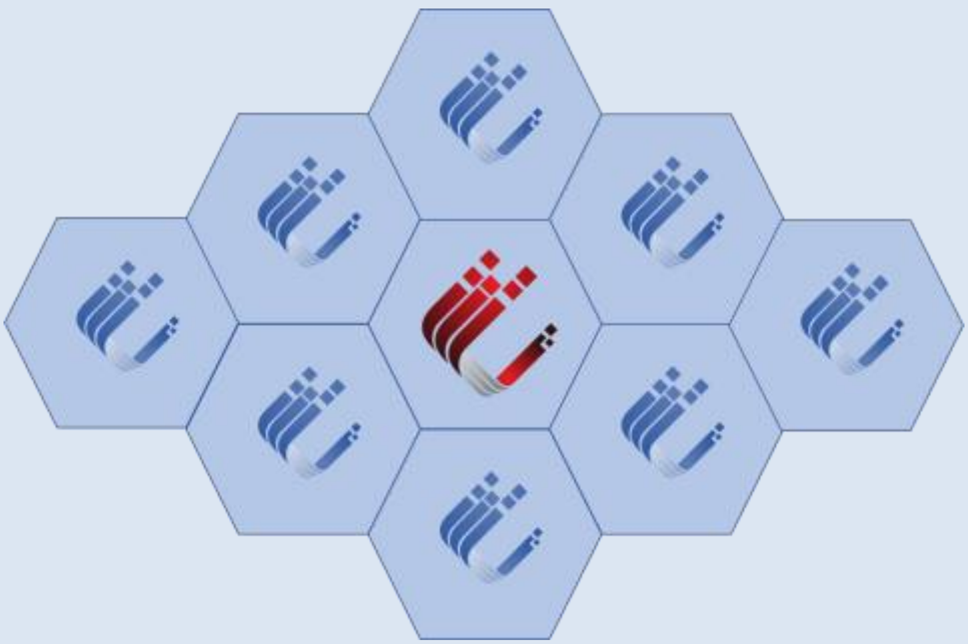
CORD Project | Whitepaper

M-CORD as an Open Reference Solution for 5G Enablement



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M-CORD as an Open Reference Solution for 5G Enablement

Abstract

M-CORD is an open source reference solution built on the pillars of SDN, NFV and cloud technologies. It leverages open source software, disaggregation and virtualization of RAN and core functions of mobile wireless networks. M-CORD enables mobile edge applications and innovative services using micro-services architecture. This white paper provides an overview of M-CORD and highlights a few example infrastructural innovations and innovative services such as public safety as a service and adaptive analytics service towards realizing the 5G vision. Offering both open source as well as commercial versions of core and RAN functions, M-CORD is an ideal rapid innovation platform for community participation and collaboration towards 5G networks, allowing mobile operators to experiment with 5G technologies today, without having to wait for the ratification of the 3GPP 5G standards.

Introduction

Over the past several years, carrier networks have had to support tremendous growth in wireless data traffic with expensive investment on spectrum and LTE network deployment. The continuation of the explosive growth of user demands along with the flattening of the revenues present vital challenges for all the service providers. Today's telecom infrastructure is built with proprietary vertically integrated devices leading to inefficient utilization of network resources. Further, it is hard to customize the current network for different customer needs or locations and its architecture does not lend itself to the creation of emerging services.

5G is positioned to enable a truly "Networked Society" by providing seamless connectivity for people and things [1] and it adds another set of challenging requirements for the mobile infrastructure and its providers. For example, 5G aims to provide access to information and ability for data sharing for people as well as things at any time and in any location. As a key enabler for the Internet of Things, 5G will need to provide connectivity to a massive number of devices with possibly stringent energy and transmission constraints. 5G networks will also need to support mission critical services requiring very high reliability and/or low latency. It is also certain that we will have a densification of small cells and a family of radio access technologies (RAT) and they must work seamlessly. And mobile operators want to offer connectivity-based innovative services in numerous vertical sectors, such as health, automotive, home, energy, and many others.

