TECHNICAL REPORT

TR-413
SDN Management and Control Interfaces for CloudCO Network Functions

Issue: 1
Issue Date: December 2018

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Issue History

Issue Number	Approval Date	Publication Date	Issue Editor	Changes
1	17 December 2018	17 December 2018	Duane Remein Huawei Technologies Co.,Ltd., Mauro Tilocca Telecom Italia, Marco Marcon Telecom Italia	Original

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Executive Summary

This Technical Report specifies the Management and Control interfaces of Cloud Central Office (CloudCO) (see TR-384 [4]) network functions and specifies their Northbound Interfaces (NBIs). These NBIs are defined via the supported macro-functionalities and linked to YANG Data Models (DMs).

This work enables the migration from SNMP/MIB towards NETCONF/YANG interfaces and potentially other protocols to exercise not only traditional Fault Configuration Accounting Performance Security (FCAPS) management functions but also control of flows across Virtual Network Functions (VNFs) and Physical Network Functions (PNFs) network service graphs.

1 Purpose and Scope

1.1 Purpose

The CloudCO architecture, with its Data Plane functional components (essentially PNFs and VNFs) and Management and Control Plane functional components (essentially Software Defined Network – SDN – Managers and Controllers), enables new management capabilities. The CloudCO Domain Orchestrator guarantees that these two orthogonal planes, i.e., the Data Plane and the Management and Control Plane, evolve in space and time as required for proper operation of the CloudCO domain.
The purpose of this Technical Report is to specify the Network Functions' (NFs) NBIs that allow the interactions between these planes. The evolved NFs' NBIs are a key step towards Software Defined Networking introduction and the automation and orchestration of PNFs and VNFs in a CloudCO architecture.

This Technical Report is an interface specification that defines what DMs are exposed and what protocol requirments are supported by the NBI of a specific NF and of the Broadband Access Abstraction (BAA) layer's Northbound Abstraction Interface (NAI) and Southbound Adaptation Interface (SAI). The required DMs depend on the set of features actually implemented by the NF.

This Technical Report complements the functional specifications (e.g., other BBF TRs or standards published by other Standards Development Organizations) that define the features implemented inside a NF.

1.2 Scope

This Technical Report specifies the NBIs for Access PNFs and the SAIs and NAIs for the BAA layer and links them to the required YANG DMs.

This Technical Report addresses NETCONF/YANG interfaces, and potentially other protocols, to exercise not only traditional FCAPS management functions but also flow control (not to be confused with Ethernet Flow Control per IEEE 802.3 [28]) across VNFs and PNFs network service graphs.

The interface requirements of this Technical Report refer to the YANG DMs and NETCONF requirements already published at the time of its issue. Both aspects are in continuous development by the BBF and other Standards Development Organizations and are expected to be integrated in future Issues of this Technical Report as they become mature.

For a comprehensive implementation and field adoption of an SDN and automation architecture, the set of applicable YANG DMs, NETCONF features and node types is wider than those covered in this Issue 1. At the time of publication of this Technical Report there is work ongoing that could help increase this ideal coverage in the following areas:

- YANG DMs for certain Layer 2 (L2) functionalities and for all Layer 3 (L3) functionalities to define the interfaces for Edge PNFs and VNFs, and

- NETCONF requirements for Optical Line Terminals (OLTs) and other types of nodes and stand-alone NFs.

The orchestration interfaces are being addressed in other BBF deliverables related to CloudCO.

2 References and Terminology

2.1 Conventions

In this Technical Report, several words are used to signify the requirements of the specification. These words are always capitalized. More information can be found be in RFC 2119 [9].

MUST	This word, or the term “REQUIRED”, means that the definition is an absolute requirement of the specification.
MUST NOT	This phrase means that the definition is an absolute prohibition of the specification.
SHOULD	This word, or the term “RECOMMENDED”, means that there could exist valid reasons in particular circumstances to ignore this item, but the full implications need to be understood and carefully weighed before choosing a different course.
SHOULD NOT	This phrase, or the phrase "NOT RECOMMENDED" means that there could exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications need to be understood and the case carefully weighed before implementing any behavior described with this label.
MAY	This word, or the term “OPTIONAL”, means that this item is one of an allowed set of alternatives. An implementation that does not include this option MUST be prepared to inter-operate with another implementation that does include the option.

2.2 References

2.2.1 Published References

The following references are of relevance to this Technical Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Technical Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.

A list of currently valid Broadband Forum Technical Reports is published at http://www.broadband-forum.org.

Document	Title	Source	Year
[1] TR-301i2	Architecture and Requirements for Fiber to the Distribution Point	BBF	2017
[2] TR-355a1	YANG Modules for FTTdp Management	BBF	2018

[3]	TR-383i1a1	Common YANG Modules for Access Networks	BBF	2018
[4]	TR-384	Cloud Central Office Reference Architectural Framework	BBF	2018
[5]	MEF 38	Service OAM Fault Management YANG Modules	MEF	2012
[6]	MEF 39	Service OAM Performance Monitoring YANG modules	MEF	2012
[7]	OpenFlow v. 1.4.0	OpenFlow Switch Specification	ONF	2013
[8]	RFC 1157	A Simple Network Management Protocol (SNMP)	IETF	1990
[9]	RFC 2119	Key words for use in RFCs to Indicate Requirement Levels	IETF	1997
[10]	RFC 2578	Structure of Management Information Version 2 (SMIv2)	IETF	1999
[11]	RFC 3535	Overview of the 2002 IAB Network Management Workshop	IETF	2002
[12]	RFC 4114	Introduction to version 2 of the Internet-standard Network Management Framework	IETF	1993
[13]	RFC 5277	NETCONF Event Notifications	IETF	2008
[14]	RFC 6022	YANG Module for NETCONF Monitoring	IETF	2010
[15]	RFC 6241	Network Configuration Protocol (NETCONF)	IETF	2011
[16]	RFC 6470	Network Configuration Protocol (NETCONF) Base Notifications	IETF	2012
[17]	RFC 6536	Network Configuration Protocol (NETCONF) Access Control Model	IETF	2012
[18]	RFC 6728	Configuration Data Model for the IP Flow Information Export (IPFIX) and Packet Sampling (PSAMP) Protocols	IETF	2012
[19]	RFC 6991	Common YANG Data Types	IETF	2013
[20]	RFC 7223	A YANG Data Model for Interface Management	IETF	2014

