow the <u>impact</u>

opencord.org

CORD Project Collaborators

"Many people might not realize that running their own cellular networks is not only possible but also doesn't require substantial technical expertise" – Khashif Ali, Facebook

Key Takeaways

CORD is bringing economics of the datacenter and agility of the cloud to the access network through open source collaboration
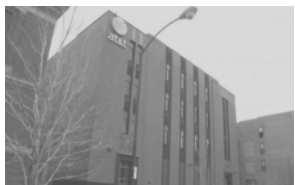
M-CORD is CORD optimized for the mobile network – both access and core are virtualized and disaggregated

M-CORD is the perfect platform for building 5G solutions

CORD (Central Office Re-Invented as Data Center)
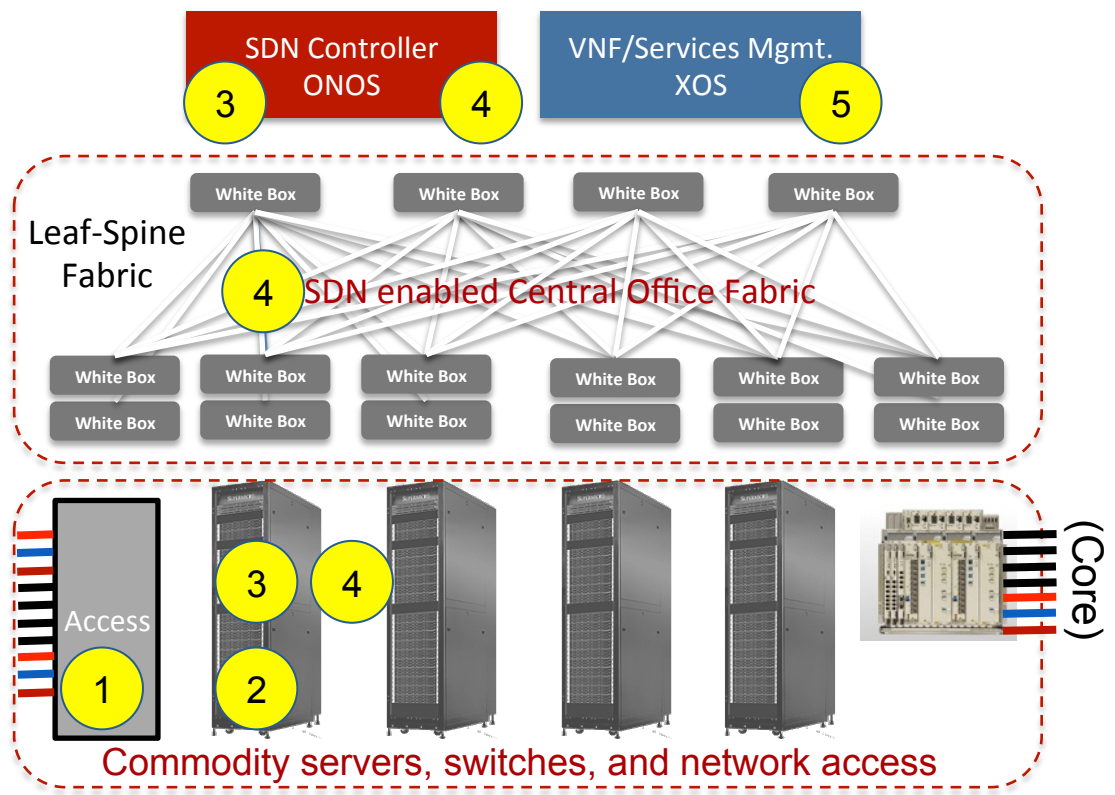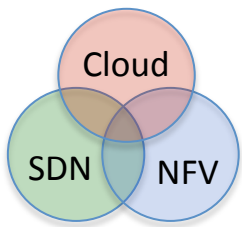## High Level Architecture

CORD Project

CORD Vision

- Built around **commodity servers** and **white-box switches**, and to the extent possible, leverages merchant silicon.

- Enables **disaggregation**, and is not restricted to running bundled legacy VNFs in virtual machines.

- Leverages **SDN** to both interconnect the virtual and physical elements and as a source of **innovative services**.

- **Extensible platform** that can be customized to include multiple access technologies and services.

- Adopts best practices in building, composing, and operating **scalable multi-tenant cloud services**, including support for multi-tenancy.

