



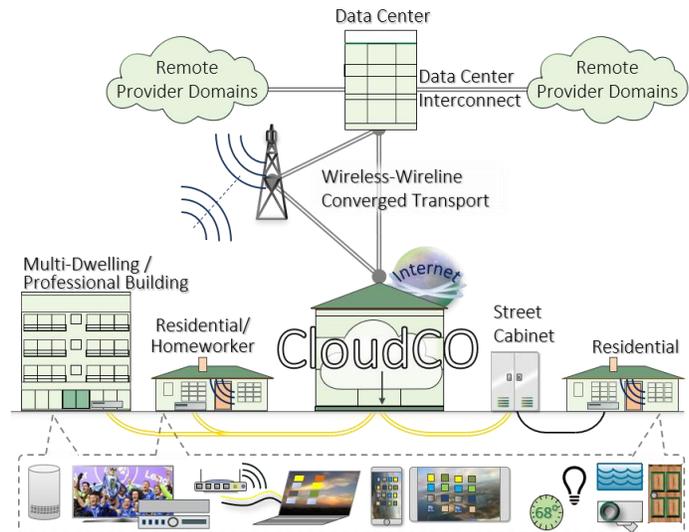
Cloud Central Office (CloudCO)

1 Enabling Cloud-Based Broadband Services

Cloud-based Central Office (CloudCO) is a recasting of what constitutes a Central Office hosting infrastructure. It utilizes SDN, NFV and Cloud technologies to support network functions and is aligned with the Forum’s Open Broadband vision and movement to agile implementation frameworks.

In doing so, it radically redefines the architectures of the access and aggregation networks that have developed incrementally in previous Broadband Forum specifications such as [TR-101](#) and [TR-178](#).

CloudCO enables significantly faster & more efficient provisioning of new Cloud-based services that require a higher level of automation, greater performance (e.g. lower latency) and are able to provide rapid availability of new revenue-generating services.



1.1 Choice and adaptability

Mostly Providers have had to decide on an implementation – and then they are stuck with it. CloudCO gives provider more choices and then the adaptability to choose again as conditions and markets evolve. Choice to select best of breed vendors, choices to tailor infrastructure and services to regional conditions that rarely develop uniformly are examples. It also creates an agile environment where failing fast accelerates revenue generation compared to long drawn out product introduction cycles based on theoretical models. This is particularly true in virtualized environments that are not deterministic/predictable. It brings the ability to adapt rapidly and makes decisions less stressful.

Table of Contents

1	ENABLING CLOUD-BASED OPEN BROADBAND SERVICES	1
2	DEFINITION, SCOPE AND OVERVIEW OF CLOUDCO PROJECTS	2
3	DEPLOYMENT	7
4	RELATIONSHIP TO OTHER BROADBAND FORUM WORK	8
5	CLOUDCO SUMMARY	9
6	TERMINOLOGY	9
7	ACKNOWLEDGEMENTS	10
8	ABOUT THE BROADBAND FORUM	10

1.2 Migration, co-existence and agility.

CloudCO addresses the industry's biggest challenge: how to introduce new technologies and devops approaches while minimizing risk of disruption to business viability, technical stability of providers and customer services alike.

The foundational specification is a Reference Architectural Framework ([TR-384](#)) for implementation of new software defined access models that enable

- Seamless migration driven by market acceptance, revenue, RoI
- Long term co-existence to protect investment and local conditions
- Agile architecture capable of adapting to rapidly emerging Software Defined Access models

This aligns closely with the complementary Open Broadband - Broadband Access Abstraction project referenced later.

In addition to TR-384, the CloudCO project deliverables include a series of interface specifications with uses cases, scenarios, application notes, test cases, migration and implementation strategies. These are structured to leverage the Broadband Forum's Open Broadband Labs initiative.

CloudCO's functionality can be accessed through a northbound API, allowing operators, or 3rd parties, to consume its functionality, while hiding how the functionality is achieved from the API consumer. To achieve this, SDN & NFV techniques are leveraged, running on a cloud-like infrastructure deployed at Central Offices.

