



TECHNICAL REPORT

TR-359

A Framework for Virtualization

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Executive Summary

This Technical Report describes an architectural framework for Network Function Virtualization (NFV) in existing Multi-Service Broadband Networks (MSBN). The framework integrates architectural frameworks (e.g., TR-178) specified by the Broadband Forum with architectural frameworks specified by other organizations (e.g., ETSI NFV ISG) thereby identifying the relevant reference points needed for other work in the Broadband Forum to effectively reference and specify systems that incorporate aspects of NFV. In addition, new entities and/or reference points are described where existing architectural frameworks do not identify needed reference points or existing reference points do not adequately describe the purpose of the reference point in the context of this Technical Report.

1 Purpose and Scope

1.1 Purpose

The purpose of this Technical Report is to establish an architectural framework that is used by other work in the Broadband Forum to facilitate incremental deployment of NFV in the MSBN.

1.2 Scope

The scope of this Technical Report is to identify and describe entities in existing MSBN augmented with references points used in the deployment of NFV. These entities and reference points are described in the technical reports of the Broadband Forum and reports and specifications from other organizations (e.g., ETSI NFV ISG, TMForum). Where new entities and/or reference points are needed this Technical Report identifies and provides a description of the entity and/or reference point.

2 References and Terminology

2.1 References

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

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

Document	Title	Source	Year
[1] TR-001	<i>ADSL Forum System Reference Model</i>	BBF	1996
[2] TR-018	<i>References and Requirements for CPE Architectures for Data Access</i>	BBF	1999
[3] TR-134 Corrigendum 1	<i>Broadband Policy Control Framework (BPCF)</i>	BBF	2013
[4] TR-145	<i>Multi-service Broadband Network Functional Modules and Architecture</i>	BBF	2012
[5] TR-146	<i>Subscriber Sessions</i>	BBF	2013
[6] TR-156I3	<i>Using GPON Access in the context of TR-101. Issue 3</i>	BBF	2012
[7] TR-178	<i>Multi-service Broadband Network Architecture and Nodal Requirements</i>	BBF	2014
[8] TR-300	<i>Policy Convergence for Next Generation Fixed and 3GPP Wireless Networks</i>	BBF	2014
[9] TR-304	<i>Broadband Access Service Attributes and Performance Metrics</i>	BBF	2015
[10] TR-317	<i>Network Enhanced Residential Gateway</i>	BBF	2016
[11] TR-345	<i>Broadband Network Gateway and Network Function Virtualization</i>	BBF	2016
[12] ETSI GS NFV 003	<i>Network Function Virtualisation (NFV); Terminology for Main Concepts in NFV</i>	ETSI NFV ISG	2013
[13] ETSI GS NFV-MAN 001	<i>Network Functions Virtualisation (NFV); Management and Orchestration</i>	ETSI NFV ISG	2014
[14] ETSI GS NFV-INF 005	<i>Network Functions Virtualisation (NFV); Infrastructure; Network Domain</i>	ETSI NFV ISG	2014

[15]	ETSI GS NFV-IFA005	Network Functions Virtualisation (NFV); Management and Orchestration; Or-Vi reference point - Interface and Information Model Specification	ETSI NFV ISG	2016
[16]	ETSI GS NFV-IFA006	Network Functions Virtualisation (NFV); Management and Orchestration; Vi-Vnfm reference point - Interface and Information Model Specification	ETSI NFV ISG	2016
[17]	ETSI GS NFV-IFA007	Network Functions Virtualisation (NFV); Management and Orchestration; Or-Vnfm reference point - Interface and Information Model Specification	ETSI NFV ISG	2016
[18]	ETSI GS NFV-IFA008	Network Functions Virtualisation (NFV); Management and Orchestration; Ve-Vnfm reference point - Interface and Information Model Specification	ETSI NFV ISG	2016
[19]	ETSI GS NFV-IFA013	Network Functions Virtualisation (NFV); Management and Orchestration; Os-Ma-nfvo reference point - Interface and Information Model Specification	ETSI NFV ISG	2016
[20]	NIST Special Publication 800-145	<i>The NIST Definition of Cloud Computing</i>	NIST	2011
[21]	TMForum TR234	<i>ZOOM Informational Model Snapshot</i>	TMForum	2015
[22]	RFC 2119	<i>Key words for use in RFCs to Indicate Requirement Levels</i>	IETF	1997

2.2 Definitions

The following terminology is used throughout this Technical Report.

Access Provider	The entity responsible for operation and management of the access facilities extending from the U reference point to the NFVI.
Application Author	The entity responsible for origination and maintenance of the source code for a network function.
Application Provider	The entity responsible for deployment and management of a network function.
Customer Layer	[ETSI GS NFV-INF 005] The customer layer which consists of packets originating with and/or terminated by the customer end-system or host.