CORD - Multi Access Architecture
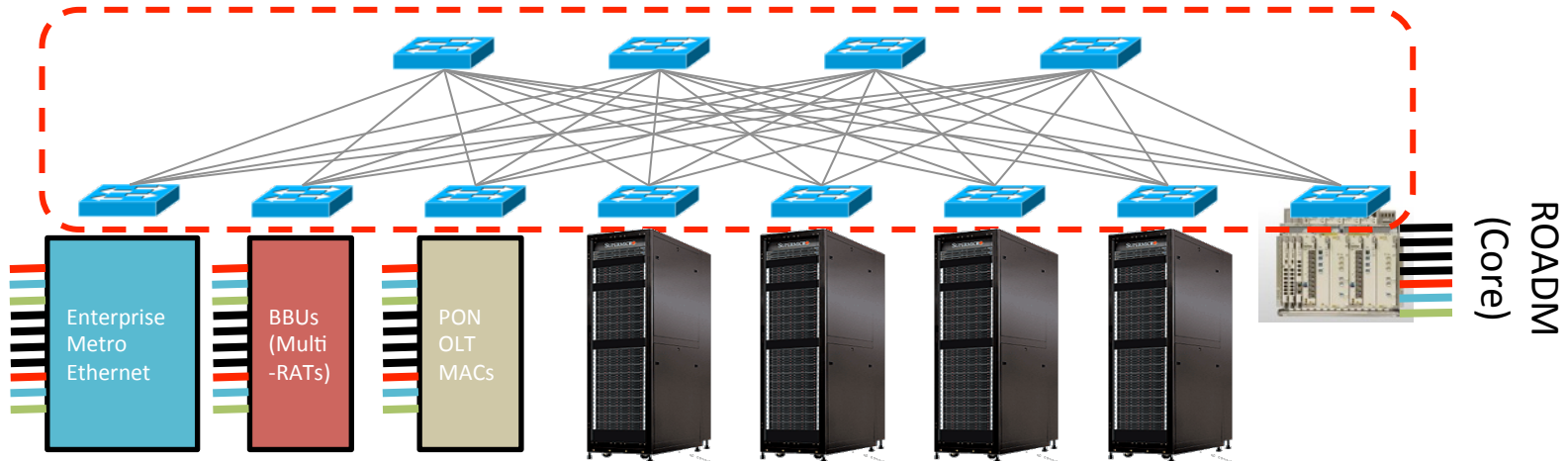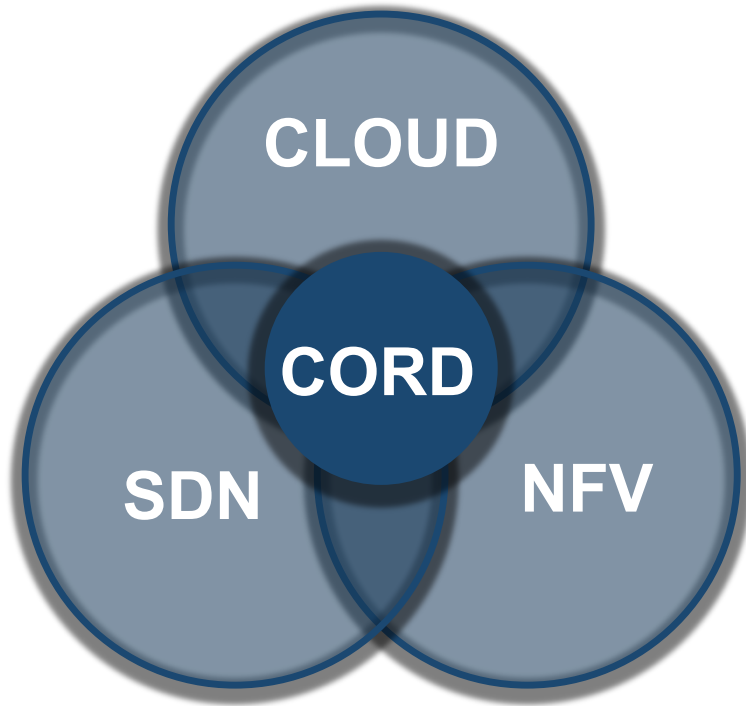
- EPC – Disaggregated and virtualized - running on (distributed) access cloud over programmable VN/fabric

- RAN - Disaggregated (split stack into CU & RU), virtualized CU, configurable and programmable by ONOS

M-CORD as an Access Cloud
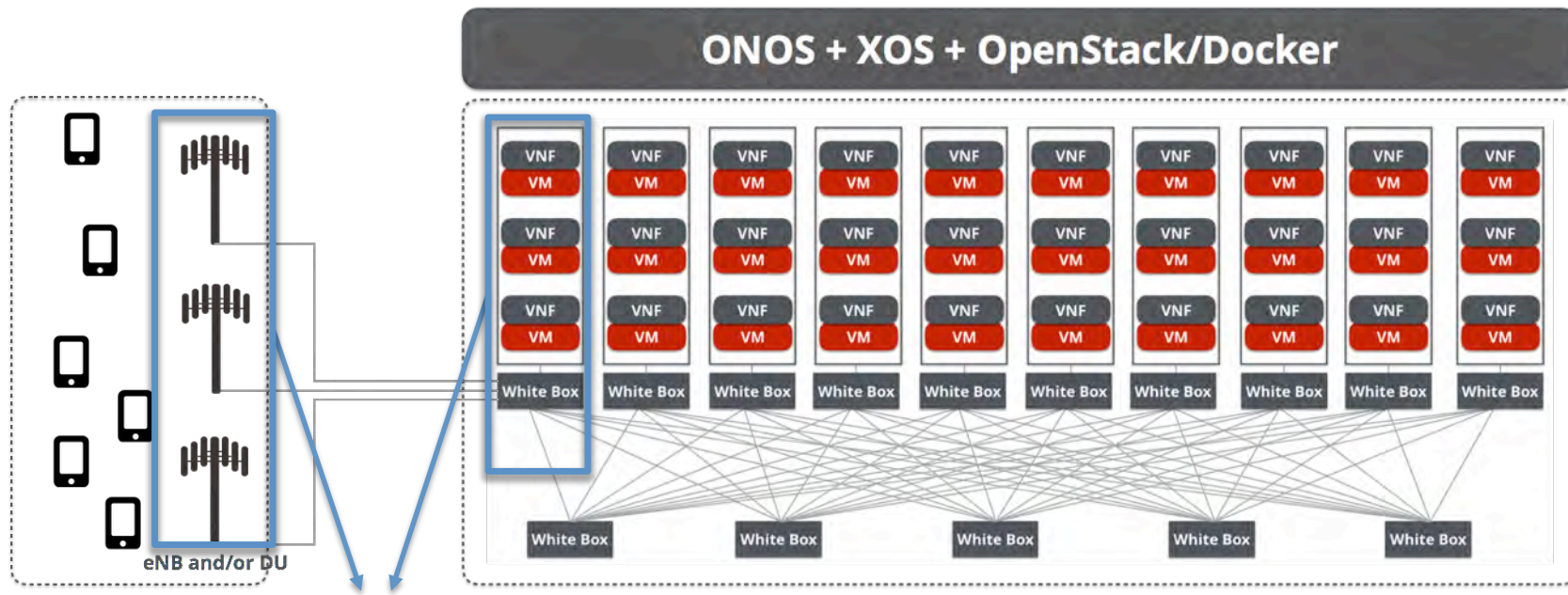
ONOS-Controlled eNB (slicing)
Radio Access-as-a-Service – customized business solutions for verticals

