Technical Report

TR-484
Access Network Abstraction

Issue: 1
Issue Date: September 2022

© The Broadband Forum. All rights reserved.

Notice

The Broadband Forum is a non-profit corporation organized to create guidelines for broadband network system development and deployment. This Technical Report has been approved by members of the Forum. This Technical Report is subject to change. This Technical Report is owned and copyrighted by the Broadband Forum, and all rights are reserved. Portions of this Technical Report may be owned and/or copyrighted by Broadband Forum members.

Intellectual Property

Recipients of this Technical Report are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of this Technical Report, or use of any software code normatively referenced in this Technical Report, and to provide supporting documentation.

Terms of Use

1. License

Broadband Forum hereby grants you the right, without charge, on a perpetual, non-exclusive and worldwide basis, to utilize the Technical Report for the purpose of developing, making, having made, using, marketing, importing, offering to sell or license, and selling or licensing, and to otherwise distribute, products complying with the Technical Report, in all cases subject to the conditions set forth in this notice and any relevant patent and other intellectual property rights of third parties (which may include members of Broadband Forum). This license grant does not include the right to sublicense, modify or create derivative works based upon the Technical Report except to the extent this Technical Report includes text implementable in computer code, in which case your right under this License to create and modify derivative works is limited to modifying and creating derivative works of such code. For the avoidance of doubt, except as qualified by the preceding sentence, products implementing this Technical Report are not deemed to be derivative works of the Technical Report.

2. NO WARRANTIES

THIS TECHNICAL REPORT IS BEING OFFERED WITHOUT ANY WARRANTY WHATSOEVER, AND IN PARTICULAR, ANY WARRANTY OF NONINFRINGEMENT AND ANY IMPLIED WARRANTIES ARE EXPRESSLY DISCLAIMED. ANY USE OF THIS TECHNICAL REPORT SHALL BE MADE ENTIRELY AT THE USER’S OR IMPLEMENTER'S OWN RISK, AND NEITHER THE BROADBAND FORUM, NOR ANY OF ITS MEMBERS OR SUBMITTERS, SHALL HAVE ANY LIABILITY WHATSOEVER TO ANY USER, IMPLEMENTER, OR THIRD PARTY FOR ANY DAMAGES OF ANY NATURE WHATSOEVER, DIRECTLY OR INDIRECTLY, ARISING FROM THE USE OF THIS TECHNICAL REPORT, INCLUDING BUT NOT LIMITED TO, ANY CONSEQUENTIAL, SPECIAL, PUNITIVE, INCIDENTAL, AND INDIRECT DAMAGES.

3. THIRD PARTY RIGHTS

Without limiting the generality of Section 2 above, BROADBAND FORUM ASSUMES NO RESPONSIBILITY TO COMPILE, CONFIRM, UPDATE OR MAKE PUBLIC ANY THIRD PARTY ASSERTIONS OF PATENT OR OTHER INTELLECTUAL PROPERTY RIGHTS THAT MIGHT NOW OR IN THE FUTURE BE INFRINGED BY AN IMPLEMENTATION OF THE TECHNICAL REPORT IN ITS CURRENT, OR IN ANY FUTURE FORM. IF ANY SUCH RIGHTS ARE DESCRIBED ON THE TECHNICAL REPORT, BROADBAND FORUM TAKES NO POSITION AS TO THE VALIDITY OR INVALIDITY OF SUCH ASSERTIONS, OR THAT ALL SUCH ASSERTIONS THAT HAVE OR MAY BE MADE ARE SO LISTED.

All copies of this Technical Report (or any portion hereof) must include the notices, legends, and other provisions set forth on this page.

Issue History

Issue Number	Approval Date	Release Date	Issue Editor	Changes
1	13 September 2022	13 September 2022	Mauro Tilocca, TIM Kalimani Venkatesan, Capgemini	Original

Comments or questions about this Broadband Forum Technical Report should be directed to info@broadband-forum.org.

Editors: Mauro Tilocca, TIM

Kalimani Venkatesan, Capgemini

Work Area Director(s): Mengmeng Li, China Mobile

Bruno Cornaglia, Vodafone

Project Stream Leader(s): Bruno Cornaglia, Vodafone

 © The Broadband Forum. All rights reserved

Table of Contents

© The Broadband Forum. All rights reserved

Table of Figures

 © The Broadband Forum. All rights reserved

Executive Summary

This Technical Report specifies a Broadband Access Abstraction (BAA) Layer as part of a Software Defined Access Network (SDAN) architecture capable of:

- Seamlessly supporting a multi-vendor, multi-technology network of Access Nodes (AN)
- Connecting different designs of physical ANs, e.g., traditional chassis-based and disaggregated ANs
- Disaggregating Management Plane and Control Plane functions from the physical ANs and hosting the functions on centralized or distributed NFVI locations

This Technical Report describes the key functional components of a SDAN architecture, specifies the BAA Layer system and complements the family of Broadband Forum's CloudCO specifications related to the access domain (e.g., TR-384 [9], TR-411 [12], TR-413 [13], TR-435 [14], TR-451 [15], WT-477 [18]).

 © The Broadband Forum. All rights reserved

1 Purpose and Scope

1.1 Purpose

This Technical Report specifies a Broadband Access Abstraction (BAA) Layer as part of a Software Defined Access Network (SDAN) architecture which includes Access SDN Management and Control elements that are aligned with the CloudCO family of specifications (e.g., TR-384 [9], TR-411 [12], TR-413 [13], TR-435 [14], TR-451 [15], WT-477 [18]).

The SDAN architecture used in the context of the CloudCO framework is capable of:

- Seamlessly supporting a multi-vendor, multi-technology network of Access Nodes (AN)
- Connecting different designs of physical ANs: from ANs with traditional chassis-based to disaggregated ANs (e.g., whitebox and other "colored-box" OLTs)
- Disaggregating Management Plane and Control Plane functions from the physical ANs and hosting the functions on centralized or distributed NFVI locations

For Access Nodes to be used in the specified SDAN architecture, the requirements of the Network Functions (NF) along with NFs' User Plane, Control Plane, and Management Plane interfaces and protocols are specified and use existing CloudCO specifications where appropriate.

Under this standpoint this Technical Report describes the key functional components of a SDAN architecture, specifies a BAA Layer system, and complements the family of Broadband Forum's CloudCO specifications related to the access domain.

1.2 Scope

The scope of this document specifies the following:

- Principles and architectural options of SDAN and the specifics related to access domain transformation, including disaggregation of NFs traditionally associated with physical ANs that are used in whitebox and other "colored-box" solution deployments
- A BAA Layer system and high-level description that provides more detail and improves the general definition of the BAA Layer within TR-384 [9] and other BAA Layer-related specifications
- Descriptions of the relocation of the Management and Control Plane functions of a SDAN architecture with regards to traditional access solutions
- Detailed descriptions of the BAA Layer's mediation characteristics as key enabler of the overall SDAN architecture
- SDAN deployment scenarios based on different allocations of management and control functions to the Access SDN Management and Control element and the BAA Layer; these scenarios are applicable, but not limited to, a CloudCO context
- BAA Layer requirements, including those related to protocols and data models for BAA Layer interfaces, cross-referencing existing CloudCO specifications where appropriate
- Recommendations to facilitate SDAN implementations that support CloudCO deployments and other deployments.

© The Broadband Forum. All rights reserved

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 [17].

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 listed references by checking at the web links reported below. A list of currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org/technical-reports.

Users also may find useful BBF's searchable Resources database for Technical Reports and other BBF deliverables. The most recent edition of BBF's published YANG Data Models can be found at YANG Projects.

© The Broadband Forum. All rights reserved

Document		Title	Source	Year
[1]	TR 101 Issue 2	Migration to Ethernet-Based Broadband Aggregation; Issue 2	BBF	2011
[2]	TR-156 Issue 3	Using PON Access in the context of TR-101, Issue 3	BBF	2012
[3]	TR-167 Issue 2	PON-fed TR-101 Ethernet Access Node, Issue 2	BBF	2010
[4]	TR-178 Issue 1	Multi-service Broadband Network Architecture and Nodal Requirements	BBF	2014
[5]	TR-280 Issue 2	ITU-T PON in the Context of TR-178	BBF	2022
[6]	TR-301 Issue 2	TR-301 Architecture and Requirements for Fiber to the Distribution Point, Issue 2	BBF	2017
[7]	TR-355	YANG Modules for FTTdp Management	BBF	2016
[8]	TR-383	Common YANG Modules for Access Networks	BBF	2017
[9]	TR-384	Cloud Central Office (CloudCO) Reference Architectural Framework	BBF	2018
[10]	TR-385	ITU-T PON YANG Modules	BBF	2019
[11]	TR-408	Cloud CO Migration and Coexistence	BBF	2020
[12]	TR-411	Definition of interfaces between CloudCO Functional Modules	BBF	2021
[13]	TR-413	SDN Management and Control Interfaces for CloudCO Network Functions	BBF	2018
[14]	TR-435	NETCONF Requirements for Access Nodes and Broadband Access Abstraction	BBF	2020
[15]	TR-451	vOMCI Specification	BBF	2022
[16]	TR-454	YANG Modules for Network Map & Equipment Inventory	BBF	2021
[17]	RFC 2119	Key words for use in RFCs to Indicate Requirement Levels	IETF	1997

2.2.2 Draft References

The reference documents listed in this section are applicable to this Technical Report but are currently under development within the respective body 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
[18]	WT-477	CloudCO Enhancement - Access Node Hardware Disaggregation	BBF	TBD

2.3 Definitions

The following terminology is used throughout this Technical Report.

BAA Layer	BAA is an abstraction layer that allows to expose Access Nodes to northbound elements (e.g., an Access Management and Control system) via standard interfaces. The BAA layer also hosts southbound adapters to connect to Access Nodes.

 © The Broadband Forum. All rights reserved

2.4 Abbreviations

This Technical Report uses the following abbreviations:

ADAM	Access Device Abstraction Manager
AN	Access Node
BAA	Broadband Access Abstraction
BAA–Act (or Act)	BAA–Actuator
BAA NAI	BAA Northbound Abstraction Interface
BAA SAI	BAA Southbound Adaptation Interface
BAA–ADAM (or ADAM)	BAA–Access Device Abstraction Manager
CNF	Containerized Network Function
CLI	Command Line Interface
CloudCO	Cloud Central Office
CNF	Containerized Network Function
CP	Control Plane
DM	Data Models
DS	Datastore
D-OLT	Disaggregated OLT
EMS	Element Management Systems
FTTA	Fiber To The Antenna
FTTCab	Fiber To The Cabinet
FTTdp	Fiber To The distribution point
FTTH	Fiber To The Home
GbE	Gigabit Ethernet
GPON	Gigabit Passive Optical Network
GPB	Google Protocol Buffer
gRPC	Google Remote Procedure Call
InP	Infrastructure Provider
KNF	Kubernetes Network Function
L1	Layer 1
L2	Layer 2
L2-3	Layer 2 and/or 3
L3	Layer 3
M&C	Management and Control
M&CP	Management and Control Plane
ME	Management Entity
MP	Management Plane
NC/Y	NETCONF/YANG
OLT	Optical Line Terminal

© The Broadband Forum. All rights reserved

OMC	ONU Management and Control
OMCI	OMC Interface
OSS	Operation and Support System
PM	Performance Monitoring
SDAN	Software Defined Access Network
SDN	Software Defined Networking
SNMP	Simple Network Management Protocol
SP	Service Provider
SPM	Service and Physical Layer Mapping
TL1	Transaction Language 1
TR	Technical Report
UP	User Plane
VNF	Virtualized Network Function
VNO	Virtual Network Operator
WA	Work Area
WT	Working Text
xNF	VNF/CNF/KNF

© The Broadband Forum. All rights reserved

3 Technical Report Impact

3.1 Energy Efficiency

Energy Efficiency may be impacted migrating from legacy access network to SDAN and BAA Layer based deployments. In fact, moving some functions to external server can increase the energy consumed. On the other hand, virtualising and sharing certain functions in the BAA Layer to manage and control multiple access resources can improve energy efficiency.
Regulatory differences related to electrical power, Heating, Ventilation and Air Conditioning (HVAC) and fire protection between traditional Central Offices and datacenters are out-of-scope for this document.