CloudCO is located at the heart of the broadband ecosystem and is a unifying framework for all of the service developments important to providers and that fall under the Forum's umbrella of projects.

The Purpose of this paper is:

- To provide an overview of the work as an introduction to each of the projects that comprise the CloudCO initiative. It also introduces closely-linked implementation strategies
- To raise the awareness of the importance of the work
- To encourage as many interested parties as possible to actively participate in this and future Broadband Forum related projects so that all the requirements are properly handled

2 Definition, scope and overview of CloudCO projects

2.1 CloudCO defined

CloudCO is defined by a comprehensive set of deliverables (framework, use cases, interfaces, hardware and software implementations) that collectively enable the migration to a new dramatically faster, more efficient provisioning of Cloud-based services.

It brings compute resources and applications closer to the residential and business consumers to capitalize and combine with ultrafast access to provide a new level of user experience. It leverages trends in edge cloud, fog and edge computing for enhanced services delivery.

It defines 'Black Boxes' of functionality that re-uses well-known concepts and standards and defines Interfaces between them. It also enables the CloudCO to be distributed beyond the traditional physical boundaries of a "central office."

It leaves the system integrator/operators to choose Open Source versus vendor-provided software for any of the functional black boxes and to onboard and build services.

Interface definitions and test cases are added incrementally over the lifecycle of the project, based on operator Input derived from use case descriptions.

The CloudCO project will aid co-existence with and migration from legacy Broadband Systems, such as the one defined in [TR-178](#).

2.2 Scope of CloudCO

CloudCO is a multi-project initiative currently consisting of the following projects at time of writing:

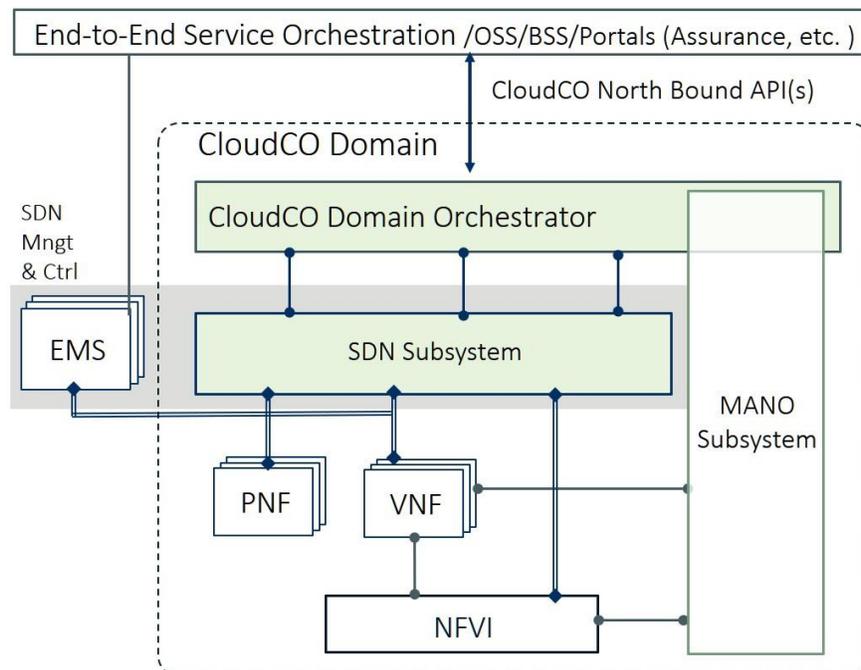
1. CloudCO Reference Architectural Framework	published as TR-384 .
2. CloudCO Use Cases and Scenarios	published as TR-416 .
3. Co-existence with/migration from legacy systems	WT-408*
4. Application notes for CloudCO, 14 defined*	
5. Functional Module Interface definitions	WT-411*
6. Test cases for CloudCO systems in Open Broadband Labs	WT-412*
7. Migration to SDN-enabled management and control	WT-413*

* Works in progress available to Broadband Forum members

2.3 CloudCO Reference Architectural Framework (TR-384)

This specification defines the reference architectural framework of the CloudCO. Functional modules are defined, but not the details of their internal operation. This framework starts from basic northbound API capabilities so that function composition, initialization, and management of the CloudCO resources can be supported and created as a byproduct of end-to-end service composition. This was the first published specification in the multiphase project.