[21] RFC 7317	A YANG Data Model for System Management	IETF	2014
[22] RFC 7895	YANG Module Library	IETF	2016
[23] RFC 7950	The YANG 1.1 Data Modeling Language	IETF	2016
[24] RFC 8348	A YANG Data Model for Hardware Management	IETF	2018
[25] RFC 8349	A YANG Data Model for Routing Management (NMDA Version)	IETF	2018
[26] Std 802.1AX	Link Aggregation	IEEE	2014
[27] Std 802.1Xck	Port-Based Network Access Control Amendment: YANG Data Model	IEEE	2018
[28] Std 802.3	IEEE Standard for Ethernet	IEEE	2018

2.2.2 Draft References

The reference documents listed in this section are applicable to this Technical Report as shown in informative Appendix I but are currently under development and are expected to be released in the future. Users of this Technical Report are advised to consult the source body for current status of the referenced documents or their successors.

Document	Title	Source	Year
[29] WT-385	ITU-T PON YANG Modules	BBF	unspecified
[30] draft-ietf-bess-l2vpn-yang-08	YANG Data Model for MPLS-based L2VPN	IETF	unspecified
[31] draft-ietf-bess-l3vpn-yang-03	Yang Data Model for BGP/MPLS L3 VPNs	IETF	unspecified
[32] draft-ietf-ippm-twamp-yang-11	Two-Way Active Measurement Protocol (TWAMP) Data Model	IETF	unspecified
[33] draft-ietf-lime-yang-connectionless-oam-18	Generic YANG Data Model for the Management of Operations, Administration, and Maintenance (OAM) Protocols that use Connectionless Communications	IETF	unspecified
[34] draft-ietf-lime-yang-connection-oriented-oam-model-07	Generic YANG Data Model for Connection Oriented Operations, Administration, and Maintenance(OAM) protocols	IETF	unspecified

[35] draft-ietf-mpls-base-yang-06	A YANG Data Model for MPLS Base	IETF	unspecified
[36] draft-ietf-ccamp-alarm-module-01	YANG Alarm Module	IETF	unspecified
[37] draft-ietf-netmod-schema-mount-10	YANG Schema Mount	IETF	unspecified
[38] draft-ietf-opsawg-nat-yang-14	YANG Data Model for Network Address Translation (NAT)	IETF	unspecified
[39] Draft Std 802.1Qcx	YANG Data Model for Connectivity Fault Management	IEEE	unspecified
[40] Draft Std 802.3.2	IEEE Draft Standard for Ethernet YANG Data Model Definitions	IEEE	unspecified

2.3 Definitions

The following terminology is used throughout this Technical Report.

Ghs	The handshake functionality of DSL and Fast technologies
xDSL	One of several variations of Digital Subscriber Line technology
YANG Data Model	A collection of YANG modules which describe a high-level or system level function of a network component (i.e., VNF or PNF)
YANG module	YANG code in a single file which describes a low-level function or sub-function of a Data Model

2.4 Abbreviations

This Technical Report uses the following abbreviations:

10G-EPON	10 Gigabit Ethernet Passive Optical Network
AN	Access Node
BAA	Broadband Access Abstraction
CloudCO	Cloud Central Office
DHCP	Dynamic Host Configuration Protocol
DM	Data Model
DPU	Distribution Point Unit
EPON	Ethernet Passive Optical Network
Fast	Fast access to subscriber terminals
FCAPS	Fault Configuration Accounting Performance Security
GPON	Gigabit Passive Optical Network
IEEE	Institute of Electrical and Electronic Engineers

IETF	Internet Engineering Task Force
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
L1	Layer 1
L2	Layer 2
L3	Layer 3
L4+	Layer 4 and higher
LACP	Link Aggregation Control Protocol
LAG	Link Aggregation
MELT	Metallic Line Testing
MIB	Management Information Base
MPLS	Multiprotocol Label Switching
MSBN	Multi-Service Broadband Network
NAI	Northbound Abstraction Interface
NAT	Network Address Translation
NBI	Northbound Interface
NE	Network Element
NF	Network Function
NFVI	Network Function Virtualization Infrastructure
OAM	Operations, Administration, and Maintenance
OLT	Optical Line Terminal (also Optical Line Termination)
ONU	Optical Network Unit
p2p-Eth	point to point Ethernet
PM	Performance Management
PNF	Physical Network Function
PON	Passive Optical Network
PPPoE	Point-to-Point Protocol over Ethernet
QoE	Quality of Experience
QoS	Quality of Service
RPC	Remote Procedure Calls
SAI	Southbound Adaptation Interface
SBI	Southbound Interface
SDN	Software Defined Network
SELT	Single-Ended Loop Testing
SNMP	Simple Network Management Protocol
VDSL	Very-high-bit-rate Digital Subscriber Line
VLAN	Virtual Local Area Network
VNF	Virtual Network Function

VPN	Virtual Private Network
TR	Technical Report
XPON	10 Gigabit Passive Optical Network
YANG	Yet Another Next Generation

3 Technical Report Impact

3.1 Energy Efficiency

TR-413 has no impact on energy efficiency.

3.2 IPv6

TR-413 has no impact on IPv6.

3.3 Security

Any solution, like the interfaces specified in this Technical Report, that provides a mechanism to manage, monitor, diagnose, and control a connected NF must prioritize security to protect user data and prevent malicious use of the system.

This Technical Report specifies interfaces based on NETCONF and YANG and the security considerations reported in relevant IETF RFCs (e.g., RFC 7950 [23] and RFC 6241 [15]) apply.

