CORD: Multi-Access Edge Cloud
—Building an Extensible Edge Platform—
Larry Peterson
Background

CORD is a multi-access edge cloud

- Built using commodity servers and white-box switches/access devices (PON, RAN)
- Runs both scalable cloud services and disaggregated Telco services (BNG, EPC)
- Configured as Base Platform + One or more Service Profiles

XOS is a framework for configuring and operating a cloud platform

- Decouples Service Control Plane and Service Data Plane
- Generates the control plane from a set of declarative models

CORD and XOS are open source projects of the ONF

- Working with network operators to take these technologies to production
CORD – Reinventing the Network Edge

Users

Edge Cloud

Telco Cloud

Public Clouds

White Box Peripherals
Data Center

WAN Routers

Switching Fabric

Compute Storage
Reference Design – Multi-Access Edge Cloud

Global Automation

Local Service Control

Cloud Orchestrator

Servers / Accelerators

VNF1

VNF2

VNF3

Overlay

Fabric

VNF4

VNF5

SDN Controller

Leaf-Spine Fabric

SD-PON

PON Controller

OLT

SD-RAN

RAN Controller

BBU

Access Peripherals

Telco Cloud

RAN Controller

PON Controller

OLT

BBU

Access Peripherals

Telco Cloud
Exemplar Platform – CORD

Global Automation

XOS

- vSG
- vEPC
- ... (Openstack/Kubernetes)
- OCP Servers

- ONOS
- OCP Switches (+ P4 Runtime)

- vOLT
- ONOS
- VOLTHA
- OCP OLT

- vRAN
- ONOS
- BBU

Access Peripherals

Telco Cloud

VTN
- Fabric
- vRouter
- ...

Fabric

Exemplar Platform – CORD

- vSG
- vEPC
- ... (Openstack/Kubernetes)
- OCP Servers

- ONOS
- OCP Switches (+ P4 Runtime)

- vOLT
- ONOS
- VOLTHA
- OCP OLT

- vRAN
- ONOS
- BBU

Access Peripherals

Telco Cloud
Disaggregation

– Micro-Services & SDN Applied to the Central Office –
Legacy Central Office

CPE – Customer Premises Equipment
OLT – Optical Line Termination
BNG – Broadband Network Gateway
Disaggregation

CPE – Customer Premises Equipment
OLT – Optical Line Termination
BNG – Broadband Network Gateway
Disaggregation

CPE – Customer Premises Equipment
OLT – Optical Line Termination
BNG – Broadband Network Gateway
Functional Specification

Service Graph for Residential CORD
CORD – An Extensible Platform

– Configuring and Controlling an Integrated System –
Challenge

Use Cases (Trials)

Extensible Platform

Building Blocks

CORD

VOLTHA  xRAN  Fabric  vEPC  vRouter  ...

AT&T  China unicomm  COMCAST  Google  Deutsche Telekom  NTT Group  Türk Telekom
Automated Configuration

TOSCA Workflows
- Provision & Configure Services
- Runtime Operation

Protobuf (xproto) Models
- Schema that Model Services
- Core set Loaded at Boot Time
- Dynamically Updated at Runtime

Helm Charts
- Containers that Implement Services
- Core set Loaded at Boot Time
- Dynamically Updated at Runtime

Lifecycle Management

XOS
- Ctrl App
- VNF

ONOS

Kubernetes (OpenStack)

CORD POD
- OCP Hardware

Kubernetes (Optionally MaaS)
Lifecycle Management

XOS is responsible for *Service Control Plane*
- Support for *configuring and controlling* services
- Support for incremental upgrades (transitioning state/interfaces)

Kubernetes is responsible for *Service Data Plane*
- Support for *implementing* services (scale up/down, HA)
- Support for incremental upgrades (rollout/rollback)
XOS provides Visibility and Control at the granularity of per-subscriber service chains.

...a PaaS for Service Chains
- Provision
- Isolate
- Distribute
- Migrate
Mobile Cloud

– Value of Service Chains –
What’s Different about 5G?

Earlier generations were about improving broadband technology

5G is fundamentally about supporting new services
  • Internet-of-Things
  • Immersive UIs
  • Public Safety

What unique capability does the mobile access network offer?
  • Low-latency proximity to end-users
  • Intrinsic support for mobility

Challenge of 5G is to Simultaneously Support...
  • Low Latency – Moving functionality to the edge, closer to devices
  • Mobility – Accessing that edge functionality while continuing to be mobile
Central Challenge of 5G is to Simultaneously Support...

- Low Latency – Moving functionality to the edge, closer to devices.
- Mobility – Accessing that edge functionality while continuing to be mobile.

Other Factors...