3.2 Security

The BAA Layer is subject to the security concerns applicable to the legacy access deployments and described in other BBF technical reports, like TR-101 [1], TR-178 [4], TR-156 [2] and TR-280 [5].
The BAA Layer interfaces protocols include capabilities for providing secure, authorized, and authenticated communication between the BAA Layer and access network resources.
Generally speaking, measures are needed to ensure that only authorized parties can access, or modify, configuration for underlying network infrastructure and that traffic associated with one subscriber/tenant cannot be intercepted by other subscribers/tenants.
Operators consider using these capabilities as an important means for preventing attacks intended (for example) to divert or disable data forwarding capabilities through control plane impersonation.

3.3 Privacy

The BAA Layer is subject to the privacy concerns applicable to the legacy access deployments and described in other BBF technical reports, like TR-101 [1], TR-178 [4], TR-156 [2] and TR-280 [5] and TR-384 [9].
In network protocols, privacy concerns, beyond the protection of potentially private data, focus on two aspects:

1. The potential for tracking of users through exposure of Personal Identifying Information (PII)
2. The potential for correlation of user activity over time through persistent use of network identifiers

Additionally, privacy involves the need to ensure that information to, from, and between subscribers/tenants can only be accessed by those who have the right to do so. Further, privacy requirements can vary by regulatory region. In general, two ways to ensure privacy is recognized:

- Preventing data, from being copied to a non-intended destination.
- Encrypting data, so that it cannot be understood even if it is intercepted.

Because of its disaggregated nature, the same (or highly correlated) identifying information may be seen at several points in the network, allowing for identification of a target subscriber or network component. This increases the number of network elements with potential exposure to privacy violations.

 © The Broadband Forum. All rights reserved

4 Software Defined Access Network Description

The Software Defined Access Network defines how the functionality of traditional and disaggregated access nodes and management and control functions associated with the access network (see TR-384 [9] section 5.2.6) are deployed and used in Service Provider's SDN solutions.
This section describes deployment of the SDAN in the context of the CloudCO framework as depicted in Figure 1 below.

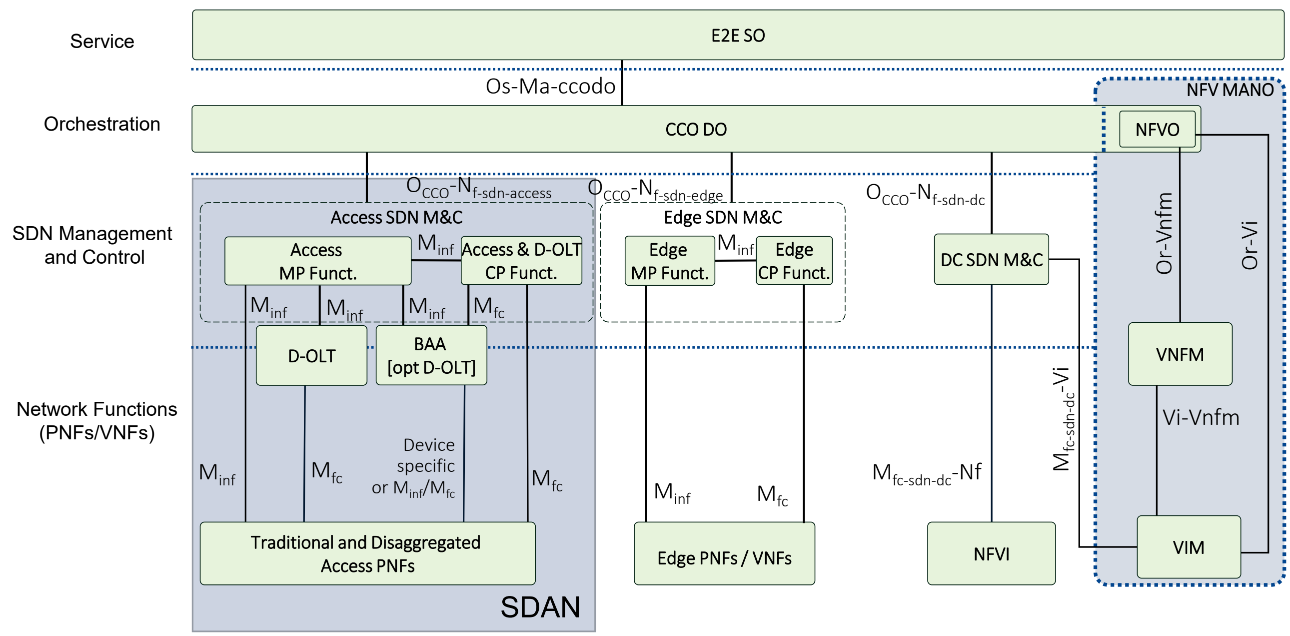

Figure 1: SDAN deployment in CloudCO

SDAN functions within the CloudCO framework use the SDN Management and Control functionalities described in section 6.2.1 of TR-411 [12], where the access network management and access node related control functions are deployed in SDN control elements. These elements perform the management and control of the access network and nodes and can be geographically distributed as described in section 4.2 of TR-408 [11]. In a SDAN architecture, the access network functions that are centralized are assigned to the Access MP and CP functional layer and the access network functions that are distributed are assigned to the BAA Layer as described in section 4.1.
The disaggregated AN control functions can be centralized in the CP functional layer or as a stand-alone SDN control entity for a specific type of access node (e.g., D-OLT). Likewise, the disaggregated AN control functions that are distributed closer to the physical node are deployed either in the BAA Layer as described in section 4.1 or as a stand-alone SDN control entity for a specific type of access node (e.g., D-OLT). For AN control functions, the determination to use a stand-alone control entity (e.g., D-OLT) versus the more generalized access SDN control elements is an operational preference by the service provider or if the underlying access nodes require protocol or information model adaptations, the BAA Layer or Access SDN M&C control elements are used.

4.1 BAA Layer in a SDAN and Access Disaggregation Context

This section provides an overview of the BAA Layer, including the interactions between the BAA layer and other CloudCO elements using the M_{inf} and M_{fc} reference points defined in the CloudCO architectural framework TR-384 [9] and the detailed interface specifications in TR-411 [12], TR-413 [13] and WT-477 [18].
This is shown in Figure 2 which also shows the relevant M_{inf} and M_{fc} reference points for SDN Management and Control elements to interface with the BAA Layer. The elements depicted in Figure 2 mainly use

 © The Broadband Forum. All rights reserved

standardized models to interact with Access Network devices, southbound, as well as SDN Management and Control functions, northbound.

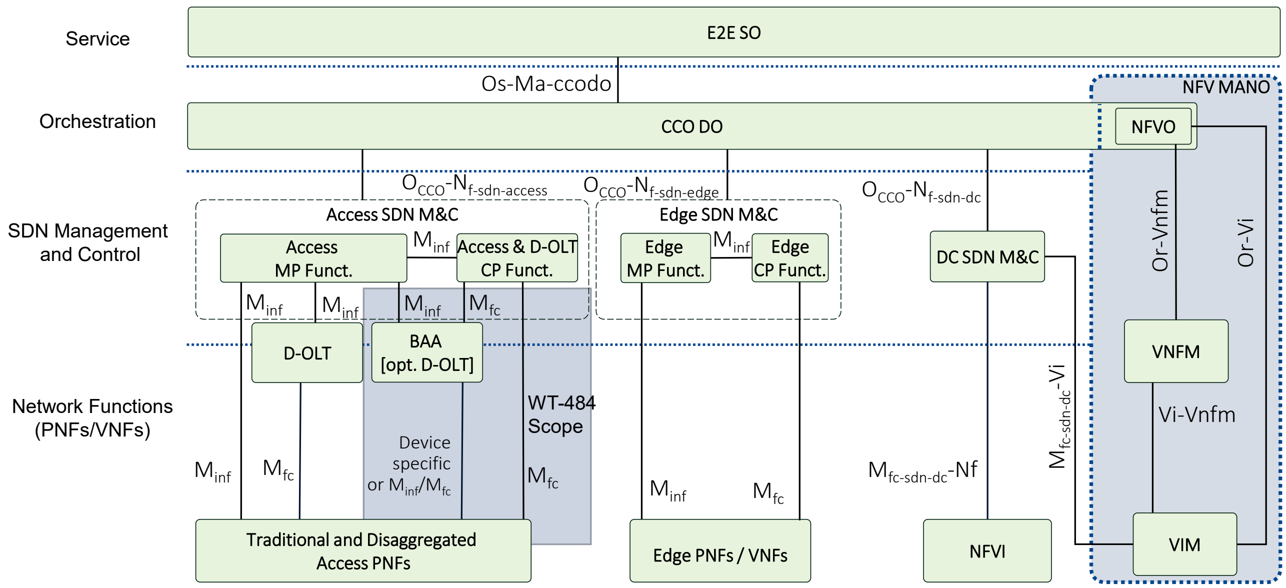

Figure 2: SDAN architecture with BAA Layer as part of a CloudCO infrastructure

The M_{inf} and the M_{fc} reference points specify a unique set of BBF standard interfaces which apply southbound of the Access SDN M&C functions and, of course, northbound of the elements, be it an Access Node itself or a BAA Layer or another mediation component.

A key requirement for the BAA Layer is compliance with the interfaces and the Data Models specified in TR-413 [13] for the BAA Layer and Access PNFs.

The main objective of this Technical Report is to specify the BAA Layer and its requirements, which means to define its interfaces, functionalities, and internal behaviour. Nevertheless, Figure 2 shows the broader context for this Technical Report that touches also upon the CloudCO elements at the BAA Layer boundaries.

As described in section 6.3.2.7 of TR-384 [9], the BAA Layer exposes Access PNFs' APIs and related attributes across the M_{fc} and M_{inf} reference points toward northbound Access SDN M&C functions as depicted in Figure 2.

These APIs and attributes are exposed through standardized data models that provide a vendor independent representation of several types of Access PNFs. In some functional variants (see section 5.3), the exposed APIs and attributes would additionally provide an abstract functional view of access devices that is access technology independent.

As described in TR-413 [13], the device types to be managed and controlled by the BAA Layer include:

- OLTs and ONUs as specified in TR-156 [2] and TR-167 [3]
- DPUs as specified in TR-301 [6]. In an FTTdp architecture the PMAs and the PMA Aggregator may be implemented via the BAA Layer
- Other ANs (e.g., DSLAMs) as specified in TR-101 [1] and TR-178 [4]

Furthermore, the BAA Layer is suitable to manage and control Access Nodes based on disaggregated as well as traditional access PNFs provided that standard TR-413 [13] and WT-477 [18] interfaces are supported natively by the AN or by a device-specific adapter developed to interwork with that AN type, brand and model.

The BAA Layer can be deployed as a software function hosted in the CloudCO NFVI either in centralized or distributed locations as needed (see section 5.4.1).

 © The Broadband Forum. All rights reserved

The fundamental mediation function of the BAA Layer consists in exposing, via a standardized NB API, a vendor independent representation of Access PNFs and an abstracted logical view of L2-3 resources that is also access technology independent.

The BAA Layer enables:

- Access Network persistency – It offers a persistent repository aligned with the status of access resources regardless of reachability/presence of the physical AN. It also provides the capability to issue and verify configurations and commands in offline mode and then push them down to the physical AN when it becomes reachable (e.g., after recovery from a fault or when activated) or when planned and/or triggered by a given condition. This is relevant for Operator's pre-/bulk-provisioning activities.
- Access Network exposure – It exposes a technology and vendor agnostic L2-3 representation of access resources, like one of the stages of a distributed switch, enabling end-to-end automation.
- Decoupling of Network Operation&Assurance vs Service Provisioning&Automation – It ensures unified and much simpler Network Operation and Assurance by providing a clean separation between L2-3 management and flow control from L1 device management.

  This helps decouple the responsibilities of Service Modelling/Provisioning departments from those of Network Engineering/Operation departments in the same organization. This is even more important in FANS scenarios with an Infrastructure Provider (InP) and multiple Virtual Network Operators (VNOs).
- Coexistence/Migration – By applying adaptation at the southbound (SB) interface and abstraction at the northbound (NB) interface, the BAA Layer facilitates coexistence of various AN designs and migration towards new technologies and access equipment.
- Lean Access Network production – the standardized Southbound Adaptation Interface (SAI) enables streamlined and repeatable processes (e.g., for design, update, and upgrade cycles) for developers of access equipment and SDN Management and Control elements. At the same time Operators can accelerate and improve their processes for industrialization and deployment in the network.