For example, the following is an excerpt from section 17 of RFC 7950 [23]:
"… Security issues are related to the usage of data modeled in YANG. …
Data modeled in YANG is dependent upon:

- the security of the transmission infrastructure used to send sensitive information.
- the security of applications that store or release such sensitive information.
- adequate authentication and access control mechanisms to restrict the usage of sensitive data.

YANG parsers need to be robust with respect to malformed documents. Reading malformed documents from unknown or untrusted sources could result in an attacker gaining the privileges of the user running the YANG parser. In an extreme situation, the entire machine could be compromised."

3.4 Privacy

Privacy involves the need to ensure that customers' and tenants' information can only be accessed by those who have the right to do so.

CloudCO enables sharing the same infrastructure between different tenants which may create issues related to the privacy of customers' and tenants' data.

It is necessary to define methods for isolating the control and management planes of all tenants and Infrastructure Provider as well as isolating customers' and tenants' information. In this specification, privacy is assured by the separation of the of interests, roles and responsibilities among CloudCO Infrastructure Provider and tenants that administratively and technically is provided by the CloudCO Domain Orchestration and/or SDN Management and Control functions, and the operational interfaces that connect these functional blocks.

4 Network Functions Interfaces

This chapter specifies the NFs NBIs, i.e., PNFs (assembled into Network Elements – NEs) and VNFs as well as the BAA SAIs and NAI, as part of the overall CloudCO Management and Control framework. This framework intends to cover both the classical FCAPS management functions and the flow control functions.