Customer Located Equipment	CPEs that are owned and managed by the Service Provider.
Customer Owned Equipment	CPEs that are owned by the Customer and can be managed by either the Service Provider or the Customer.
Deployment Template	[ETSI GS NFV MANO 001] The deployment template describes the attributes and requirements necessary to realize such a VNF and captures, in an abstracted manner, the requirements to manage its lifecycle.
End System	The electronic device via which an End User originates and terminates network traffic.
End User	The subscriber or a delegate of the subscriber (e.g., family member, employee, IoT application) who directly consumes services from the service provider. [TR-317] A person who uses a service, likely through an end-device.
Infrastructure Provider	The entity that owns and manages the infrastructure that hosts network functions.
Network Function	[ETSI GS NFV 003] The functional block within a network infrastructure that has well-defined external interfaces and well-defined functional behavior. When a NF implements the virtualization reference points (i.e., Vn-Nf, Ve-Vnfm-vnf) the NF is considered a VNF otherwise the NF is considered a PNF.
NFVI Gateway Function	[TR-345] The GWF maps traffic from the external network to NFVI L2 and/or L3 networks. The NFVI Gateway Function (GWF) is common to a number of platform instantiations.
NFVI-PoP	[ETSI GS NFV 003] A network PoP where a Network Function is or could be deployed as a Virtual Network Function.
Network Service	[ETSI GS NFV 003] The composition of Network Functions and defined by its functional and behavioral specification.
Network Service Provider	[ETSI GS NFV 003] A type of Service Provider implementing the Network Service.
Platform Provider	The entity that owns and manages the platform (software environment) that hosts virtual network functions.
Policy	An administrative rule or set of rules that specifies the action(s) to be taken when specified condition(s) occur.
Service Graph Layer	This corresponds to the service layer described in [ETSI GS NFV-INF 005]. Renamed for clarity. The service graph layer, which exists exclusively within the NFVI and has end to end significance between the point of ingress to the NFVI and point of egress to the NFVI of the customer traffic.

Service Provider	<p>The entity that owns the relationship with the Subscriber and is responsible for delivering services consumed by the Subscriber. The Service Provider may enter a relationship with other Service Providers in order to deliver the service to the Subscriber.</p> <p>[TR-304] An operator of a data network. This includes providers of Internet service to consumers or businesses, Internet transit services, Content Delivery Networks (CDN), Internet-based applications, as well as enterprise networks.</p> <p>[ETSI GS NFV 003] Defined as a company or organization, making use of an electronics communications network or part thereof to provide a service or services on a commercial basis to third parties (as defined in TR-134 Corrigendum 1).</p>
Subscriber	<p>A legal entity (individual or business) who owns the relationship with a service provider.</p> <p>[TR-317] Legal customer from a contractual perspective .</p>
Trusted Application	<p>Any application employed by the service provider as part of a service for which the service provider has a trusted relationship with (e.g. via direct relationship with the application author, or application provider).</p>
Untrusted application	<p>Any application available to an End User via the service provided by the service provider for which the service provider has no direct responsibility for (e.g. the Internet).</p>

2.3 Abbreviations

This Technical Report uses the following abbreviations:

AAA	Authentication, Authorization, and Accounting
AF	Application Function
AN	Access Node
BBF	Broadband Forum
BPCF	Broadband Policy Control Function
BSG	Multi-service Broadband Service Gateway
BSS	Business Support System
CDN	Content Delivery Network
CFS	Customer Facing Service
CLE	Customer Located Equipment
CPE	Customer Premises Equipment
COE	Customer Owned Equipment
DMCF	Domain Management Coordination Function
EM	Element Management
EMS	Element Management System

ETSI	European Telecommunications Standards Institute
FCAPS	Fault, Configuration, Accounting, Performance, Security
GW	Gateway
GWF	NFVI Gateway Function
IaaS	Infrastructure as a Service [20]
ISG	Industry Standards Group
MAN	Metropolitan Area Network
MD	Managed Device
MS-BNG	Multi-service Broadband Network Gateway
MSBN	Multi-service Broadband Network
NE	Network Element
NERG	Network Enhanced Residential Gateway
NF	Network Function
NFV	Network Function Virtualization
NFVI-GW	Network Function Virtualization Infrastructure Gateway
NFVO	NFV Orchestration
NMS	Network Management System
NT	Network Termination
PaaS	Platform as a Service [20]
PDP	Policy Decision Point
PE	Provider Edge Router
PEP	Policy Enforcement Point
PCRF	Policy and Charging Rules Function
PIM	Physical Infrastructure Manager
PNF	Physical Network Function
PoP	Point of Presence
RFS	Resource Facing Service
RG	Residential Gateway
SaaS	Software as a Service [20]
TMN	Telecommunications Management Network
TR	Technical Report
UD	Unmanaged Device
VIM	Virtual Infrastructure Manager
VM	Virtual Machine
VNF	Virtual Network Function
VNFD	VNF Descriptor
VNFM	VNF Manager

WAN	Wide Area Network
WG	Working Group

3 Technical Report Impact

3.1 Energy Efficiency

This Technical Report is a framework document that contains no implementation requirements. It is intended to facilitate the adoption of NFV by service providers. NFV has the potential to provide energy savings by the statistical multiplexing of compute resources implied by virtualization, and applying cloud management techniques to load management.

