

AT&T Open XGS-PON
NFV 1RU OLT Specification

Revision 1.2

Author: Thomas Anschutz

Revision History

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Scope

This document defines the technical specifications for the AT&T Open XGS-PON 1RU OLT submitted to the Open Compute Project. This is a derivative work from the AT&T Open GPON NFV OLT Line Card Specification and re-uses much of that design. This scope of this specification is not to detail a single design, but rather to describe a family of acceptable designs that would be sufficiently interchangeable to allow for easy substitution in a mixed deployment and operations environment. In other words, the intent of this spec is to allow multiple designs from different manufacturers to be used interchangeably.

Normative Language

This specification uses language to differentiate between design elements and options that are mandatory to meet the specification vs. those that are optional. The spec defaults to mandatory aspects of a design. If a feature, function, or description is provided without optionality, then it is mandatory. If an aspect of the specification is not mandatory, then it is optional and terms like *may, should*, and *might* are used to describe it. Optional items are also be annotated as (optional).

Overview

This document describes the technical specifications of the AT&T Open XGS-PON 1RU OLT. The system is a physical 1RU that is self- contained, and not part of a physical chassis system. However, like the GPON system, this physical box is attached to a fabric (e.g. leaf and spine) that interconnects many to create large scale-out virtual network elements[1]. The Open XGS-PON 1RU OLT is a high-performance access design focused on NFV Infrastructure deployments which support symmetric 10Gbps XGSPON access connectivity and provide up to 100Gbps uplinks to the ToR (Top of Rack) or Spine layer of the network.

The switch supports 16x XFP XGS-PON ports that each operate at 10Gb downstream (egress) and 10Gb upstream (ingress), four QSFP28 ports that operate as up to four 28Gb ports each. These 4 physical ports are arranged in a 1-1 active-standby arrangement, where each lane in a primary port has a corresponding backup in a failover port. Other applications are also envisioned and described below.

The Open XGS-PON 1RU OLT is a PHY-Less design with the XFP connections directly attaching to the XFI and SERDES interfaces of the Broadcom BCM68620 xPON SoC for OLT. The Open XGS-PON 1RU OLT supports traditional features found in Top of Rack switches such as:

- Redundant field replaceable power supply and fan units
- A variety of supported power supply voltages
- Support for “Front to Back” or “Back to Front” air flow direction
- A 1RU design that supports standard 19” rack deployments as well as standard 21” Open Rack and also 23” telco rack deployments.

Applications of this design include some specific variations and considerations in order to address a broader market and set of collaborators for this project. Specifically, the set of variations considered include:

1. The line card application for a virtualized scale-out OLT.
2. A small, simplified, self-contained traditional OLT device that can be used in non-NFVI environments.
3. The ability to manage and control the device using a separate out-of-band port.
4. The ability to synchronize and distribute timing from upstream toward ONUs.

The four variations are not mutually exclusive, and are now described in more detail.

Virtual OLT

The first application embodies the virtual OLT. In this application the device is envisioned to be part of a NFVI deployment, where compute, storage, and other cloud infrastructure are part of the environment. In this environment, the Open XGS-PON 1RU OLT connects to leaf or spine devices that aggregate traffic and also provide transport for management and control.

The management and control plane processes that might be typically performed by a supervisor processor on a traditional OLT are performed outside the Open XGS-PON box, in a separate commodity server. This allows managing many Open XGS-PON OLT devices from a small number of commodity servers, which conserves compute and storage for large deployments. The arrangement also allows for an overall system

[1] This type of system is described in ETSI NFV architecture, where it comprises the Infrastructure that supports Network Functions Virtualization – often called NFVI. Additionally, the open software beyond that described in this specification is collected and distributed by the Linux Foundation as part of the CORD project: http://opencord.org

design where there are fewer single points of failure that affect an entire Open XGS-PON 1RU OLT and allows application of cloud application architecture to software that was previously hosted on embedded processors.

This system is described as a disaggregated or virtual OLT because the various software and hardware components that were once integrated into a single physical device have been separated and supported in a distributed way across NFV infrastructure. By doing this it becomes more likely to re-use components among disparate networking functions and to independently scale resources and investments according the specific application of the technology.