CORD Software Components

Orchestration (ONAP…)

Service definitions (Tosca…)

XOS – Data Model, Synchonizers

VM, Container as a service (OpenStack, Docker…)

Network as a service (ONOS…)
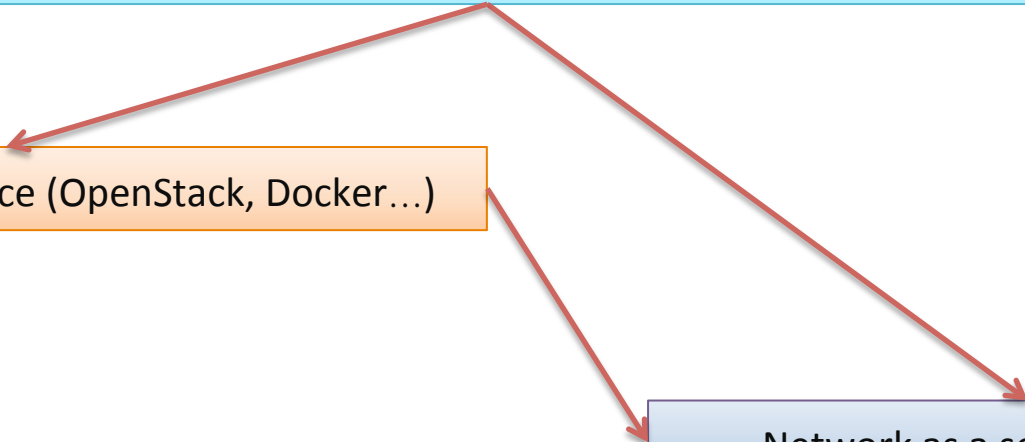
Reference Implementation – Software

Access- as-a-Service	EPC- as-a-Service	RAN-Slice- as-a-Service	CN-Slice- as-a-Service	Connectionless- EPC-as-a-Service	GTP-less EPC-as-a-Service	Public Safety- as-a-Service	Monitoring & Testing as-a-Service

XOS

CU	vMME	vHSS	vS-GW-u	vP-GW-u	Net Cookie Check
Ceilometer	vMM	vSM	vS-GW-c	vP-GW-c	vIoT-GW-u

OpenStack/Docker

VTN	Fabric Control	SD-RAN Control	Slicing Control	vS-P-GW-c

ONOS

Reference Architecture: Model-Based
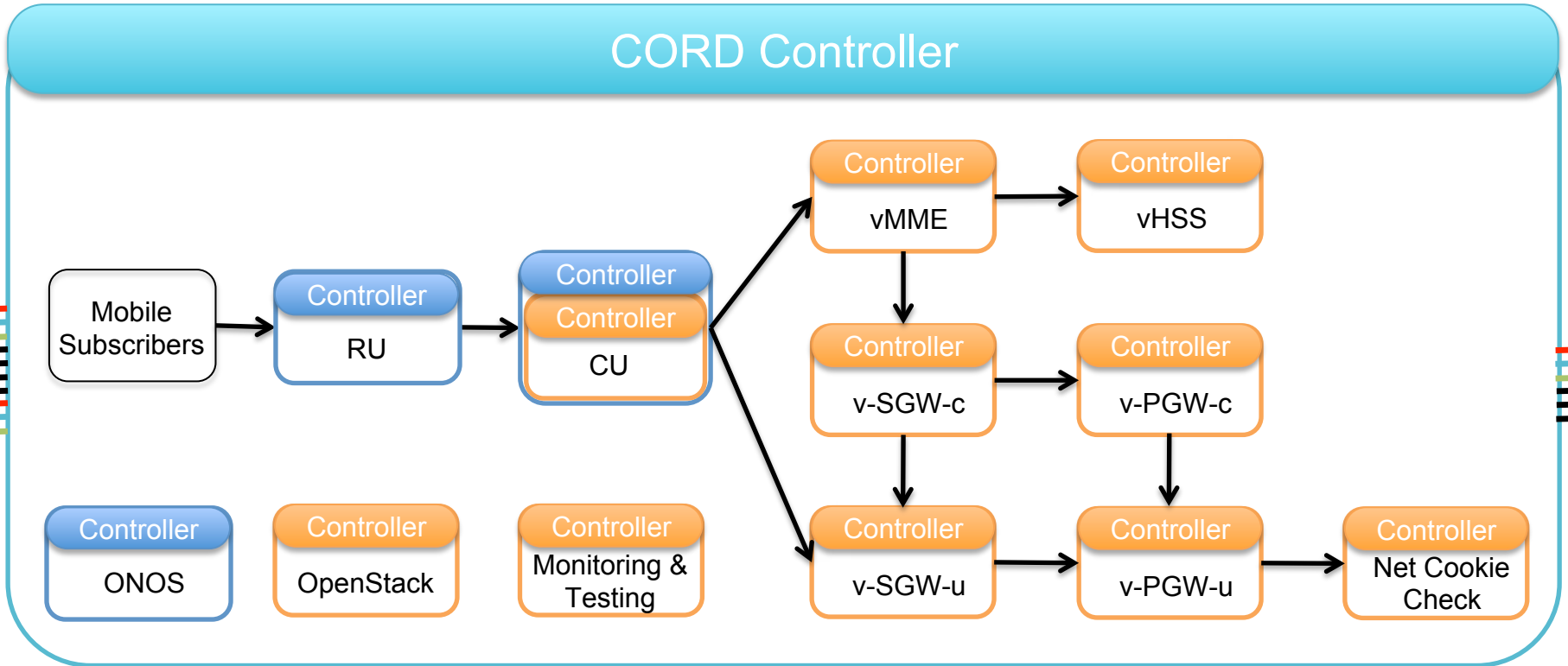
Arrows show associations, not data flow