Our research community, mobile wireless industry and various standards organizations are busy inventing the new mobile network architecture that can cope with the various challenges and requirements and help realize the 5G vision. At the same time, we believe there is a need for a reference platform that is open and programmable for rapid innovation and experimentation. This platform should also serve in field trials and scale for potential production deployments. The reference platform needs to satisfy several requirements:

1. Programmability: The platform should empower developers to innovate new infrastructure capabilities as well as new services for use cases whose demands from the network are vastly different.
2. Orchestratability: The architecture should provide an open orchestration platform for the mobile operator on which innovations for new services, as well as service provisioning and orchestration are dynamically feasible.
3. Scalability: The platform needs to be scalable – both up and down for hardware and software – in a similar manner observed in today's cloud networks, so the solutions based the platform can be used in different scenarios and locations.
4. Use of Merchant Silicon: The platform should take advantage of network device disaggregation and merchant silicon to the maximum extent possible to allow for significant CAPEX and OPEX savings and thus avoid vendor lock-in.
5. Use of Open Source Software: To extend possible, the platform should be based on open source software to meet the needs of experimentation and innovation by wide developer community. It is desirable that the family of network functions that make up the cellular network to be based on open source.
6. Programmatic Closed Loop Control for Self-Organized Networks: The architecture for 5G networks will require real time observability and openly defined abstractions toward self-organized networks and smart applications.

The answer to these requirements lay in the CORD platform [2], a new design of telco central office that exploits NFV, SDN, cloud technologies replacing closed and proprietary hardware with software running on commodity servers, switches and access devices. Following the micro-services architecture, CORD aims to disaggregate the network functions as much as possible. Then, using a cloud-based orchestration model, these disaggregated network functions are represented as scalable services. The CORD architecture has been used to address the needs of different access networks and given rise to several flavors of CORD. M-CORD or Mobile-CORD is a solution based on CORD that is focused on addressing the needs of the mobility networks. It has been influenced by the emerging 5G use cases and is applicable to a range of performance targets, so that different services with widely different demands can be deployed on the same platform. An overview of the M-CORD architecture is presented in the next section. Next, we provide descriptions of several innovations that have already been implemented.

Overview of the CORD and M-CORD Architecture

CORD's mission is to bring datacenter economies and cloud agility to service providers for their residential, enterprise, and mobile customers using an open reference implementation with an active participation of the community. The reference implementation of CORD is being built from commodity servers, white-box switches, disaggregated access technologies and open source software to provide an extensible service delivery platform. This gives network operators the means to configure, control, and extend CORD to meet their operational and business objectives. The reference implementation is sufficiently complete to support field trials. CORD has two ambitious goals for the reference implementation: The first is to be a complete solution, ready for evaluation in field trials on commercial operator networks and the second is to serve as a general-purpose platform that is capable of delivering a wide range of innovative services from access services (e.g., 5G, LTE, Fiber-to-the-Home) to conventional cloud services (SaaS); from services implemented in the data plane (NFV) to services implemented in the control plane (SDN); from trusted operator-provided services to untrusted third-party services; and from bundled legacy services to disaggregated greenfield services.

CORD software architecture suite integrates four open-source projects: 1) *OpenStack* is the cloud datacenter management platform providing IaaS capability, 2) *Docker* is the software platform allowing one to deploy and interconnect services inside software containers, 3) *ONOS* is the Open Network Operating System [3] controlling the underlying white-box switch fabric that is organized in a leaf-spine topology, hosting a collection of control applications that implement the necessary ONOS-controlled services and embedding virtual networks into the underlay fabric for the OpenStack-controlled services, 4) *XOS* is the Anything-as-a-Service (XaaS) Operating System which is responsible from assembling and composing services.