3.2 IPv6

This Technical Report is a framework document that is independent of the protocols used to ultimately implement virtualized systems, as such TR-359 has no impact on IPv6, and vice versa.

3.3 Security

The introduction of virtualization into provider networks will have complex security implications. However due to the encapsulating nature of virtualization the attack surface will be limited. Note that the deployment of additional policy and safeguards on interfaces in the virtualization infrastructure will be required. Single subscriber network functions that are re-architected to support an aggregate of subscribers will become susceptible to denial of service attacks and will require additional safeguards.

This Technical Report facilitates new relationships between various actors which by definition will expose business boundaries that will have both trust and policy implications.

3.4 Privacy

This Technical Report is a framework document that is independent of the protocols used to ultimately implement virtualized systems; as such TR-359 has no impact on Privacy.

4 Architectural Models

4.1 ETSI NFV Reference Architectural Framework

The ETSI NFV ISG working group (ETSI-NFV) has published a series of specifications to define how Network Functions that are virtualized interact across a data or user plane and are maintained by various Management and Control Systems in the respective management and control planes. In order to define the interactions between NFs, Management Systems and Control Systems, ETSI-NFV has defined a reference architectural framework that describes functional blocks and the main reference points between the functional blocks in clause 5 of the NFV Management and Orchestration specification [13].