Think of service *graphs*, not just chains

Runtime Interface
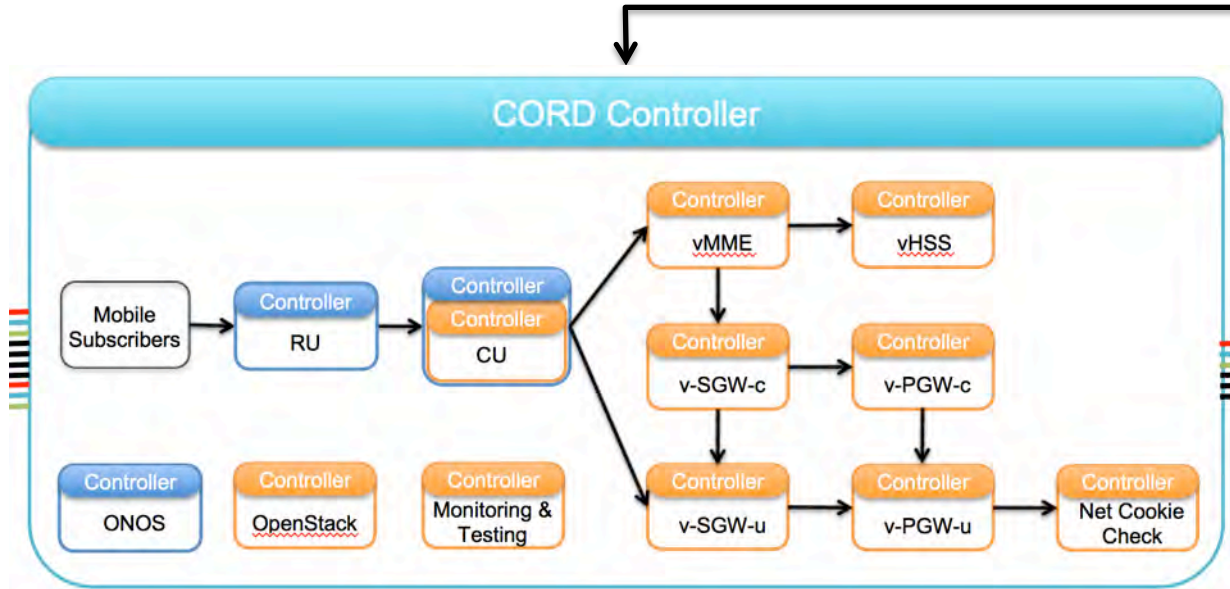
Runtime Interface
 – On-board, Provision Services
 – Instantiate, Control Instances
 – Report Inventory, Analytics

Scale Down – Lite-and-Right CORD
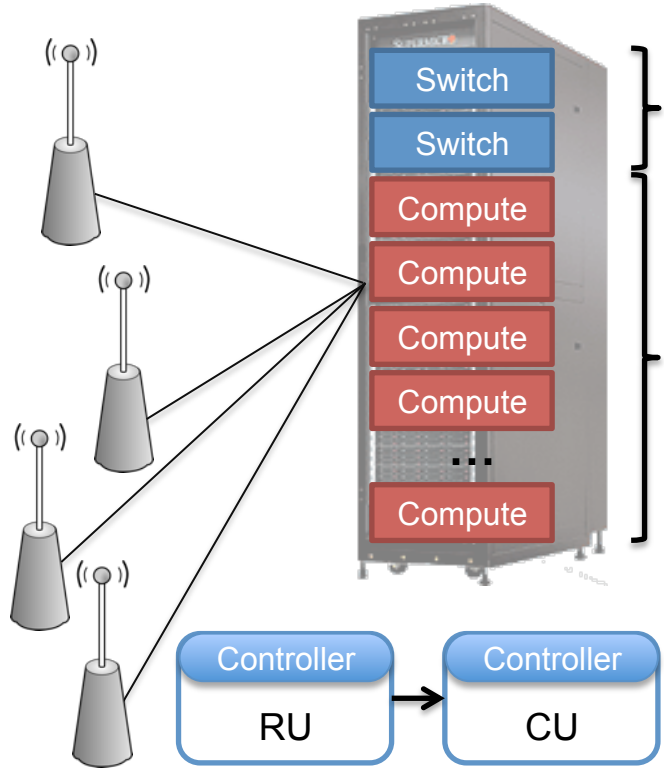
Single/Partial Rack (No Spine Switches)

