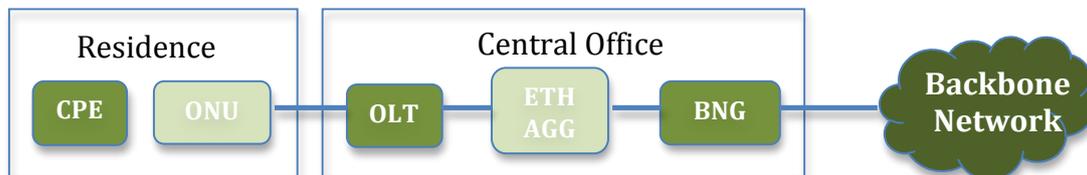


Making your FTTH Network ready for CORD infrastructure

Central Office Re-architected as a Data center (CORD) is the response from Telecom Operators to benefit from economies of scale (infrastructure constructed from a few commodity building blocks) and agility (the ability to rapidly deploy and elastically scale services) that commodity cloud providers enjoy.

Residential-CORD (R-CORD) is a new design of a Telco central office (CO) that replaces closed and proprietary hardware with software running on commodity servers and white-box switches, coupled with disaggregated packaging of media access technologies. These devices are then organized into a rack-able unit, called a POD that is suitable for deployment in a Telco CO¹.

First thing to be done in order to achieve a R-CORD FTTH access infrastructure is the disaggregation of legacy devices involved in a GPON access network.



Disaggregating/Virtualizing the OLT

OLT are mainly organized in racks of closed and proprietary hardware that terminate access for tens of thousands of subscribers. Virtualizing OLT is especially challenging because, unlike network appliances that are actually implemented by software running on vendor-branded commodity servers, OLT is implemented primarily in hardware.

OLT terminates the optical link in the CO, with each physical termination point aggregating a set of subscriber connections. The first challenge to virtualize it was to create an I/O blade with the PON OLT medium access control (MAC), but under control of a remote control program via OpenFlow. The resulting control program, called virtual OLT (vOLT), could run on top of ONOS (**Open Network Operating System**), and implements all other functionality normally contained in a legacy OLT chassis (e.g., GPON protocol management, 802.1ad-compliant VLAN bridging). That is, vOLT implements

authentication on a per-subscriber basis, establishes and manages VLANs connecting the subscriber's devices to the CO switching fabric, and manages other control plane functions of the OLT.

There are two pieces of software that work together to implement the vOLT functionality. The first is a vOLT agent runs in a container or VM and facilitates a connection between ONOS and the hardware. The agent exposes an OpenFlow interface northbound, which enables it to be controlled by ONOS. It then maps OpenFlow messages to the native APIs of the hardware device and OMCI messages that manage the PON ONTs. The second piece of software is a set of functions that manage some of the control plane functions of a traditional OLT, like 802.1X, IGMP Snooping, VLAN bridging, and OAM. These control functions are implemented as applications running on top of ONOS, facilitate subscriber attachment, authentication (AAA), establishes and manages VLANs connecting consumer devices and the central office switching fabric on a per-subscriber basis, and manages other control plane functions of the OLT.

The vOLT agent also performs a bootstrap operation. During this process the agent discovers the IO blade and establishes a control connection to it. The vOLT software then exposes an OpenFlow interface to ONOSⁱⁱ who then uses that interface to program the vOLT agent. The agent converts these OpenFlow messages to OMCI for provisioning of the ONUs.

Disaggregating/Virtualizing the ONU/CPE

CPE, including both the GPON-terminating ONT and also a "home router" or "residential gateway," is installed in the customer's premises. They often run a collection of essential functions such as Dynamic Host Configuration Protocol (DHCP) and Network Address Translation (NAT) and optional services (e.g., firewall, parental control, VoIP) on behalf of residential subscribers. By extending the capabilities of CPE in the cloud, new value-added services as well as customer care capabilities can be provided where they could not before because of limitations in the hardware.

The virtualized version of CPE, called virtual subscriber gateway (vSG), also runs a bundle of subscriber-selected functions, but it does so on commodity hardware located in the CO rather than at the customer's premises. There is still a device in the home (to which we still refer as the CPE), but it can be simplified, with some of the functionality that ran on the original CPE moved into the CO and running in a VM (Virtual Machines) on commodity servers. In other words, the "customer LAN" includes a remote VM that resides in the CO, effectively providing every subscriber with direct ingress into the Telco's cloud.

R-CORD permits a wide range of implementation choices for subscriber bundles, including a full VM, a lightweight container, or a chain of lightweight containers.

End-to-end packet flow

Assuming the subscriber already has an account. When the subscriber powers up the home router, an 802.1x authentication packet is sent over GPON to the CO. Upon arrival at a GPON I/O blade port, the packet is passed up (through

ONOS) to the vOLT control program, which authenticates the subscriber using an account registry like RADIUS. Once authenticated, vOLT assigns VLAN tags to the subscriber and installs the appropriate flow rules in the I/O blade and switching fabric (via ONOS), asks vSG to spin up a container for that subscriber, and binds that container to the VLAN. vSG, in turn, requests a routable IP address from vRouter, which causes vRouter (via ONOS) to install the flow rules in the switching fabric and software switches needed to route packets to/from that subscriber's container.

Once set up, packets flow from the home router over a VLAN to the subscriber's container; those packets are processed according to whatever bundle is associated with the subscriber's account (and configured into the container), and then forwarded on to the Internet using the assigned source IP address.

This description is obviously high-level, glossing over both many low-level details about each component (e.g., how VLAN tags are assigned, precisely what flow rules are installed, the exact composition of functions in each container) and the mechanisms by which the various agents (ONOS, OpenStack, Docker, vOLT, vSG, vRouter) are actually plumbed together.