4.2 Access Disaggregation Principles

Access Network disaggregation refers to the transformation of traditional monolithic hardware nodes with tightly coupled software to a set of distributed and cooperating functions that can be hosted on different platforms that include the traditional nodes, general purpose hardware appliances, or virtualized as network functions (xNFs[1]) within cloud platforms.
Per the principles described above and bearing operational efficiency in mind, Access Network disaggregation requires:

- introduction of SDAN elements (e.g., D-OLT, BAA Layer, Access M&C functions) to more flexibly, nimbly, and sustainably evolve and manage the access assets
- reorganization and modernization of the aggregation infrastructure towards bandwidth flexible Leaf/Spine architectures to follow service and traffic needs in an invest-as-you-grow fashion
- migration from traditional Delivery and Assurance chains to unified, multi-vendor/multi-technology, and automated SDN platforms to manage and control the underlying assets and service flows

[1] In the remainder of this document, xNF will be used to refer to software Network Functions regardless of them being implemented as Virtualized NF (VNF) in a Virtual Machine, Containerized NF (CNF) in a Container or Kubernetes NF (KNF) in a Kubernetes cluster.

 © The Broadband Forum. All rights reserved

The disaggregation of the Access Network into a set of distributed and cooperating functions provides benefits to Service Providers in terms of:

- overcoming chronic issues
- introducing improvements to current practices for the network and service engineering, deployment, and operations.

WT-477 [18] provides a set of principles and technology enablers as well as requirements and interface specifications about disaggregated Network Functions in the Access Network.

The Access Network exposure offered by the BAA Layer, refers to a technology and vendor agnostic representation of network resources which includes also implementations based on disaggregated xNFs associated to the physical PNFs. This unifies and preserves the workflows and interactions from/to the northbound SDN elements and favours coexistence of traditional and disaggregated Access Nodes and migration.

 © The Broadband Forum. All rights reserved

5 BAA Layer Theory of Operation

The BAA Layer theory of operation identifies BAA Layer's functional variants and deployment options and describes the involved system functions.

5.1 Management and Control Plane Functional Relocation

One of the key principles of Software Defined Networking (SDN) is to separate the User Plane (UP) and the Control Plane (CP), traditionally tied together within legacy network nodes, and exercise the control functions in a centralized entity (the SDN Controller) to achieve flow and service automation.

Disaggregation of flow control functions from the physical AN is covered by WT-477 [18]. The BAA Layer allows the “re-composition” of the disaggregated xNFs and physical PNFs into a single consolidated view of the overall Access Nodes as depicted in Figure 8. For example, depending on the deployment scenarios, some disaggregated xNFs can be deployed in different locations with respect to the BAA Layer as depicted in Figure 8 and described in section 5.4.2.

Another key principle of SDN is programmability of network functions (xNFs, including physical and/or virtual functions) via standardized interfaces and data models.
In the access domain, like in other networking domains, these interfaces historically implemented proprietary Data Models (DMs) and management protocols (e.g., SNMP, TL1 or even CLI) typically not suitable for automation.
The BAA Layer can be used to superimpose standard interfaces and data models where the xNFs do not directly provide them.

5.2 Mediation Characteristics

When applying disaggregation principles as described in WT-477 [18], mediation plays a fundamental role providing essential system characteristics that can be identified as Adaptation, Awareness, Agnosticism, Abstraction:

- Abstraction means to decouple forwarding and control (L2-3) related functions from device and physical (L1) functions by logically separating the L2-3 M&CP interfaces (M_{fc}, M_{inf_L2-3}) from the L1 M&CP interfaces (M_{inf_L1}).
- Agnosticism is achieved by the exposure of a view of the underlying resources that is vendor independent and purely made of logical L2-3 ports and their topology.
- Awareness is achieved by maintaining a view of the underlying resources that is technology and equipment specific. In some BAA Layer functional variants this view of ANs may be organised in a topological map.
- Adaptation is obtained via the implementation of a standardized SAI combined with a library of equipment (and technology) specific adapters that expose altogether an adaptive SBI per each physical AN.

The BAA Layer provides these characteristics for both disaggregated xNFs and those NFs implemented in the PNFs.

5.3 Functional Variants

The BAA Layer is expected to be deployed as a software function that provides mediation between SDN Management and Control elements and Access PNFs. In a CloudCO context such function is likely to be hosted on a server of the NFVI.

In the following sections two functional variants are considered:

 © The Broadband Forum. All rights reserved

- BAA Layer – Actuator, acting as aggregating entity that provides capabilities for actuating the inputs of control and management functions expressed by northbound SDN M&C elements
- BAA Layer – Access Device Abstraction Manager (BAA-ADAM), taking on the same functions of the Actuator functional variant plus more management functions

5.3.1 BAA - Actuator (BAA–Act)

In deployments where the SDN Management and Control element(s), north of the BAA Layer, implements M&CP functionalities specific to access networks, the BAA Layer can be deployed as an Actuator that executes the inputs received from the Access SDN M&C element(s) and may act as a proxy of the data (flows information, PM, alarm reports, notifications, etc.) received from the ANs.
The benefits of deploying the BAA Layer as an Actuator is that it exposes a virtual representation of ANs acting as the authoritative source for interactions with these.
In addition to the virtualization of the ANs, the BAA Layer proxies/relays selected data from the ANs toward management elements (e.g., control, PM and alarms).

Figure 3 depicts the BAA Layer deployed as an Actuator: the M_{inf_L1} interface provides a vendor agnostic representation of L1 management plane while the M_{inf_L2-3} and M_{fc} interfaces provide an abstract (i.e., vendor and technology agnostic) representation of the L2-3 management and control plane. The functionalities exposed by those interfaces map with standard Data Models (e.g., TR-385 [10] for OLTs and ONUs, TR-355 [7] for DPUs, TR-383 [8] for Firmware management, Forwarding and other modules).

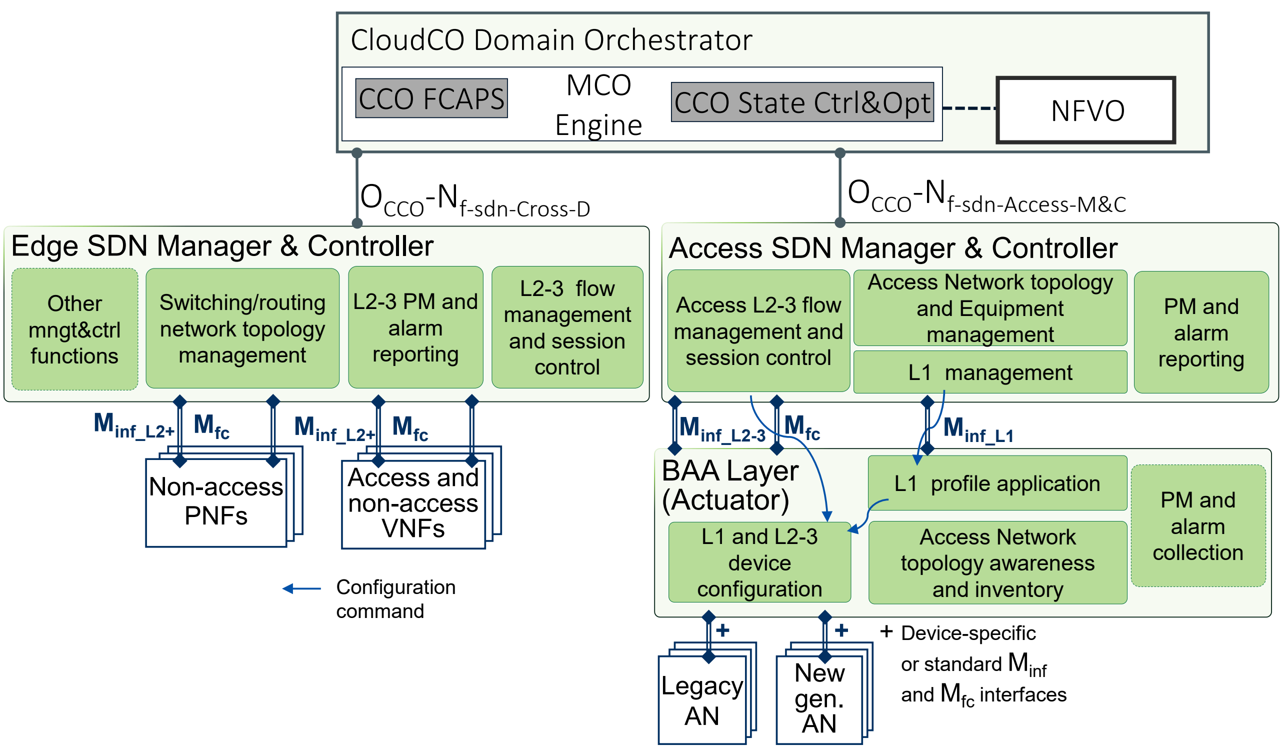

Figure 3: BAA Layer as an Actuator of an Access SDN Manager and Controller

As said, the BAA Layer – Actuator works well in combination with the specific capabilities of an Access SDN Manager and Controller.

 © The Broadband Forum. All rights reserved

5.3.2 BAA - Access Device Abstraction Manager (BAA–ADAM)

As an alternative to the BAA–Act functional variant, the BAA Layer can be deployed as an Access Device Abstraction Manager (ADAM). In this case, the BAA Layer provides the same capabilities of the Actuator functional variant plus those of an Access Manager and Controller. The BAA–ADAM interfaces directly with an access-unaware SDN Manager and Controller. This latter element is agnostic to any particular access technology, operating across different network segments in the CloudCO (notably Edge and Access), and exercising end-to-end management and flow control capabilities.
On its NBI, the ADAM provides representations of ANs that are generic to any specific access technology (e.g., an Access Node is represented as a "generic switch"). This BAA–ADAM capability is similar to the one in the BAA–Act functional variant, as well as the exposure of the M_{inf_L2-3} and M_{fc} interfaces. In addition, the BAA-ADAM functional variant performs a comprehensive set of L1 management functions.

Figure 4 depicts the BAA Layer deployed as a ADAM and interfacing directly with a Cross-domain SDN Manager and Controller.