Minimal Compute (All services, including ONOS, XOS and RAN CU, run in containers)

If you also "scale down" the software so the Service Graph includes just RU + CU, the resulting configuration = *"SD-RAN"*

Why Model Driven? Beyond Micro Services

Micro Service Arch

- Single Application
  - Single Trust Domain
  - Fixed Set of Services
- Fixed Infrastructure
  - Virtualization Technology
  - Network Functionality

CORD's Service Control Plane

- Multi-Tenant Platform
  - Mediate Trust Across Domains
  - Configurable Set of Services
- Programmable Infrastructure
  - Multiple Virtualization Technologies
  - SDN Control Apps as Services

Model-Driven Design

Models are the definitive specification of the architecture

      Defines the abstract objects and the relationships among them

      Predicates (first order logic) defines actions on models

Architecture is "executed" to operationalize the system

      Represents the system's authoritative state

      Auto-generates all Northbound APIs

      Enforces security policies and engineering invariants

      Activates the data plane (backend components)

Model-Driven Design

Architecture evolves over time

On-board new models to extend the architecture

Add invariants (predicates) to reflect experience

New user requirements (from operators)

New engineering constraints (from developers)

Summary – beyond micro services

Micro-Services are a tried-and-true way to build scalable apps

DevOps is an agile way to manage and control scalable services

But...

- Limited security model → Single trust domain
- Limited flexibility → A solution, not a platform
- Limited use of SDN → Plumbing, not a source of services

Solution...

- Layer Operations-as-a-Service on top of Micro-Services
- Leverage centralized Data Model to "drive" DevOps tools
- Leverage SDN as a source of innovative services

M-CORD PODs

M-CORD Micro

- Built with Intel NUCs and 4-port OF Switches
- 2 x 3 spine-leaf
- Lowest cost
- Targeted for demos and lab trial

M-CORD Mini

- OCP compliant
- 6U compact
- x86 and ARM COTS servers
- Low cost
- Targeted for lab trial and PoCs

M-CORD Mini (ARM)

- OCP compliant
- 6U compact
- ARM COTS servers
- Low cost
- Targeted for lab trial and PoCs

M-CORD POD

- Telco OCP compliant
- 16U
- Targeted for field trial
- Modular and scalable
- x86 and ARM COTS

Mobile CORD Enhancements to LTE

Radio Access Network

1. Build CORD Platform: commodity HW, open source SW

2. Disaggregate, virtualize boxes
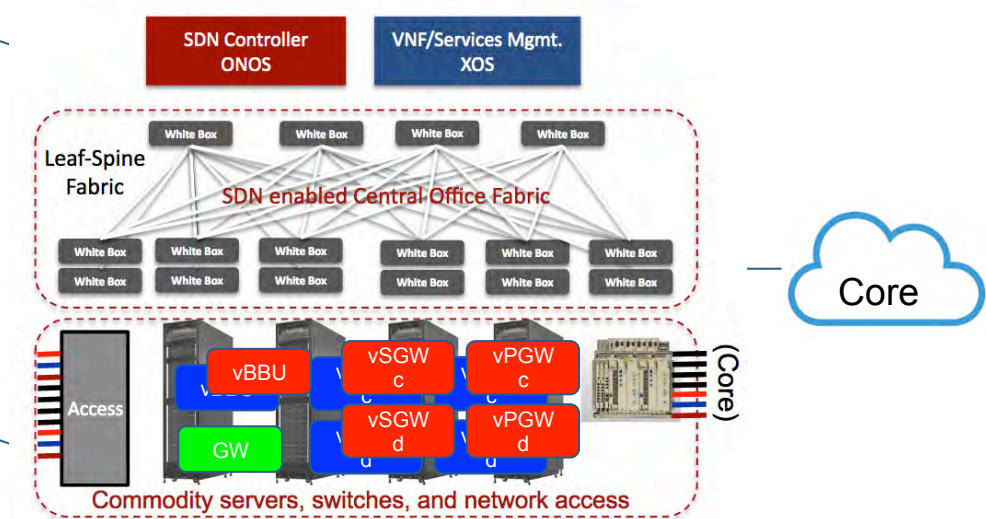
4. Add "network cookies" to apps and classification at RAN

RRU

SDN Controller ONOS

VNF/Services Mgmt. XOS

Leaf-Spine Fabric

White Box White Box White Box White Box

SDN enabled Central Office Fabric

White Box White Box White Box White Box White Box White Box
White Box White Box White Box White Box White Box White Box

Core

Access

vBBU vSGWc vPGWc
GW vSGWd vPGWd

(Core)

Commodity servers, switches, and network access
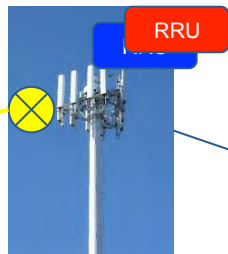
3. "Slice" the RAN and Core (Cloud scaling)