2.3.1 Top-level architectural view – CloudCO Domain

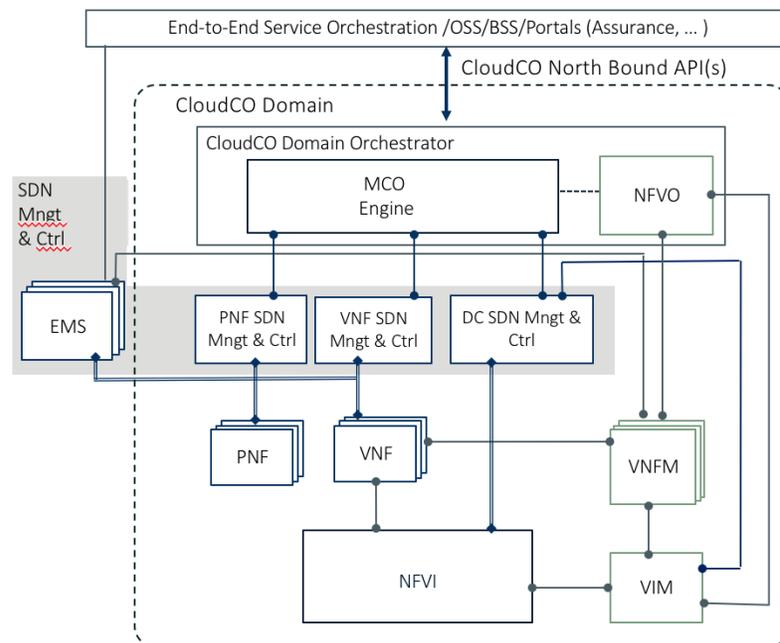


A CloudCO 'Domain' is an ensemble of network, compute, storage, and application components that work together to deliver networking and customer services, located in one or more network sites, are orchestrated by a single CloudCO Domain Orchestrator and share a common, uniquely addressable CloudCO northbound interface.

Each CloudCO Domain uses both existing ETSI/ISG NFV and new functions and interfaces:

- End-to-end Service Orchestrator, which coordinates all client interfaces. It also coordinates across multiple CloudCO Domains, or across other non-CloudCO and CloudCO Domains
- A CloudCO Domain Orchestrator, which manages, controls and orchestrates across the different functional elements inside the CloudCO Domain
- ETSI NFV MANO Subsystem
- The SDN Subsystem which can perform SDN operations across both VNFs and PNFs, including an Access Abstraction layer

2.3.2 Reference architecture key features

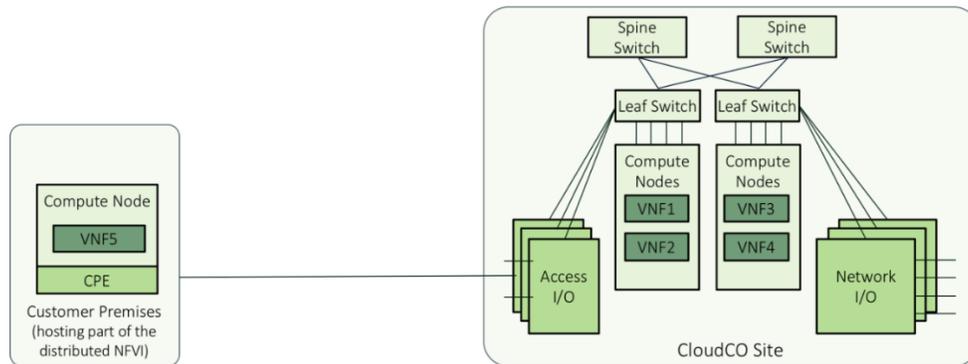


The following can be observed in the expanded figure below:

- The standard ETSI MANO suite is used to perform Virtual Infrastructure Management (VIM), Network Function Orchestration (part of the CloudCO Domain Orchestrator), and either generic or VNF-specific VNF Managers
- The Data Center (DC) SDN Manager & Controller, which aids in directly accessing NFVI networking resources to implement functions via configuration of underlying physical network infrastructure
- The Management Control Orchestration (MCO) Engine, which is a functional component inside the CloudCO Domain Orchestrator that expresses a continuum of Management, Control and Orchestration (MCO) tasks and CloudCO state transitions and supervision tasks
- PNF and VNF SDN Managers & Controllers, which are responsible for Fault, Configuration, Accounting, Performance, Security (FCAPS) and flow control management functionalities respectively for PNFs and VNFs

2.3.3 CloudCO physical architecture example

A CloudCO Architecture connects Access I/O functions directly into a typical, cloud-like infrastructure that leverages commodity compute and networking facilities. An example is shown below:



Note that in this example implementation, the Access I/O (GPON, etc.) functional elements are connected directly into a Top-Of-Rack switch (such as the spine and leaf switches in the above diagram). Several Top-Of-rack switches can be interconnected, typically in a ‘Leaf-Spine’ fashion. Access to the backbone of the Service Provider network is provided using Network I/O functional elements, which are again connected to a Top-Of-Rack switch. The compute facilities allow hosting VNFs, specific to the given service the CloudCO Operator is building, as well as hosting all necessary components to implement the Management, Control and Orchestration functionality. Also in this example, the NFVI is distributed across the Central Office and the customer premises.

2.4 CloudCO Use Cases and Scenarios (TR-416)

This specification defines fourteen CloudCO “Scenarios” and twelve ‘Use Cases.’ Some of the use cases are enabling legacy scenarios, and some cover new CloudCO-only use cases. The intention of the use cases is to test the validity of the architecture and to allow consideration of the information that needs to be exchanged across the interfaces between the functional blocks of the architecture.

Each of the following scenarios covers the architectural diagrams and actors involved:

- Residential Broadband Access using PPPoE
- Residential Broadband Access using IPOE/ Extensible Authentication Protocol
- Fixed Mobile Convergence - Interworking
- IPv4 Address optimization with Carrier Grade Network Address Translation
- Parental Control
- Lawful Intercept
- Network Enhanced Residential Gateway
- Hybrid Access
- Virtual Business Gateway
- Residential Broadband Access, User watches IPTV
- Business Broadband Access, L2VPN activation
- Fixed Access Network Sharing
- Public Wi-Fi Access
- Home network virtualization scenario

As mentioned above, the Use Cases enable existing and new CloudCO scenarios. They include residential broadband diagnostics and optimization, flat logical subscriber link, value added services, residential broadband access using , multicast control in CloudCO, deploying an off-network virtual business gateways SD-WAN functionality.