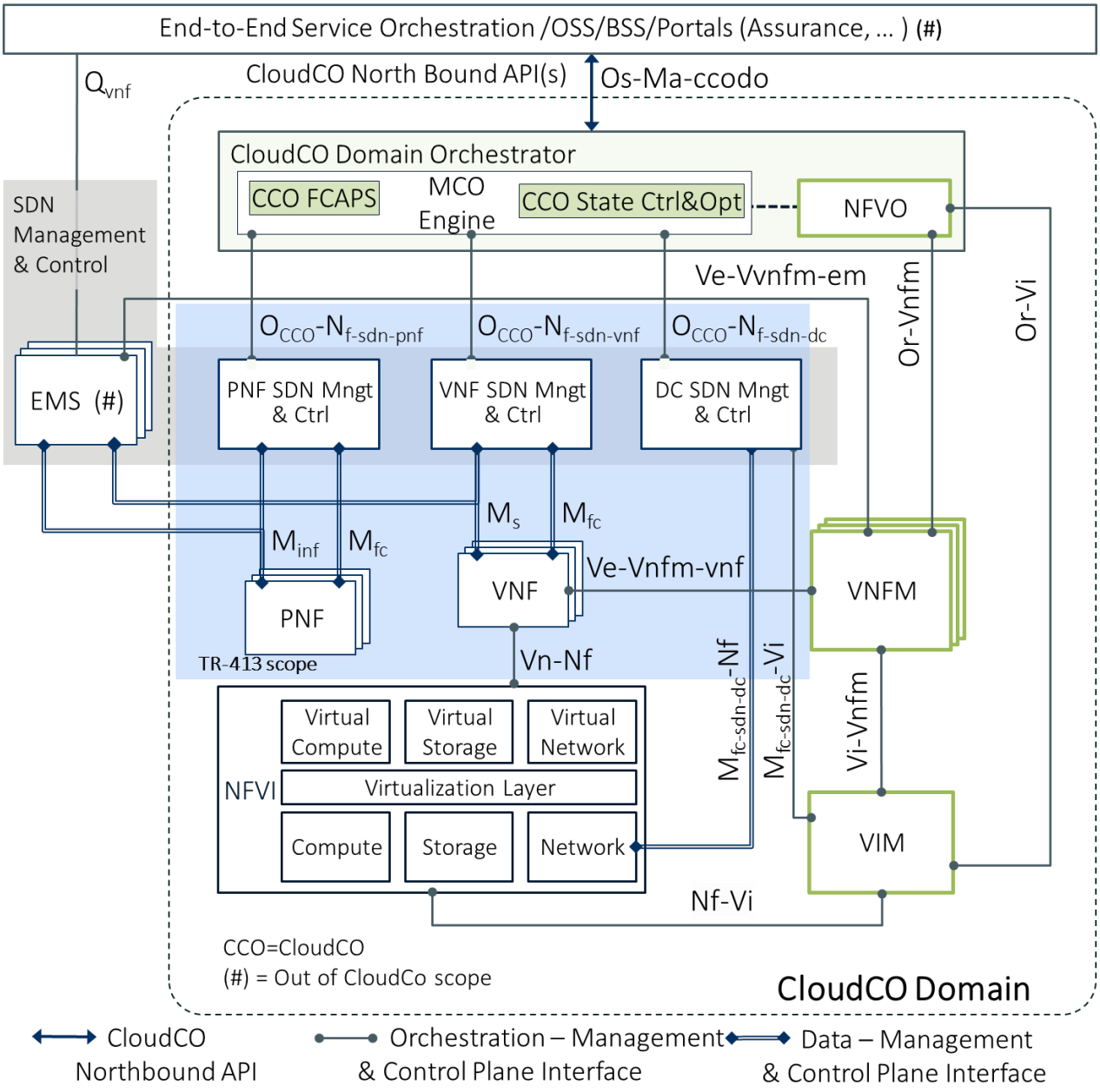

Figure 1: CloudCO Architecture and Reference Points

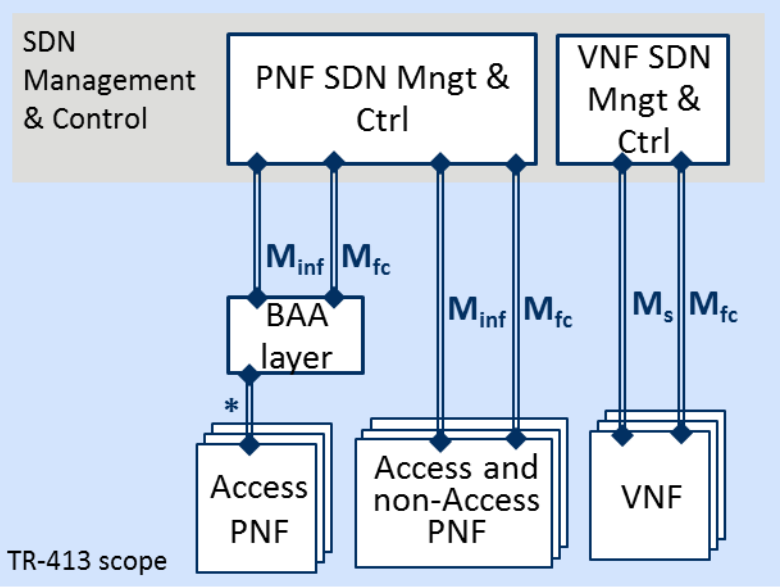

Figure 2: Focus on TR-413 scope adding the BAA layer

Figure 1 and Figure 2 illustrate the CloudCO reference architecture. Figure 1 illustrates the entire CloudCO architecture. Figure 2 focuses on the SDN Management and Control elements and the resources they interact with southbound, and introduces the Broadband Abstraction Layer (BAA). The box marked "TR-413 scope" highlights the interfaces in the scope of this Technical Report.

These interfaces are:

- M_{inf} reference point for FCAPS on infrastructure NEs,
- M_s reference points for FCAPS on VNFs in the Multi-Service Broadband Network (MSBN),
- M_{fc} reference point for the flow control of data in the NFs.

See TR-384 [4] for a complete list of reference points and definitions.

4.1 Northbound Interface for Network Elements

The following is a list of the NBIs of the most relevant MSBN NEs (i.e., PNFs), potentially subject to standardization via YANG modeling.

As a convention they conform to the following naming structure; $M_{inf\text{-}node\_name}$ or $M_{fc\text{-}node\_name}$.

- Broadband Network Gateway:
  $M_{inf\text{-}BNG}$ / $M_{fc\text{-}BNG}$
- Provider Edge (PE):
  $M_{inf\text{-}PE}$ / $M_{fc\text{-}PE}$
- OLT:
  $M_{inf\text{-}OLT}$ / $M_{fc\text{-}OLT}$

- Access Node (AN):
  $M_{inf\text{-}AN}$ / $M_{fc\text{-}AN}$ (these interfaces may apply to e.g., a Passive Optical Network (PON) fed AN)
- Distribution Point Unit (DPU):
  $M_{inf\text{-}DPU}$ / $M_{fc\text{-}DPU}$
- Optical Network Unit (ONU):
  $M_{inf\text{-}ONU}$ / $M_{fc\text{-}ONU}$
- Business Customer Premise Equipment also known as Business Gateway:
  $M_{inf\text{-}BG}$ / $M_{fc\text{-}BG}$

4.2 Catalog of Network Functions

This section provides a catalog of the functional modules that are typically implemented in MSBN nodes. These modules can be seen as logical NFs, some of which may be implemented as VNFs. Part of these NFs have already been specified in YANG language, whereas others are candidates for being modeled in YANG.

The portfolio of modules below is grouped into Layer 1 (L1), L2, L3, and Layer 4 and higher (L4+) functions for convenience, along with common management modules.

Each NF could be seen as a stand-alone functional component with its own NBI that is used to manage and control it.

This modular approach allows this notation to be applied to legacy MSBN architectures with monolithic PNFs and to reuse it for a CloudCO architecture with PNFs and VNFs.

Depending on their implementation, NFs (e.g., NF1, NF2, …, NFn) could be accessed via:

- the NE NBI which aggregates each NF NBI:
  $M_{inf\text{-}NE} \supset [M_{inf\text{-}NF1}, M_{inf\text{-}NF2}, \ldots, M_{inf\text{-}NFn}]$
- the NBI of a single NF ($M_{s\text{-}NF1}$, $M_{s\text{-}NF2}$, …, $M_{s\text{-}NFn}$) if implemented as stand-alone VNFs

Table 1 – Catalog of applicable functional modules

L1	L2	L3	L4+	Common management
Fast VDSL xDSL SELT MELT Ghs GPON XPON p2p-Eth L1 PM	DHCP VLAN multicast PPPoE OAM L2 authentication L2 QoS L2 load balancing L2 PM MPLS L2 VPN	NAT IPv4 routing IPv6 routing L3 authentication L3 QoS L3 VPN L3 load balancing L3 PM L3 security	deep packet inspection firewalling parental control universal threat management caching Content Distribution Network QoE measurement application load balancing user security	monitoring event/alarm management diagnostics charging billing upgrade backup/restore equipment and inventory

4.3 Broadband Access Abstraction layer

The main task of the BAA layer is to adapt the PNFs interfaces to a consistent set of SDN Management and Control interfaces. The BAA layer introduces an adaptive Southbound Interface (SBI) by combining a standard SAI and a device adapter which typically acts as a DM and a protocol translator. The BAA NBI allows, by means of protocol adapters, translation of the standard NAI protocol into the protocol expected by each SDN Manager and Controller to which the BAA layer is connected.

In addition to traditional FCAPS capabilities, another task performed by the BAA layer is to abstract access resources to allow technology agnostic and vendor agnostic flow control.

Figure 3 shows the BAA layer in the context of an SDN Management and Control chain.