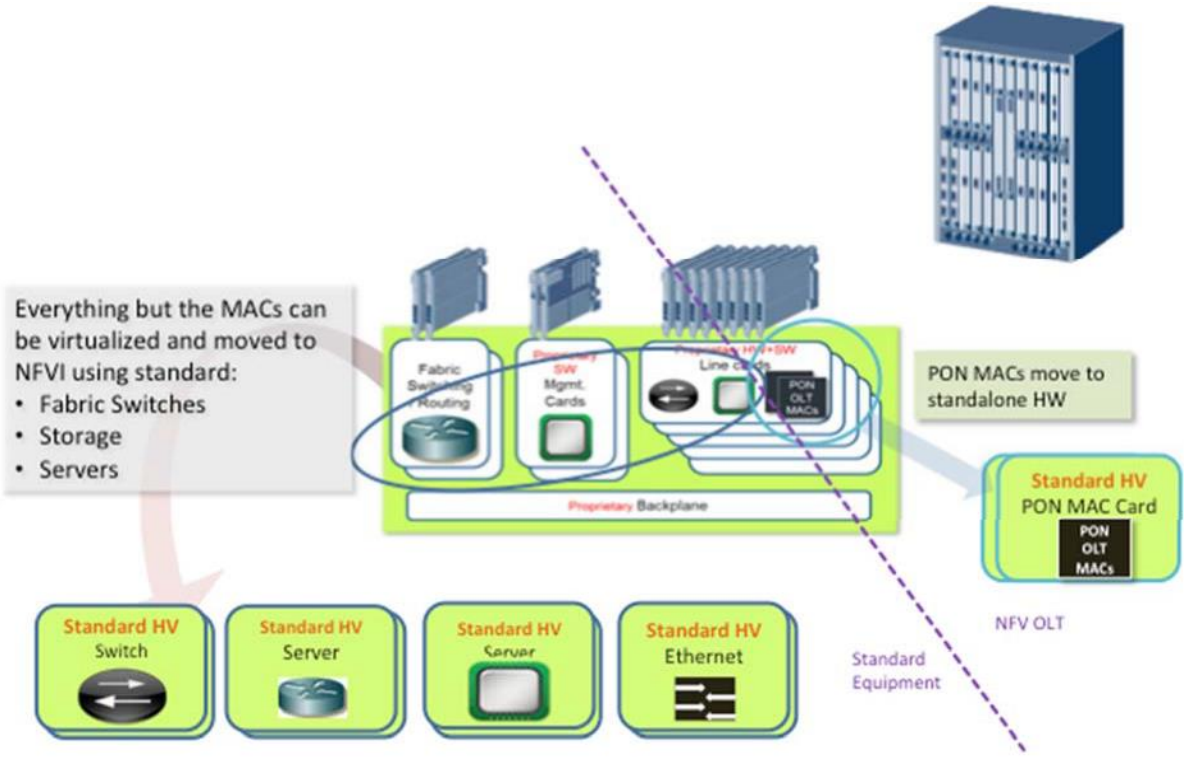


Figure 1 - Virtual OLT

Figure 1 shows the disaggregation of a typical OLT and the mapping of its functions to NFV infrastructure. The backplane or fabric of the OLT is mapped to the fabric of NFVI (ToR and EoR / leaf & spine switches). The interfaces to the fabric (what were card edge connectors) become simple Ethernet interfaces. The control and management functions are embodied in SDN control and Orchestration with a software stack that will be described shortly. Processing and configuration are mapped to compute and storage in NFVI. The figure shows that almost all the components in an OLT, those to the left of the dashed line, can be mapped to standard high-volume (HV) components found in NFVI. The exception is in the XGS-PON PHY and MAC. Those are not typically found in NFVI and this specification describes a standard HV device that supports them.

In the Virtual OLT, the application of the AT&T Open XGS-PON 1RU OLT is to facilitate attaching XGS-PON silicon to the fabric of NFVI – as shown in Figure 2.

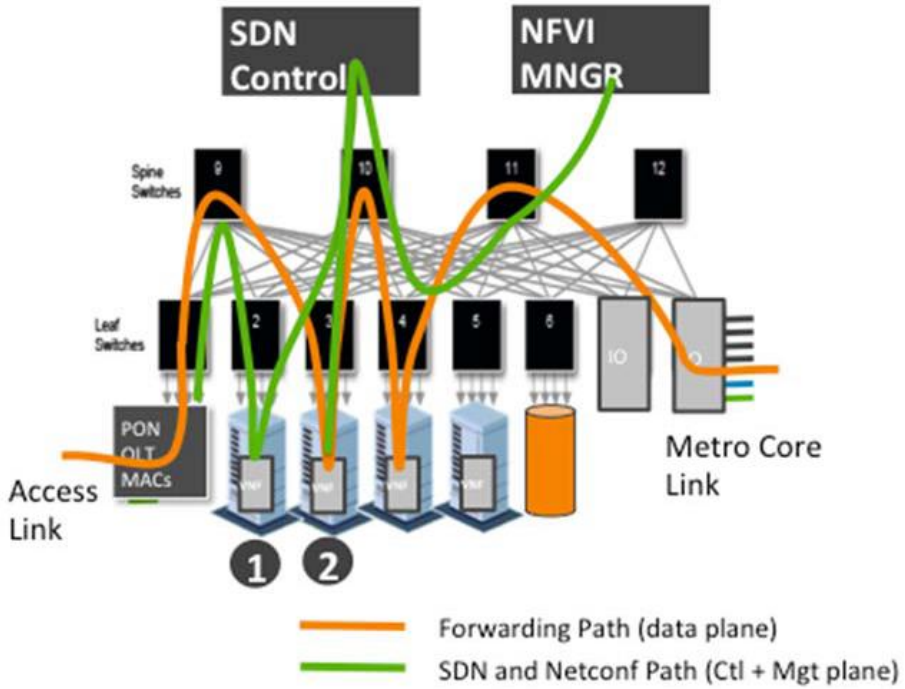


Figure 2 - Typical application of XGS-PON 1RU OLT

Figure 2 shows the Open XGS-PON 1RU vOLT attached to typical ToR (Leaf) switches in the lower left corner. Shown prominently at the top are processes that are run inside the compute VNFs at point 1 and 2. These processes provide the management and control plane functions that manage and control the overall system including the XGS-PON silicon within the Open XGS-PON 1RU OLT.

The software used to support this system is partly shown in Figure 3. At the lowest level of the figure we find firmware and hardware drivers that are part of the software loaded and run on the BCM68620 SoC chip. That software is loaded on the chip and then subsequently configured and managed through a matching low-level API along with an OMCI stack which is run on a commodity data center (DC) server. These elements are colored blue because they are proprietary and specific to the BCM68620, and would need to be replaced to support other chips and PHY technologies.

The next layer up is shown in purple and represents open source software. The lowest layer of this software consumes OLT API calls and OMCI signaling and creates a homogenized abstraction of an OpenFlow controlled OLT – largely patterned after an Ethernet switch. This abstraction is then plugged into the southbound side of an OpenFlow agent and configuration management block, and that software comprises all the code to generically manage and control the Open XGS-PON 1RU OLT.

The next layer in the software stack is an OpenFlow Controller and configuration. These might be combined or separate software. Finally, in green, we see the applications that embody the control plane and management applications for a number of access technologies and instances of each.