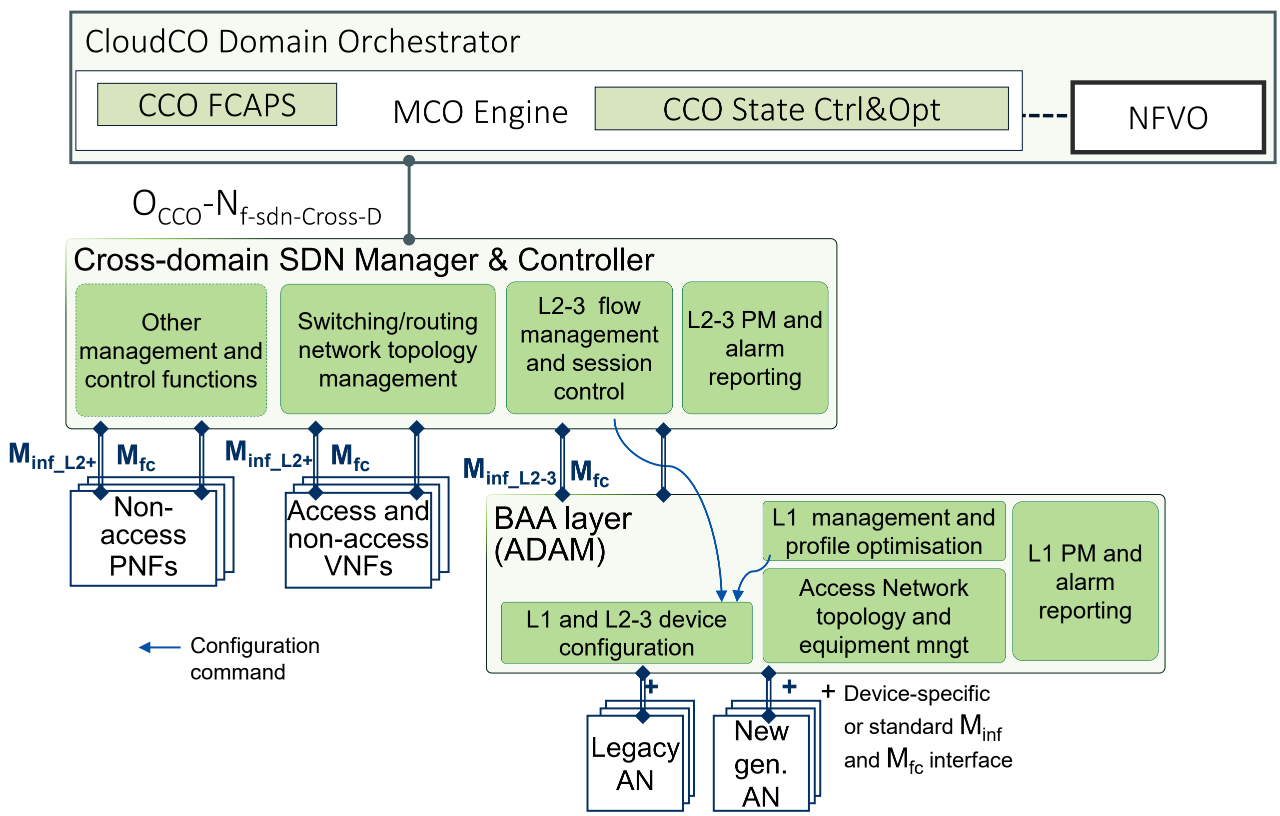

Figure 4: BAA Layer as an ADAM interfacing with a Cross-domain SDN Manager and Controller

Alternatively, the BAA–ADAM could be deployed aside an Edge SDN Manager and Controller, replacing the BAA-Act and the Access SDN Manager and Controller in the exact same architecture depicted in Figure 3.

5.4 Architecture and Deployment Scenarios

The disaggregation of functionalities from Access Nodes and the introduction of SDAN elements (e.g., D-OLT, BAA Layer, Access SDN M&C functions) and collaborating xNFs, opens to numerous architectures and deployment scenarios.
As shown in Figure 2, when deployed, the BAA Layer takes a mediation role between the SDN Management and Control elements and the access network resources, which in a disaggregated scenario are represented by physical ANs and disaggregated xNFs.

 © The Broadband Forum. All rights reserved

Hence, there are BAA Layer deployment scenarios related to:

- BAA Layer functional variants and geographical location
- disaggregated xNFs implementation and location.

5.4.1 BAA Layer Deployment Scenarios

This section describes example deployment scenarios related to different functional variants of the BAA Layer described in section 5.3. These are the BAA-Actuator and the BAA-ADAM which support different sets of functionalities.
The following deployment scenarios can be identified depending on the BAA Layer functional variant being deployed, network scale versus delay, and other trade-offs:

- BAA-Actuator deployed at CO locations
- BAA-Actuator deployed at Aggregation or Regional network locations
- BAA-ADAM deployed at Central network locations

These deployment scenarios are not strictly mandatory though they are the most plausible ones based on the location and the BAA Layer functional variants.

The deployment architecture in Figure 5 focuses mainly on the BAA Layer acting as a mediation and adaptation layer deployed close to access resources. Each BAA Layer instance operates as a single-entry point to SDN M&C elements for the resources (physical ANs and associated xNFs) it manages, while offering a unified standard NBI to expose ANs with different kinds of interfaces (proprietary vs standard, based on legacy vs recent protocols/DMs).

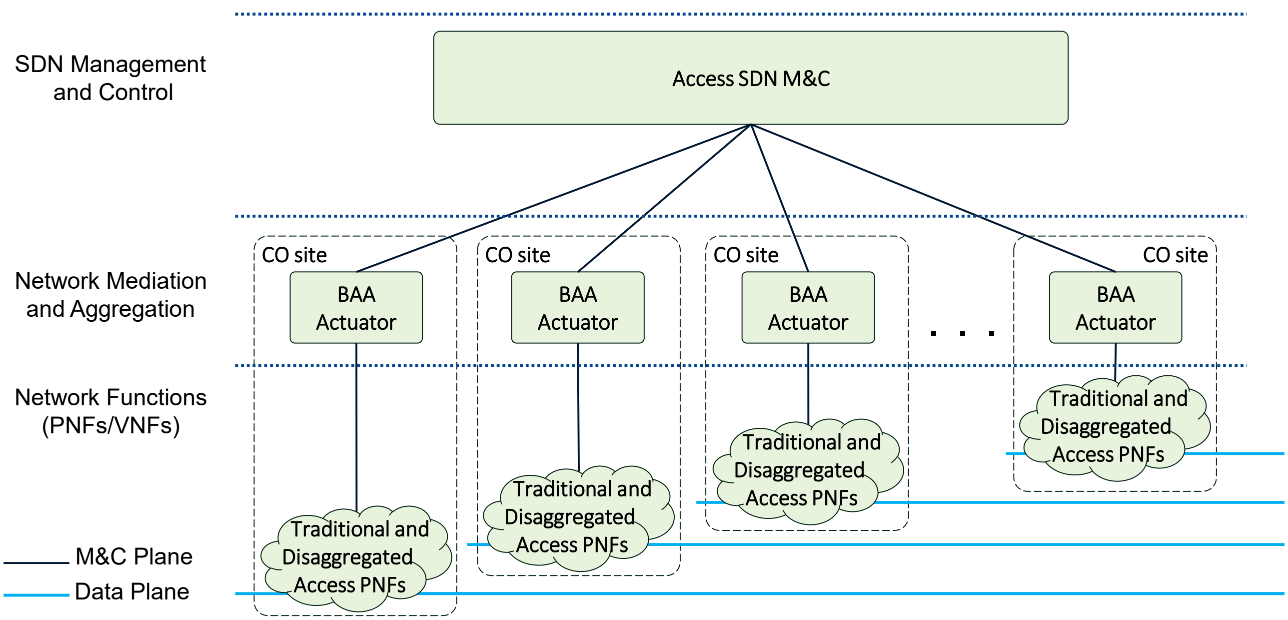

Figure 5: BAA-Actuator deployed at CO locations

The deployment architecture in Figure 6, relies on instances of a BAA-Actuator deployed in Network Aggregation or Regional datacenter locations to provide mediation and adaptation layer capabilities but at a larger scale than when deployed at CO locations. In case of disaggregated xNFs integrated in or collocated with the BAA Layer described in section 5.4.2, the location where the BAA Layer is deployed must account for delay requirements of the xNFs. This is particularly important for Control Plane xNFs.

 © The Broadband Forum. All rights reserved

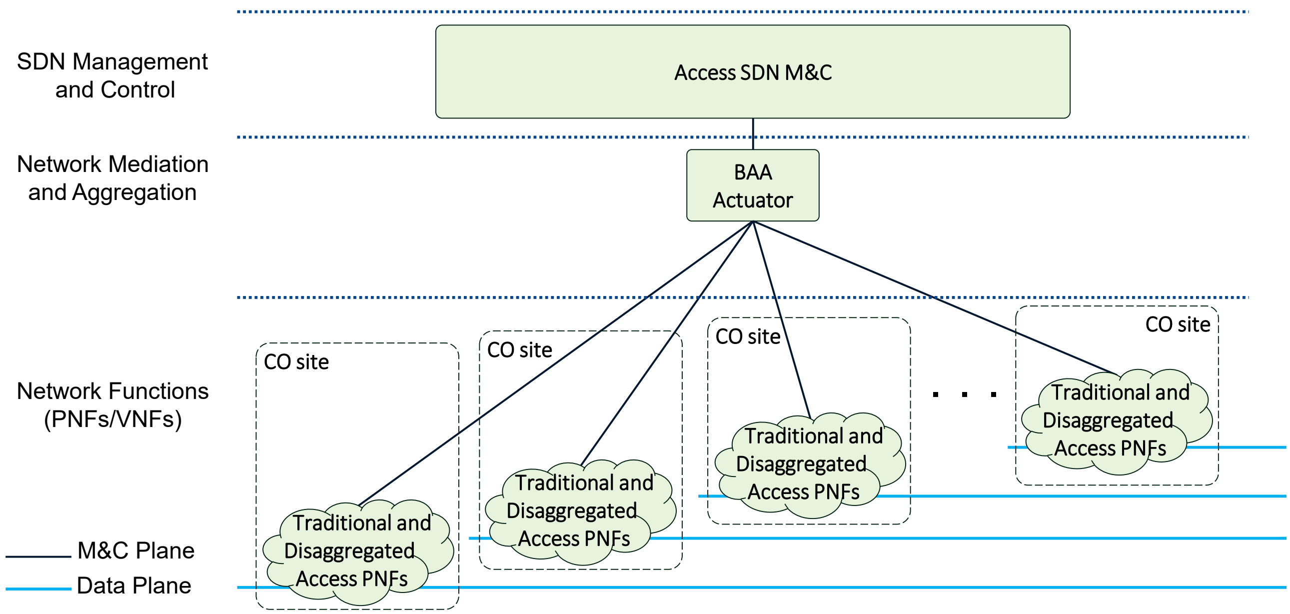

Figure 6: BAA-Actuator deployed at Aggregation or Regional network locations

In the architecture in Figure 7, the BAA Layer is deployed at the Centralized Data Center location as a BAA-ADAM that collaborates with a Cross-domain SDN M&C. The BAA-ADAM exposes a fully abstracted view of the network to the Cross-domain SDN M&C element that oversees the network and the services end-to-end.

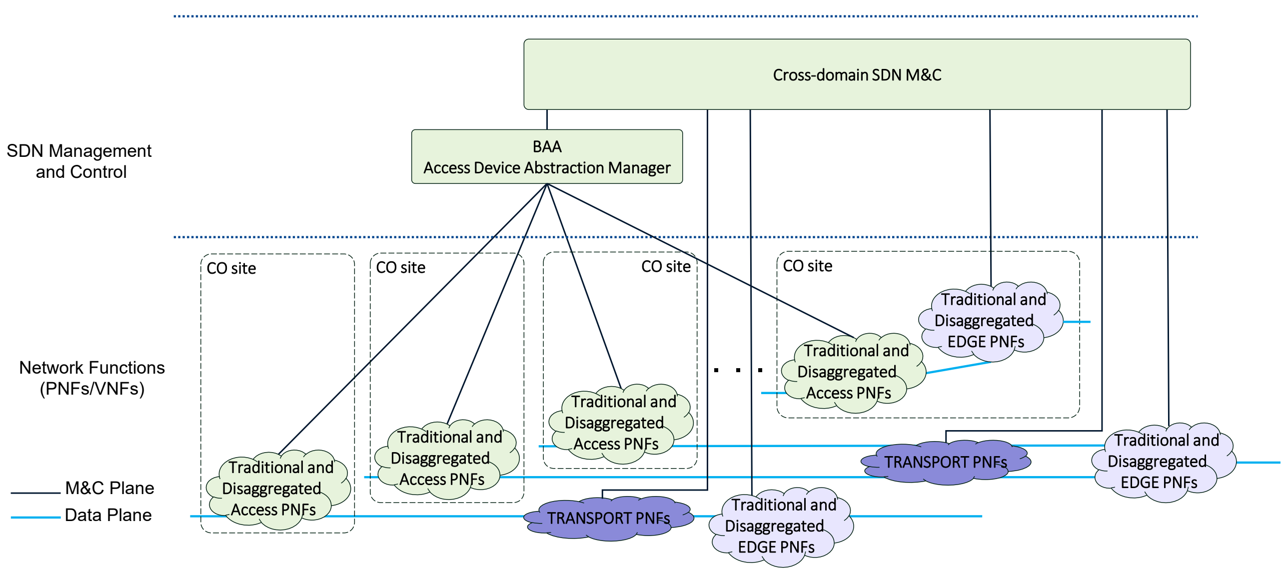

Figure 7: BAA-ADAM deployed at Central network locations

5.4.2 BAA Layer Deployed with xNFs

This section describes the deployment architectures of a BAA Layer with respect to its interaction with xNFs that have been disaggregated from the Access Nodes.