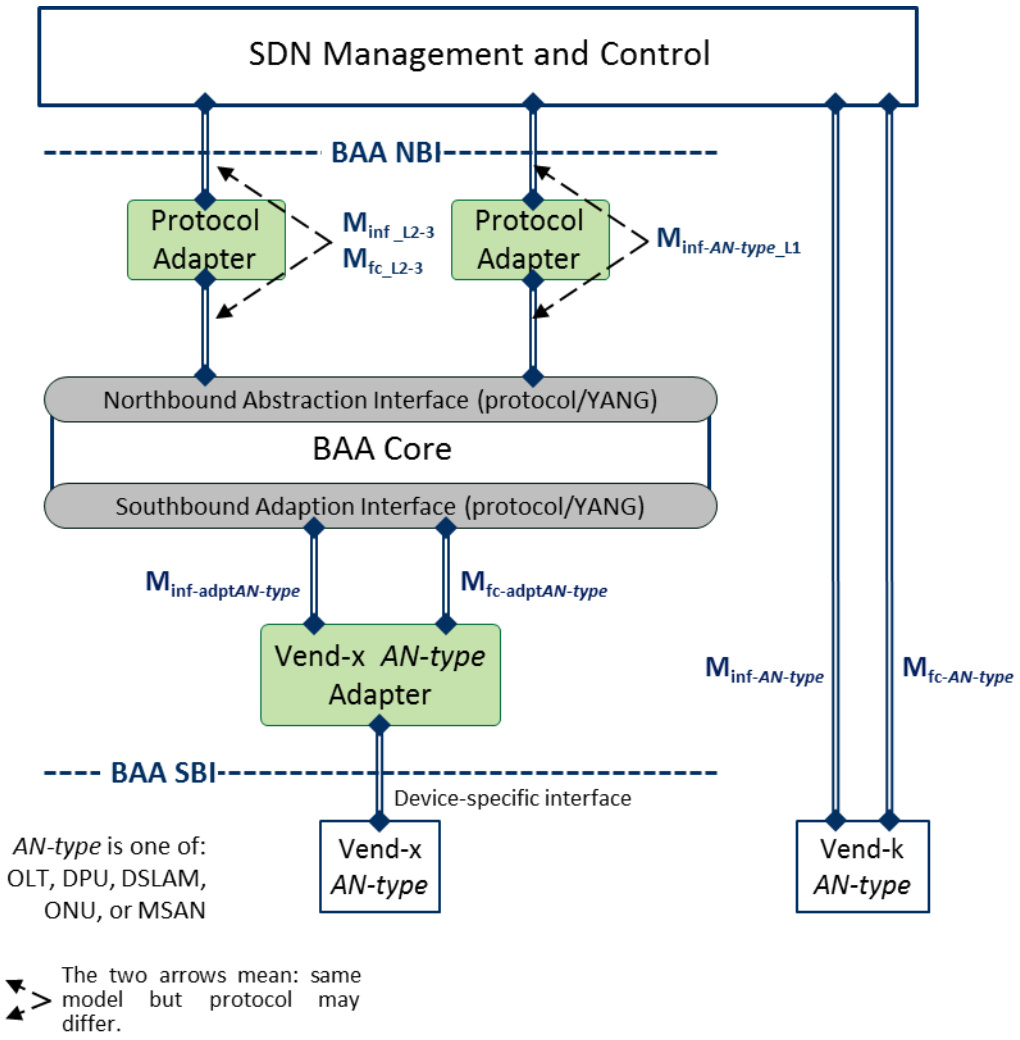

Figure 3: BAA layer interfaces and directly managed AN interfaces

When the BAA layer is part of the architecture, the Vend-x AN-type adapter exposes standard $M_{inf\text{-}adpt\textit{AN-type}}$ and $M_{fc\text{-}adpt\textit{AN-type}}$ interfaces to it (where *AN-type* ranges among the AN types the BAA layer supports), at the SAI level. So the AN-specific interface of the AN is adapted to standardized YANG DMs.

This implies that the BAA SAI specification reported in the columns of Table 3 applies also to the NBI of BAA adapters developed by AN manufactures or third parties.

In Figure 3, the interfaces labeled with *AN-type* highlight similar interfaces between those exposed by the AN natively supporting the standard NETCONF/YANG interfaces (specified in Table 2) and the analogous interfaces exposed by AN-specific adapters. The $M_{inf\text{-}adpt\textit{AN-type}}$ ($M_{inf\text{-}adptOLT}$, $M_{inf\text{-}adptDPU}$, $M_{inf\text{-}adptDSLAM}$, etc.) and the $M_{fc\text{-}adpt\textit{AN-type}}$ ($M_{fc\text{-}adptOLT}$, $M_{fc\text{-}adptDPU}$, $M_{fc\text{-}adptDSLAM}$, etc.) interfaces at the SAI level of the BAA expose a complete L1, L2 and L3 representation of the physical AN and comply with Table 3.

At the NAI of the BAA layer, the $M_{inf\_L2\text{-}3}$ and $M_{fc\_L2\text{-}3}$ interfaces highlight the ability for the BAA layer to expose a pure L2-L3 abstraction of the physical AN. On the other hand, the M_{inf_L1} highlights the management related aspects and, when combined with $M_{inf\_L2\text{-}3}$ and $M_{fc\_L2\text{-}3}$, exposes the whole set of features depending on the tasks and roles of each SDN Management and Control element on which they are terminated.

The $M_{inf\_L2\text{-}3}$ and $M_{fc\_L2\text{-}3}$ interfaces comply with the YANG DMs applicable to L2 and L3 (depending on the AN's supported features) as detailed in Table 2.

The $M_{inf\text{-}AN\text{-}type\_L1}$ ($M_{inf\text{-}OLT\_L1}$, $M_{inf\text{-}DPU\_L1}$, $M_{inf\text{-}DSLAM\_L1}$, etc.) interfaces use the technology-specific L1 YANG DMs in Table 2, depending of the managed ANs.

The BAA maintains a library of the YANG DMs needed to internally represent the physical nodes it manages, tailored on the type and model of the node.

In addition to the interfaces shown in Figure 3, the management of physical nodes require additional interfaces to expose an Access Network Map and Equipment inventory information to the SDN Management and Control ($M_{inf\_net\text{-}map}$ and $M_{inf\_eq\text{-}inv}$). The YANG DMs for these interfaces are not yet specified.