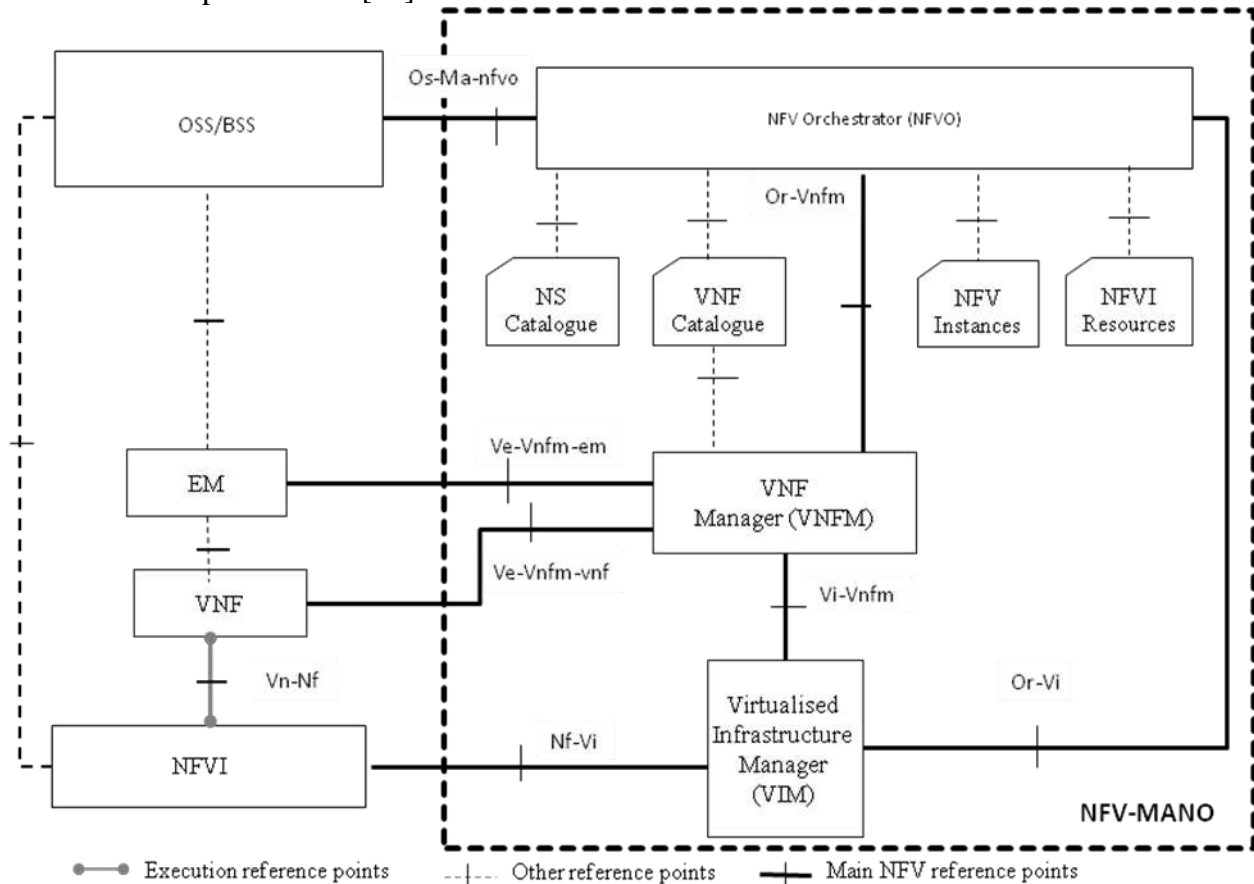


Figure 1: ETSI-NFV reference model

4.2 TMForum Reference Architectural Framework

The TMForum provides an information model [21] that describes different types of service: Customer Facing Services, Resource Facing Services and Network Services in support of the ETSI NFV reference model where the ETSI NFV concept of a Network Service is used to comprise Resource Facing (RFS) and Customer Facing Services (CFS). This distinction between Customer Facing, Resource Facing and Network Services is important in order to appropriately describe the

types of services that would be transferred across the reference points associated with the CFS/RFS Service Orchestration and Assurance functional layers.

4.3 BBF Reference Architectural Frameworks

The Broadband Forum has defined the function sets and reference points for multi-service broadband networks in section 4 of TR-145 [4].

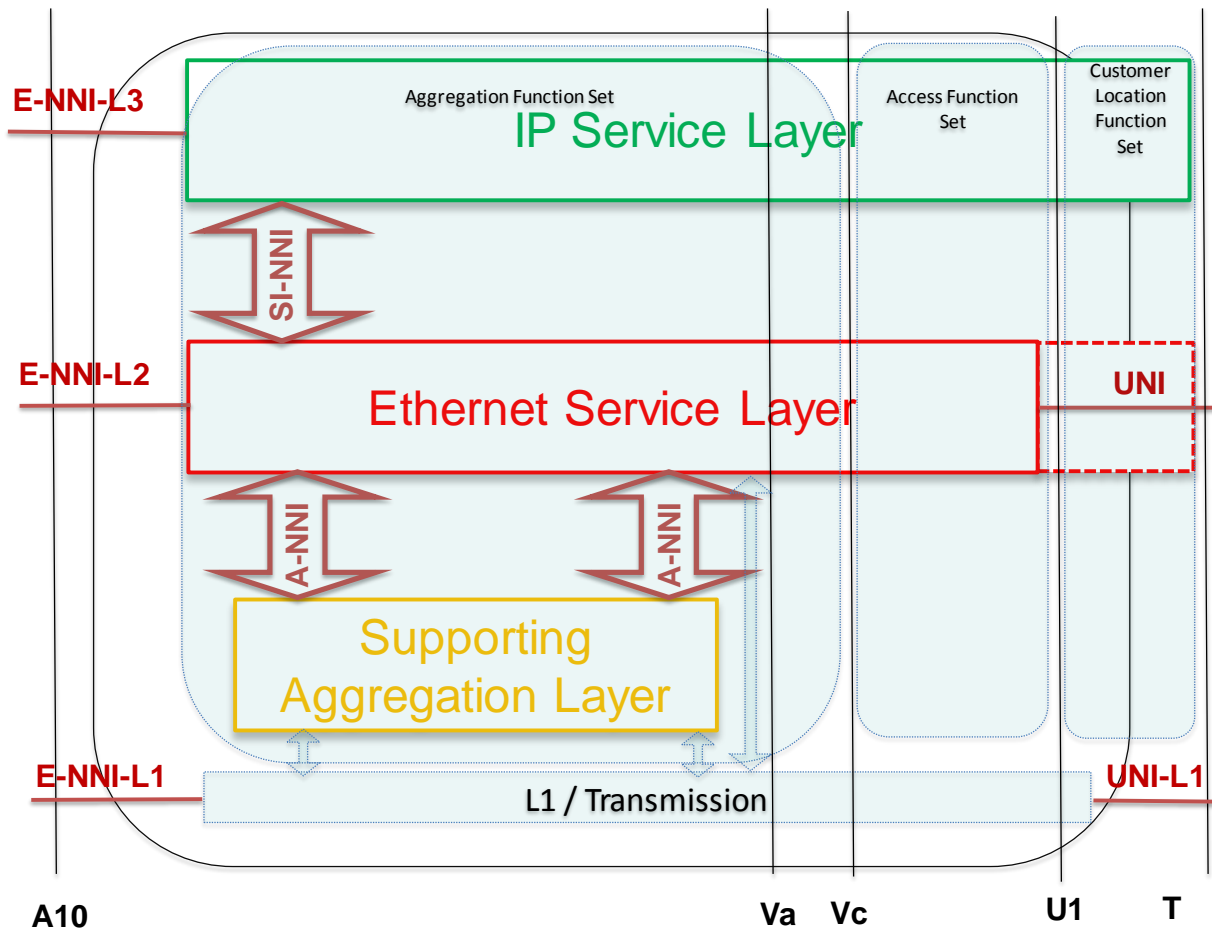


Figure 2: BBF TR-145 reference model

The TR-145 reference model is primarily focused on the interactions between data/user plane function sets; relying on the policy control plane function sets defined in TR-134 Corrigendum 1.

