M-CORD

Enabling the Programmable Mobile Edge Cloud

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Telcos’ Dilemma

- More than 8-fold between 2017-2022
  - Mainly due to video
  - CapEx & OpEx requirements continue to overtake value from traffic growth
  - OTTs, cloud providers, digital media companies garner a greater share of revenue
  - They do so without bearing the brunt of infrastructure cost

Voice Dominant

Traffic

Revenues & Traffic Gap

Mobile Broadband Dominant

Revenues

Time
Telcos’ Dilemma

Transform their networks to lower CapEx/OpEx and allow for rapid services innovation & deployment

Position themselves more deeply in the digital services ecosystem

DYNAMIC CONTROL /CONFIG OF MOBILE NETWORKS
PROGRAMMABLE E2E NETWORK SLICING
DYNAMIC SERVICE CHAINING
M-CORD
Enabling the Programmable Mobile Edge Cloud
**M-CORD: Enabling the Programmable Edge Cloud**

- **Disaggregate** CORE
- **Virtualize** all components
- Realize virtualized components in the **cloud**
- **SDN’ize** for programmability
- **Programmatically** instantiate CORE network slices for use case specific core network slices

- **Disaggregate** RAN
- **Virtualize** some of its components
- Realize virtualized components in the **cloud**
- **SDN’ize** for programmability
- **Programmatically** instantiate RAN slices for different use cases
M-CORD as the Edge Cloud
M-CORD as the Edge Cloud

- MMEaaS
- SGWuaaS
- SGWcaaS
- PGWuaaS
- PGWcaaS
- RANSliceaaS
- xRANaaS
- CUaaS

EPCSliceaaS

ONOS

Open Stack

CORD CP

3GPP CP

3GPP UP
M-CORD Service Graph

Controller

- Controller RU
- Controller CU
- Controller MME
- Controller HSS
- Controller SPGW-c
- Controller PCRF
- Controller SPGW
- Controller ONOS
- Controller Open Stack
- Controller CORD
- Controller SPGW-u
M-CORD XOS Interface
M-CORD Demos at MWCA 2017

- Multi-Access CORD
- E2E Network Slicing with Link Aggregation & CBRS Based Private LTE
- Open Source EPC
- xRAN Integration
- All ARM + XPliant CORD
M-CORD Roadmap: xRAN
xRAN

xRAN.org was formed to develop, standardize and promote a software-based extensible radio access network (RAN).

The xRAN architecture transforms today’s static, highly proprietary RAN infrastructure into an extensible, software-based service delivery platform capable of rapidly responding to changing user, application, and business needs.
M-CORD Roadmap: xRAN

CURRENT: xRAN ONOS App supporting xRAN SB API v4.0
ROADMAP: Support xRAN SB API v5.0
TARGET: CORD 5.0 Release
xRAN 5.0 APIs

Summary

The southbound interface of xRAN includes signaling to support the following:

• Cell configuration
• UE capability query
• Admission control
• Handover management
• Bearer management
• Measurement configuration
• Radio Resource Management
• Carrier Aggregation Control
• Dual Connectivity Control
xRAN Demo: QoE-Based Load Balancing

Initial Network State

<table>
<thead>
<tr>
<th>UE</th>
<th>Connected to Cell 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSRP</td>
<td>SINR (dB)</td>
</tr>
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Cell 1: 1TX x 20 MHz
Frequency: f1

App: Real-time video
QCI: 2 (GBR), 14 Mbps
CQI: (Cell 1: 8, Cell 2: 0)

When connected to Cell 1
Expected Load: 61%
Actual Load: 50%
QoE: NOT MET

Cell 1: 1TX x 20 MHz
Frequency: f2

App: Real-time video
QCI: 2 (GBR), 14 Mbps
CQI: (Cell 1: 7, Cell 2: 6)

When connected to Cell 1
Expected Load: 78%
Actual Load: 50%
QoE: NOT MET
xRAN Demo: QoE-Based Load Balancing

Network State Post ONOS Controlled Load Balancing

| UE | Connected to Cell 1 | | Connected to Cell 2 | |
|----|---------------------|----------------|
| RSRP | SINR (dB) | CQI | Spectral Eff | PRBs/TTI | Throughput |
| 35  | ~16 | 8 | 1.91 | 61 | ~14Mbps |
| UE 2 | Connected to Cell 2 | | Connected to Cell 2 | |
| RSRP | SINR (dB) | CQI | Spectral Eff | PRBs/TTI | Throughput |
| 31  | ~12 | 6 | 1.18 | 100 | ~14Mbps |

Cell 1: 1TX x 20 MHz
Frequency: f1

Cell 1: 1TX x 20 MHz
Frequency: f2

App: Real-time video
QCI: 2 (GBR), 14 Mbps
CQI: (Cell 1: 8, Cell 2: 0)

When connected to Cell 1
Expected Load: 61%
Actual Load: 61%
QoE: MET

App: Real-time video
QCI: 2 (GBR), 14 Mbps
CQI: (Cell 1: 7, Cell 2: 6)

When connected to Cell 2
Expected Load: 99%
Actual Load: 99%
QoE: MET
When UEs start streaming their respective videos, both eNBs become loaded.