M-CORD is focused on addressing the needs of the mobile networks. It has been influenced by the emerging 5G use cases and is programmatically applicable to a range of performance targets on the same platform. M-CORD transforms the mobile network so that SDN control and data planes are decoupled, SDN control plane is logically centralized, cellular network functions as well as operator specific services are disaggregated and virtualized, virtualized functions and services are composed as scalable services and the overall cellular network is orchestrated so that use case-specific set of services are on-boarded and dynamically scaled.

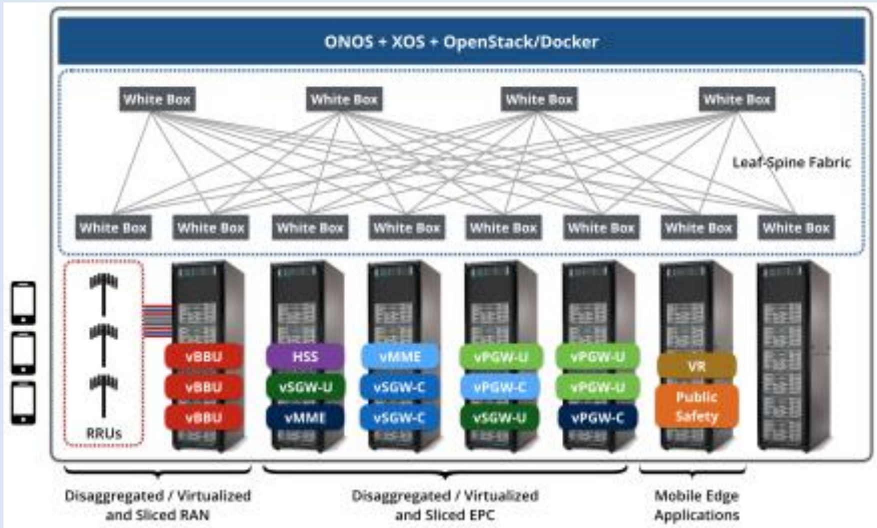

Figure 1. LTE over M-CORD allowing for Split RAN and End-to-End Network Slicing

A representative M-CORD architecture for an LTE implementation that allows for a split RAN realization and end-to-end network slicing is illustrated in Figure 1.

The following pages illustrate several innovations enabled by M-CORD.

Optimized CORE for Static IOT Devices

By 2020, the number of IoT devices will show a dramatic growth as things that were never on the network – say, clothing, sporting goods equipment, bridges, and even your body – will come online. This massive growth in IoT devices combined with new applications on LTE handsets will cause excessive control plane signaling overhead on the current LTE core network.

The optimized Core POC described below shows an innovative solution to address this trend. It exploits M-CORD's open source core network elements and software defined programmability and control to create an optimized mobile CORE architecture that can scale to handle massive numbers of stationary IoT devices. The solution integrates disaggregated MME functions, core slicing capability, slicing selection service and a new connectionless gateway to eliminate traditional GTP tunneling overhead for IoT traffic.

The optimized Core sets up separate core slices for regular mobile devices and stationary IoT devices. M-CORD's open source MME has been enhanced with functionality to classify a regular mobile device from a static IoT device based on criteria like IMSI or APN name. In the case of regular LTE handset, the mobility management takes the user data over to interface with traditional SGW and PGW. However, the enhanced MME connects IoT devices directly to new connectionless gateway, a combined S and P gateway, thereby removing any mobility or periodic signaling related traffic of traditional LTE. As shown in Figure 2, the optimized connectionless gateway connects static IOT devices directly with their applications and is programmable through OpenFlow based light session control.