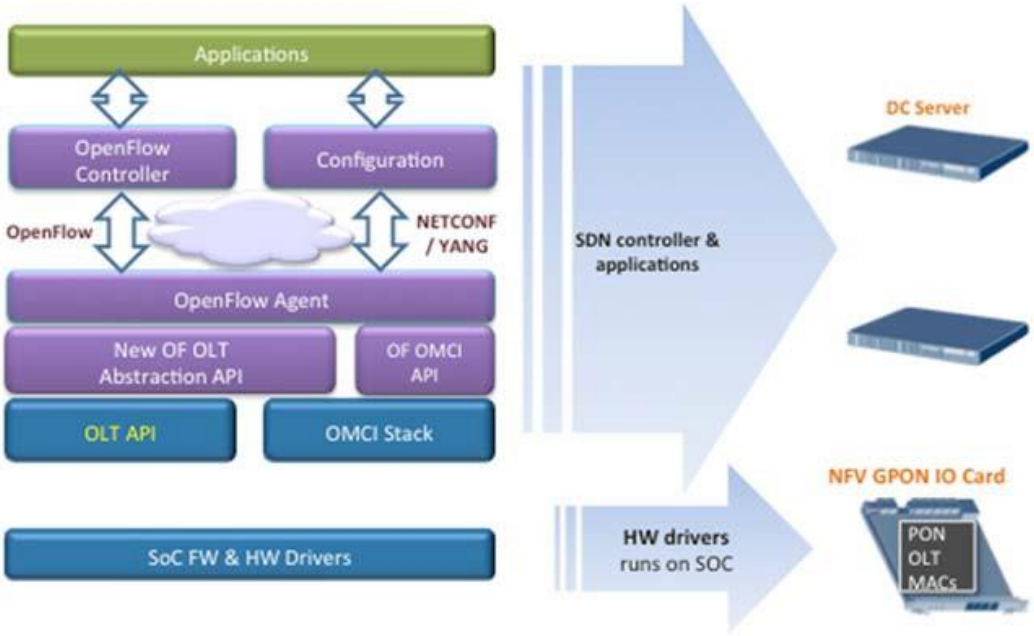


Figure 3 - Software stack for Open VOLT XGS-PON 1RU OLT

To support this application, the Open XGS-PON 1RU OLT minimizes the number of components populated on the system board and leverages external, scalable, available and re-usable components instead.

This is the most basic and economic instantiation of this design. Management is performed through external processes and is communicated through a virtual LAN that isolates that traffic from customer traffic. Specifically, there is a need to support OOB (out of band management) LAN. The design does still support a variety of power supply options, airflow options, and a baseboard management controller (BMC) to manage these resources.

Mini OLT

The next application of this technology moves to the opposite extreme. In this case the Open XGS-PON 1RU OLT is extended with Processing, Storage, and an internal communications to facilitate the device becoming a stand-alone OLT system. From a hardware perspective, the board is populated in addition to the components of the virtual OLT with a CPU, RAM, and Flash storage. This application is useful in one-off applications, in lab and development environments, and in places where NFVI isn't available or desired. The software stack for this device can be identical to that used in the virtual OLT: where either part or even all the software shown in **Error! Reference source not found.** is hosted on the onboard CPU. However, it is also possible to optimize. For example, control and management applications could be written directly to the merchant silicon APIs. Obviously, hybrid approaches are also possible by making other software placement choices, and other software not shown above could also be run on the CPU.

Timing

The next application covers a case for timing distribution. This application is largely independent of the previous ones. That is, regardless of whether there is an onboard software, processor and storage, there are situations when distributing timing is desired. The typical case for including timing distribution is where XGS-PON is used to provide backhaul for cell sites, but this is not a universal requirement for using XGS-PON for cell site backhaul. In this application an optional Synchronization Management Unit is added to the system to facilitate SyncE and IEEE 1588 timing paths.

This overall design supports all the aforementioned use cases, and allows the omission or depopulation of various components as manufacturing options to source the device for the various use cases.

XGS-PON Network

A 10 Gigabit Services PON (XGS-PON) network supports symmetrical 10G/10G communications to enable a variety of applications. Some key features include:

- Data rates of ~10Gbps (9953Mbps) in each direction
- At least 128 ONTs (downstream PON endpoints) per PON Link
- ToD synchronization
- ONT power saving operation
- Optional downstream AES encryption for each port
- IPv6
- Dual-stack IPv4 and IPv6
- Symmetric bandwidth allocation

Figure 4 shows a typical XGS-PON Network. The XGS-PON OLT devices shown at the right of the figure represent the device described in this specification. These devices are deployed with passive splitter devices that divide downstream optical power among the served customers. Typical customer types are shown on the left of the figure.