5. Add connectionless gateway

M-CORD as an Enabler for Rapid Innovation

Addressed 5G Key Principles and Concepts	M-CORD Solutions
Control and User Plane Separate (CUPS)	CUPS Compliant EPC
Disaggregation and modularization	Disaggregated EPC, Further Disaggregation of MME
Network Slicing	Programmable Core Network Slicing Programmable RAN Slicing Orchestratable E2E Slicing
Flow Based QoS Mechanism	Use of Network Cookies for UE-programmable flow based differentiation
Reusable Services	XOS treats everything as a service – a service may be invoked by another service

M-CORD as an Enabler for Rapid Innovation

Addressed 5G Key Principles and Concepts	M-CORD Solutions
GTP-Tunnel Establishment Overhead for IoT	A GTP-Tunnel-less EPC Slice for IoT
Scalable user plan functions (UPF)	A scalable UPF with associated CPF realized on the SDN control plane

Open Source Disaggregated EPC* **+** Programmable E-UTRAN (3GPP RAN) **+** M-CORD **=** LTE+

*Radisys and Sprint/Intel versions both 3GPP compliant

M-CORD Innovations at ONS 2017

INFRASTRUCTURE

I   **Optimized CORE for IoT**

II   **Scalable & Connectionless CORE**

III   **End to End Network slicing**

OPEN SOLUTION FOR
SDN NFV
5G
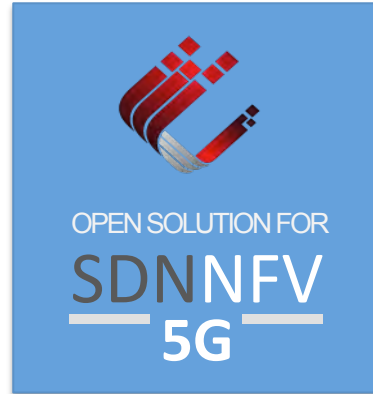
SERVICES

IV   **Premium Safety Service**

V   **Analytics as a Service**

Virtualized, Disaggregated, and Programmable

M-CORD Innovations: Optimized CORE for IoT

INTERNET OF THINGS

4G LTE

Static IoT on current LTE leads to excessive signal overhead

M-CORD

| Mobile Edge Services | Disaggregated & Virtualized RAN and CORE | Analytics Services |

CORD MANAGEMENT & CONTROLLER

Leaf-Spine Fabric

OPEN COMPUTE HARDWARE

+
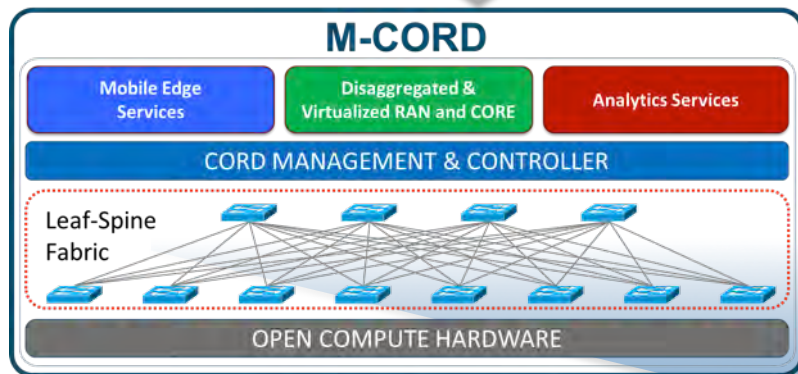
- MME disaggregation
- IoT GW
- Core slicing

Optimized Mobile CORE for Static IoT

IoT + Non-IoT on current LTE leads to excessive signal overhead

M-CORD

Mobile Edge Services

Disaggregated & Virtualized RAN and CORE

Analytics Services

CORD MANAGEMENT & CONTROLLER

Leaf-Spine Fabric

OPEN COMPUTE HARDWARE

+
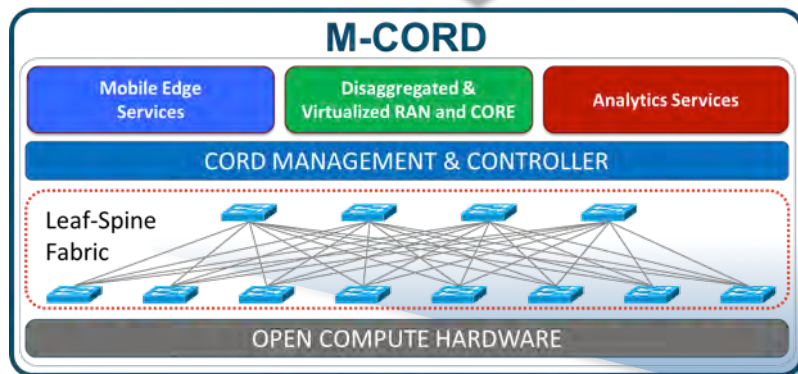
- Flow classification at RAN
- GTP & GTP-less support
- Scalable Connectionless GW

SDNized Scalable & Connectionless CORE

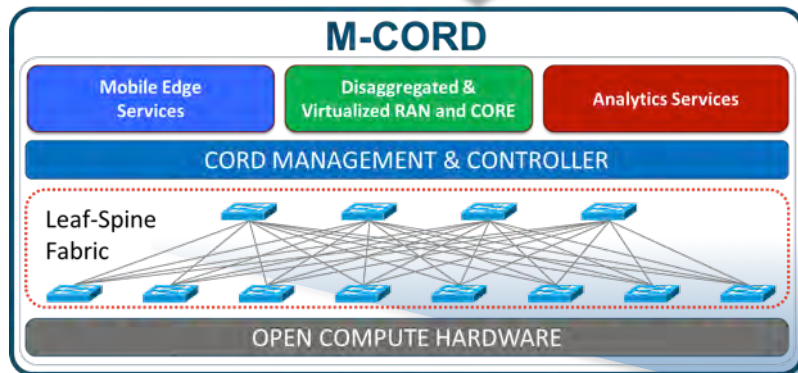# M-CORD Innovations: End to End Slicing

5G REQUIREMENTS

- Network slicing
- Differentiated traffic treatment for diverse devices, users, & services
- Mobile Virtual Network Operator (MVNO)