These architectures are basically characterised by xNFs integrated in, collocated alongside, or located away from the BAA Layer and a combination of these cases. These architectures are applicable regardless of the

 © The Broadband Forum. All rights reserved

nature of disaggregated xNFs, whether they are Management Plane xNFs, e.g., the vOMCI functions described in TR-451 [15] or Control Plane xNFs like those described in WT-477 [18].

These architectures are, to a large extent, orthogonal to the deployment scenarios described in section 5.4.1. For this reason, only the BAA Layer, rather than the full SDN management and control chain, is shown in Figure 8. There are delay considerations that can arise for xNFs that are sensitive to message latency and jitter in case of BAA Layer deployments at Central locations.

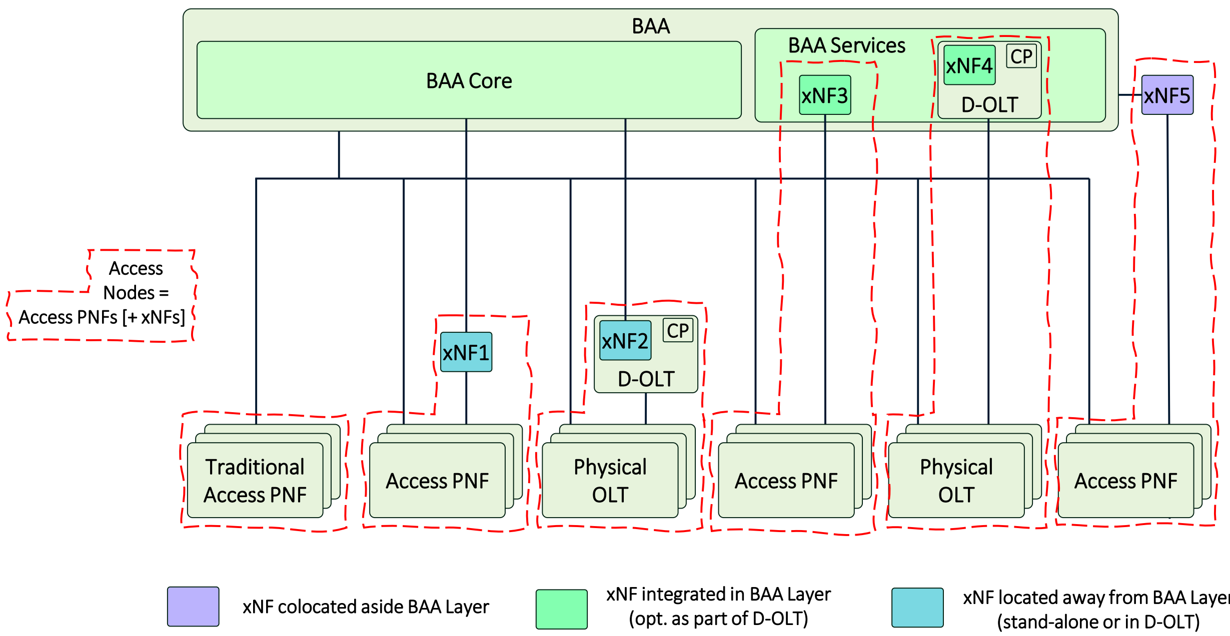

Figure 8: BAA Layer deployed with xNFs

Figure 8 also highlights that when Access Nodes are disaggregated, they are composed of a physical Access PNF, handling the Data Plane and Management/Control plane functions that have not been disaggregated, and one or more disaggregated software components in charge of Management and Control Plane functions and workflows. Note that in certain cases (i.e., xNF1 and xNF5) a disaggregated xNF can be deployed as a stand-alone function hosted on the NFVI.
Hence, the management and control of disaggregated Access Nodes are performed via multiple interfaces whose adapters and endpoints need to be documented in the BAA Layer or the SDN M&C element.
Similarly, these resources need to be described considering the disaggregated software components that make up for the Access Node's overall set of functionalities and hence the models used for equipment inventory have to document these components.

5.5 Coexistence and Migration in the Access Domain

This subject is dealt with in section 5.1.1 of TR-408 [11].

 © The Broadband Forum. All rights reserved

6 BAA Layer System Description

The high-level functional diagram for the BAA Layer is shown in Figure 9.

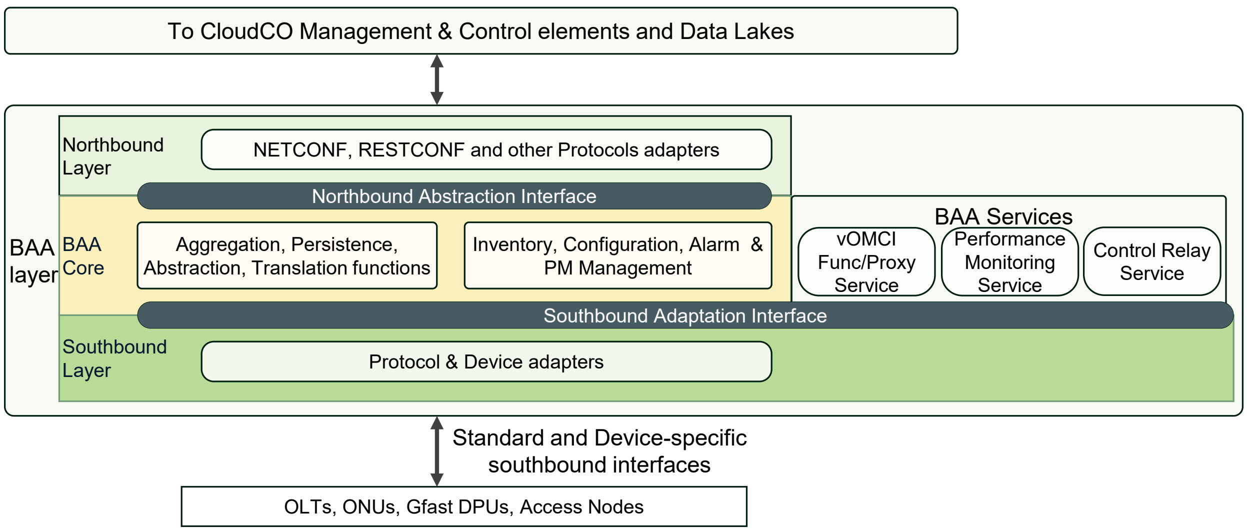

Figure 9: BAA Layer System Context

6.1 BAA Core

The BAA Core provides the management and control functions needed to govern Access Nodes (AN), either legacy or disaggregated (see also section 5.4.2). These functions are defined independently from the protocols and models used to communicate with the Access Nodes to the south or with the Management and Control Elements to the north. This independence is achieved by using standardized network abstraction interfaces at the northbound edge and device adaptation interfaces at the southbound edge of the BAA Core.
The BAA Core implements the PMA Datastore where the AN device configuration is persisted as standard vendor-agnostic representation. Along with the aggregation of Access Nodes configurations the BAA Core possibly hosts a topological representation of the access network and resources it manages.

The Northbound Abstraction Interface (NAI) and Southbound Adaptation Interface (SAI) are combined with protocol-specific adapters and, in the case of SAI, also device-specific adapters to expose the BAA NBIs and SBIs, i.e., the external interfaces that allow the interaction with the SDN Manager and Controller and the Access Nodes respectively.

The combination of the NBI/NAI–Core–SAI/SBI converts generic messages from the SDN Management and Control elements into protocol-specific/device-specific messages used to communicate with access devices and vice versa.

6.2 Southbound Layer and Adaptation Interface (SAI)

6.2.1 Southbound (SB) Layer

The Southbound layer (SB) contains device adapters that support communication with the access devices in the network. These adapters may be device-specific in that they provide a low-level interface to device hardware or accommodate for vendor-specific variations on devices. Alternatively, device adapters may be

 © The Broadband Forum. All rights reserved

generic, i.e., designed to interface with devices compliant with standard interfaces, regardless of the vendor who manufactures them.
In either case, the device adapter, to correctly interoperate with the BAA Layer must comply with the SAI API which is the interface exposed by the BAA Core on its south edge. Since communication with a specific Access Node relies on a device adapter, the interface between the adapter and the Access Node (e.g., the external BAA's SBI) is allowed to be device-specific and it is not considered a point of interworking. This is because it has to be assumed that an AN and the corresponding device adapter (Vendor specific or Standard) fully interoperate by design.
Device adapters may use protocol libraries provided as common resources of the SB layer, or they can embed their own protocols as needed.

6.2.2 Southbound Adaptation Interface (SAI)

The SAI is a standard compliant interface based on the applicable data models and procedures specified by BBF and other standardization organizations. The SAI provides a first degree of adaptation between the BAA Core and the Access Nodes to the south.

6.3 Northbound Layer and Abstraction Interface (NAI)

6.3.1 Northbound (NB) Layer

Northbound the BAA Layer communicates with one or more Management and Control elements, e.g., Access or Cross-domain SDN Management and Control Systems. These systems may use different protocols to communicate with functions in the BAA Core. The BAA's NB layer exposes one or more NBIs with the appropriate protocol(s) by applying protocol adapters at the NAI. This leaves flexibility for redefining the systems to north of BAA and their interfaces can be updated to use a different protocol (e.g., RESTCONF or NETCONF) with minimum redesign.
Since the BAA's NBI needs to rely only on common protocol adapters, there is no analogy with the concept of device-specific interfaces at the SBI, and the behavior of the protocol adapters should be defined by standards per each of the applicable protocols. However, the data carried by the protocols are specified at the Northbound Abstraction Interface (NAI).

6.3.2 Northbound Abstraction Interface (NAI)

The NAI is a standard compliant interface based on the applicable data models and procedures specified by BBF and other standardization organizations. It exposes a standard representation of access resources that allows the interworking between the BAA Core and the SDN Management and Control elements to the north. For some functional variants (see section 5.3), the BAA Layer also exposes standardized technology-specific interfaces to manage physical layer and other AN specific attributes.

6.4 Example - Device Abstraction in an FTTH Scenario

Via the BAA Layer, a service based on a Fiber to the Home architecture can be configured, without being aware of the OLT and ONU brands or the details of the PON configuration. In addition, for some functional variants (see section 5.3), the BAA Layer can abstract specific PON technology attributes and can take care of coordinating ONU and OLT configurations. The same applies to other FTTx deployments and related access technologies (e.g., FTTdp/G.fast, FTTA/GbE, FTTA/PON, FTTCab/VDSL2).
The BAA Layer can also provide management of a PON in a vendor agnostic fashion. In addition, in some implementations the OLT and ONUs are exposed northbound as a single AN where the PON abstraction function in the BAA Core performs the conversion between the abstract view at the NBI and the detailed

 © The Broadband Forum. All rights reserved

management and control functions (configuration, PM and alarm reporting, session initiation, etc.) for each of the physical devices connected to the PON at the SBI.

6.5 BAA Services

BAA services are optional services that are embedded in the BAA layer and execute a specific function as a micro-service. These services may also be hosted elsewhere in the network/cloud and/or as stand-alone function. They may fulfill a specific role for a specific disaggregated control or management function.

Examples are a vOMCI function and vOMCI proxy as defined in TR-451 [15]. Other example is a Control Relay function as defined in WT-477 [18]. Yet another example is a performance monitoring function that assists in collecting, processing, and filtering of performance data gathered from the PNFs.

When these services are embedded as BAA services in the BAA layer, they can interact with BAA core functions. Similarly, the BAA services, depending on their nature, may also interact directly with the PNFs. The specification of BAA Services interfaces is outside the scope of this WT. The interface(s) of certain BAA Services are defined in other documents (e.g., WT-477 [18] for the Control Relay function).

 © The Broadband Forum. All rights reserved

6.6 vOMCI Solution Deployment

Appendix I.3 of TR-451 [15] provides the options for deploying the vOMCI solution in CloudCO framework. As described in the appendix, the BAA Layer provides functionality and capabilities associated with the vOLTMF and interfaces with the physical AN, vOMCI Function, and vOMCI Proxy network functions.

