Tutorial

Optical Access Evolutions Towards SDN and Disaggregated Hardware: an Operator Perspective

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Interne Orange

Outline

1. Baseline, Terminology
   a. Optical Access Network Terminology
   b. Current Management of Networks: Orange-France Example
2. Two reference architectures
   a. ONF's SEBA and VOLTHA
   b. BBF's Cloud Central Office and BAA
3. Hardware Evolutions
   From Legacy OLT Shelfs to General Purpose Hardware
4. Interoperability Challenge from an Operator Perspective
5. Enabled Evolutions and Trends
   a. OSS evolution
   b. FAN sharing
   c. Improving mobile reliability and availability
   d. 5G Slicing and edge computing

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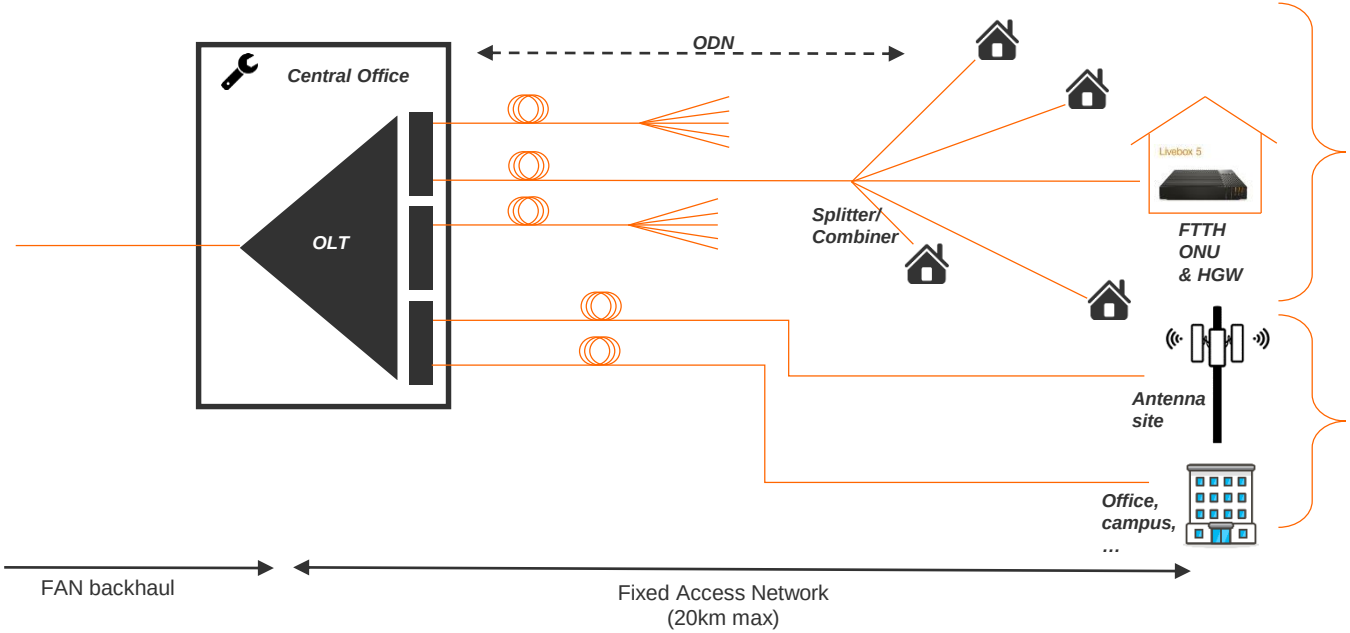
Fixed Access Network (FAN) – Overview and Terminology - Transport



PON: Passive Optical Network.

PON Tree: 1 Fiber split up to 64/128 ONUs, using passive splitters. 20km reach. Point-to-multipoint topology

ONU: Network termination at customer side, managed by the OLT through OMCI/PLOAM/TR069

HGW: Home Gateway. Access point to home network (Wifi, Ethernet, ..)

Ethernet: for Radio Xhaul or for business offers (1/10GE)

OLT: active access equipment located at the Central Office (CO)

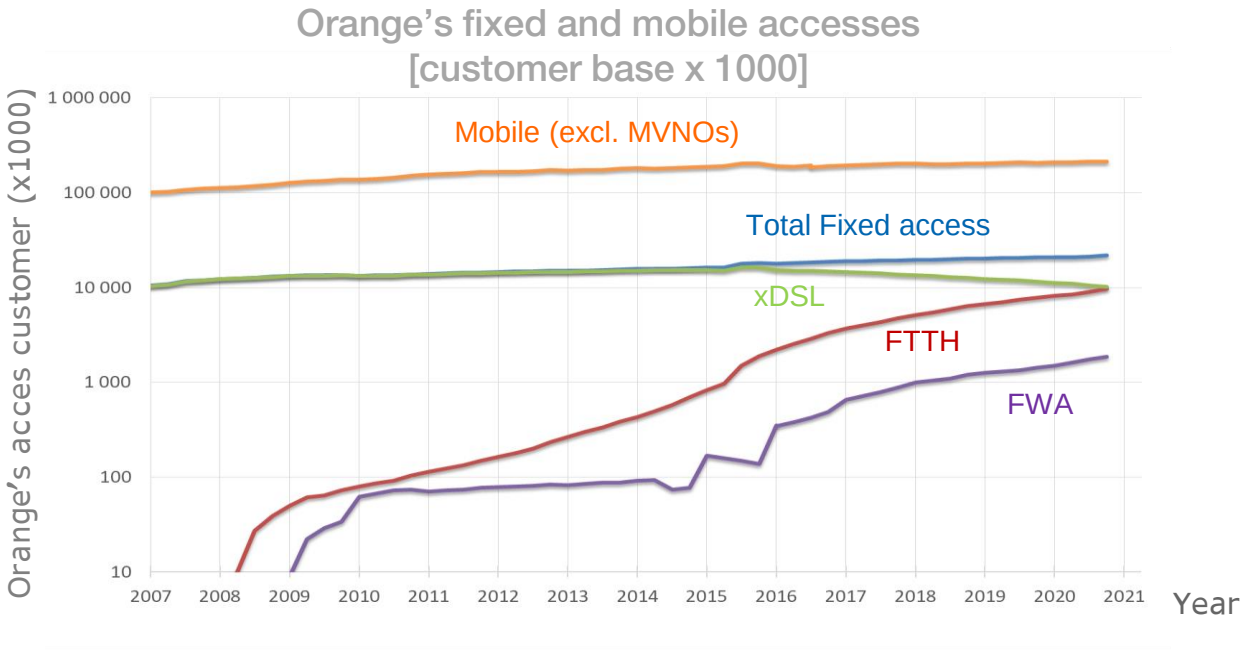
Central Office: Premises hosting the FAN OLT

ODN: Optical Distribution Network. Passive optical infrastructure

- Fixed Access Network (FAN) today: one aggregation node (OLT), but two topologies…
  - Point-to-multipoint with Passive Optical Networks (PON), widely used for FTTx
  - Point-to-point: Ethernet for Radio X-haul or for business offers (1/10GE).
- … and many applications ! Residential, mobile networks, offices, …

(Note: we will mainly focus on ITU-T PON, not IEEE)