- Performance dictates that functionality be implemented in the most appropriate hardware (e.g., GPUs, Switching Fabric).
- Autonomy dictates that different stakeholders will be responsible for controlling and managing different components.
- Monetization dictates the need to offer differentiated services to different classes of subscribers/applications.
- Costs dictates a distributed solution, with some functions running in the datacenters and some running in a scalable number of edge sites.
- Dynamicity dictates the need for local (edge) control with tight control loops.
Mobile Broadband (2G – 4G)
Move Functionality to the Edge

Access-Edge

Datacenter
Mobile Cloud (5G)
Mobile Cloud (5G)
Requirements

Heterogeneous – Range of functional element implementations

Multi-Tenant – Multiple stakeholders managing functional elements

Distributed – Functional elements span multiple clouds

Isolation – Differentiated resource allocation between service chains

Mobility – Move service chains from one edge cloud to another
XOS Overview

– A PaaS for Service Chains –
CORD Innovations

Virtualization and Disaggregation

• Pre-requisite for moving functionality to the edge
• Ability to run functionality in both switches and servers

Explicit Support for Service Chains

• A first class abstraction that defines a control framework
• Operations to provision, distribute, isolate, and migrate
What is XOS?

**xproto** – A declarative language for specifying models
  - *Protocol Buffers*: extended to support inheritance, relationships, and predicates

**xosgenx** – An extensible toolchain to enforce models on an operational system
  - *Targets*: APIs, Access Control, ORM, Synchronizer Framework,…

**core.xproto** – A default (and malleable) set of core models
  - *Models*: Service, ServiceDependency, ServiceInstance, ServiceInstanceLink,…

**Chart.yaml** – A Helm Chart (plus set of container images) to deploy XOS
  - *Micro-services*: xos-core, xos-gui, xos-tosca, xos-db, xos-ws, redis,…
Local Service Control (XOS)

XOS Constructed from Micro-Services

- GUI
- REST API
- TOSCA
- ... (Views (UIs))
- Event Bus
- XOS Core
- DB (Data Model)
- Backend Services and Resources (Synchronizers)
Example Model and Policy

```python
policy grant_policy < ctx.user.is_admin
    | exists Privilege:Privilege.object_type = obj.object_type
    & Privilege.object_id = obj.object_id
    & Privilege.accessor_type = "User"
    & Privilege.accessor_id = ctx.user.id
    & Privilege.permission = "role:admin" >

message Privilege::grant_policy (XOSBase)
{
    required int32 accessor_id = 1 [null = False];
    required string accessor_type = 2 [null = False, max_length=1024];
    required int32 controller_id = 3 [null = True];
    required int32 object_id = 4 [null = False];
    required string object_type = 5 [null = False, max_length=1024];
    required string permission = 6 [null = False, default = "all", max_length=1024];
    required string granted = 7 [content_type = "date", auto_now_add = True, max_length=1024];
    required string expires = 8 [content_type = "date", null = True, max_length=1024];
}
XOS Generative Toolchain

- GUI
- REST API
- TOSCA
- ...
- Event Bus
- XOS Core
- DB
- Sync
- Sync
- Sync
- Sync

Generated Code
- API Tests
- Northbound Interfaces
- Enforce Security Policy
- Object Relation Mapper
- Synchronizer Framework
Core Models

- Controller
- Service
- Slice
- Instance
- Compute
- Instance
- (Control)
- (Resources)
- ONOS
- Ctl App

ONOS Ctl App
Core Models

Controller

Service

Service

Service

Service

Service

Service Instance

(Control)

(Distributed, Layered, and Composite Services)
Service Control and Data Planes

Controller A

Controller B

Controller C

Controller D

Controller E

Service Graph

Service Control Plane

Service Data Plane

Functional Elements

Legacy VNF Running in a VM

Horizontally Scalable Micro-Service

SDN Control App

Container Per Subscriber

...
Service Graph – Residential Case

Service Graph

Service Chain = At the granularity of subscribers (or subscriber classes)
Service Graph – Mobile Case

Controller

vMME

vSPGW-c

Controller

SPGW Control

Controller

vSPGW-u

Controller

vHSS

Composite Services

Network Slicing
Service Graph – Mobile Case

Composite Services
Network Slicing
Off-load VNFs (to fabric)
Conclusion

CORD is a Multi-Access Edge Cloud
- Includes both Access-as-a-Service and Software-as-a-Service
- Uses Merchant Silicon and Function Disaggregation

XOS is a Framework for Configuring and Operating a Cloud Platform
- Supports Services as a Unifying Abstraction (implementation agnostic)
- Decouples Service Control Plane and Service Data Plane
- Uses Declarative Models and Generative Toolchain to Specify & Enforce Behavior
Conclusion

CORD integrates Access-as-a-Service into a multi-tenant cloud platform

- Disaggregated functionality with a mix of server- and switch-based implementations

XOS integrates the disaggregated components into a coherent whole (PaaS)

- Programmable framework with visibility and control at the granularity of subscribers
Conclusion

IoT Service  Analytics Service  Low Latency Service  Residential Service  Mobile BB Service

ONOS  VOLT  xRAN  ProgRAN

VOLTHA

OLT  ACCESS NODES  RAN

OpenStack  Kubernetes

VMs  Containers

IaaS APIs

SaaS APIs

PaaS APIs

NaaS APIs

AaaS APIs

Trellis  DHCP  MCast  vRouter

NETWORKING FABRIC

COMPUTE INFRASTRUCTURE