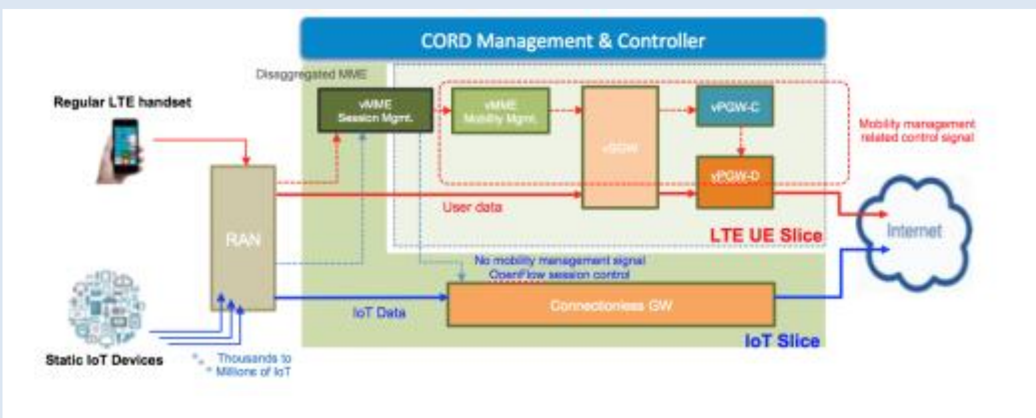

Figure 2. Optimized mobile core for static IoT

Programmable and Scalable Connectionless CORE

5G networks are expected to connect billions of IoT devices including a vast majority of devices that are stationary, i.e. water, power and gas meters, city lights and sensors etc. Such devices do no need the complex functionality needed by mobile devices. On the other hand, the LTE core has been designed to support mobility and cannot turn off mobility related functionality or signaling for just the stationary devices, thus preventing it from handling large numbers of stationary devices.

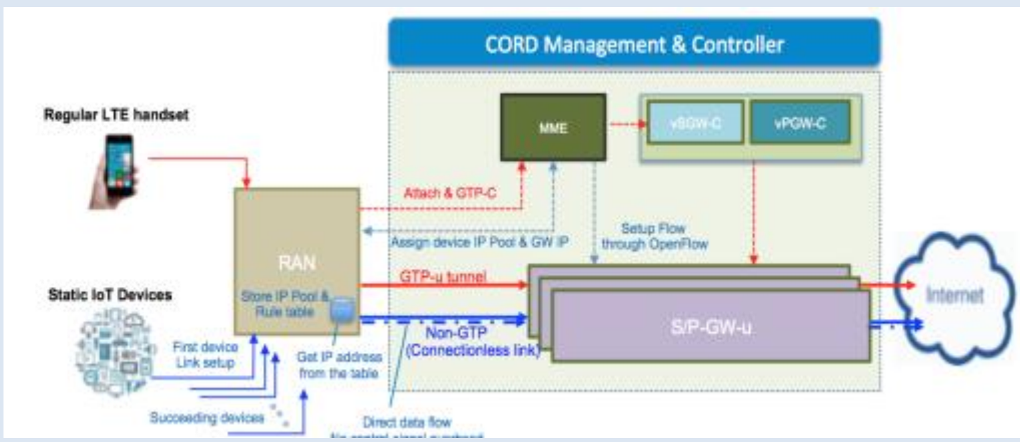

Figure 3. Programmable and Scalable Connectionless CORE on M-CORD

Although the integration of programmable and scalable connectionless core into M-CORD is still in progress and not completed yet, the innovations in this POC demonstrate how networks can support both regular mobile devices and large numbers of stationary IoT devices. The key methods to achieve this are: (a) Significantly reduce signaling and state overhead for stationary IoT by classifying traffic at the RAN itself and routing connectionless non-encapsulated IoT traffic straight to the S/P-gateway, but also support traditional mobile device traffic with GTP tunnels and regular signaling. (b) Use a SDN-based scalable core network with separated control and user planes for S/P-gateways that enables independent horizontal scaling of user and control planes to handle corresponding traffic. (c) Achieve high performance in the user plane via use of DPDK (Data Plane Development Kit – dpdk.org) technology. M-CORD's support for scalable SDNized and connectionless core is illustrated in Figure 3.