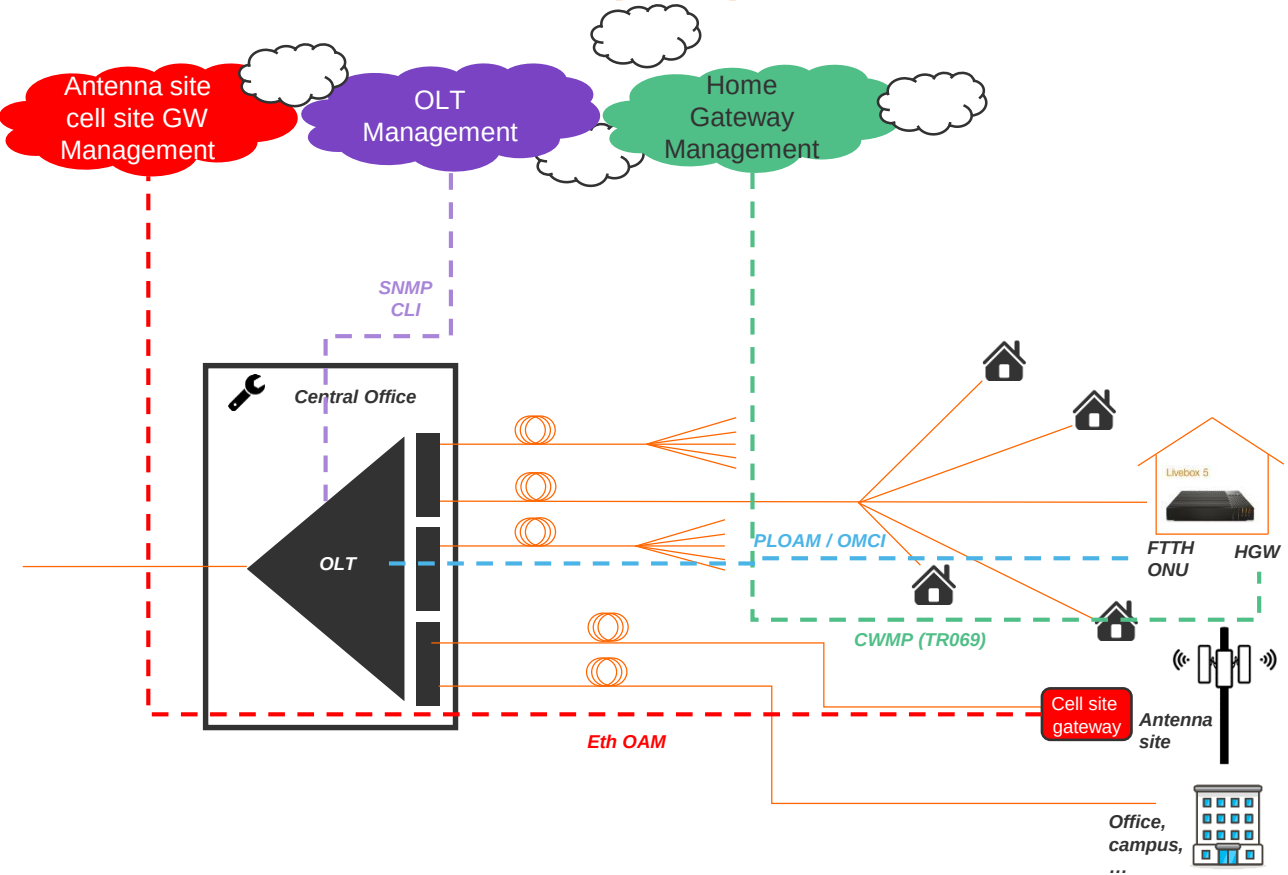
Orange presence and customers



FWA: Fixed Wireless Access
FTTH: Fiber to The Home
xDSL : Digital Subscriber Line
MVNO: Mobile Virtual Network Operator

Orange around the world

Fixed Access Network (FAN) – Overview and Terminology - Management



PLOAM: Phys. Layer Operation Admin. & Management

OMCI: ONU Management and Control Interface

SNMP: Simple Network Management Protocol

CLI: Command Line Interface

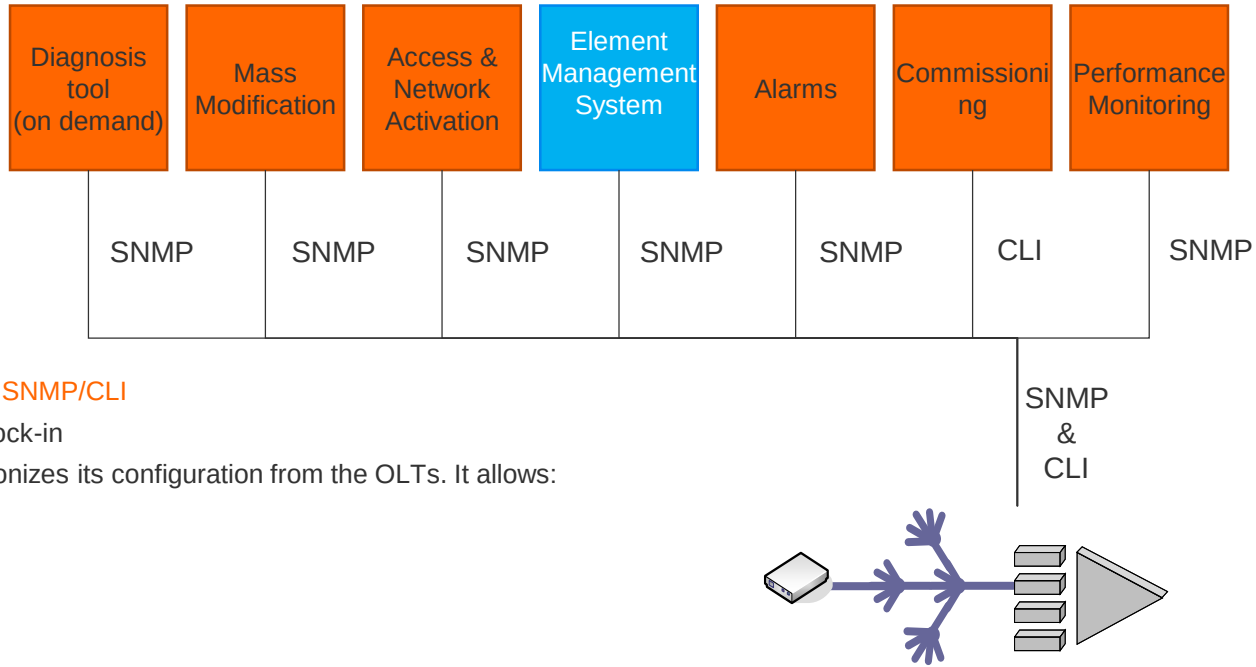
CWMP: CPE WAN Management Protocol (or a.k.a. TR-069)

Eth. OAM: IEEE Standard for Local and Metropolitan Area Networks Virtual Bridged Local Area Networks Amendment 5: Connectivity Fault Management(IEEE 802.1ag)

How is managed such a network, today ?