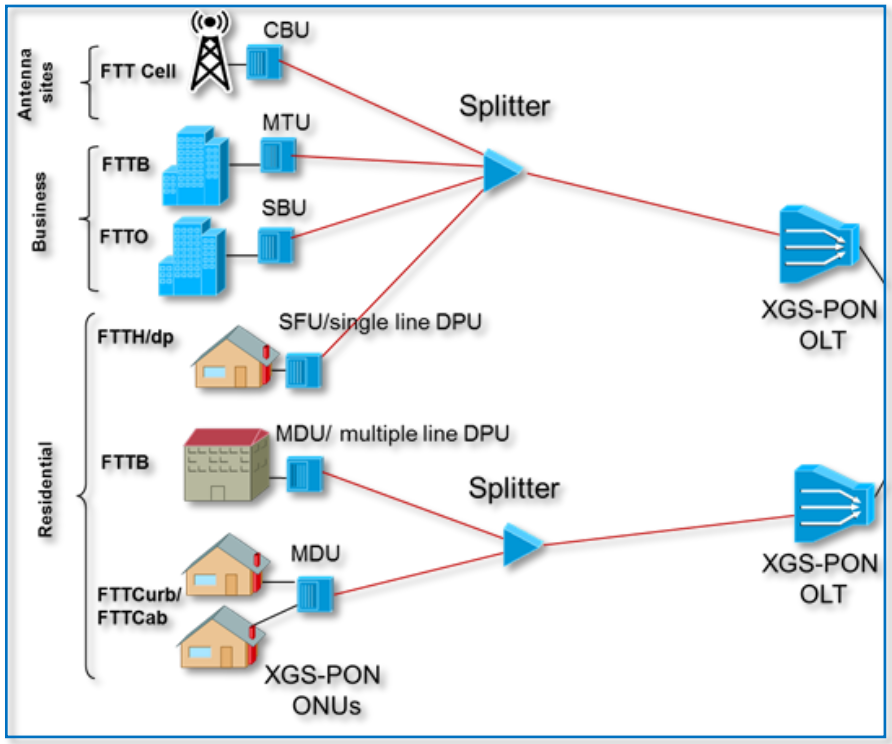


Figure 4 - XGS-PON Network

System Overview

An overview of the system in terms of functional blocks is seen in Figure 5.

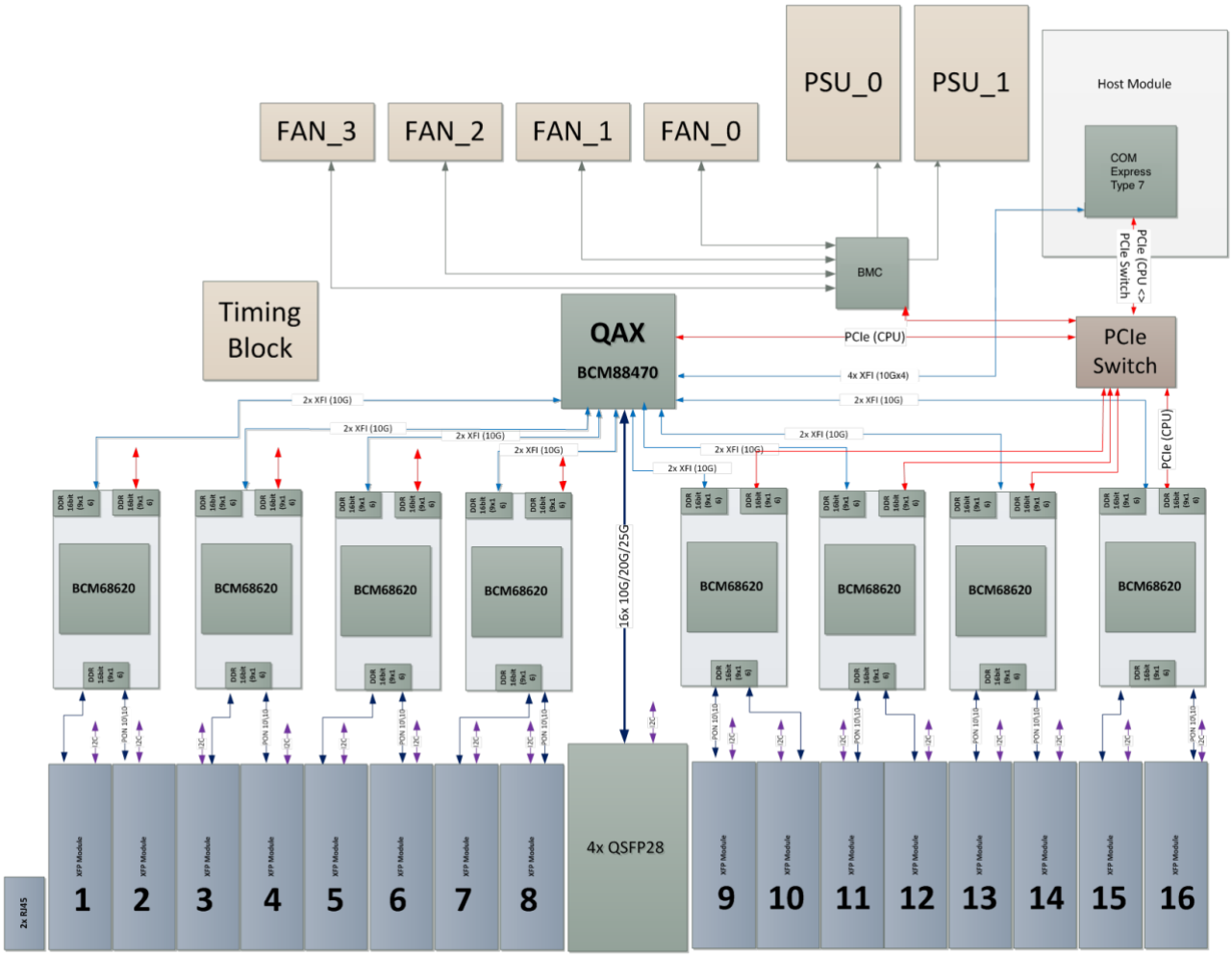


Figure 5 - Main system Block diagram

The block diagram in Figure 5 shows 8x BCM68620 devices connected to the QAX switch.

- The BMC/CPLD provides basic chassis management.
- The BCM68620 and BCM88470 devices are managed either:
  - by the host module using PCIe interface and the PCIe switch device, or
  - in band from remote management software. The host module is not needed in this mode.
- The host module is mandatory when the BCM devices are managed locally through PCIe. This is the current model of operation for the software stack that supports control and management of the device. However, future enhancement of the software is expected to allow for in-band management of the BRCM devices, and that will make the host module optional.
- In band connectivity to the host module supports additional bandwidth for VNFs hosted on the host module, and for resiliency approaches that decouple the host module from the managed box.
- All the chassis devices are connected through an I2C network such as FANs, PSMs, Optical transceiver modules, Thermals, and System LEDs.
- The BMC/CPLD provides I2C multi master support, and Chassis Management arbitration.
- Each BCM68620 SoC connects directly to the PON XFP cage using the PON link physical

connection. Also two 10G XFI links connect to the QAX device for the network uplink.
- Uplink resiliency is managed by the QAX switching device.