End-to-End Slicing

The upcoming 5G networks not only have to support increasing data rates but also must provide a common infrastructure on which new wireless services with vastly different network QoS requirements with lower delay are delivered. To address such needs, a 5G platform needs the ability to dynamically create programmable virtual networks and differentiated traffic treatment utilizing solutions such network slicing. While today's LTE networks do not support network slicing, the M-CORD platform allows operators to experiment with and realize network slicing on an LTE network without having to wait for the 5G standards to be ratified.

The POC demonstrates dynamic and programmable end-to-end slicing in an M-CORD based LTE network, showing how mobile devices placed in different slices gain different QoS treatments from the network. The network slicing solution utilizes M-CORD's key features such as disaggregated and virtualized RAN and EPC components, open source building blocks for RAN and EPC that allows us to customize and modify, and fully follows its software defined approach. M-CORD provides necessary functionality to program slice definitions and appropriately stitch the RAN and CORE slices. At the RAN side, the slicing includes virtualization of resource blocks and allocation of subset of these resources block to different slices and corresponding control functions like scheduling, handoff, admission control, etc. On the CORE network side, slicing includes associating disaggregated virtualized EPC components to each slice. Figure 4 presents a high-level illustration of the concept.

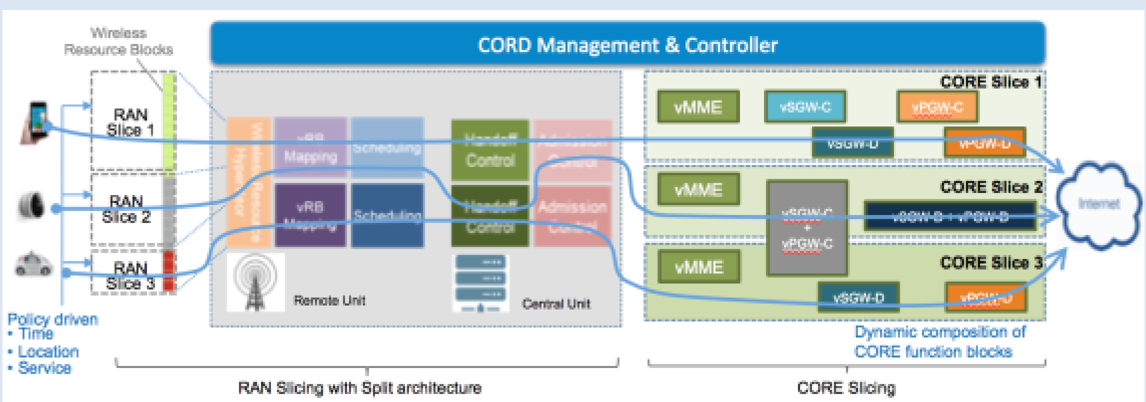

Figure 4. End-to-End Slicing on M-CORD

Premium Public-Safety-As-a-Service

Every single network in the world provides support for emergency services like 911. When users call 911 they get connected to emergency services, regardless of the caller's billing, subscription and authentication conditions. But today's networks support voice calls only when it is possible to support emergency services with more than voice: video, location, and information about the emergency-caller. But how does the network distinguish emergency related traffic to provide it the necessary QoS, but continue to treat other traffic from the emergency-caller according to their SLA? This is especially harder to identify when today's data streams are encrypted and come from multiple content providers.

To address these challenges, M-CORD has integrated a 'network cookies' service, based on an open and secure API developed at Stanford to map traffic based on their network cookie to different SLAs in the network, even when this traffic is encrypted or comes from multiple CDNs and public data-centers. Armed with its network cookie, traffic from a public safety application can be treated with a special SLA that bypasses credit checks on an emergency-caller and provides sufficient bandwidth needed during emergency situations. It should be noted that this network cookie service is not limited to just public safety applications, but can be used in other scenarios as well. Its use can be user-driven, where the user can benefit from premium services by indicating his or her preferences using shared network cookies. The realization of Public-Safety-as-a-Service on M-CORD is illustrated in Figure 5.