- OSS and BSS
  - Enable the management of end-to-end services, independently from network technologies
  - Business Support System
    - Management of product, customers, revenue, order
  - Operations Support System (OSS)
    - The operational components
    - Network management systems (NMSs), Service delivery, Service fulfillment (provisioning), Customer care
- Hundreds of applications
  - Compose the Operator information system
  - Several application for each segment (conf, fault, diagnostic, passive infra supervision, …)

Legacy OSS for Access-Backhaul domain (Orange France example)



The OSS directly controls devices through SNMP/CLI

The OSS is multi-vendor, thus no vendor lock-in

The Element Management System synchronizes its configuration from the OLTs. It allows:

- Network visualization
- Troubleshooting
- Software management
- Configuration backup

The main challenge is the evolution of management interfaces/policy with more protocols, data models, architecture, software

Hardware evolution is more opportunistic

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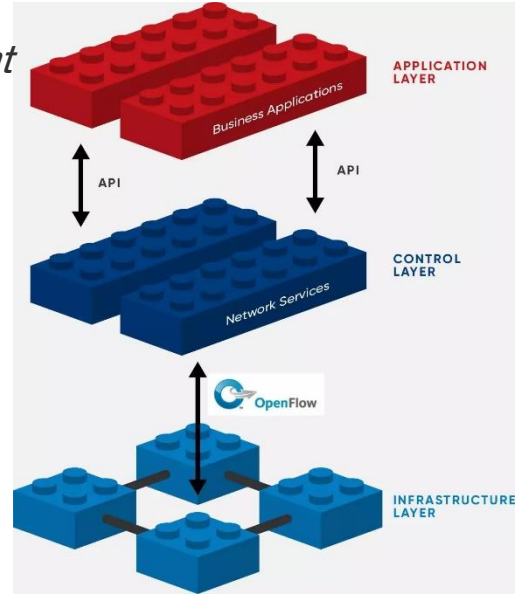
Software Defined Networking

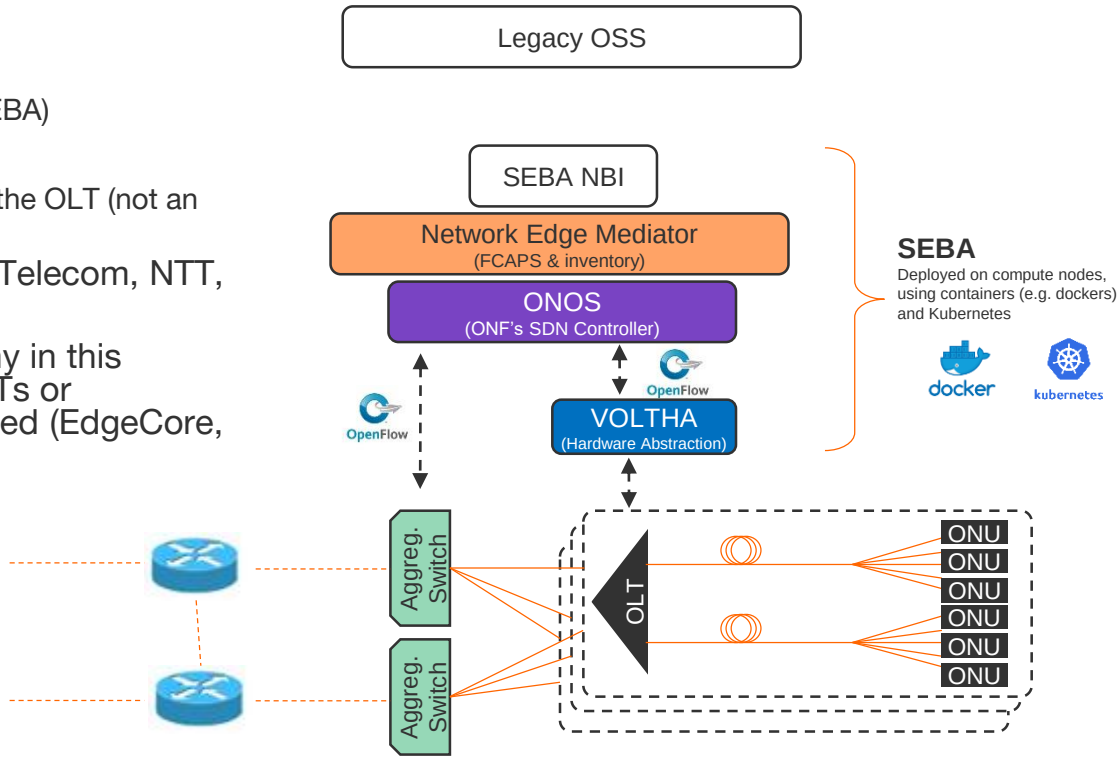
OPEN NETWORKING FOUNDATION

- Open Networking Foundation: a non-profit operator-driven consortium, founded in 2011, to transform network infrastructure towards open source software and software defined standards
- *"Software-Defined Networking (SDN) is an emerging architecture that is dynamic, manageable, cost-effective, and adaptable"* *[ONF1]*
  - Directly programmable
  - Agile
  - Centrally Managed
  - Programmatically Configured
  - Open-standards based and vendor neutral
- Openflow protocol decouples the network control and forwarding functions
- Basically, SDN tends to provide more agility in the networks, using the cloud infrastructure technologies



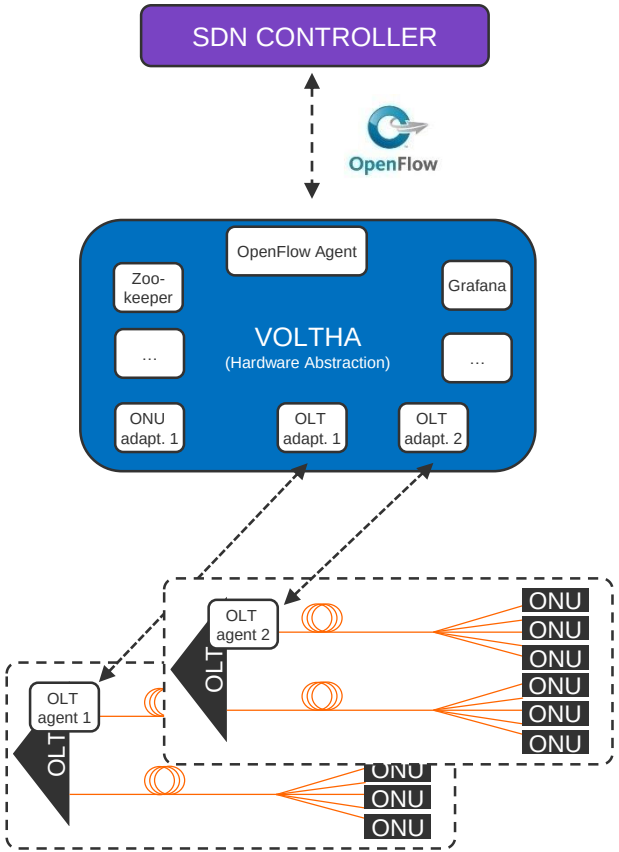
ONF's SEBA

- SEBA is a consolidated version of ONF's R-CORD
- Open Source
- It includes
  - the NEM (mediation between OSS and SEBA)
  - An SDN controler (e.g. ONOS)
  - VOLTHA, an abstraction layer to manage the OLT (not an easy task directly in OpenFlow)
- Major operators involve AT&T, Deutsh Telecom, NTT, Türk Telecom
- Legacy/major OLT vendors are a bit shy in this project. Newcomers with whitebox OLTs or disaggregated OLTs are well represented (EdgeCore, Tibit, …).