The Open XGS-PON 1RU vOLT system is a physical 1RU box that consists out of the following functional hardware modules:

XGS-PON SoC

The XGS-PON media access controller is a Broadcom BCM68620 “Maple B0” chip. Eight chips are used to support 16 ports of XGS-PON in this specification.

- The BCM68620 is a high-performance, single-chip, cost-effective OLT PON MAC SoC that supports XGPON1, XGS-PON, NGPON2 and 10G-EPON.
- The SoC is able to provide two ports of XGS-PON (10G/10G).
- The BCM68620 integrates NNI SerDes and MAC interfaces, ICF (Interconnect Function), PON MACs, and Burst mode PON SerDes interfaces.
- Supports external packet buffer for XGS-PON reassembly. Supports 800 MHz, 32-bit DDR3
- Size: 33 mm X 33 mm

Switching and Traffic Management

Switching and traffic management is performed by a single Broadcom BCM88470 QAX “Qumran” chip. It also provides an interworking function between XGS-PON and Ethernet. The need for this interworking function drove this specification to differ from the previous AT&T Open GPON OLT specification. In the earlier design the interworking and traffic management functions were integrated in the GPON SoC, so aggregation could be placed off-board in the ToR switches.

1) The BCM88470 is a high-performance, single-chip, cost-effective switch and traffic manager
2) Performance - 300Gbps; 300Mpps
3) Line Interfaces - 120x1GE, 48x2.5G, 2x100GE,48x10GE,16x40GE,4xILKN
4) OAM, 1588, SyncE Telecom DPLL
5) Traffic Management - 32K queues, 32Mb on-chip buffering, Packet packing for improved burst absorption
6) Max classification rules – can be the number of LLIDs/GEMs (Tunnel IDs) – 64K
7) Size: 40x40 mm

Host CPU Module

Designs that meet this spec must support a host module with an Intel D-1500 processor with at least 16G RAM and 32G M.2 SSD. The Host Module should use a COM-Express type 7 form factor or another existing OCP accepted modular design.

The modular design is required because a future version of the software stack used with this platform is planned to make use of in band management and control of the BRCM chips just described. Once that software stack is available, the host module can be omitted, or used to host VNFs, or used to host the BMC. These other applications of the host module suggest that other CPUs with different performance and price-points will be desired.

BMC

The BMC is associated with CPLD logic and allows for managing the Open XGS-PON 1RU vOLT. The BMC may be instantiated with a separate physical device, or a software component available with high reliability from the host module. When the BMC is provided on the host module, then the design must include a simplified, low-cost CPU

module to host the BMC software in those cases where a more functional CPU is not desired and the CPU module would normally be omitted from a build. The BMC is used in two ways:

1) Serves for general box management. E.g.: I2C control, LEDs, Interrupts + I/O expander, Fan and PS control, Power sequencing. Remote reset.
2) Supports Open BMC

Physical Overview

The following sections describe the overall physical dimensions as well as the required and optional layout of ports and indicators on the front, fans and power supplies on the rear, and high level interior design aspects. Illustrative figures are provided to show how the design can be embodied, but are not intended to restrict designs to an exact match.

Maximum Dimensions

Table 1 shows typical dimensions for a physical design. The 1RU faceplate should be within tolerance for typical rack designs, however the depth can be substantially less than the specification with shorter devices being preferred,

Table 1 - Maximum Physical Dimensions

	Inches	Millimeters
Depth	24	609.6
Width – 19” rack	17.5 with ears for 19”	444.5
Height – 1 RU	1.75	44.45
Note: Width does not include mounting ears – which must have holes or closed slots. Depth does not include PSU handles.		

Top View

The top view of the Open XGS-PON 1RU OLT shows the PCBs and associated components in the system (illustrative only).