UEs experience inter-cell-interference (ICI) on the downlink channels.

Neither UE's QoE requirement is met.
xRAN Demo: QoE-Aware ICIC

ONOS xRAN sends ICIC commands to the eNBs:

- DL Video Streaming (YouTube)
  - Requested Data Rate: 18 Mbps
  - CQI without ICI: 11
  - CQI with ICI: 11
  - Expected Load at CQI 11: 45%
  - QoE: MET

- UE 1
- UE 2

Cell 1: 1TX x 20 MHz
Frequency: f1

Power

PRB #
M-CORD Roadmap: NGIC
M-CORD Roadmap: Open Source NGIC

- **HSS**
- **MME**
- **SPGW-c**
- **ONOS App**
- **SPGW-u**
- **PCRF**
- **Billing**
- **CDR**

- Available Today as Open Source
- Available Today as Binary
- Will be Available 1Q18

(ONOS App will also be Open Source)
M-CORD Roadmap: MWC
M-CORD Roadmap: MWC

Partner Booth

ONF Booth

Partner Booth
M-CORD Roadmap: SDN’IZATION OF 3GPP UP
Current Vision on NFV & SDN

Vertically Integrated Network Function → Virtualized Network Function → 1 or more VNFs Running on Commodity Servers In the Cloud → Use SDN to control or configure forwarders to enable connectivity

GRANDFATHERED FROM TRADITIONAL CLOUD PLATFORMS
Traditional Cloud Platforms

**PRIMARY RESOURCES ARE COMPUTE & STORAGE**

**NETWORKING IS USED TO PROVIDE SCALABILITY, SYNCHRONIZATION AND/OR PROVISION OF CONNECTIVITY BETWEEN SERVICE COMPONENTS**

- **COMPUTE AND/OR STORAGE REQUEST**
- **COMPUTE AND/OR STORAGE RESPONSE**
Edge Cloud is Primarily an “Access” Cloud

Primary resources are networking.

Access cloud fabric needs to forward user and control traffic between service provider central or public clouds and the peripherals.

Process flows in VNFS.
Edge Cloud is Primarily an Access Cloud

**Primary Resources Are Networking**

**Access Cloud Fabric Needs to Forward User and Control Traffic Between Service Provider Central or Public Clouds and the Peripherals**

**What If the Service is a “Networking” Service? E.G. Access Platform Specific Routing / Switching**

- Realize It on Servers? - VNF Service -
- Realize It on Programmable Switches Controlled by SDN Applications? - SDN Control Service -
Programmable SDN Fabric for the CORE
Programmable SDN Fabric for the CORE

SDN Fabric

SDN Control

Fabric Control

VTN Control

Services OS

HSS
VM

MME
VM

SGW-c
VM

SGW-u
VM

PCRF
VM

PGW-c
VM

PGW-u
VM
Programmable SDN Fabric for the CORE

- Programmable SDN Fabric (e.g. P4)
- Services OS
- Fabric Control
- VTN Control
- SDN Control
- HSS
  - VM
- MME
  - VM
- SGW-c
  - VM
- SGW-u
  - VM
- PCRF
  - VM
- PGW-c
  - VM
- PGW-u
  - VM
Programmable SDN Fabric for the CORE
Programmable SDN Fabric for the RAN
Programmable SDN Fabric for the RAN
Programmable SDN Fabric for the RAN
Programmable SDN Fabric for the RAN

- Services OS
- SDN Control
- EPC / NG CORE
- SDN Fabric

CU-c H
CU-c L
VM
CU-u
VM
Programmable SDN Fabric for the RAN
Programmable SDN Fabric for the RAN
Programmable SDN Fabric for M-CORD

Programmable SDN Fabric (e.g. P4)

SDN Control

Fabric Control

RAN CU-L VM

CORE CP VM

xRAN

CORE UP

Services OS

VTN Control
THANK YOU