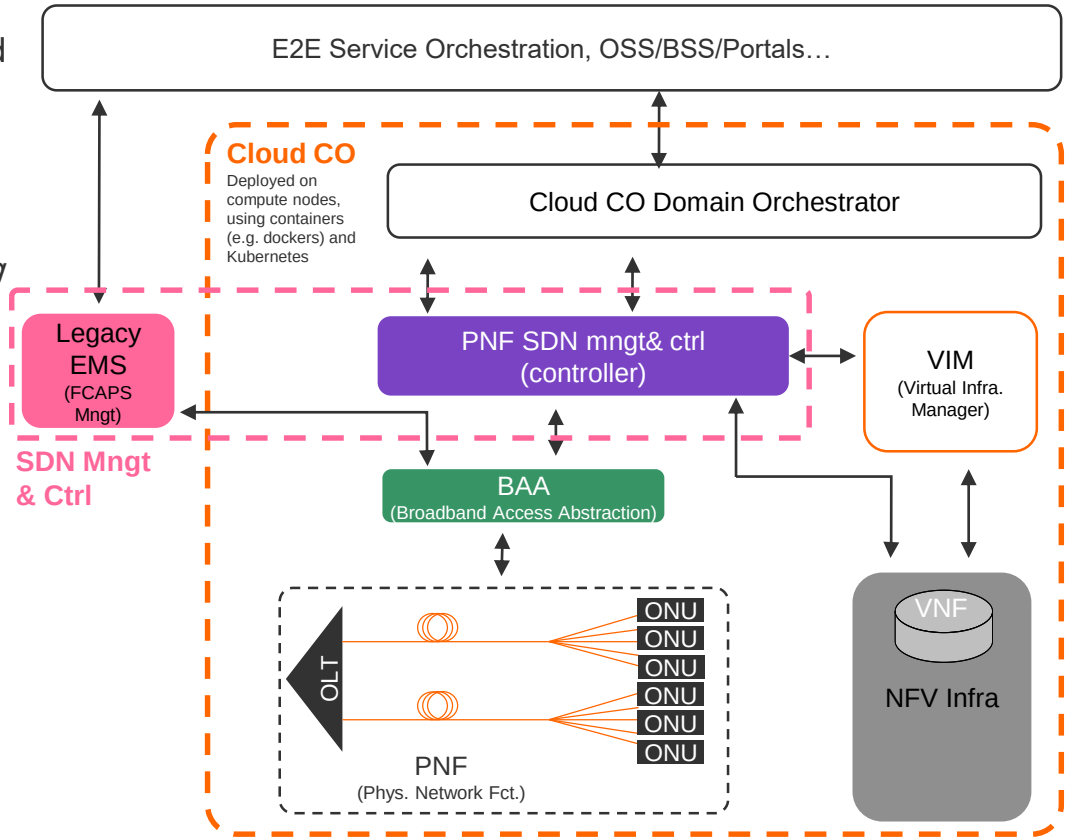
ONF's VOLTHA

- VOLTHA: Virtual OLT Hardware Abstraction
- "Makes an access network look like an abstract programmable switch"
- North Bound Interface:
  - VOLTHA makes the OLT appear as a programmable ethernet switch to sthe SDN Controller. Openflow is a prefered solution
  - It hides the OLT specificies
- South Band Interface:
  - PON-VOLTHA communication through vendor specific protocols
  - Vendors provide their « adaptors » to be embedded in VOLTHA
- Multi-vendor (vendor agnostic)
- A collection ~10+ Containers: ofagent, grafana, BBSIM/PonSim, zookeeper, nginx, …



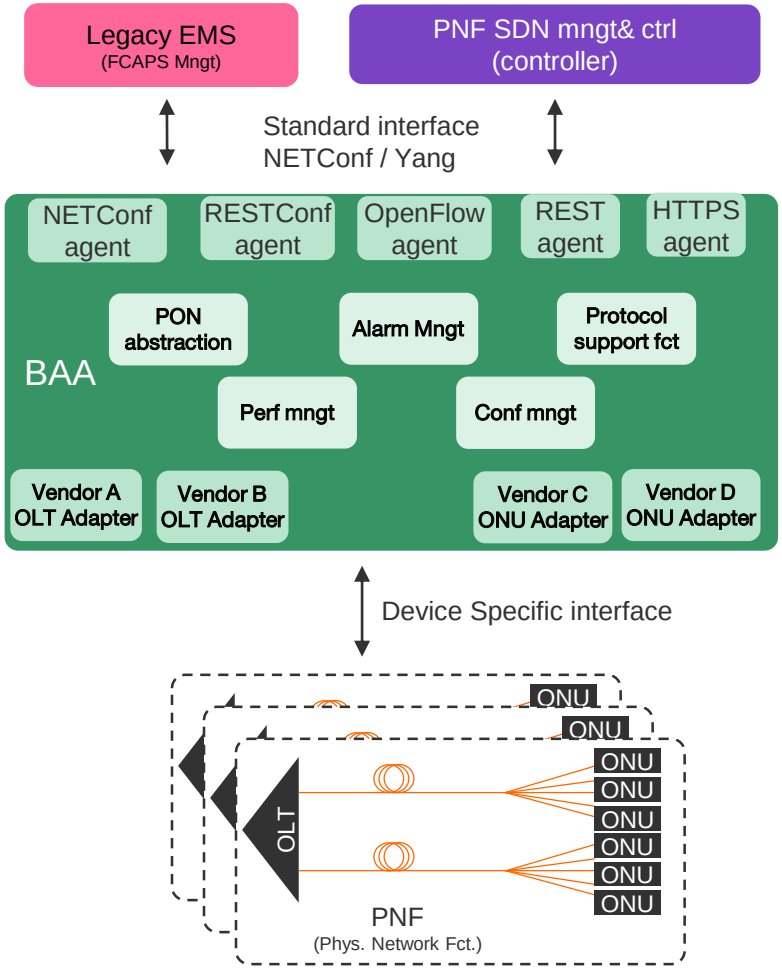
BBF's Cloud CO

- Broadband Forum: a consortium dedicated to the development of broadband network specifications
- Cloud CO: BBF TR-384 (Jan 2018)
- *"Cloud Central Office (CloudCO) is a recasting of the Central Office (CO) hosting infrastructure that utilizes SDN, NFV and Cloud technologies to support network functions"*
- Disaggregation: separating the nodal functionalities. More modularity
- Virtualization: softwarization of functionalities to host them on generic hardwares (servers) as "Virtual Network Functions (VNFs). If not softwarizable (e. g. time-sensitive), keep them as Physical Network Functions (PNFs)



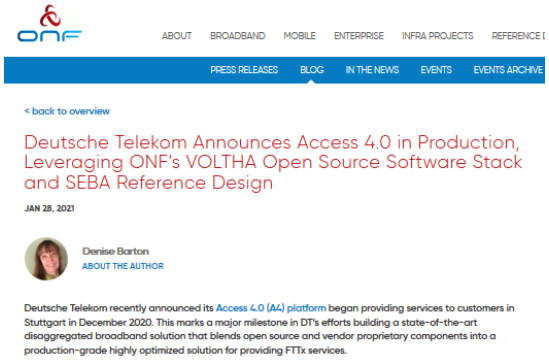
BBF's BAA

- Open Broadband - Broadband Access Abstraction (BAA)
  - Exposes standardized interfaces to SDN mngt and control
    - BBF TR383 & TR385 Yang models
    - Netconf protocol, borned from SNMP limits (IETF RFC 3535, 2002)
  - Enables legacy hardware integration (brown field), including legacy OLT but also DSL, G.fast
  - Northbound layer: mainly NETConf protocol (+Yang)
  - Southband layer: device specific hardware.
  - BAA hides vendors specificities and exposes « standard » OLTs and ONUs (abstraction): a flavor of virtual OLTs and ONUs (vOLT/vONU)
  - BAA layer unnecessary if OLT is natively NetConf/Yang (standard) compatible



ONF/SEBA/VOLTHA vs. BBF/CloudCO/BAA ..?