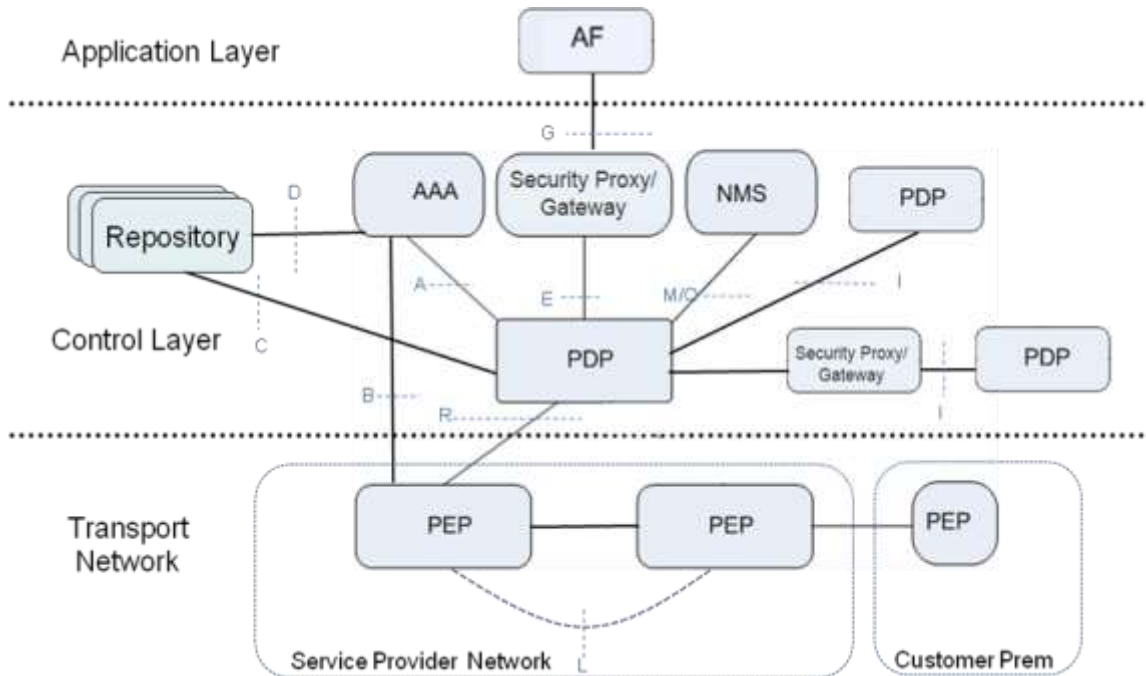


Figure 3: BBF TR-134 Framework Interface Architecture

4.4 Combined BBF and ETSI-NFV Reference Model

4.4.1 Overview

The reference models of the BBF and ETSI NFV can be combined such that the functional components and reference points of the BBF TR-145 and TR-134 reference models and ETSI NFV reference model are depicted for the management and control of Services along with the interworking of the user/data plane of the BBF reference models with the infrastructure (NFVI) layer of the ETSI NFV reference model.