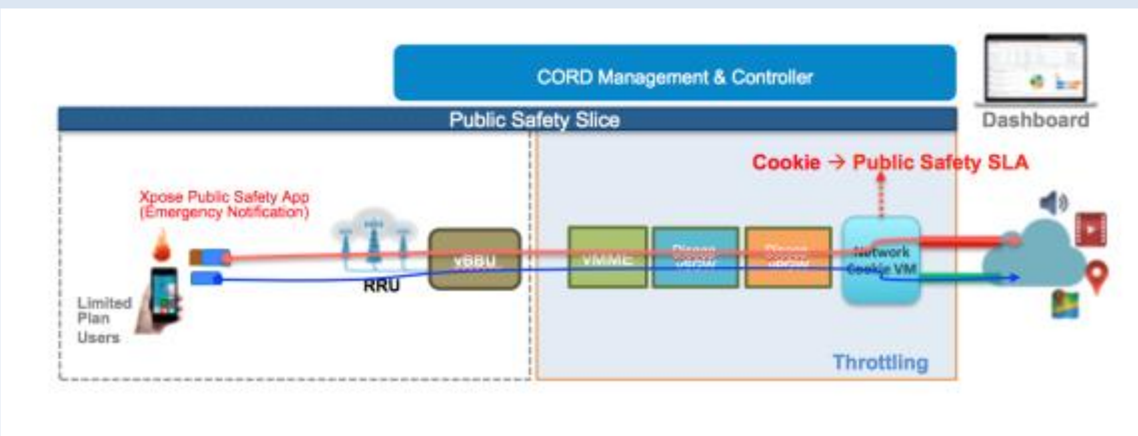

Figure 5. Public-Safety-as-a-Service on M-CORD

Adaptive Analytics Service

Service providers when launching new services need to be able to rapidly detect, identify and resolve service impairments. In this POC, we show the flexibility and effectiveness of providing test and assurance functions as model driven *services* that can be chained into other network service models. This service chaining, enables the test and assurance capabilities to be automated *together* with the main service deployment. These test and assurance services can then be used, in real time, to drive root cause analysis and enable closed loop automation of network control to improve the network's behavior and help reliably deliver new carrier grade services.

The Adaptive Analytics Service takes advantage of M-CORD platform's ability to instantiate test and monitoring agents utilizing CORD's model driven services composition tools. CORD's monitoring as a service can be used within network service designs, to enable operational readiness. The resulting service model combines a precise definition of the service function itself and the quality metrics needed to test and assure that service. This innovation combines the use two main concepts in testing: (a) Passive network traffic monitoring setup by a service called Assurance as a Service (AaaS), which collects only relevant network traffic, creates the service quality metrics defined in the service model and publishes them through an open feed to external analytics functions. (b) Active measurement as a service also called Test as a Service (TaaS) which uses synthetic traffic to feed service path performance monitoring needed by analytics applications such as root cause segmentation along the service path. An overview of the Adaptive Analytics Service on the M-CORD platform is illustrated in Figure 6.