R-CORD example from OPENCORDⁱⁱⁱ

In this example a virtualized version of CPE, called virtual Subscriber Gateway (vSG), runs a bundle of subscriber-selected functions, but does so on commodity hardware located in the Central Office rather than on the customer's premises. There is still a device in the home (still referred to as the CPE), but it can be reduced to a bare-metal switch, with most of the functionality that ran on the original CPE moved into CO and running in a virtual compute instance (e.g., a VM or container) on commodity servers.

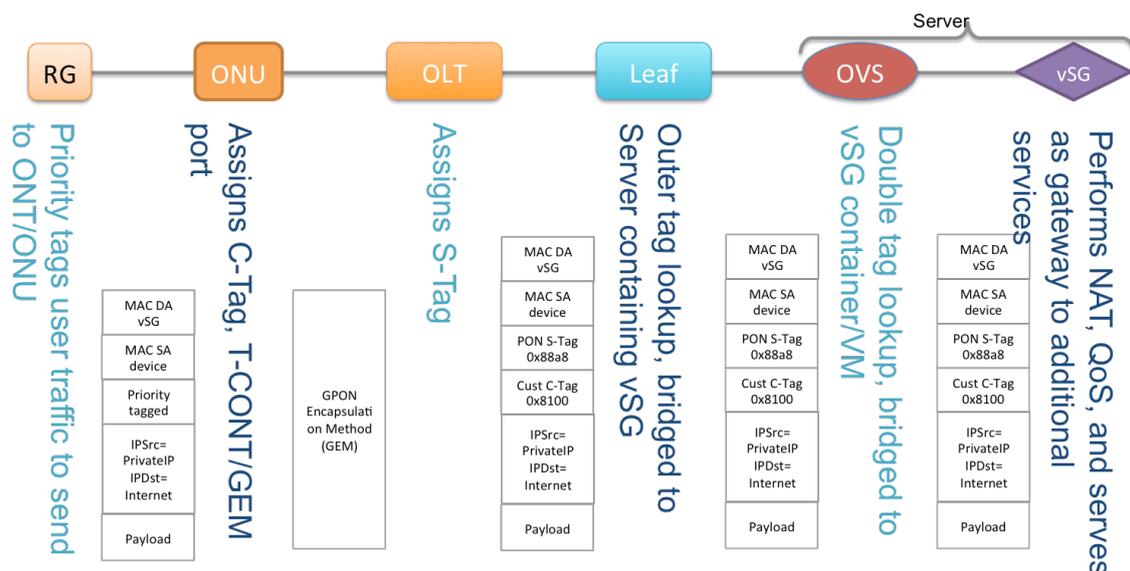


Figure above shows where VLAN tagging happens as traffic flows from a subscriber's home to the Internet. Within the home there are no VLAN tags. A priority VLAN tag (VLAN ID 0) is added at the physical home CPE/RG in order to

carry Ethernet precedence bits. The OLT instructs the ONT (via OMCI messaging sent from the vOLT agent) to add/remove the appropriate C-Tag to the traffic inside the PON, and the OLT adds an S-Tag to the packet in order to uniquely identify the subscriber's traffic in the fabric (This is 1:1 VLAN mapping in GPON systems. Other mappings (i.e. N:1) are also possible). The inner tag (C-tag) identifies the specific subscriber within the PON. The outer tag (S-tag) identifies the PON. Taken together, these two tags can identify a subscriber uniquely across all OLT devices in the system. The fabric maps the outer VLAN tags to a server, which hosts the vSGs for all the subscribers in the PON (i.e. outer Tag). This limitation will be removed by adding the capability to place the vSG for a subscriber anywhere in the cloud. The vSG strips the VLAN tags, performs its functions, and then forwards the packet along the service graph. VLAN tags are not needed after the vSG because the vSG also NATs the traffic to the vSG's WAN address, which is unique in the system.

FTTH R-CORD Monitoring and Troubleshooting

GPONDoctor Analyzers are the perfect tool for R-CORD GPON access network validation.

They are of key importance during the following steps:

- CPE/ONU provision, which is done by the OLT during the setup the communication channel to the vSG. GPONDoctor will not only capture the OMCI messages exchanged, it will also provide the entities created within the ONU with critical information like the "Extended VLAN" where all the information about how the Tagging for ingress and egress traffic is done (Critical for R-CORD).
- Real time User traffic extraction. By been able to extract the traffic within the PON in real time, it is possible to verify that the VLAN IDs (C-Tags) and P-bits are correctly inserted by the ONU, that the subscriber authentication process is done correctly and that all information exchanged with the vSG follow the rules agreed.
- Bandwidth allocation and consumption. It is of prime importance to monitor that the bandwidth allocated and consume by each CPE are according to the SLA. The Bandwidth monitoring function of the GPONDoctor will allow visualizing, in Real time, the downstream and upstream bandwidth per ONU/CPE avoiding bottlenecks during the customer service provisioning.

GPONDoctor provides the tool to acquire full knowledge of the strengths and weakness of your R-CORD network devices. It will help to get R-CORD implementations faster and more Resilience while ensuring that customer will always get the best User Experience.

ⁱ Central Office Re-architected as a Data Center. Larry Peterson, Ali Al-Shabibi, Tom Anshutz, Scott Baker, Andy Bavier, Saurav Das, Jonathan Hart, Guru Palukar and William Snow. IEEE Communications Magazine- October 2016.

ⁱⁱ P. Berde et al., "ONOS: Towards an Open, Distributed SDN OS," HotSDN 2014, Aug. 2014.

ⁱⁱⁱ <https://wiki.opencord.org/display/CORD/Residential+CORD>