The deployment of these entities involved in the vOMCI solution (i.e., vOLTMF, vOMCI Proxy, vOMCI Function) within the BAA Layer is defined as follows:

- vOLTMF: deployed in the BAA Core cooperating with the ANMF, it interfaces with the vOMCI Proxy and/or vOMCI Function
- vOMCI Function: deployed as BAA Service
- vOMCI Proxy: deployed as a BAA Service

Figure 10 depicts the entities of the vOMCI solution described above:

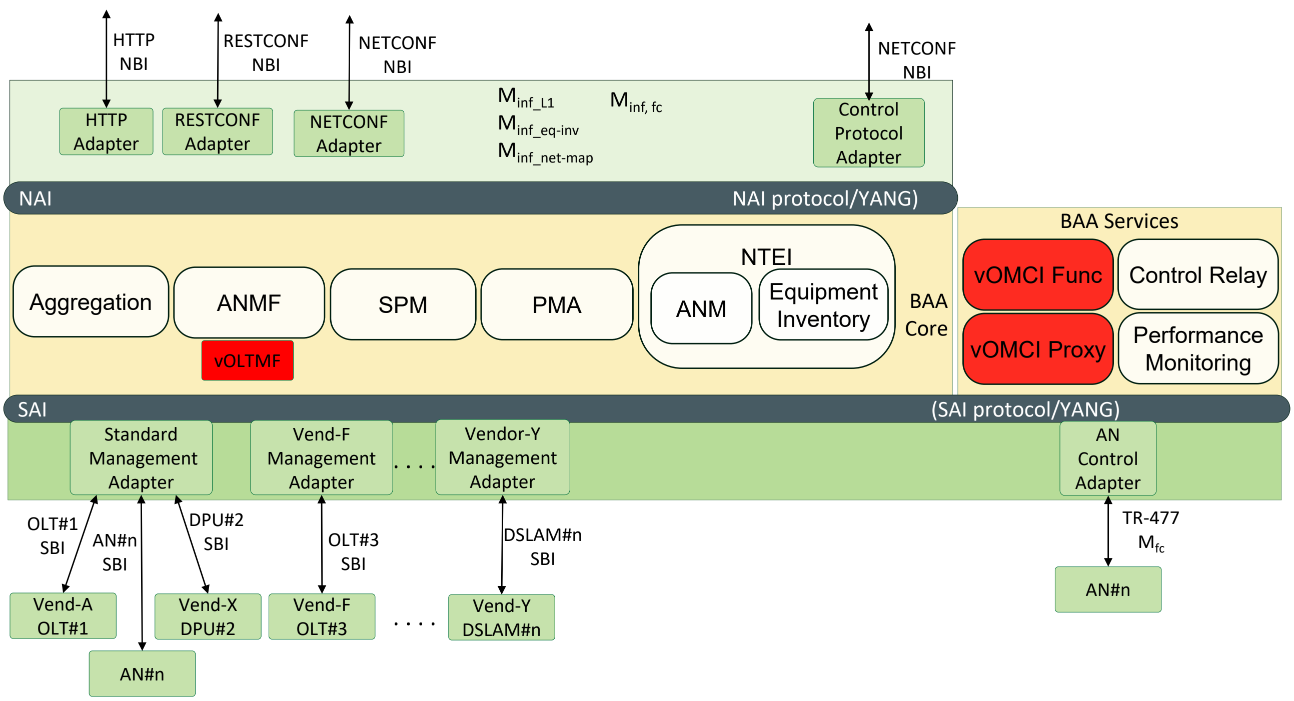

Figure 10: vOMCI solution deployment

 © The Broadband Forum. All rights reserved

7 BAA Layer Requirements

This section specifies the requirements for the following elements that comprise the BAA Layer:

- BAA Core
- Northbound Interface (NBI) for protocol adaptation
- Northbound Abstraction Interface (NAI)
- Southbound Adaptation Interface (SAI)
- Southbound Interface (SBI) for protocol and device-specific adaptation

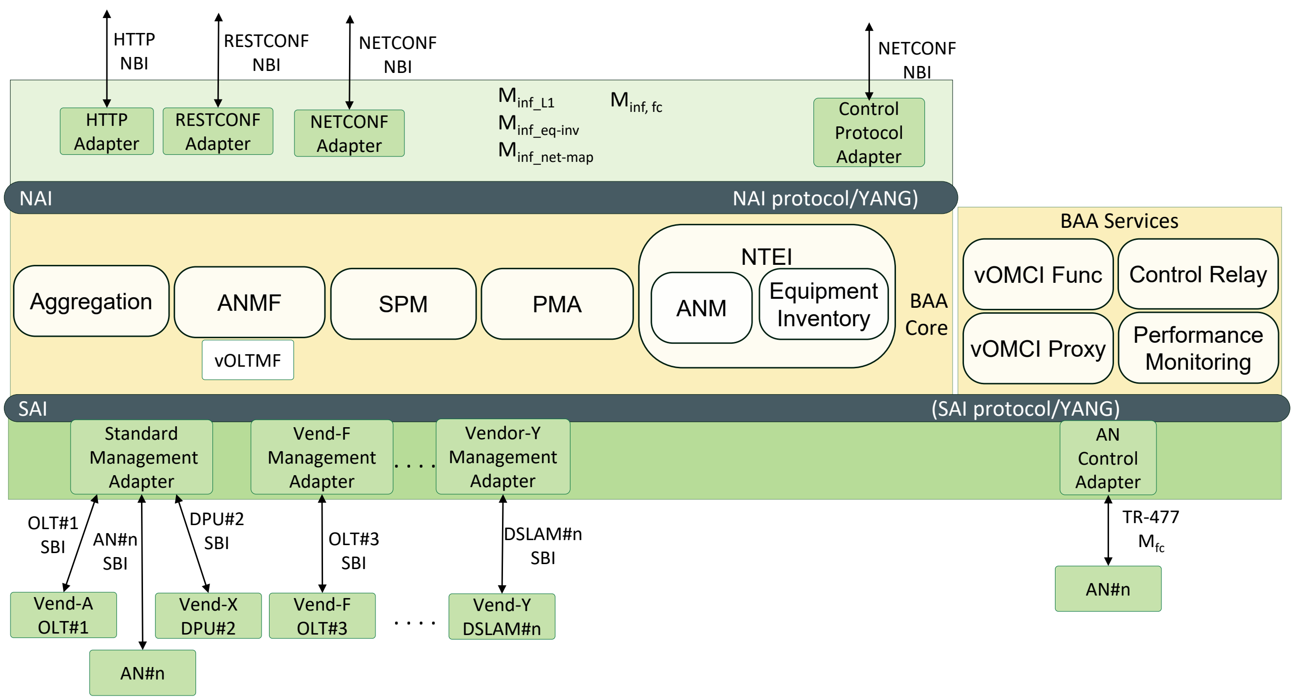

Figure 11: BAA Layer Capabilities

The requirements in this section apply to both BAA Layer functional variants with the exception of those marked with [ADAM] which apply only to the BAA – ADAM variant.

© The Broadband Forum. All rights reserved

7.1 BAA Core

The BAA Core provides the capabilities needed to implement the M&C Plane functional relocation described in section 5.1.

The BAA Core provides management plane functions that include device management and configuration, alarm handling, PM collection and transformation, aggregated network views of access xNFs for inventory, planning and operational purposes. Additionally, the BAA Core includes the functionalities needed to interface with xNFs that have been disaggregated from the Access Node either by directly interacting with the disaggregated xNF (e.g., vOMCI function for ONU management) or by acting as a control plane relay between the physical Access Node and the disaggregated xNF.

Figure 12 depicts the capabilities provided by the BAA Core, which include:

- Access Node Management Function (ANMF)
- Aggregation
- Network Topology and Equipment Inventory (NTEI)
- Service and Physical Layer Mapping (SPM) (only applicable to ADAM)

The BAA Core interacts with BAA Services like:

- Control Relay
- PM collection and transformation
- Virtualized ONU Management (vOMCI)

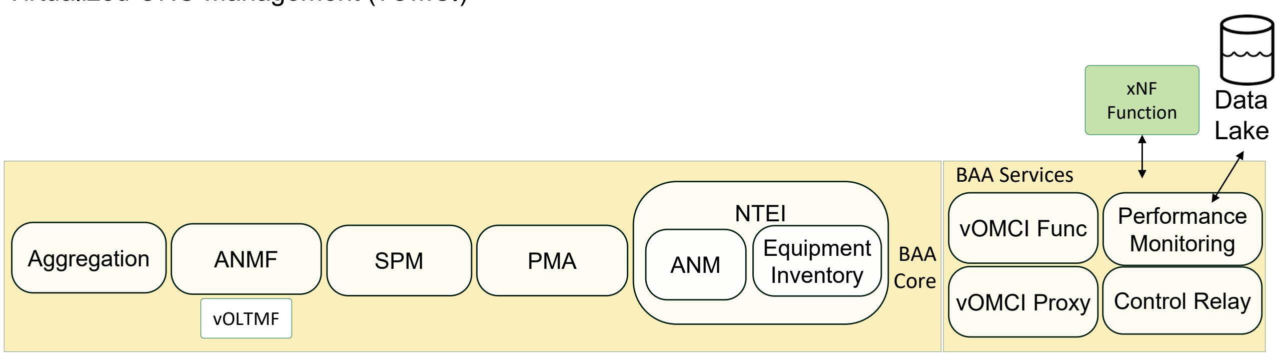

Figure 12: BAA Core Capabilities and some examples of BAA Services

The ANMF is the primary BAA Core function that is responsible for the majority of the Management Plane functionalities that include the capability to create/modify/delete nodes and establish the appropriate SBIs towards these resources including the deployment of the needed adapter(s).
The ANMF also interacts with other BAA Core capabilities to fulfill its tasks, that include interactions with the:

- Aggregation function to receive inputs from the NBI
- NTEI function to identify nodes and their equipment and inventory information
- SPM function to translate abstracted commands to full configurations for the nodes and associated xNFs
- SPM function for profile selection and optimization
- PMA function to store the standard data instances
- Datastores to maintain configuration and operational data

 © The Broadband Forum. All rights reserved

7.1.1 Network and Equipment Creation

To support this operational phase, the BAA Core provides functionality to maintain the Network Topology and Equipment Inventory (NTEI) by implementing the TR-454 [16] Access Network Map (ANM) and Equipment Inventory for managed devices. Along with ANM and equipment inventory, the ANM provides a topological organization of its elements that can be very useful both for end-to-end service provisioning and to separate geographic domains of competence (e.g., regions, districts) in the access network.

As part of the Network and Equipment Creation operational phase, the BAA Core provides device management capabilities for the administration and management of Access Nodes that include an aggregated view of the physical Access Nodes and network functions managed by the BAA Layer. The BAA Layer incorporates a Persistent Management Agent (PMA) capability that provides the system's source of truth for the managed devices even when they are not connected. The Device Management and PMA functions are an evolution, in a software-defined and automated network world, of the notion of node-based Management Entity (ME) outside the physical AN, effectively decoupling the User Plane from the M&C Plane.

7.1.1.1 Representations of the Physical Access Node

The BAA Core has the capability to provide a representation of the physical AN and associated xNFs as a pAN-representation that contains the overall description and updated status of an AN, hosted in the BAA Layer Datastore and constitutes the single source of truth of network information. The pAN-representation includes the instance of an AN type based on a standard AN model with L1 and L2-3 attributes (e.g., a TR-413 [13] compliant OLT) called an AN-instance. Additionally, the pAN-representation provides additional information needed for other equipment related functions (e.g., inventory, backup/restore, environmental variables).

A pAN-representation can be exposed northbound of the BAA Layer via a:

- [L1+L2-3] interface, compliant with TR-413 [13] interfaces and Data Models specifications.
- [L2-3 abstracted] interface which exposes the physical AN as a 1-port:N-port switching/routing function, where N access ports are multiplexed into a single backhauling port; this is a generic physical AN representation that doesn't include technology specific L1 nor the equipment related information.

As the pAN-representation is based on a specification for the type of Access Node (e.g., the OLT, DPU, and ONU representations specified in TR-413 [13]), the BAA Layer provides the capability to maintain and associate a catalog of standard TR-413 [13] models for each type of physical AN.