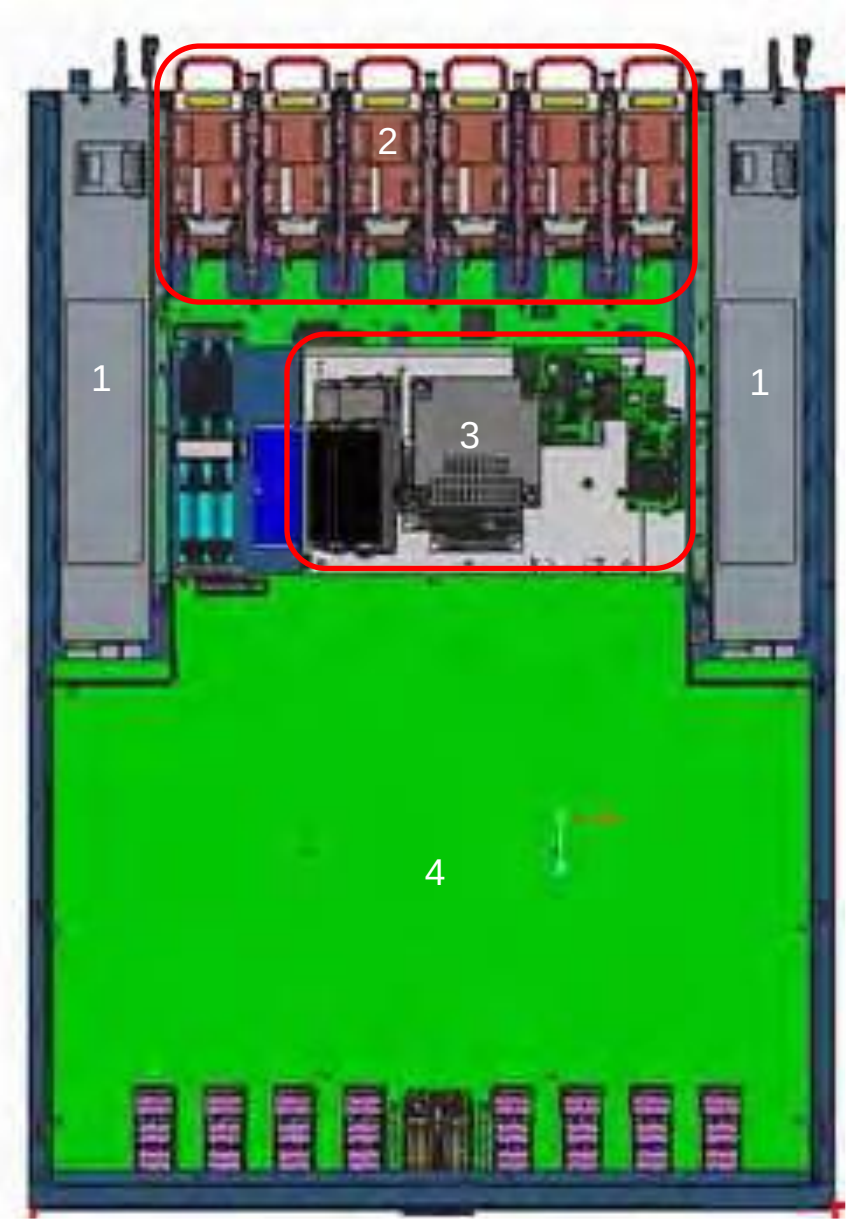


Figure 6 - Top View (Illustrative)

Figure 6 shows an interior view with modular essential design elements labeled. Those elements are:

1. Hot swappable power supply
2. Hot swappable fan modules
3. CPU module
4. 16 XGS-PON ports mapped to 8 devices and 1 aggregating switch – 8 x BCM68620 + 1 x BCM88470

Front Panel



Figure 7 - Front Panel (Illustrative)

Figure 7 shows an illustrative front panel layout as well as mandatory and also optional features for the front panel. The front panel includes all ports except power. The ports and indicators include:

- PON Links: 16x XFP ports
- Uplink Ports: 4x QSFP28
  - Each module supports up to 4x 25Gb per link
- LEDs (See further detail in Table 2)
  - XFP Module status
  - QSFP28 port status
  - System and PSU LED indicators
  - System Finder LED
- RJ45 10/100/1000 Ethernet out of band management port
  - Connected to BMC and optional system CPU
  - Optional serial over LAN for virtual console
  - Optional Sync-E reference source
- RJ45 Console Port (optional)
- USB Type A port (optional) for external storage, updates
- Reset switch (optional)

The indicator lamps (LEDs) must convey the information described in Table 2. The number, colors, and flash behaviors are desired but not mandatory.

Table 2 - LED Definitions

LED Name	Description	State
PSU1	Led to indicate status of Power Supply 1	Green - Normal Amber - Fault Off – No Power
PSU2	Led to indicate status of Power Supply 1	Green - Normal Amber - Fault Off – No Power
Diag	LED to indicate system diagnostic test results	Green – Normal Amber – Fault detected
FAN	LED to indicate the status of the system fans	Green – All fans operational Amber – One or more fan fault
LOC	LED to indicate Location of switch in Data Center	Blue Flashing – Set by management to locate switch Off – Function not active

XFP LEDS	LED built into XFP cage to indicate port status	On Green/Flashing – Port up with active ONTs Flashing indicates activity On Amber – Port up with no active ONTs Off – No Link/Port down
QSFP Break out LEDs	Each QSFP28 has four LEDs to indicate status of the individual 10-25G ports	On Green/Flashing – Individual 25G port has link at 25G. (yellow for 10G?) Flashing indicates activity Off – No Link
OOB LED	LED to indicate link status of 10/100/1000 management port	On Green/Flashing - port has link Off – No link

Rear Panel



Figure 8 - Rear Panel (Illustrative)

The rear panel of the Open XGS-PON 1RU vOLT is shown in Figure 8 and includes hot-swappable fans and power supplies. The layout of these components is flexible, and the number of fans is flexible as long as they achieve the following:

- Multiple (N+1) redundant hot swappable fan modules (Including Color coding to indicate airflow direction). System must be able to operate with N fans cooling
- Two hot swappable power supply modules. The system must be able to operate with one failed power supply. And it must be possible to operate the system with only one power supply installed. This may require a blank or cover plate as a build option.
    - LED per power supply to indicate status
    - Color coding to indicate airflow direction

Field Replaceable Units

This section describes field replaceable modules used in the design. These include optical XFP and QSFP transceivers, fans and power supplies. All modules must be hot swappable without the use of tools.

Power Supply Modules

The Open XGS-PON 1RU vOLT supports two hot swappable Power Supply Modules (PSMs) and needs only one to operate. Please use the below as a general guidelines for the PSUs selection:

- The PSM form factor should re-use an existing OCP form factor. (optional)
- The PSM must meet the power requirements of the design: e.g. 640W or more.
- The system must accept different PSM types (e.g. AC or DC) which have the same form factor.
- All PSMs must be available with F2B and B2F airflow.
- AC PSMs must support AC input between 100 & 240 VAC.
- AC PSMs must have a mechanism that prevents accidental dislodging of the cord.
- DC PSMs must support DC input between -57 & -40VDC.
- DC PSMs have additional physical connection requirements listed in AT&T TP 76450, section 2.4.