4.4 Management and Control protocols

According to TR-384 [4], the BAA SBI to the Access PNFs may be device specific. Device specific communication relies on device adapters, thus, the protocol between the BAA SBI and the device is not considered a point of interoperability. The device adapters may use southbound protocol libraries provided as common resources, e.g., if the attached OLT supports a standardized YANG Data Model as defined in WT-385 [29], the BAA SBI might employ NETCONF protocol for communication. Otherwise they can embed their own specific protocols as needed.

The BAA NBI may also use various protocols to communicate with the SDN Management and Control element(s) via protocol adapters. However, the data carried by these protocols is compliant with M_{inf} and M_{fc} interfaces described in section 5 above. Since most of the DMs over these interfaces are specified through the YANG language, a protocol such as NETCONF or RESTCONF is preferred. This is not meant to exclude the use of other protocols in the NBI of the BAA layer.

5 Network Function Northbound Interface specifications

This chapter describes the NBIs listed in section 4.1 by mapping to each NBI a superset of the NFs applicable to them. Notice that, whereas L1 NFs need to be bound to a physical node, in principle almost all the L2 to L4+ and common functions can be implemented either as part of PNFs or as VNFs.

Table 2 and Table 3 indicate applicability of PNFs to specific physical nodes. Similarly, where multiple L1 technology functions are marked by the "√" symbol for the same node type this means that at least one is applicable and not necessarily that all are expect to be supported on the same node type.

Table 3 specifies the NAI and SAI at the BAA Core boundaries.

The reader is reminded that this Technical Report is an interface specification document defining the protocol requirements to be supported by a given NF's interface and the list of DMs to be exposed by that interface. These DMs reflect the set of features supported by the NF but this Technical Report does not define what features are to be supported by which NF.

The cells in the Table 2 and Table 3 are populated per the following convention:

- "√" means that the function reported in the corresponding row is to be supported by the NBIs, BAA SAIs and BAA adapters NBIs associated to the corresponding column via the indicated YANG DM.

  For the BAA NAIs specified in the rows of Table 3, "√" means that the function reported in a given row is supported via the indicated YANG DM.
- " - " means that the function reported in the corresponding row is not applicable to flow control NBIs, BAA SAIs, BAA adapters NBIs and BAA NAIs; this applies, e.g., to flow control of PHY layer and hardware related functions which by definition do not handle flows.
- " ° " means that the function reported in the corresponding row is not typically supported by the NBIs, BAA SAIs and BAA adapters NBIs associated to the corresponding column but if that function is supported by that interface the corresponding YANG DM is to be used.

  For the BAA NAIs specified in the rows of Table 3, " ° " means that if the function reported in a given row is supported by the BAA SAI then it is to be supported also by the BAA NAI and the corresponding YANG DM is to be used.
- "N/A" means that the function reported in the corresponding row is not applicable to the NBIs BAA SAIs and BAA adapters NBIs associated to the corresponding column nor to the BAA NAI; this applies to specific PHY layer functions which are not applicable to certain AN types.

The reader should be aware that some of the DMs referenced in Table 2 and Table 3 are NMDA compliant per RFC 8349 [25] and may not be compatible with all BBF DMs.

5.1 Access Physical Network Function Northbound Interfaces

[R-1] The Access PNF NBIs listed in the columns of Table 2 MUST implement the YANG DM corresponding cells marked with the "√" symbol unless they are connected through a device-specific adapter to the BAA layer. In this latter case refer to section 5.2.

Note: as shown in Figure 2, Access PNF NBIs are defined either at the northern boundary of an Access PNF itself or, equivalently, at the northern boundary of the device-specific adapter ($M_{inf\text{-}adpt\textit{AN-type}}$ and $M_{fc\text{-}adpt\textit{AN-type}}$ inside the BAA layer) developed for that specific Access PNF.

[R-2] The Access PNF NBIs listed in the columns of Table 2 MUST implement the NETCONF protocol unless they are connected through a device-specific adapter to the BAA layer. In this latter case refer to section 5.2.

[R-3] If a DPU implements NETCONF based Management and Control, the $M_{inf\text{-}DPU}$ and $M_{fc\text{-}DPU}$ interfaces MUST comply with the NETCONF requirements of TR-301i2 [1].

For DSLAMs and ONUs that implement a native NETCONF interface, the related NETCONF requirements are not yet specified.

Table 2 Access PNFs Northbound Interface and YANG functional modeling

NFs	YANG DM reference	PNFs ($M_{inf\text{-}NE}$ aggregates $M_{inf\text{-}NF1}$, …, $M_{inf\text{-}NFn}$)							
		$M_{inf\text{-}OLT}$	$M_{fc\text{-}OLT}$	$M_{inf\text{-}DSLAM}$	$M_{fc\text{-}DSLAM}$	$M_{inf\text{-}DPU}$	$M_{fc\text{-}DPU}$	$M_{inf\text{-}ONU}$	$M_{fc\text{-}ONU}$
L1									
Fast	TR-355a1	N/A	N/A	√	-	√	-	√	-
VDSL	TR-355a1	N/A	N/A	√	-	√	-	√	-
xDSL	TR-355a1	N/A	N/A	√	-	N/A	N/A	√	-
SELT	TR-355a1	N/A	N/A	√	-	√	-	√	-
MELT	TR-355a1	N/A	N/A	√	-	√	-	√	-
Ghs	TR-355a1	N/A	N/A	√	-	√	-	√	-
GPON [1]				N/A	N/A				
XPON [1]				N/A	N/A				
EPON [1]				N/A	N/A				
10G-EPON [1]				N/A	N/A				
p2p-Eth	TR-383i1a1 bbf-ethernet-performance-management, Std 802.3.2 Cl 5	√	√	√	√	√	√	√	√
L1 PM	TR-383i1a1 bbf-interfaces, RFC 7223 ietf-interfaces	√	√	√	√	√	√	√	√