Additionally, when an AN-instance is created in the BAA Layer to represent a deployed vendor-Y AN, the ANMF uses the vendor information associated with the AN to retrieve the device adapter suitable for vendor-Y AN. The adapter could be either a standard adapter (e.g., NETCONF/YANG) or device-specific adapter that fits the AN by its vendor, model, software release information. Hence an adapter for vendor-Y AN is loaded and connected to the standard BAA SAI to deploy an adaptive SBI tailored to manage and control that physical AN.

7.1.2 Service Creation, Monitoring, and Assurance

To carry out this operational phase, the ANMF and PMA functions perform key roles for Service Creation, Monitoring, and Assurance tasks.

Whereas the BAA-Actuator functional variant is expected to receive [L1+L2-3] configuration commands, in the BAA-ADAM functional variant, an additional function called the Service and Physical Layer Mapping Function (SPM) is needed to issue configurations or commands to a physical AN and/or network function. The SPM function implements a mapping logic that can match per-technology physical layer configurations with the bandwidth, delay, priority, policy settings of the L2-3 commands received by the BAA Layer from northbound SDN elements. The mapping logic, upon the received L2-3 settings, identifies the most suitable physical layer data rate, delay parameters and those that influence flow priority (e.g., tagging, mapping, encapsulation,

 © The Broadband Forum. All rights reserved

allocation of transmission grants). The mapping logic can also implement quality and robustness algorithms to optimise the physical layer over time via the profiles contained in a L1-profile library. To define the actual L1 and L2-3 configuration to be issued over a given port, the SPM function has the capability to perform a consistency check to avoid conflicts with existing L2-3 settings on that port and on the ensemble of the AN. Furthermore, the SPM function has to avoid conflicts with L1 settings that are global on the whole AN; for example, the setting of spectrum and vectoring parameters for VDSL2 and G.fast technologies. These consistency checks rely on the actual AN status that is provided by the BAA Layer's Datastore.

7.1.3 BAA Core Requirements

This section of the document defines the requirements for the BAA Core functions and capabilities.

Note: requirements marked as [ADAM] apply only to the BAA-ADAM functional variant.

R-1 The BAA Core MUST support a Network Topology and Equipment inventory (NTEI) function.

R-2 The BAA Core MUST support an Access Node Management Function (ANMF) for management of physical ANs and associated xNFs.

R-3 The BAA Core MUST support an Aggregation function to support the management of physical ANs and associated xNFs.

R-4 [ADAM] The BAA Core MUST support a Service & Physical-layer Mapping (SPM) function for L1+L2-3 profile selection.

R-5 The BAA Core MUST support the ability to interact with BAA Service xNFs to enable specific workflows in the BAA Layer.

R-6 The BAA Core MUST provide the capability to relay Mfc_SCi and Mfc_CPRi control plane messages to a designated D-OLTs as defined in WT-477 [18].

R-7 The NTEI function MUST support and maintain an Access Network Map (ANM) as defined in TR-454 [16].

R-8 [ADAM] The ANM MUST provide a topological network view of the underlying physical ANs and comply with TR-454 [16].

R-9 The NTEI function MUST support and maintain the Equipment Inventory as defined in TR-454 [16].

R-10 The NTEI function MUST host a library of pAN-representations models as a unified (i.e., vendor-agnostic) technology-specific representation of a given AN type, based on a standard AN model with L1 and L2-3 attributes and all the other equipment functions (e.g., inventory, backup/restore, environmental variables, etc.) for the types of AN and functional modules defined in TR-413 [13].

R-11 Upon creation/deletion of a physical AN, the ANMF MUST instantiate/de-instantiate the corresponding AN-instance within the Datastores (DS) maintained within the BAA Layer.

R-12 An AN-instance DS is based on the appropriate pAN-representation's model taken from the library specified in R-10. In addition, the DS contains specific information of that physical AN (e.g., vendor, model, software release) in compliance with the models defined in TR-454 [16].

The AN-instance DS MUST represent each AN by documenting the corresponding physical AN and, if applicable, the associated xNFs in compliance with the models defined in TR-454 [16]. Note that the same xNF, typically being a shared software module, is usually associated to and documented in multiple AN-instances. These concepts are depicted in Figure 8.

R-13 The NTEI Function MUST update each AN-instance DS upon inputs from the underlying physical nodes, from the SDN element(s) northbound and other potential inputs to the NTEI itself.

R-14 The ANMF MUST support Device Management capabilities to perform administration and management of AN-instances.

R-15 The Aggregation capability MUST provide an aggregated view of the physical Access Nodes and associated xNFs managed by the BAA Layer.

 © The Broadband Forum. All rights reserved

R-16 The PMA capability MUST allow to store the persistent configuration and other information of the physical ANs and their associated xNFs, even when a physical AN and/or xNF are not reachable.

R-17 The ANMF MUST provide the capability to retrieve PM from a physical AN and associated xNFs by interacting with a PM collection service, internal or external to the BAA Layer.

R-18 The ANMF MUST provide the capability to receive alarm data from a physical AN and associated xNFs.

R-19 The ANMF MUST be able to perform a software update/rollback over a physical AN and associated xNFs by issuing the appropriate command to the corresponding AN-instance.

R-20 The ANMF MUST be able to perform a backup/restore over a physical AN and associated xNFs by issuing the appropriate command to the corresponding AN-instance.

R-21 The ANMF MUST host a local library of device-specific adapters that fit the superset of physical ANs and associated xNFs managed by the BAA Layer instance.

R-22 The ANMF MAY access a centralized library of device-specific adapters.

R-23 Upon creation of an AN-instance, the ANMF MUST retrieve from the local library, specified in R-21, the appropriate device-specific adapter based on the known information (e.g., device type, vendor, model, software release).

R-24 The ANMF MUST load the device-specific adapter and "plug" it to the standard SAI to deploy an adaptive BAA SBI tailored to fully manage and control that physical AN and associated xNFs.

R-25 The ANMF MUST convert generic L2-3 configuration commands[2] for a target logical port, received from the northbound SDN element(s), and generate standard technology-specific L2-3 configurations for the target port of pAN-representation.

R-26 The ANMF MUST convert technology agnostic L1 PM and alarm reporting commands for a target transmission port (on the physical AN) and generate standard technology-specific[3] commands to, for example, start/stop PM collection, set thresholds, enable reporting.

R-27 The ANMF MUST be able to access L1 PM counters and alarms data (i.e., raw data rather than post-processed) collected from the physical AN and associated xNFs and dispatch them to the requesting or a different SDN element.

R-28 [ADAM] The ANMF function MUST provide the capability to direct L2-3 policy enforcement/flow creation commands to the SPM function for further processing.

R-29 [ADAM] The ANMF function MUST provide the capability to proxy L2-3 PM and alarm reporting commands to the SPM function for further processing.

R-30 [ADAM] The SPM function MUST be capable of retrieving information about the access technology of a target port to be configured on the physical AN and its associated xNFs, its current L1 profile and L2-3 settings and potential L1 profile constraints applicable to the whole physical AN.

R-31 [ADAM] The SPM function MUST provide the capability to maintain a library of L1 profiles. This library MUST be managed via an administrative interface of the BAA Layer.

R-32 [ADAM] The SPM function MUST support a mapping logic to identify a L1 profile to match L2-3 requests from the northbound SDN element(s) and generate a complete [L1+L2-3] configuration command.

R-33 [ADAM] The mapping logic of the SPM MUST implement technology-specific algorithms to address the configuration mapping for different AN types: OLT, DSLAM, DPU, MSAN.

---

[2] These are commands for configuring L2-3 port settings (e.g., flow creation or change) and L2-3 flow control (e.g., policy enforcement, forwarding, classification and scheduling, filtering).

[3] Technology-specific refers to the access technology (e.g., VDSL2, EPON, XGS-PON) of the target logical port being configured. The BAA Core is not supposed to go beyond that provided that it is the duty of the SB layer adapters to produce device-specific configurations.

© The Broadband Forum. All rights reserved

R-34 [ADAM] The SPM function MUST send any generated command, via the PMA function, to the correct port on the physical AN via the appropriate BAA SBI.

R-35 [ADAM] Before sending any configuration command to a target port, the SPM function MUST perform a consistency check to avoid conflicts with existing L1 and L2-3 settings on that port and on the whole AN.

R-36 [ADAM] In case the consistency check of the [L1+L2-3] configuration command issued by the mapping logic, specified in R-35, leads to a conflict or sub-optimality with respect to existing physical AN setting, the SPM MUST refrain from pushing the configuration command and MUST send a notification to the issuing SDN element.

R-37 [ADAM] The ANMF function MUST provide the capability to store, and post-process reported L1 PM counters and alarm data in order to generate elaborated information (e.g., aggregation, filtering, trend logs, graphs, etc.) to be exposed via a human or machine interface or to be further forwarded to the requesting or a different SDN element.

R-38 [ADAM] The SPM MUST convert generic L2-3 configuration commands[4] for a target logical port and generate standard technology-specific L2-3 configurations including an optimal L1 profile as selected by the mapping logic of the SPM Engine.

7.2 Southbound Adaptation Interface (SAI) and Southbound Interface (SBI)

The SAI and SBI demark the boundaries of the interfacing/adaptation modules that allow the communication between the BAA Core and the physical ANs and associated xNFs connected through the SBI including the protocol specifics required for device communication between the BAA Layer and the physical AN.

The SAI is an intra-layer standard interface exposed by the BAA Core to interact with the Management and Control Adapters. The SAI represents the BAA Layer southbound interoperability reference point. It exchanges information elements represented using YANG and the operations are conveyed using a local interface API provided by the BAA Core (e.g., JAVA interface classes).

The SBI is the reference point between the Management and Control Adapters and the physical AN and xNFs. The information elements and protocols conveyed between the physical AN and xNFs can be proprietary (e.g., SNMP, gRPC/GPB) or use standards-based interfaces (e.g., TR-413 [13] M_{inf}, TR-451 [15] $M_{vOMCI\text{-}OLT}$, TR-477 [18] M_{fc})

[4] These are commands for configuring L2-3 port settings (e.g., flow creation or change) and L2-3 flow control (e.g., policy enforcement, forwarding, classification and scheduling, filtering).

© The Broadband Forum. All rights reserved

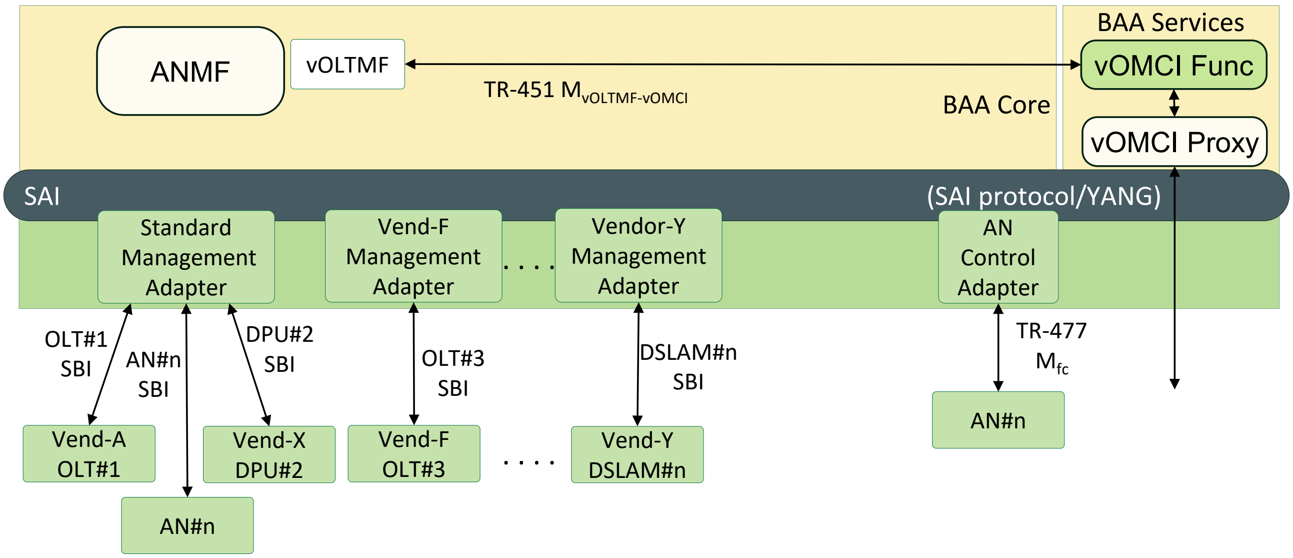

Figure 13: SAI and SBI Capabilities

R-39 The SAI MUST support the capability to exchange YANG information elements between Management and Control Adapters and the ANMF using the SAI API.