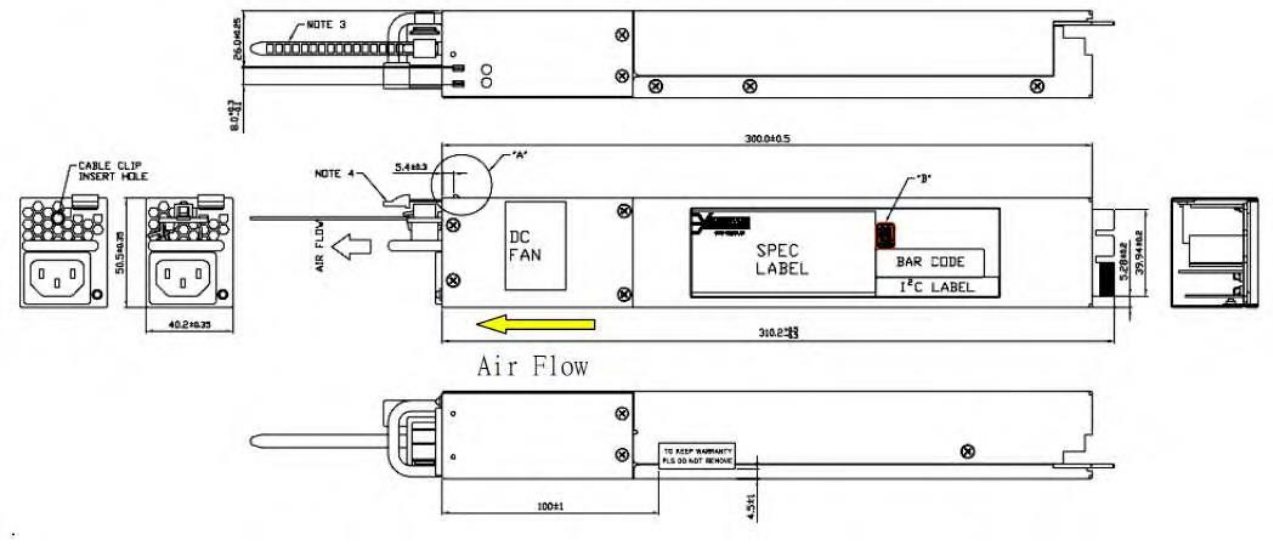


Figure 9 – Power Supply (Illustrative)

Fan Modules

The Open XGS-PON 1RU vOLT supports multiple individual fan modules in an N+1 scheme where N modules are sufficient to cool the device. Fan modules may use different designs for number and size of fan, as long as the overall design cools appropriately with a failed device. In 1RU designs, a typical fan module might have two 40mmx40mmx54mm fans. An example of a suitable fan module is show from the front and back in Figure 10. There are two fan module types differentiated by airflow, Front-to-back and back-to-front (F2B and B2F).

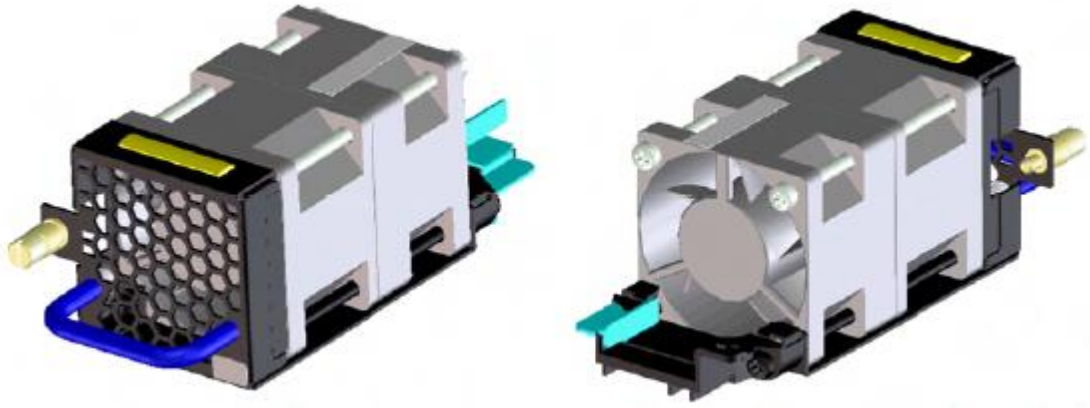


Figure 10 – Fan (Illustrative B2F)

The design should re-use fan modules typically found in existing OCP specs.

Optical Modules

The Open XGS-PON 1RU vOLT system is designed to support up to 16 XGS-PON Optical transceiver modules. The modules use XFP form factor as described in Table 3

Table 3 - XFP Modules

10Gb XGS-PON XFP Modules	Standard 10Gb XGS-PON XFP modules

The Open XGS-PON 1RU vOLT system is designed to support up to 4 modules with 4 links per module on the uplink side. All links are connect the four QSFP28 cages placed in the front panel to the BCM88470 QAX switching device. Optical modules can be placed in 1 to 4 of these cages depending on bandwidth and redundancy needs

The links from the BCM88470 towards the QSFP28 modules can be configured to work in different link/SERDES configurations (e.g. 10G, 20G or 25G)

Uplink redundancy is flexible, and uses the QSFP28 modules located on the front panel. Redundancy is managed and controlled by the vOLT application.

Table 4 - QSFP Modules

100Gb QSFP28 Optical Modules	Standard 100Gb QSFP28 modules including but not limited to: 100GBASE-SR4, 100GBASE-CWDM4OCP, 100GBASE-LR4, 100GBASE-ER4
40Gb QSFP+ Optical Modules	Standard 40Gb QSFP modules including but not limited to: 40GBASE-SR4, 40GBASE-FR, 40GBASE-LR4, 40GBASE-ER4
100Gb QSFP28 Direct Attach Cable	Standard DAC cables including but not limited to: 100GBASE-CR4.
40Gb QSFP+ Direct Attach Cable	Standard DAC cables including but not limited to: 40GBASE-CR4.