NFs	YANG DM reference	PNFs ($M_{inf\text{-}NE}$ aggregates $M_{inf\text{-}NF1}$, …, $M_{inf\text{-}NFn}$)							
		$M_{inf\text{-}OLT}$	**$M_{fc\text{-}OLT}$**	**$M_{inf\text{-}DSLAM}$**	**$M_{fc\text{-}DSLAM}$**	**$M_{inf\text{-}DPU}$**	**$M_{fc\text{-}DPU}$**	**$M_{inf\text{-}ONU}$**	**$M_{fc\text{-}ONU}$**
L2									
VLAN/L2 Forwarding	TR-383i1a1 bbf-forwarding and sub-interfaces	√	√	√	√	√	√	√	√
LAG/LACP	Std 802.1AX	√	√	◦	◦	◦	◦	◦	◦
multicast	TR-383i1a1 bbf-multicast	√	√	√	√	√	√	√	√
PPPoE	TR-383i1a1 bbf-pppoe	√	√	√	√	√	√	√	√
Ethernet OAM [1]									
L2 authentication	Std 802.1Xck	√	◦	√	◦	√	◦	√	◦
L2 QoS	TR-383i1a1 bbf-qos	√	√	√	√	√	√	√	√
L2 PM	TR-383i1a1 bbf-interfaces-performance-management	√	√	√	√	√	√	√	√
L2 VPN [1]									
DHCP (v4 and v6)	TR-383i1a1 bbf-l2-dhcpv4 and bbf-lrda	√	◦	√	◦	√	◦	◦	◦
L3									
	intentionally blank pending DM development								
Common management									
performance monitoring	RFC 6728 (IPFIX)	√	◦	√	◦	√	◦	√	◦
event/alarm management [1]									
upgrade	TR-383i1a1 software	√	-	√	-	√	-	√	-

NFs	YANG DM reference	PNFs (M_{inf-NE} aggregates $M_{inf-NF1}$, …, $M_{inf-NFn}$)							
		$M_{inf-OLT}$	**M_{fc-OLT}**	**$M_{inf-DSLAM}$**	**$M_{fc-DSLAM}$**	**$M_{inf-DPU}$**	**M_{fc-DPU}**	**$M_{inf-ONU}$**	**M_{fc-ONU}**
equipment and inventory	RFC 7317 YANG for System Management, RFC 8348 YANG Data Model for Hardware Management	√	-	√	-	√	-	√	-
access control	RFC 6536 NETCONF Access Control Module	√	-	√	-	√	-	√	-
notifications	RFC 5277 NETCONF Event Notifications, RFC 6470 NETCONF Base Notifications	√	-	√	-	√	-	√	-
Reverse Power Feeding									
Reverse Power Feeding	TR-355a1	°	-	°	-	√	-	√	-

1. See Appendix I.

5.2 Broadband Access Abstraction layer Northbound Abstraction Interface and Southbound Adaptation Interface

As exposed in paragraph 4.3, the BAA NAI and SAI, see Figure 3, implement the YANG DMs corresponding to the PNF types managed by the BAA layer.

[R-4] The BAA layer NAI MUST implement the interfaces specified in Table 3 depending on the AN types it has to manage.

[R-5] The BAA NAI MUST separately expose the L2 and L3 functionalities from the L1, common management functionalities as defined in the row grouping in Table 3 as indicated in the left side of the table.

[R-6] To maintain a library of YANG DMs and related mount points for each managed AN type, the BAA layer SHOULD support RFC 7895 [22] and draft-ietf-netmod-schema-mount-10 [37].

[R-7] The BAA layer SAI and BAA adapter NBI MUST implement the same DMs specified in Table 3, depending on the AN types it has to be managed.

[R-8] The BAA NBI MUST implement the NETCONF protocol for Management and Control functionalities.

Table 3 specifies the BAA SAI and the BAA NAI in a single table.

The BAA SAI is conceptually similar to the ANs interfaces (if they are YANG based) and it is specified in Table 3 columns in the form of AN type specific adaptation interfaces ($M_{inf\text{-}adptAN\text{-}type}$ and $M_{fc\text{-}adptAN\text{-}type}$).

The BAA NAI, instead, is conceptually split into different functional interfaces that can be exposed to different SDN Management and Control elements. This is reflected in the left side of Table 3 where the BAA NAI is shown as the functional split between a pure L2-3 interface (providing vendor-/technology-agnostic abstraction of the AN) and a L1 vendor-agnostic but technology-specific interface.

It then depends on what the BAA is required to interact with on its south and north edges that defines what columns (i.e., AN types) and/or what groups of rows (i.e., functional groups) are applicable northbound for a given deployment.

Table 3 BAA NAI/SAI and YANG functional modeling

	NFs	YANG DM reference	BAA SAI and BAA adapter NBI							
			$M_{inf-adptOLT}$	$M_{fc-adptOLT}$	$M_{inf-adptDSLAM}$	$M_{fc-adptDSLAM}$	$M_{inf-adptDPU}$	$M_{fc-adptDPU}$	$M_{inf-adptONU}$	$M_{fc-adptONU}$
	L1									
BAA NAI $M_{inf-AN-type\_L1}$	Fast	TR-355a1	N/A	N/A	√	-	√	-	√	-
	VDSL	TR-355a1	N/A	N/A	√	-	√	-	√	-
	xDSL	TR-355a1	N/A	N/A	√	-	N/A	N/A	√	-
	SELT	TR-355a1	N/A	N/A	√	-	√	-	√	-
	MELT	TR-355a1	N/A	N/A	√	-	√	-	√	-
	Ghs	TR-355a1	N/A	N/A	√	-	√	-	√	-
	GPON [1]				N/A	N/A				
	XPON [1]				N/A	N/A				
	EPON [1]				N/A	N/A				
	10G-EPON [1]				N/A	N/A				
	p2p-Eth [1]	TR-383i1a1 bbf-ethernet-performance-management	√	√	√	√	√	√	√	√
	L1 PM	TR-383i1a1 bbf-interfaces, RFC 7223 ietf-interfaces	√	√	√	√	√	√	√	√