M-CORD

| Mobile Edge Services | Disaggregated & Virtualized RAN and CORE | Analytics Services |

CORD MANAGEMENT & CONTROLLER

Leaf-Spine Fabric

OPEN COMPUTE HARDWARE

+

- RAN & CORE slicing
- E2E Orchestration & Network Slicing as a service

Dynamic & Programmable End to End Slicing

M-CORD SERVICES: Network Cookies & Public Safety

911 EMERGENCY

Safety service

Requires more intelligence with diverse destination & format

audio   video   location   map

M-CORD

Mobile Edge Services | Disaggregated & Virtualized RAN and CORE | Analytics Services

CORD MANAGEMENT & CONTROLLER

Leaf-Spine Fabric

OPEN COMPUTE HARDWARE

+
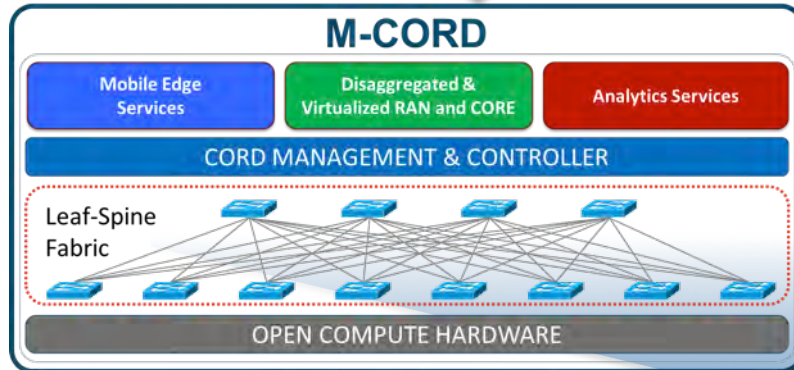
- Traffic classification
- Network cookie
- User-driven application

Premium Public Safety Service
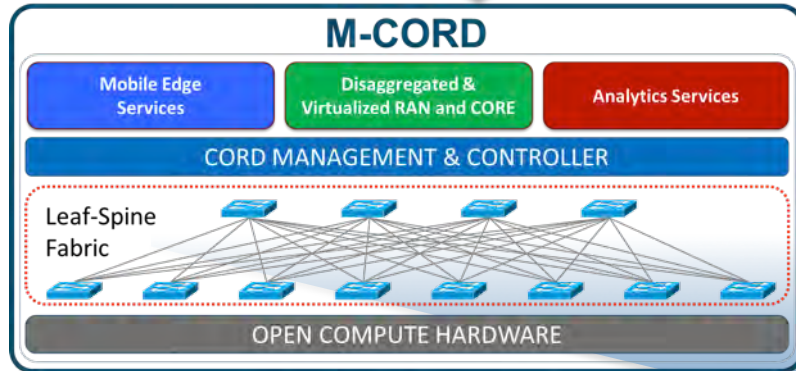
CORD Project and xRAN Consortium Align to Build Carrier Grade Software for Next Generation Radio Access Network (RAN)

FEBRUARY 23, 2017

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xRAN and M-CORD partnership show immediate value of ONF's new software defined standards approach

xRAN Consortium

Extensible Radio Access Network

Common Goal – modular, extensible RAN

Decouple Control and User planes

Modular eNB stack

Standard NB/SB interfaces

Multi-vendor

Logically centralized control

Dr. Sachin Katti, Stanford professor, xRAN founder is Chief Scientist for Mobility at ONF

XRAN+M-CORD: A Standard Software Substrate for Next Generation Mobile Infrastructure

APPLICATION ADMISSION CONTROL   NETWORK SLICING MANAGEMENT   PUBLIC SAFETY APPLICATIONS   ECOMP ORCHESTRATION

XRAN Standardized Northbound API

ONOS (w/ XRAN Controller) + XOS + OpenStack/Docker

XRAN Standardized Southbound API

DISAGGREGATED (SPLIT) VIRTUALIZED RAN   EDGE CLOUD   DISAGGREGATED (SPLIT) VIRTUALIZED EPC

M-CORD

ON.Lab to focus on implementation of xRAN into M-CORD platform with active guidance and participation of Sachin Katti

XRAN

Architecture and interface/API spec

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ETWORK"   "CHINA UNICOM & CAVIUM TRIAL M-CORD"   "AMC LAUNCHES PREMIUM TV OPTION FOR XFINITY TV"   "KONTRON, S&T MERGE"   "CLOUD BECOMES THE UNIFIED ENTRANCE

▶ MOBILE / MEC (MOBILE EDGE COMPUTING)

China Unicom & Cavium Trial M-CORD

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6/30/2017

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SAN JOSE, Calif. and SHANGHAI, China -- Cavium, Inc. (NASDAQ: CAVM), a leading provider of semiconductor products that enable secure and intelligent processing for enterprise, data center, wired and wireless networking and China Unicom today announced a targeted program for testing 5G target use cases on M-CORD SDN/NFV platform by using Cavium silicon-based white box hardware in M-CORD racks populated with ThunderX® ARM-based data center COTS servers and XPliant® programmable SDN Ethernet switch-based white box switches.