PCB Board Set

The Open XGS-PON 1RU vOLT is composed of several modules or PCBs. The design must have a separate board for the CPU to allow for different build options and for the CPU board to be omitted from a build completely.

The design may have additional modularity in PCB layout. For example, it's acceptable to have a separate fan board module as a re-useable component across different system designs. Similarly so for other build options, like timing modules, and standard components like a BMC module.

Preferred designs for this spec. will re-use existing modules from other OCP Accepted designs.

Software Support

The Open XGS-PON 1RU vOLT supports a base software package composed of the following components:

BMC support

AMI BMC or OpenBMC v1.0.5 or greater

U-Boot (Optional CPU Module)

U-boot v2014.10 or greater will be supported

ONIE (Optional CPU Module)

ONIE version 2014.08 or greater will be supported

Open Network Linux (Optional CPU Module)

See http://opennetlinux.org/ for latest supported version

Overall System Software

See http://opencord.org for information and documentation

See https://github.com/opencord/cord for software source

General Specifications

Power Consumption

The total estimated system power consumption of the AT&T Open XGS-PON 1RU vOLT is ~650 Watts. This is based upon worst case power assumptions for traffic, optics used, and environmental conditions. A summary of power contributors is shown in Table 5.

Table 5 - Power Consumption Estimate

Power Consumption Estimation Table			
Main Components	Watts each	Quantity	Total Watts
BRCM PON and QAX chips			166.33
DDR3-1600	0.6	40	24
DDR4-3200	1.3433325	6	8.06
DDR3_VTT075	1.096875	8	8.78
DDR4_VTT060	0.756	1	0.76
4 QSFP transceiver	4.95	4	19.8
16 XFP transceivers	5.8	16	92.8
BCM54616S	0.947454	1	0.95
PEX8614 (PCIE switch)	3.01	1	3.01
CPLD	2.01	3	6.03
LED	6.6	1	6.6
USB connector+ USB2.0 Hub controller	6.056	1	6.06
SPI flash	0.2244	8	1.80
Fan Module	3.3	1	3.3
FAN	19.92	6	119.52
CPU Module (Intel BD-1518)	86.8	1	86.8
Clock	19.8	1	19.8
Subtotal			574.37
Total (Including Efficiency=90%)			638.19

Specification Requirements

AT&T has established specifications for servers and NFVI communications equipment that are intended to be used in Central Offices. These specs revisit classical NEBs requirements – particularly in the face of new resiliency and availability architectures. Servers and switches that are not a single point of failure for their services (e.g. follow a typical cloud resiliency model) follow ATT-TP-76207. Telco devices that do have or comprise single points of failure for their services including this specification follow ATT-TP-76208.

This specifications is subject to follow **ATT-TP-76208** which is available at this URL:

https://ebiznet.sbc.com/sbcnebs/Documents/ATT-TP-76208_vOLT%20Equipment%20Standards.pdf

These requirements are partially repeated here.

Specifications that require testing must be confirmed by an accredited agency recognized by the National Cooperation for Laboratory Accreditation or ISO/IEC Guide 25 or ISO/IEC 17025.

Note: These specifications are limitations placed on any design. The actual performance of Open XGS-PON 1RU vOLT meets or exceeds these specifications.

Power Consumption

The total estimated system power consumption must be specified in watts. This is based upon worst case power assumptions for traffic, optics used, and environmental conditions. Typical power consumption should also be provided, as well as heat dissipation.

- ATIS TEER (ATIS-0600015.2009) should be measured and provided (Preferred)
- SPECpower_ssj2008 can be substituted for ATIS TEER (Acceptable)
- US EPA Energy Star Certification is favored.
- Power terminations must be clearly labeled and fully protected with a non-metallic, non-flammable cover.
- ATT-TP-76208 lists additional power requirements for under and over voltage, grounding, and current characteristics.

Environmental

- Light weight is favored
- 15 to 40°C operating range – de-rated 1°C for every 1000 ft (300 m) above 6000ft (1830m).
- Humidity 5% to 85% non-condensing (operational and storage)
- Vibration – IEC 68-2-36, IEC 68-2-6
- Shock – IEC 68-2-29
- Acoustic Noise Level – Under 78dB in 26 degree C
- Altitude: -200ft (-60 meters) to 6000ft (1830 meters).

Safety

Fire Spread. Field conditions for telco deployment may require deployment in existing Carrier Communications Spaces that utilize Fire Code Exemptions and do not have automatic fire suppression. NFVI equipment, like the Open XGS-PON 1RU vOLT deployed in these locations must meet enhanced fire spread requirements:

Generally, the equipment must meet ATIS-0600319.2014 *Equipment Assemblies – Fire Propagation Risk Assessment Criteria* (see note below).

Note: Equipment may conform to this requirement by way of inherent design features that include all four items below:

1. Height of 2 RU or less
2. Horizontally mounted main printed circuit board
3. Metallic 5 sided enclosure with a metallic or non-metallic front cover or faceplate
4. Non-metallic materials shall comply with ATIS-0600307 4.1

For equipment that does not meet the fire spread requirements of ATIS-0600319.2014 by way of inherent design features noted above, the manufacturer must attest that the equipment has successfully passed the burn test as referenced in the ATIS document.

- UL/ Canada
- CB (Issued by TUV/RH)
- China CCC

Electromagnetic Compatibility

- GR-1089-CORE
- FCC Title 47, Part 15, Subpart B Class A

ROHS

Restriction of Hazardous Substances (6/6)

Compliance with Environmental procedure 020499-00 primarily focused on Restriction of Hazardous Substances (ROHS Directive 2002/95/EC) and Waste and Electrical and Electronic Equipment (WEEE Directive 2002/96/EC)