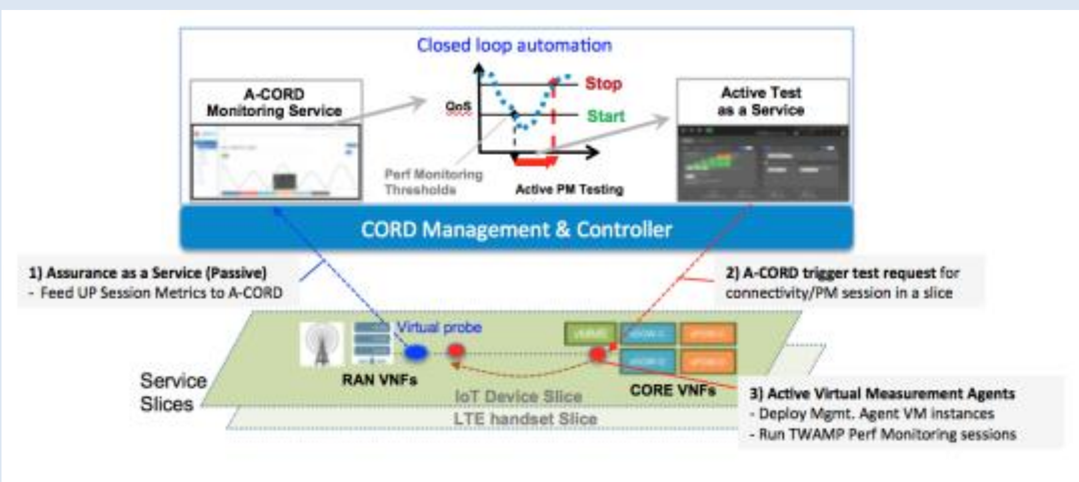

Figure 6. Adaptive Analytics Service on M-CORD

M-CORD: A Natural Fit for Mobile Edge Computing (MEC)

With emerging vertical sectors such as mission critical IoT, virtual reality, and advanced gaming which are all delay sensitive and can require high bandwidth, enabling use case specific services at the mobile edge can become a necessity. M-CORD is an ideal platform for providing dynamically programmable, orchestrate-able and scalable mobile edge services. To illustrate this capability, an M-CORD-hosted mobile edge application was demonstrated last year at the Open Networking Summit 2016 on an end-to-end working LTE system that provided enterprise specific RAN and EPC capabilities with local breakout at mobile edge as illustrated in Figure 7.

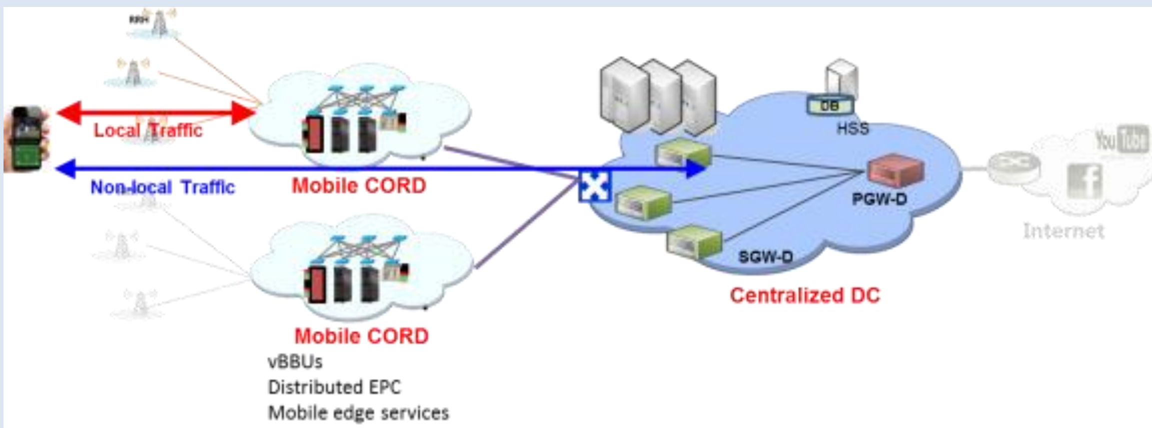

Figure 7. Mobile Edge Services on M-CORD

Conclusions

M-CORD is an open source reference solution built on the pillars of open source SDN, NFV and cloud technologies. M-CORD integrates disaggregated and virtualized RAN and core functions of the wireless network as well as mobile edge applications together programmatically in a scalable micro services-like architecture. M-CORD's features and capabilities have already paved the way for rapid innovation as demonstrated by POCs described in this whitepaper. In a short amount of time M-CORD has attracted 15 partners and over 50 collaborators forming a formidable open source community already working on the next set of innovations to empower the mobile operator. M-CORD platform allows operators to experiment with and realize 5G technologies on an LTE network running on M-CORD without having to wait for all the 5G standards to be ratified.

References

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