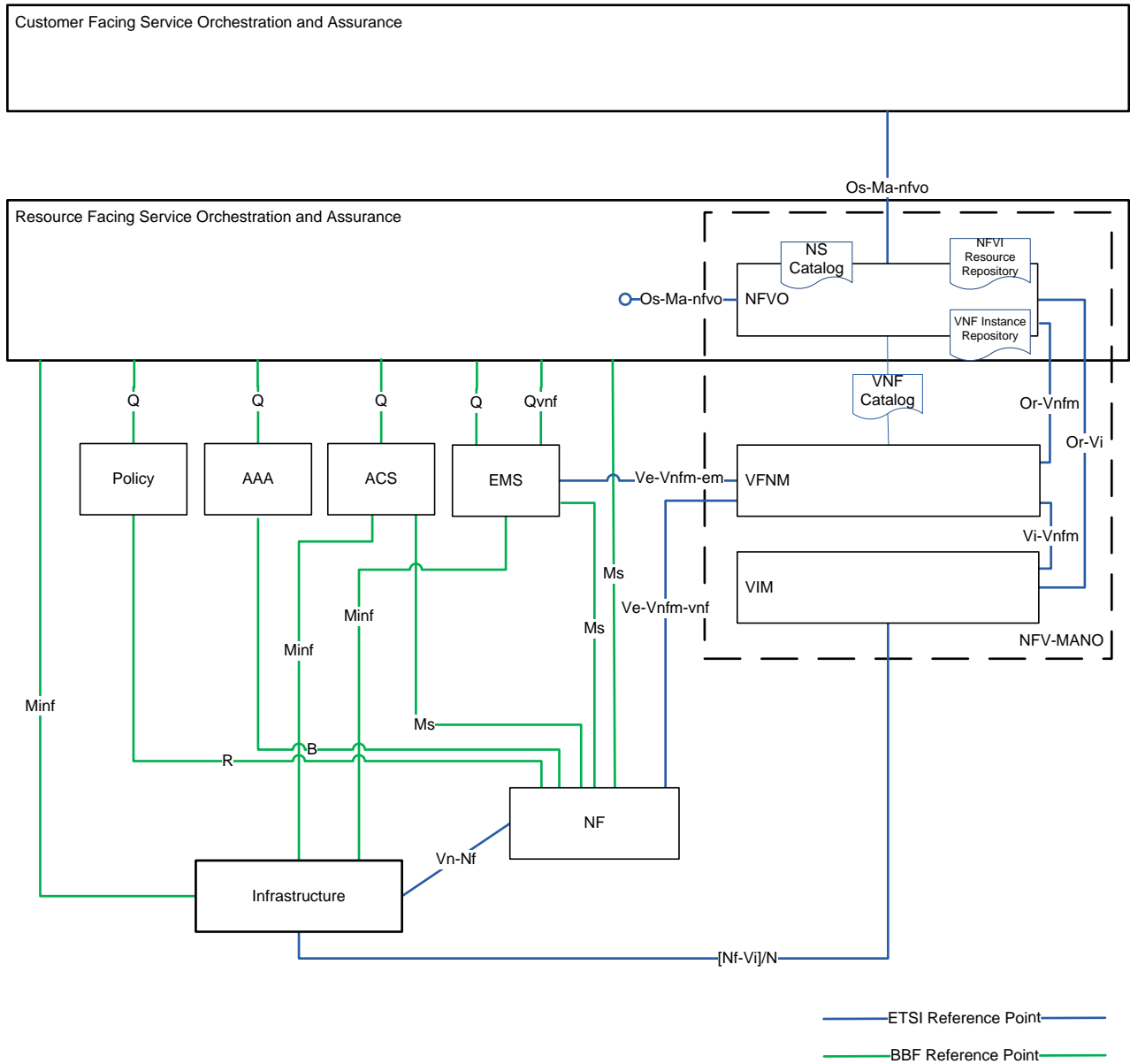


Figure 4: BBF and ETSI-NFV reference model for service management and control

Note: The Os-Ma-nfvo reference point within the Resource Facing Service Orchestration and Assurance Layer is considered an internal reference point.

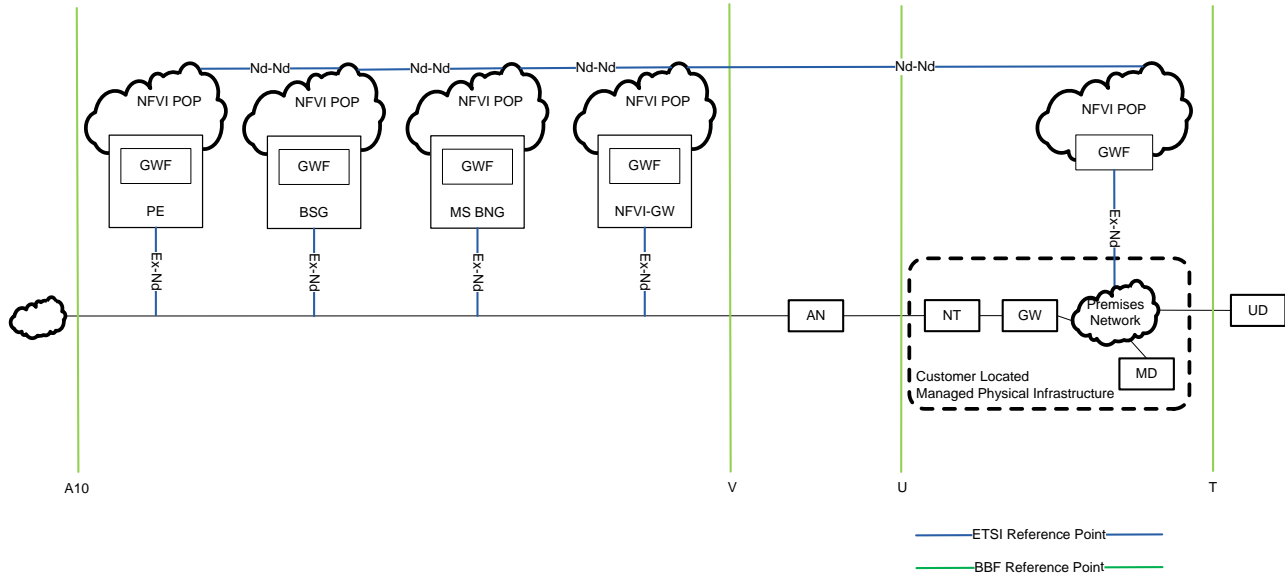


Figure 5: BBF and ETSI-NFV reference model for infrastructure interworking

Figure 4 and Figure 5 illustrate a combination of the BBF and ETSI-NFV architectures predicated on the assumption that services are hosted in NFVI that has augmented a BBF specified multi-service broadband network.