	NFs	YANG DM reference	BAA SAI and BAA adapter NBI							
			$M_{inf-adptOLT}$	$M_{fc-adptOLT}$	$M_{inf-adptDSLAM}$	$M_{fc-adptDSLAM}$	$M_{inf-adptDPU}$	$M_{fc-adptDPU}$	$M_{inf-adptONU}$	$M_{fc-adptONU}$
	L2									
BAA NAI M_{inf_L2-3} and M_{fc_L2-3}	VLAN/L2 Forwarding	TR-383i1a1 bbf-forwarding and sub-interfaces	√	√	√	√	√	√	√	√
	LAG/LACP	Std 802.1AX	√	√	○	○	○	○	○	○
	multicast	TR-383i1a1 bbf-multicast	√	√	√	√	√	√	√	√
	PPPoE	TR-383i1a1 bbf-pppoe	√	√	√	√	√	√	√	√
	Ethernet OAM [1]									
	L2 authentication	Std 802.1Xck	√	○	√	○	√	○	√	○
	L2 QoS	TR-383i1a1 bbf-qos	√	√	√	√	√	√	√	√
	L2 PM	TR-383i1a1 bbf-interfaces-performance-management	√	√	√	√	√	√	√	√
	L2 VPN [1]									
	DHCP (v4andv6)	TR-383i1a1 bbf-l2-dhcpv4 and bbf-lrda	√	○	√	○	√	○	○	○
	L3									
		intentionally blank pending DM development								

	NFs	YANG DM reference	BAA SAI and BAA adapter NBI							
			$M_{inf-adptOLT}$	$M_{fc-adptOLT}$	$M_{inf-adptDSLAM}$	$M_{fc-adptDSLAM}$	$M_{inf-adptDPU}$	$M_{fc-adptDPU}$	$M_{inf-adptONU}$	$M_{fc-adptONU}$
	Common management									
BAA NAI $M_{inf-AN-type\_L1}$	performance monitoring	RFC 6728 (IPFIX)	√	○	√	○	√	○	√	○
	event/alarm management [1]									
	upgrade	TR-383i1a1 software	√	-	√	-	√	-	√	-
	equipment and inventory	RFC 7317 YANG for System Management, RFC 8348 YANG Data Model for Hardware Management	√	-	√	-	√	-	√	-
	access control	RFC 6536 NETCONF Access Control Module	√	-	√	-	√	-	√	-
	notifications	RFC 5277 NETCONF Event Notifications; RFC 6470 NETCONF Base Notifications	√	-	√	-	√	-	√	-
	Reverse Power Feeding									
	Reverse Power Feeding	TR-355a1	○	-	○	-	√	-	√	-

1. See Appendix I

Appendix I. Draft Network Function Interface Specifications

This appendix provides information about data models that can be used for various network functions in the scope of this Technical Report but are defined as in-progress work by the owning standards bodies. The expectation is that as the work is finalized within the respective body, the finalized work will be re-assessed for use within this Technical Report.

I.1 Draft Access Physical Network Function Northbound Interfaces

Table 4 Draft Access PNFs Northbound Interface and YANG functional modeling

NFs	YANG DM reference	PNFs ($M_{inf\text{-}NE}$ aggregates $M_{inf\text{-}NF1}$, …, $M_{inf\text{-}NFn}$)							
		$M_{inf\text{-}OLT}$	$M_{fc\text{-}OLT}$	$M_{inf\text{-}DSLAM}$	$M_{fc\text{-}DSLAM}$	$M_{inf\text{-}DPU}$	$M_{fc\text{-}DPU}$	$M_{inf\text{-}ONU}$	$M_{fc\text{-}ONU}$
L1									
GPON	WT-385	√	√	N/A	N/A	√	√	√	√
XPON	WT-385	√	√	N/A	N/A	√	√	√	√
EPON	Std 802.3.2 Cl 7	√	√	N/A	N/A	√	√	√	√
10G-EPON	Std 802.3.2 Cl 7	√	√	N/A	N/A	√	√	√	√
L2									
Ethernet OAM	Std 802.3.2 Cl 8 Eth OAM, Std 802.1Qcx IEEE CFM OAM YANG model	√	√	√	√	√	√	√	√
L2 VPN	draft IETF bess-l2vpn-yang-08	√	○	√	○	√	○	○	○
Common management									
event/alarm management	draft-ietf-ccamp-alarm-module	√	○	√	○	√	○	√	○

I.2 Draft Broadband Access Abstraction layer Northbound Abstraction Interface and Southbound Adaptation Interfaces

Table 5 Draft BAA NAI/SAI and YANG functional modeling

	NFs	YANG DM reference	BAA SAI and BAA adapter NBI							
			$M_{inf-adptOLT}$	$M_{fc-adptOLT}$	$M_{inf-adptDSLAM}$	$M_{fc-adptDSLAM}$	$M_{inf-adptDPU}$	$M_{fc-adptDPU}$	$M_{inf-adptONU}$	$M_{fc-adptONU}$
	L1									
BAA NAI $M_{inf-AN-type\_L1}$	GPON	WT-385	√	√	N/A	N/A	√	√	√	√
	XPON	WT-385	√	√	N/A	N/A	√	√	√	√
	EPON	Std 802.3.2 Cl 7	√	√	N/A	N/A	√	√	√	√
	10G-EPON	Std 802.3.2 Cl 7	√	√	N/A	N/A	√	√	√	√
	p2p-Eth	Std 802.3.2 Cl 5	√	√	√	√	√	√	√	√
	L2									
BAA NAI M_{inf_L2-3} and M_{fc_L2-3}	Ethernet OAM	Std 802.3.2 Cl 8 Eth OAM, Std 802.1Qcx IEEE CFM OAM YANG model	√	√	√	√	√	√	√	√
	L2 VPN	draft-ietf-bess-l2vpn-yang-08	√	◦	√	◦	√	◦	◦	◦
	Common management									
BAA NAI $M_{inf-AN-type\_L1}$	event/alarm management	draft-ietf-ccamp-alarm-module	√	◦	√	◦	√	◦	√	◦

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