2.5 CloudCO Application Notes

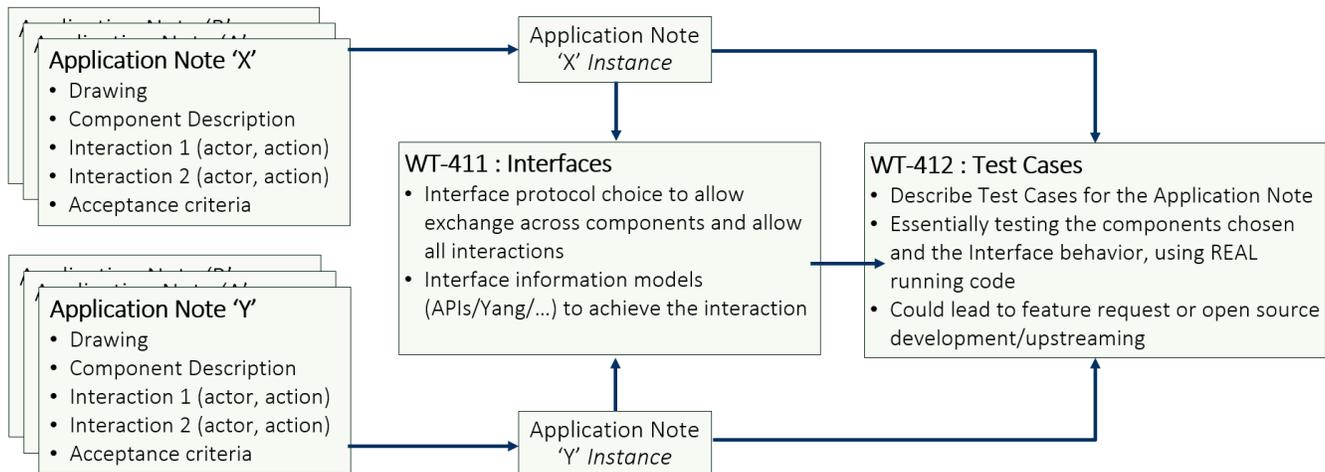
CloudCO Application Notes use the [TR-384 framework](#) to describe an implementable use case for a CloudCO 'application'. Application Notes are planned to be published on the Broadband Forum public website, with the status of untested or tested. Each Application Note contains:

- Assumptions and Preconditions
- System Description using TR-384 framework (components) and a drawing
- Description of Actors (i.e. the parties engaging with the system via the northbound API, or via a user-plane interaction)
- Interactions, which describe what information gets exchanged between the TR-384 functional elements and what happens as a result after an actor performs an 'action' i.e. an API call at the CLOUDCO NB API or a user plane packet that enters the system. There can be several interactions described, and every interaction is accompanied by a ladder diagram that shows the various interactions between the functional elements.
- Success Criteria for the interactions

Various *instances* can be instantiated which detail a given implementation of the individual components. An Application Note *Instance* is to be created for each Application Note that details the exact components to be bootstrapped /installed onto an NFVI. That is, it describes what VIM is chosen, etc., as well as e.g. software releases etc. This specific environment will then be used to document:

- Interface Descriptions (documented in WT-411, see section 0)
- Test Case Descriptions (documented in WT-412, see section 2.9)

The diagram below details the relationship between Application Notes, Application Note Instances, Test Cases, and Interface Descriptions.



2.6 Functional module Interface definitions (WT-411)

The Interfaces in the diagram above are defined in WT-411. This definition/documentation contains:

- The Interface protocol choice to allow exchange across components and allow all Application Note interactions
- The necessary Interface information models (APIs/Yang/...) to achieve the interaction

- As the Application Note instance details the components that are installed, the Interface protocol choice is often implied, and will be documented
- The interface information models might already be achievable by the implementation of the components, and again that will be documented, if so. If there is no clarity on information models, or new ones have to be created, the implementation has to be modified accordingly, and potentially submitted for standardization or upstreamed to open-source organizations

2.7 Cloud CO Migration and Co-existence (WT-408)

The most successful introduction of network technologies have almost always involved a migration strategy that avoids wholesale replacement and implements a co-existence strategy that protects investment and always seamless transition. In this discussion terms like replacement of legacy systems is misleading as currently installed installations may sometimes continue to be in use for many years. Therefore, the purpose of this CloudCO specification is to suggest methods by which a legacy broadband network may gradually migrate to a CloudCO one, and / or co-existence of the legacy and Cloud-CO architecture within segments of the same network. Specifically, the initial work identifies the typical transformation use cases that cover the majority of situations. It also specifies the detailed steps required to realize each of those cases. The Working Text also outlines requirements for operability and performance of co-existence and migration steps.