- Two approaches
  - ONF took the SDN architecture to access networks
  - … while BBF took access networks to the world of SDN
- Concurrent, but functionnaly very close, from a high level perspective
  - BAA approach eases legacy integration
  - VOLTHA more applicable on greenfield
- *« Broadband Forum and ONF ease the path to automated and open virtualized access networks"* (oct. 2019)
  - White paper about relationship between BAA and VOLTHA released
  - First evolutions appear (as BAA OpenFlow interface), but it will take time
- When will it be widely deployed ?
  - *"Deutsche Telekom Announces Access 4.0 in Production, Leveraging ONF's VOLTHA Open Source Software Stack and SEBA Reference Design"* (Jan. 2021)
    - Early stage field trials
  - For advanced deployed networks (e.g. Orange France), time window should coincide with technology migration (G-PON -> XGS-PON or XGS-PON -> HS-PON)


ABOUT BROADBAND MOBILE ENTERPRISE INFRA PROJECTS REFERENCE

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Deutsche Telekom Announces Access 4.0 in Production, Leveraging ONF's VOLTHA Open Source Software Stack and SEBA Reference Design

JAN 28, 2021

Denise Barton
ABOUT THE AUTHOR

Deutsche Telekom recently announced its Access 4.0 (A4) platform began providing services to customers in Stuttgart in December 2020. This marks a major milestone in DT's efforts building a state-of-the-art disaggregated broadband solution that blends open source and vendor proprietary components into a production-grade highly optimized solution for providing FTTx services.

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Legacy hardware

Legacy G-PON OLT
Up to 16.000 ONUs (here)

- A chassis with line cards and network cards
  - Network card for backhaul
  - Line card for PON or PtP
- Hardware dedicated (access network)
- Evolution (e.g. GPON to XGSPON) in swapping the line cards
- Managed in CLI or SNMP/MIB
- « Blackbox » (dedicated & propreitary software)

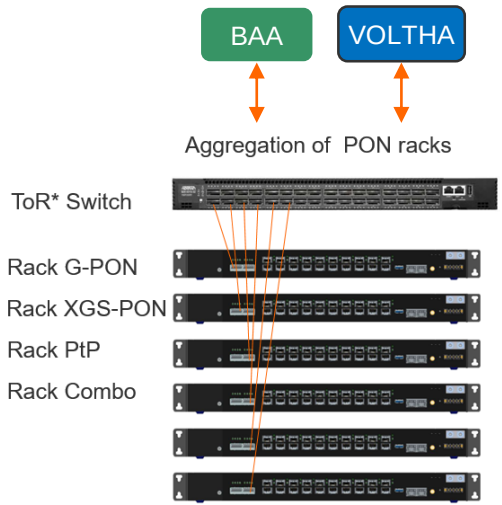
PON line card
PON access (ONU connection)
Point to multipoint (PON)
8-16 interfaces
2,5 / 1,25Gb/s / intf (G-PON)

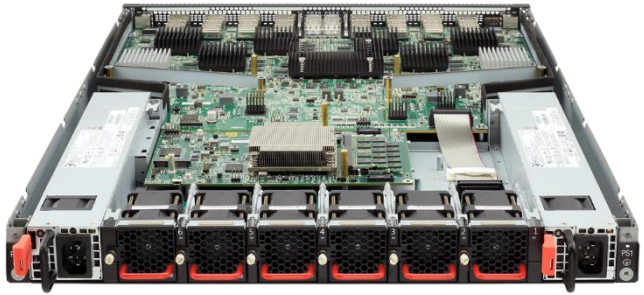
Network card
OLT backhaul
Point to point
4-8 interfaces
10 or 100Gb/s / interf

PtP line card
Businness or mobile antennas connection
Point to point
8-16 interfaces
10Gb/s typ.

Datacenter-shaped hardware (1)

- A top-of-rack switch to interconnect multiple layers
- Possibility to introduce leaf and spine architecture for redundancy
- Whitebox OLT
  - An empty hardware « shell » (in contrary to « blackbox »)
  - To be « filled » with software
  - Edgecore ASXvOLT16 example
    - Compatible with Radisys SD-PON, CapGemini SDvAS, Netsia SEBA, IP Infusion OcNOS, STL pTTx
  - Open the access networks to newcomers, and new tenants





Plugable SFP+/OLT

- Transceiver embedded real time MAC layer OLT function
  - Pluggable in any regular Switch or router
  - Increases modularity (« PON tree based » deployment, not « card based»)
  - Remote configuration
    - OLT interfaces management is performed in a virtualized environment (VNF)
    - VNF to SFP+ management channel standardized (IEEE 1904.2)
  - Tibit example
    - Both ITU-T XGS-PON and IEEE 10GEPON compatible
    - More embedded functionnalities => more energy consumption, compared to regular SFP
    - Time-related functions are executed on dedicated hardware

Generic
Ethernet Switch / Router

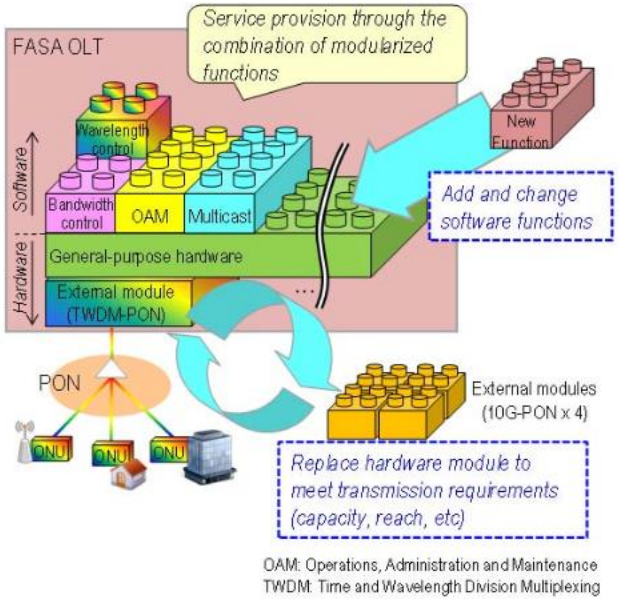
PtP 1G/10G/25G

10G-PON

TIBIT communications inc

General Purpose Hardware (1)

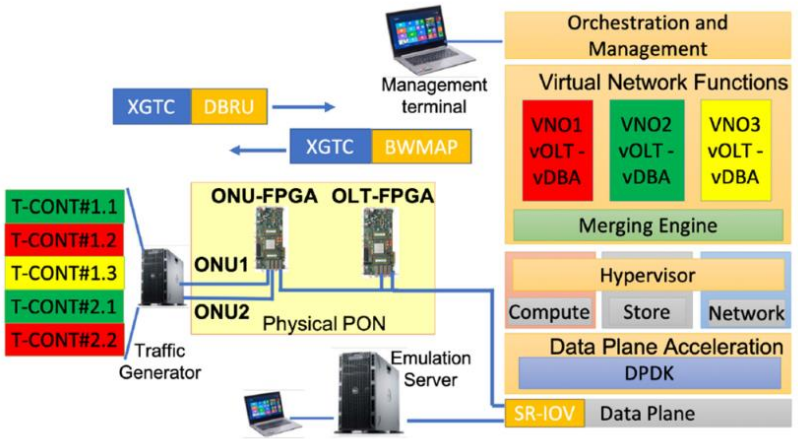
- NTT's FASA (Flexible Access System Architecture)
  - FASA OLT constructed by combining three parts:
    - Software modules
    - General purpose server
    - External modules
  - OLT functionality realized in combining appropriate software modules
  - Rapid evolution, update, with services evolution
  - Enables flexible edge applications
  - Challenges: modularize time-critical functions (DBA, ONU-sleep control, PON protection, …), and low-layer functionalities
    - Dynamic Bandwidth Allocation (DBA) algorithm: fast algo (typ. 100µs) to manage upstream PtMP bottleneck
      - The team demonstrated commodity hardware implementation
      - Standard API (BBF TR 402&403) between the algo and the engine, for service differentiation
    - Kim et al. ECOC 2021: implementation of DSP algorithms on commodity hardware GPUs (generally performed by dedicated hardware) for coherent PON (presentation in a few minutes !)
  - Today's direction towards previous open source architectures