The following notes apply to the model as a guide for comparison with previous architectural diagrams:

1. TR-145/TR-178 defined a comparatively complicated modeling of the infrastructure as adaptation and forwarding functions, with both Ethernet and MPLS instantiations of each. Such exhaustive modeling of protocols is not expected to be necessary for this work, hence the simplification of the infrastructure in that only the specific domains are referenced.
2. The infrastructure layer(s) will typically be a combination of MPLS and Ethernet augmented with datacenter overlay protocols in the services infrastructure domain.
3. The network function view of the network service layer is assumed to be IP based with the selection of the corresponding forwarding graph of the network service layer as one’s protocol of choice for implementing a forwarding graph.
4. The network functions operate on the network service layer, but are typically transparent to it (middlebox functions) and as noted in 3 above imply additional protocol layering or sub-layering to implement the forwarding graph, hence have been illustrated as part of the network service layer for clarity and to identify the management of the network function’s application layer functionality.
5. The network service view of the network service layer along with customer and resource facing services of the customer service layer are logical resources that define properties that

are used to implement the forwarding graph as noted in 3 above and implies management of the corresponding network service(s).

6. The NFVI-PoP locations in the diagrams are illustrative.

The diagram does not account for when NFVI deployments span BBF reference points (i.e., A10, V, U, T). In addition, a NFVI-PoP can exist between reference points (e.g., between U and V).

The diagram illustrates the deployment scenarios envisioned in TR-345, but does not capture all the dependencies (e.g. a PE with a GWF needs a peer MS-BNG or BSG that has an embedded PE function).

The following sub-sections of section 4.4 provide an overview of the architectural components and reference points summarized from the primary sources. It is intended only as a rough guide/tutorial, and the reader is directed to the primary sources for the authoritative view.

4.4.2 Nodes

BBF architectures have typically focused on nodal requirements and geographically sensitive deployments. This is a consequence of the physics of broadband access transmission media; be it xDSL or PON. As such, although virtualization is driving both nodal and geographic deployment independence, specific nodes do not go away on the overall architecture, hence the inclusion of the access node and residential gateway/CPE.

Similarly, certain network functions cannot be separated from physical locations. An example of which is OAM MIPs/MEPs which are instantiated to permit measurements of communication quality and facilitate fault detection and root cause diagnosis.

4.4.3 NFVI Points of Presence

The ETSI NFV framework as defined in [INF 005] introduces NFVI Points of Presence (NFVI-PoP) where NFVI compute, storage and network functions are located. The NFVI-PoPs are typically deployed at customer premises sites, central offices, regional PoPs and data centers.

The ETSI NFV framework further describes the concept of a Gateway which interworks the MAN/WAN protocols and the networking connectivity internal to the NFVI. This document assumes deployment scenarios whereby the functionality of the Gateway (referred to as the GWF) can be embedded in any of several node types specified by the Broadband Forum. ETSI also defines the Nd-Nd interface for NFVI-PoP interconnect which could similarly be embedded in various node types. The impact of Nd-Nd on Broadband Forum specifications is FFS but is included here for completeness.

4.4.4 Customer Premises Networks

Customer premises networks vary widely in terms of scale, topology, functionality, resource ownership, and management partitioning depending on the type of customer premises (i.e., Residential, Small Business, Large Enterprise).

For residential or small business networks a single gateway device typically serves as a network-boundary demarcation (NT) and provides forwarding, security, and all other network functions. Residential / small-business gateways often are managed by the service provider and can be owned and physically managed by either the service provider or the customer. For larger enterprises networks can serve hundreds of thousands of people and be spread across multiple geographic locations. These networks typically are heterogeneous in the sense that they are comprised of infrastructure, network elements, software, and management solutions owned by the service provider, third-party suppliers, and the customer.

Figure 5: BBF and ETSI-NFV reference model for infrastructure interworking depicts the customer premises network providing connectivity and forwarding functions to the attached devices. These devices can be either managed devices (MD) or unmanaged devices (UD), with MD management provided by the service provider. While unmanaged devices typically are owned by the customer, managed devices can be owned by either the customer or service provider. Managed devices include LAN switches and routers (the premises network), WiFi access points as well as controllers, compute and storage resources for VNFs, and indoor cellular-distribution networks.

4.4.5 Functions

4.4.5.1 ETSI NFV Functions

The functions defined by ETSI NFV [13] in are focused on the orchestration and management of virtual infrastructure. These functions with a brief description are:

NFVO – The NFV Orchestrator is responsible for all aspects of Network Service lifecycle management spanning multiple VIMs.