China Unicom and Cavium will shortly commence trials in several locations in mainland China to explore the new service.

Cavium and China Unicom will demonstrate Multi-access Edge Computing (MEC) use cases developed through previously announced collaboration with China Unicom utilizing the ON.Lab M-CORD (Mobile Central Office Re-architected as data center) SDN/NFV platform at the Mobile World Congress Shanghai from Jun 28th – Jun 30th 2017. The conference will take place at the Shanghai New International Expo Centre (SNIEC), in the China United Network Communications Group Co., Ltd ("China Unicom") booth at stand location W4.B20.

EDUCATIONAL RESOURCES

sponsor supplied content

■ The Self-Driving Network- Part 1: A Bolder Vision for the Industry

■ Preparing Junos OS for the Future- An Architectural Update

■ vMX Lightweight 4over6 Virtual Network Function - Juniper and Snabb in a Docker Container

■ Secure-24 Leverages Virtual Firewalls and Automation to Deliver New Managed Cloud Hosting Services in Hours

■ Four Reasons to Automate Your Network Right Now

EDUCATIONAL RESOURCES ARCHIVE

OPEN SOURCE EPC

xRAN INTEGRATION

MULTI-ACCESS CORD

PRIVATE LTE

FIELD TRIAL READY M-CORD
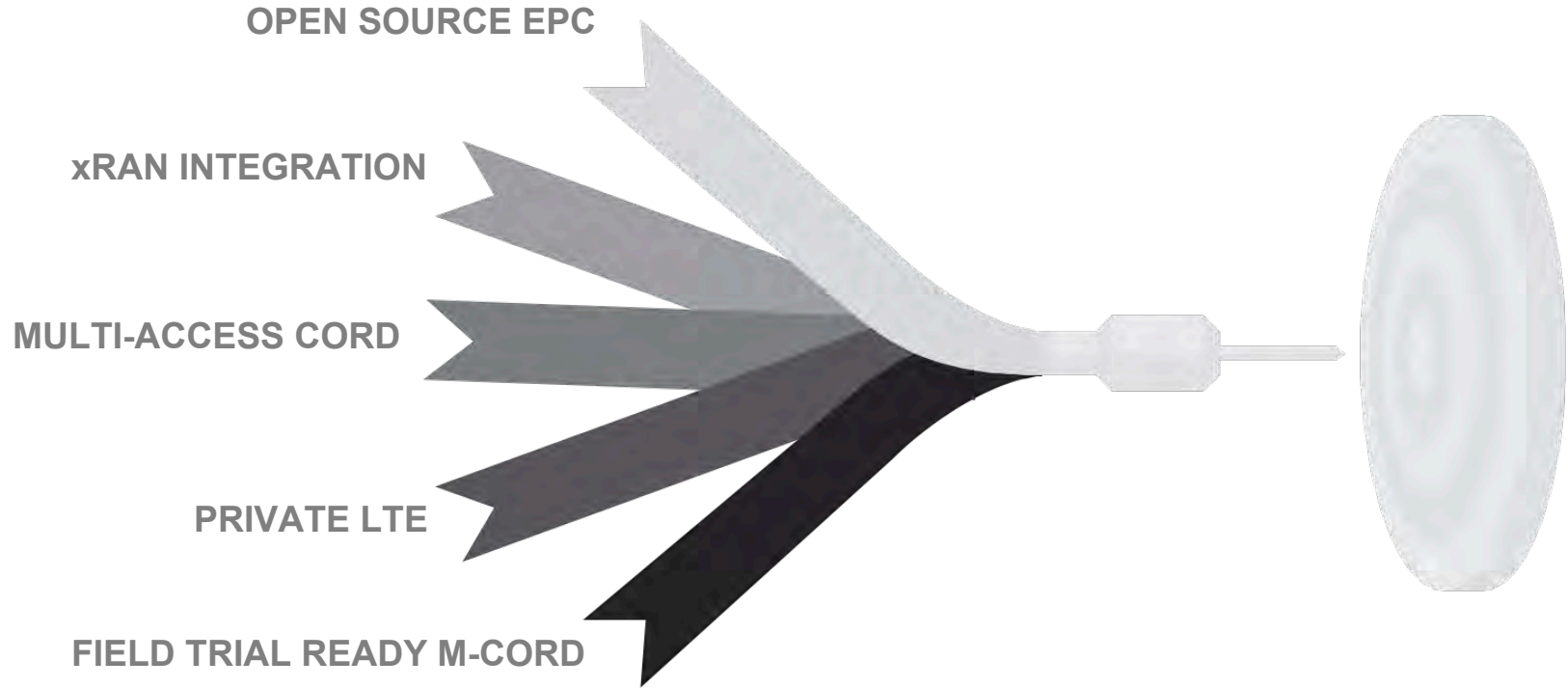
M-CORD @ MWC Americas'17

POTENTIAL POCs

xRAN	LINK AGGREGATION	PERFORMANCE TESTING
CBRS	MULTIACCESS CORD	CONNECTIONLESS v2.0
ONAP	NETWORK COOKIES	OPEN SOURCE EPC v2.0

MWC AMERICAS

SEPTEMBER 12, 2017
MOSCONE CENTER
SAN FRANCISCO, CA

Key Takeaways

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