2.8 SDN Management and Control Interfaces (WT-413)

The transition to CloudCO naturally involves the definition of new software interfaces defined by models, APIs and protocols. This key enabling project specifies the management and control framework of network functions and a formalism to specify their northbound Interfaces to identify the supported macro-functionalities and link them to existing/to-be YANG data models. It enables the migration from SNMP/MIB towards NETCONF/YANG interfaces and potentially other protocols to exercise not only traditional FCAPS management functions but also fine-grained flow control across Virtual Network and Physical Network Functions.

2.9 Test Cases for CloudCO Systems in Open Broadband Labs (WT-412)

Test Cases to test Application Note instances will be created, containing:

- Test case descriptions for the Application Note
- Methods to test the Application Note instance behavior and the interface behavior of the system under test described in the Application Note

This could lead to feature requests or open source development/upstreaming as an output of the test.

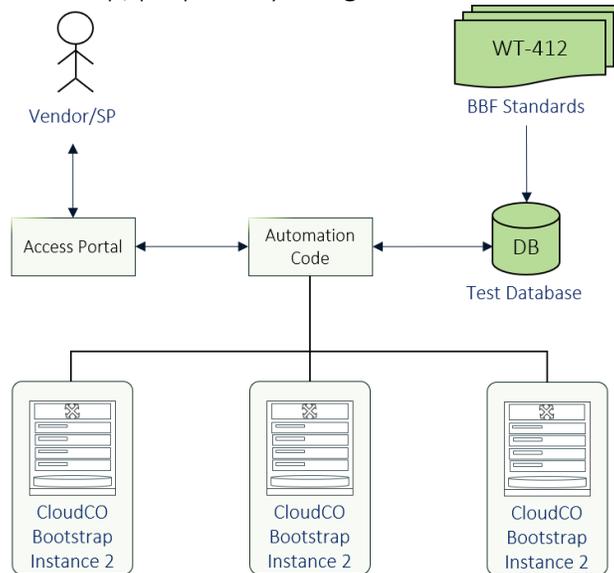
The test facilities will be provided by Open Broadband Labs and the Test Case results will be documented in WT-412. Tested Application Notes will be highlighted.

3 Deployment

CloudCO utilizes Open Broadband Labs for ongoing development, testing and deployment staging. Open Broadband Labs is a collaborative space for the integration and testing of open source, standards-based and vendor provided implementations, and a place where suppliers & operators can work together on new & existing solutions. The Open Broadband Infrastructure is a common hardware and software platform for an open laboratory.

In this way, Open Broadband fulfills important industry requirements as it accelerates go-to-market and go-to-production for new services and aids the migration from existing broadband to cloud-based

structures. Open Broadband is an open invitation to participate in a developer-friendly environment without undue financial, membership, proprietary or rigid technical constraints.



Inside an Open Broadband Labs, vendors provide hardware, standard or Open source components. The lab provides the on-demand lab facilities, such as:

- A Network Function Virtualization Infrastructure (NFVI) with its Virtualized Infrastructure Manager(s) (VIM) abstraction layer
- Secured remote and physical access, jump server for remote configuration

Customers can access a portal to:

- Bootstrap a given CloudCO Bootstrap Instance (Access I/O + Controllers + Orchestrator)
- Schedule tests and view results or build up a Test Suite (WT-412)

Open Broadband Labs will also help to document and innovate Open Interfaces between components (WT-411). For further information on Open Broadband and Open Broadband Labs including relationship to other industry initiatives visit <https://www.broadband-forum.org/ob>

4 Relationship to other Broadband Forum work

With the advent of NFV and SDN, agile approaches to defining requirements, coding software models, etc., the Forum's projects are increasingly inter-related falling under the umbrella of Open Broadband.



The following features are applied in several CloudCO related use cases and Application Notes but they are also independent, stand-alone projects including:

- OB-BAA Broadband Access Abstraction <https://www.broadband-forum.org/baa>
Demos are targeted for Q4 2018
- Network Enhanced Residential Gateway TR-317 <https://www.broadband-forum.org/nerg>
- Virtual Business Gateway TR-328 <https://www.broadband-forum.org/vbg>

Please visit <https://broadband-forum.org> for the latest information.