[Kani et al. JLT2018]

General Purpose Hardware (2)

- Trinity College Dublin and Intel Ireland work
  - OLT made of commodity server and FPGA in some papers
    - Dynamic Bandwidth Allocation (DBA) algorithm: fast algo (typ. 100µs) to manage upstream PtMP bottleneck
      - The team demonstrated commodity hardware implementation
      - Standard API (BBF TR 402&403) between the algo and the engine, for service differentiation
  - concept of virtual-DBA, where multiple DBA instances are created and operated independently by different virtual operators (VNOs)
    - A “merging engine” located in the hardware OLT is required to process the vDBA requirements and allocate the physical resources to the VNOs, solve the vDBA conflicts, and creates the “real” bandwidth mapping for the ONUs
  - Helped by DPDK, a set of libraries to offload packet processing from OS kernel to processes running in user space
  - Demonstrations (OFC 2020)
    - Fully virtualized XGS-PON OLT on general purpose processor
    - vDBA implementation
    - Another flavor of “vOLT”



[Ruffini&Slyne JLT2019]

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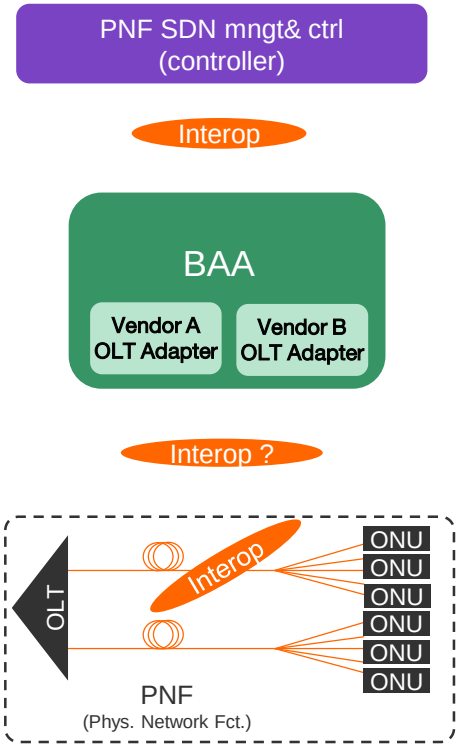
New Interoperability Challenges

- Interoperability remains a *must*
  - Legacy interop mainly concerned OLT-ONU
    - OMCI specifications
    - Huge workforce on testing/validating
      - Internally
      - Externally (plugfests, ONU certification)
    - The past 15-20 years showed that even if OMCI is standard, interoperability comes with at the cost of a strong effort
  - With new technologies, new interoperability testing required, even if interfaces are standard
    - Example of BAA:

      North bound interface of BAA to be validated

      Validation of each OLT adapter required. Can we do everything that we want through the standard (BAA NBI) interface ?

      OLT-ONU (OMCI/PLOAM) still at stake



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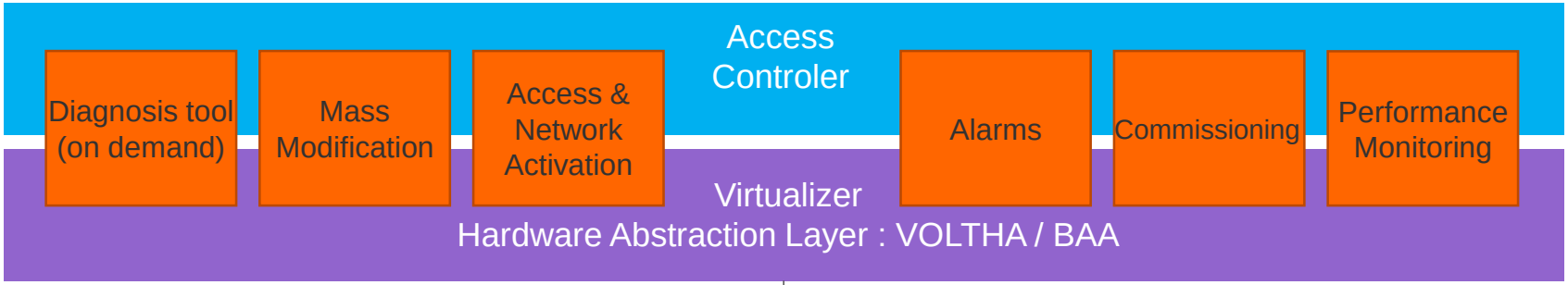
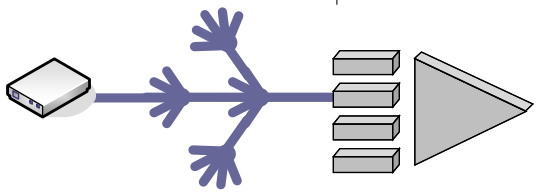
The introduction of a SDAN Controller requires a new OSS urbanism

Possible Future



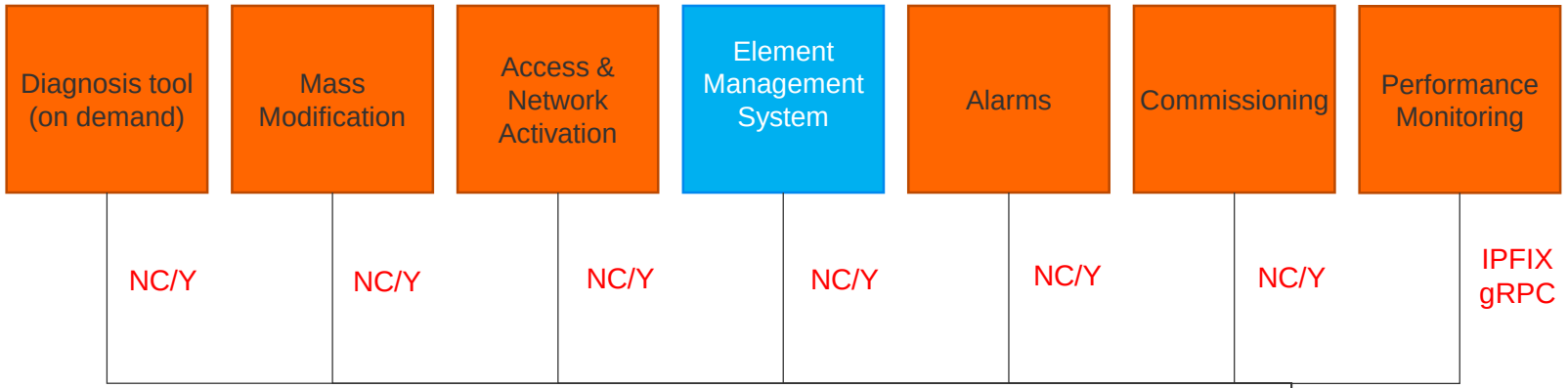
The Controller has the full control of the OLTs and the ONUs
Replacement of all OLT-facing OSS applications (config, alarms, diag…)