R-40 The SAI MAY support a JAVA interface for the exchange between Management and Control Adapters and the ANMF.

R-41 The SAI and SBI of the BAA Layer MUST support Management Adapters for the TR-413 [13] M_{inf} interface for the associated physical AN or xNF.

R-42 The SAI and SBI of the BAA Layer SHOULD support the Control Relay Adapter for the TR-477 [18] M_{fc_SCi} and M_{fc_CPRi} interfaces for physical ANs.

R-43 The SAI and SBI of the BAA Layer SHOULD support the Management or Control Relay Adapter for proprietary protocols between the BAA Layer and the physical AN and associated xNFs.

R-44 The SAI MUST implement standard YANG $M_{inf\text{-}AN}$ interfaces as specified in TR-413 [13] where "AN" ranges in the set of Access PNF and xNF types defined in TR-413 [13].

This means that Data Models implemented in the SAI MUST comply with standard DMs in terms of structure, syntax, and semantics.

Note: this requirement aligns with TR-413 [13] requirement that Access PNFs, when directly interacting with an SDN Manager and Controller, is required to support the same interfaces as those exposed by the BAA SAI.

R-45 The SAI MUST implement M_{fc} interfaces as specified in TR-477 [18].

R-46 The SAI MUST implement an Equipment Inventory management interface ($M_{inf\_eq\text{-}inv}$) as specified in TR-454 [16].

R-47 Upon establishment of a connection with the physical AN or xNF, the SAI MUST notify the ANMF to align the connected element with the pAN-representation of the element.

R-48 The SBI MUST comply with R-24.

R-49 If the SBI is based on the NETCONF protocol it MUST comply with TR-435 [14].

 © The Broadband Forum. All rights reserved

7.3 Northbound Interface (NBI) and Northbound Abstraction Interface (NAI)

The NBI and NAI hosts the interfacing functionality that allow for communication between the BAA Core and management and control systems (SDN M&C) connected through the NBI.

The NBI is the reference point between the management and control systems and the BAA's internal interface, i.e., the NAI. As the NBI supports multiple protocols toward SDN M&C elements, the NBI consists of protocol-specific adapters (e.g., NETCONF, RESTCONF, HTTP) that adapt the protocol-specific NAI interface to the aggregated YANG representation of the pANs and xNFs. The primary purpose of the protocol-specific adapters in the NBI is to expose the BAA Layer via a given protocol as required/convenient to interconnect with a target SDN element. Depending on the actual management and control architecture, the BAA Layer may be connected to one or more SDN Management and Control elements.

The NAI is an intra-layer standard interface exposed by the BAA Core to interact with the NBI protocol-specific adapters. The NAI represents the BAA layer interoperability reference point northward and provides representation of a:

- [L1+L2-3] interface: The physical representation of the AN that is exposed via management M_{inf} (i.e., M_{inf_L1} + M_{inf_L2-3}), M_{inf_eq-inv}, and $M_{inf\_net-map}$ interfaces.
- [L2-3 abstracted] interface: The L2-3 representation of an AN as a 1:N[5] switch/router that is exposed via L2-3 management (M_{inf_L2-3}) and flow control (M_{fc}) interfaces.

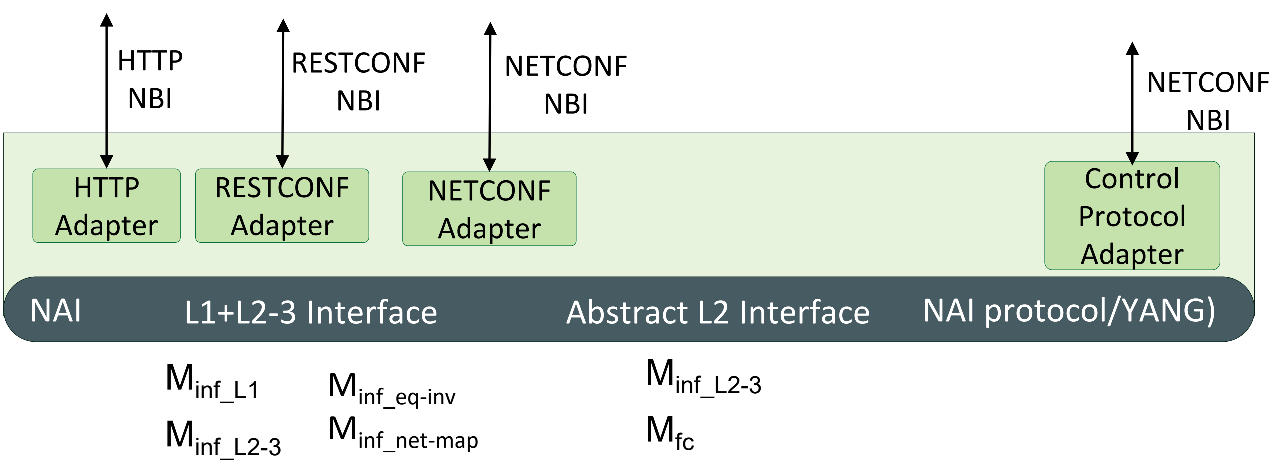

Figure 14 NBI and NAI Capabilities

[5] 1:N refers to the physical uplink and tributary interfaces of the AN. Hence a more general description would be m:N to consider m uplink interface for redundancy/multi-homing purposes.

 © The Broadband Forum. All rights reserved

If and how these fundamental interfaces are exposed depend on whether the layer is deployed as a BAA-ADAM or a BAA-Actuator. For the BAA-Actuator functional variant, the NAI needs to expose equipment inventory and network topology information to the Access SDN Manager & Controller enabling the latter to fully manage the physical AN and associated xNFs as standalone aggregated entities and as a part of a geographic deployment respectively.
For both BAA functional variants, the universal L2-3 abstraction interfaces (i.e., M_{inf_L2-3} and M_{fc}) are exposed. The full-blown technology-specific interfaces (e.g., $M_{inf-OLT\_L1}$, $M_{inf-DPU\_L1}$) are exposed by the BAA-Actuator functional variant.

All these NAIs are based on standard YANG Data Models (mainly developed by the BBF and IETF).

R-50 The NAI MUST support the capability to exchange YANG information elements of the pAN-representations between the NBI protocol-specific adapters and the BAA Core using the NAI API.

R-51 The NAI MUST support the capability to exchange YANG information elements of an abstract pAN-representation between the NBI protocol-specific adapters and the BAA Core that comply with the BAA northbound M_{inf_L2-3} and M_{fc} interfaces defined in TR-413 [13].

R-52 [*This requirement applies only to BAA-Act*] The NAI MUST support the capability to exchange YANG information elements of the pAN-representations between the NBI protocol-specific adapters and the BAA Core that comply with the BAA northbound technology specific interfaces (e.g., $M_{inf-OLT\_L1}$, $M_{inf-DPU\_L1}$, $M_{inf-DSLAM\_L1}$) defined in TR-413 [13].

R-53 [ADAM] The NAI MUST support the capability to exchange YANG information elements of the pAN-representations between the NBI protocol-specific adapters and the BAA Core that comply with the BAA northbound M_{inf_eq-inv} and $M_{inf\_net-map}$ interfaces defined in TR-413 [13] and TR-454 [16].

R-54 The NAI MAY support a JAVA interface to exchange YANG information elements of the pAN-representations between NBI protocol-specific adapters and the BAA Core.

R-55 When instructed to instantiate a NBI, the ANMF SHOULD retrieve from a local library the appropriate protocol-specific adapter for each Management and Control element to which the BAA Layer will connect.

R-56 The BAA Layer SHOULD load the protocol-specific adapter and "plug" it to the appropriate instantiation of standard NAI to deploy the required BAA NBI.

R-57 The NAI pAN-representation MUST align to the corresponding AN-instance to allow proper interaction with the corresponding target AN. This guarantees the appropriate correspondence between the attributes exposed northbound and those present on the physical AN and associated xNFs.

R-58 The translation performed by an adapter between the NAI protocol and the NBI protocol MUST preserve the integrity of the Data Model exposed by the NAI.

R-59 If the NBI is based on the NETCONF protocol it MUST comply with TR-435 [14].

7.4 vOMCI Solution Requirements

TR-451 [15] specifies a set of elements that can be deployed in the BAA Layer to provide virtual OMCI management of ONUs. Specifically, the BAA Layer can deploy functional aspects of the vOLTMF, vOMCI Proxy and vOMCI Function as described in section 1 along with its associated M_{voltmf_vomci} interface between the vOLTMF adapter and the vOMCI function and vOMCI Proxy.

R-60 For vOMCI support, the BAA Core MUST support the vOLTMF defined in TR-451 [15].

R-61 For vOMCI support, the BAA Layer MUST be capable of onboarding vOMCI function and vOMCI Proxy, defined in TR-451 [15], as BAA services.

R-62 When deploying the vOLTMF, the BAA Layer MUST implement the mandatory requirements for the vOLT Management Function as defined in section 5.6 of TR-451 [15].

 © The Broadband Forum. All rights reserved

R-63 When deploying the vOMCI function, the BAA Layer MUST implement the mandatory requirements for the vOMCI Function as defined in section 5.2 of TR-451 [15].

R-64 When deploying the vOMCI Proxy, the BAA Layer MUST implement the mandatory requirements for the vOMCI Proxy as defined in section 5.4 of TR-451 [15].

R-65 The management of ONUs that use the vOMCI function MUST implement the YANG modules defined in Annex A of WT-451 [15] for the functionality being deployed.

R-66 When implementing the M_{voltmf_vomci} interface in TR-451 [15], the BAA Layer SHOULD support Kafka as the message transport protocol, as defined in section 5.7.3 of TR-451 [15].

R-67 When deploying the vOLTMF, the vOLTMF SHOULD use the logging services and PM Datastores provided by BAA Layer.

7.5 Control Relay Requirements

The BAA Layer may act as a Control Relay function between the physical AN and one or more xNFs or D-OLTs. WT-477 [18] specifies the M_{fc} interfaces between the physical OLT and the D-OLT. The Control Relay function is comprised of a Control Relay NBI protocol-specific Adapter, a Control Relay SBI Adapter (WT-477 standard or vendor proprietary) and Control Relay Service that interacts with the BAA Core and the corresponding Adapters.

R-68 For Control Relay support, the BAA Layer MUST be capable of onboarding a Control Relay function, as a BAA service. This BAA service MAY be stand-alone or embedded in a D-OLT hosted in the BAA Layer.

R-69 If the BAA Layer hosts a D-OLT, the D-OLT MUST comply with WT-477 [18].

R-70 When deploying the SBI Control Relay Adapter, the BAA Layer MUST implement the mandatory requirements for the M_{fc} interfaces toward the physical AN as defined in WT-477 [18].

R-71 The BAA Layer MAY deploy vendor-specific Control Relay adapters toward the physical AN.

R-72 When deploying the Control Relay function as an intermediate relay, the NBI Control Relay Adapter of the BAA Layer MUST implement the mandatory requirements for the M_{fc} interfaces toward the D-OLT as defined in WT-477 [18].

R-73 The D-OLT MUST support the YANG modules of the M_{inf} interface(s) for the disaggregated xNFs. The D-OLT M_{inf} interface(s) YANG modules are defined in WT-477 [18].

R-74 When deploying the Control Relay function as part of a D-OLT, the NBI Control Relay Adapter of the BAA Layer MUST implement the mandatory requirements for interacting with the disaggregated xNF supported by the Control Relay function. These requirements are defined in WT-477 [18].

R-75 When deploying the SBI Control Relay Adapter, Control Relay function and NBI Protocol-specific Adapter, the SBI Control Relay Adapter, Control Relay function and NBI Protocol-specific Adapter SHOULD use the logging services and Configuration Datastores provided by the BAA Layer.

End of Broadband Forum Technical Report TR-484

 © The Broadband Forum. All rights reserved