5 CloudCO summary

This intention of this paper has been to highlight the various elements of the CloudCO initiative showing what is required to build and rapidly deploy standardized systems that can generate automated and self-service provisioning of virtualized broadband services.

To summarize:

- CloudCO is a recasting of a Central Office hosting infrastructure utilizing SDN, NFV and Cloud technologies and aligned with the Forum's Open Broadband vision
- It consists of a series of architecture and interface specifications with uses cases, scenarios, application notes, test cases, migration and implementation strategies
- CloudCO enables significantly faster & more efficient provisioning of new Cloud-based services to provide rapid availability of new revenue generating services
- Collectively the transformational nature of the CloudCO structure and defined functions facilitate choice, adaptability, migration/co-existence and implementation with Open Source to enable agility and a differentiation at the functional level

The projects listed have been strongly supported by the Forum membership with the Framework document ([TR-384](#)) having more than 20 contributors plus reviewers.

More than being informative, it is hoped that readers will be motivated to read the documents in detail and consider becoming a member so as to fully participate. For those who are Broadband Forum members we suggest you visit the members' collaborative site (<https://wiki.broadband-forum.org>) to examine the work in progress and then to actively participate including making sure that your requirements are properly included.

For non-members we would encourage to join and participate in this ground-breaking project. Details are at <https://www.broadband-forum.org/membership>

6 Terminology

6.1 References and abbreviations

The following references are of relevance to this document. All references are subject to revision and users of this document are therefore encouraged check for the most recent edition of the references listed below. On the Forum's public website at www.broadband-forum.org/technical-reports.

Document	Title	Source	Year
TR-101	Migration to Ethernet-Based Broadband Aggregation	BBF	2011
TR-178	Multi-service Broadband Network Architecture	BBF	2014
TR-317	Network Enhanced Residential Gateway	BBF	2017
TR-328	Virtual Business Gateway	BBF	2017
TR-384	CloudCO Reference Architectural Framework	BBF	2018
TR-416	CloudCO Use Cases and Scenarios	BBF	2018
OB-BAA 02	Open Broadband – Broadband Access Abstraction white paper	BBF	2018

6.2 Abbreviations

AN	Access Node	NFVI	NFV Infrastructure
BAA	Broadband Access Abstraction	NFVO	NFV Orchestrator
CloudCO	Cloud Central Office	OB	Open Broadband
CGNAT	Carrier Grade Network Address Translation	PNF	Physical Network Function
EAP	Extensible Authentication Protocol	SBI	Southbound Interface
ETSI	European Telecommunications Standards Institute	VIM	Virtualized Infrastructure Manager
FCAPS	Fault, Configuration, Accounting, Performance, Security	SBI	Southbound Interface
MANO	Management and Orchestration	VIM	Virtualized Infrastructure Manager
NBI	Northbound Interface	VNF	Virtual Network Function
NERG	Networked Enhanced Residential Gateway	VNFM	VNF Manager

7 Acknowledgements

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8 About the Broadband Forum

The Broadband Forum, a non-profit industry organization, is focused on engineering smarter and faster broadband networks. The Forum's flagship TR-069 CPE WAN Management Protocol has now exceeded 800 million installations worldwide.

The Broadband Forum's work defines best practices specifications and software for global networks, enables new revenue-generating service and content delivery, establishes technology migration strategies and service management for the connected home, Cloud, Access and 5G broadband ecosystem. More than 70 Technical committee projects in progress embrace all relevant emerging technologies.

The Forum's Open Broadband strategy brings together open source agility and standards-based architecture to enable large-scale markets. We develop test interoperability and certification specifications and programs to accelerate deployment. Visit www.broadband-forum.org. Twitter @Broadband_Forum.

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