Vendor Lock-in on control layer if the controller is provided by an OLT vendor
Support for 3rd party OLTs to be validated in future



Alternative approach to SDAN: OSS evolution towards NC/Y

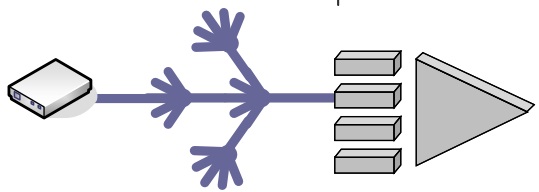
Other Future



Adapt existing OSS applications to support NETCONF/YANG interface

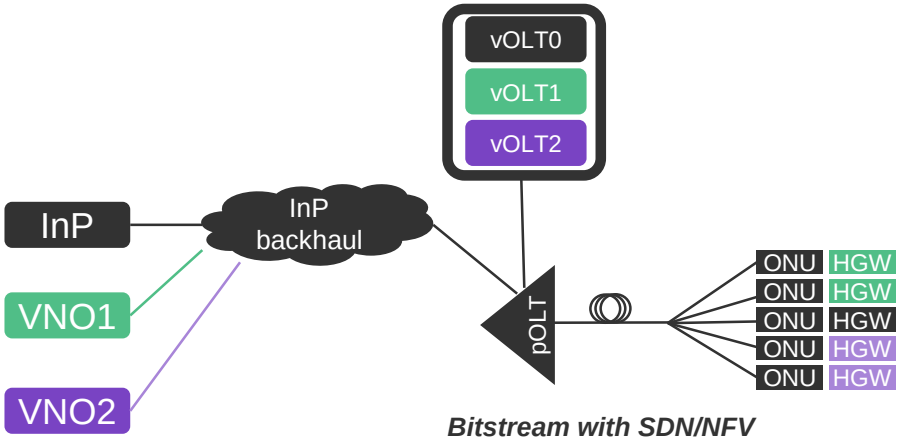
- All FCAPS* operations are based on NC/Y
- Minimal impact on OSS architecture except interfaces
- No vendor lock-in

But operational entity need to have an Element Management System with NC/Y interface

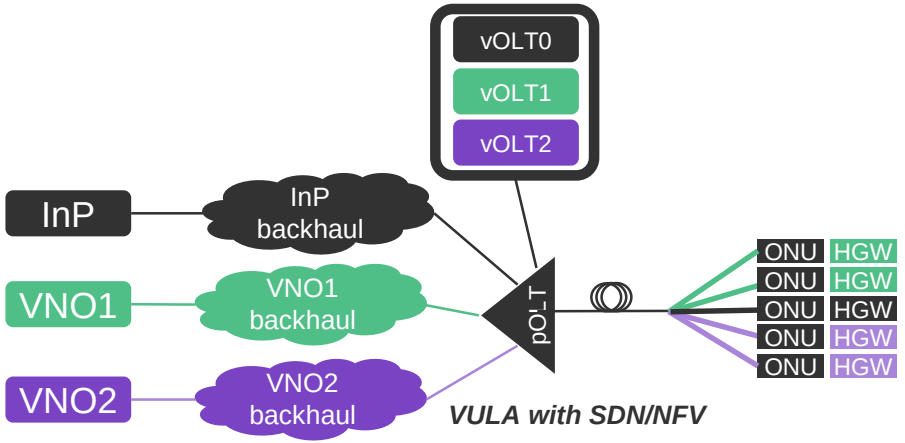


FAN Sharing

- Unbundling the network
  - Not new (enables in xDSL)
  - Make the links availables to 3rd parties
  - Opens competition
  - Several flavors:
    - Bitstream: non-exclusive lease of passive infra
    - Virtual Unbundled Local Access (VULA): Reuses the InP passive first-mile infra, avoiding ivestments
- Fixed Access Network Sharing
  - Several Virtual Network Operators (VNOs) are supported by the same physical access network, controlled by the Infrastructure Provider (InP)
  - Several level of FAN sharing depth (up to fiber-deep) but standard interfaces ease the work:
    - Shared infra can be dynamically managed, with the help of standard interfaces
    - OLT VNFs can be hosted in shared generic hardware
    - Alarms, diagnostic, etc. can more easilty go up to VNOs
- Standardized at BBF
  - TR-370 Fixed Access Network Sharing - Architecture and Nodal Requirements
  - TR-386 Fixed Access Network Sharing - Access Network Sharing Interfaces



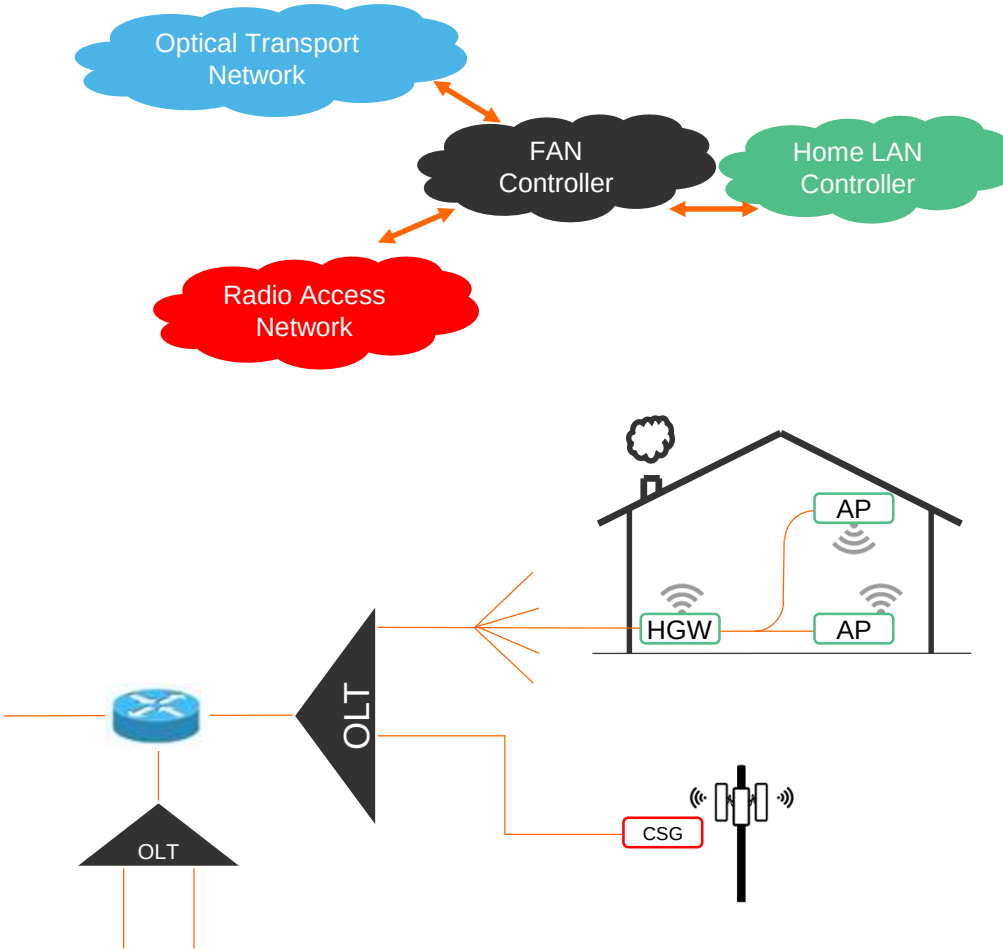
Bitstream with SDN/NFV



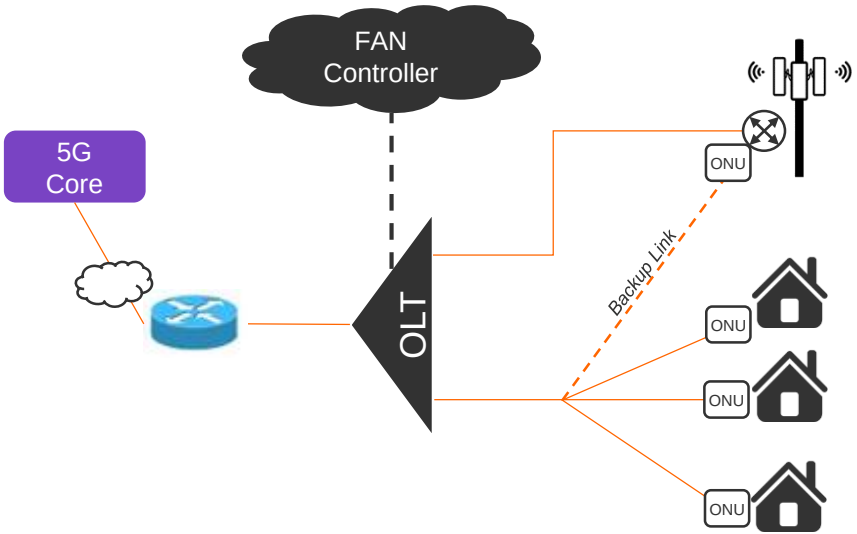
VULA with SDN/NFV

Removing the frontiers between network segments

- Optical access network is at the crossroad of other segments
  - Open interfaces enables new applications
- Home LAN
  - Quantity of access points (APs) will increase
  - Coordination and interconnection required
  - ETSI's F5G propose to « *take the paradigm of FTTH to a Fiber to Everywhere* »
- Optical Transport Network
  - Simplify end-to-end establishment of a service
- Mobile networks
  - Reduce latency (initiated by ITU-T Co-DBA)
  - … but also improve fine traffic tuning (see Wang et al. ECOC2020)
  - Improve reliability and avalability
  - Ease network slicing
  - … and many more !



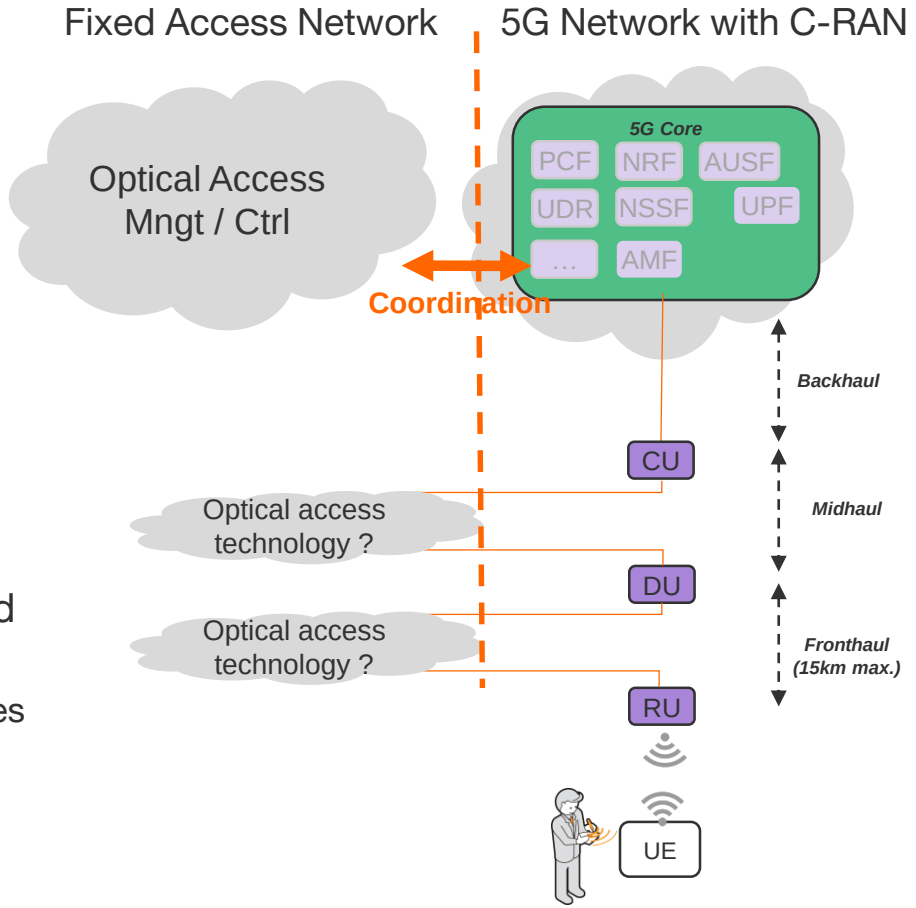
Removing the frontiers between fixed and Mobile: Mobile protection



- Availability and Reliability are key in 5G and beyond
  - 99.999% availability
- Flexible configuration ease fixed-mobile convergence
  - Deeper than FAN sharing: FAN may be shared also with mobile
  - Standard interfaces to finally make Mobile and fixed worlds work together
  - Beneficiate from already deployed infra
- Proposition of a 5G self-healing network helped by SDN and SLA coordination
  - See Wang et al. in a few minutes !

5G Slicing and Edge Computing

- 5G slicing:
  - consists of providing logical dedicated networks, with different Service Level Agreements (SLAs), to different slice tenants, over the same shared physical infrastructure
- Optical Access technologies are relevant candidates for RAN transport
  - PON for midhaul (F1 interface)
  - Point-to-point for Fronthaul
- Open & standard interfaces simplifies interactions with the mobile
- Going to generic optical access harware enables a deeper mix between mobile and fixed
  - OLT shelf could host MEC server cards…
  - …Or MEC could host disaggregated PON interfaces
  - OLT fabricants already propose “MEC cards” for legacy shelf



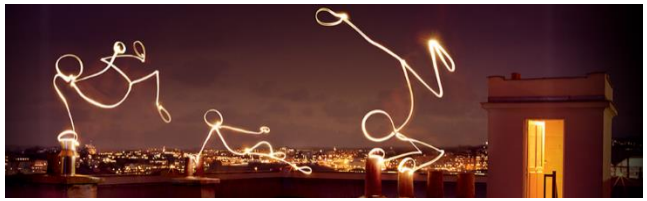
key takeaways

1
Many initiatives for SDN/NFV in optical access !
- Open source projects
- Standards
- Independent research and/or commercial work

2
Actual deployments depend on the environment
- Easier on greenfield
- Already mature FTTx networks may first only beneficiate from protocol evolution
- deeper evolutions with next technology gap ? (e.g. XGS-PON, 2025+)

3
Many things to explore regarding interactions with mobile networks
- Edge computing
- Availability, reliability
- Mobile network slicing
- What about 6G ?

Acknowledgments to 5G-COMPLETE and MARSAL projects



Thank You

Questions ?
You can also send me an e-mail ☺
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