VNFM – The Virtual Network Function Manager is responsible for all aspects of lifecycle management for a VNF instance.

VIM – The Virtual Infrastructure Manager is responsible for controlling the NFVI compute, storage and network resources. The northbound interface typically corresponds to that of the API to control IaaS.

EM – Element Management is responsible for FCAPS management functionality for a VNF. This would be analogous to EM for a PNF augmented for the deployment attributes of virtualized services.

4.4.5.2 Management Functions

BBF TR-134 and TR-178 architectures utilize the concepts of the ITU TMN layered reference model where physical Network Elements are managed by Element Management systems. The Element Management systems are in turn managed by Network Management systems. Generally BBF architectures do not consider functions provided by Service Management and Business Support systems to be in scope of the BBF specification. However this Technical Report describes additional reference points for coordination of domain specific service orchestration and assurance management functionality typically provided by Service Management, Network Management and Element Management layers in order to coordinate management actions for existing Network Elements, the NFVI, network services, network functions and the associated forwarding graphs.

4.4.5.2.1 Integration of Management for Network Element and Virtualized Functions

When management related functions (e.g., configuration, alarm correlation, OAM) of existing Network Elements (e.g., RG, CDN, BNG) are virtualized in a Service Provider network, the resulting impact to the Service Provider’s systems that support Service Orchestration and Assurance functions can be mitigated by incorporating a Domain Management Coordination Function (DMCF) that utilizes the same programming interface for the functions toward the Service Provider's systems as the management systems for the existing Network Elements.

4.4.6 Reference Points and Interfaces

4.4.6.1 BBF Reference Points

The following Broadband Forum reference points are both “in current use” and relevant to TR-359.

Table 1 – BBF Reference Points

Reference Point	Location	Original Source	Description
A10	Between the MSBN and the network of another provider	TR-018	The A10 reference point identifies an intercarrier peering point between the MSBN operator and other providers. The other provider may be a network service provider, or application provider. The defined peering may be at L0 through L3.
B	between the AAA server and the MSBN	TR-134 Corrigendum 1	This reference point identifies the communication path for Session Authentication, Admission Control, and establishment/termination information between NEs in the MSBN and the AAA servers/system. Note: In most MSBN implementations the B and R reference points are aggregated into a single protocol (RADIUS). Note: TR-001 also includes a "B" reference point pertaining to satellite TV receivers in the premises network. This reference point is not applicable to this document.
Q	between the RFS Orchestration and Assurance and EMS, ACS, Policy Decision Point and/or AAA.	TR-134 Corrigendum 1	This reference point identifies the communication path for the management of policies related to NFs. This reference point remains unchanged from TR-134 and TR-178.
R	between the BPCF and the MSBN (PDP to PEP)	TR-134 Corrigendum 1	This reference point identifies the communication path for configuring QoS scheduling and conditional access control attributes in MSBN NEs by the BPCF.

		TR-300	Note: TR-300 provides an instantiation of R for those operators choosing to use PCRF as BPCF.
T	the home LAN between customer devices and the RG/NT	TR-001	This is the point of interconnection of the home LAN to an RG/NT. For managed CPE this most recently has been overloaded as also defining the demarcation between provider managed equipment and unmanaged devices.
U	the subscriber loop between the NT and either the AN (DSL) or ONT/ONU (PON)	TR-018 TR-15613	The U reference point identifies the boundary between the network and the customer premises which fixed broadband access to the MSBN and beyond is provided.
V	between the AN (DSL) or OLT (PON) and the larger MSBN	TR-018	This reference point identifies an aggregated communication path for subscriber traffic between the access node and the larger MSBN.

4.4.6.2 Modified BBF Reference Points

As a consequence of the converging capabilities provided by network elements with the NFVI and the additional capability to manage the application layer functionality provided by the network functions the BBF reference point ‘M’ and ‘Q’ has been split into the following reference points:

Table 2 – Modified BBF Reference Points

Reference Point	Location	Original Source	Description
M _{inf}	between the RFS Orchestration and Assurance , ACS or EMS and the network elements within the physical infrastructure	TR-359	This is the reference point for FCAPS on infrastructure NEs in the MSBN. Note: Prior to TR-359 this reference point and the Ms reference point were the “M” reference point (TR-144).
M _s	between the RFS Orchestration and Assurance , ACS or EMS and the network functions.	TR-359	This is the reference point for FCAPS on user facing network functions in the MSBN.
Q _{vnf}	between the RFS Orchestration and Assurance and EMS	TR-359	This is the reference point to manage the lifecycle aspects of the VNF in the case where the EMS utilizes the Ve-Vnfm-Em reference point.

4.4.6.3 ETSI-NFV Reference Points

The following table describes ETSI-NFV reference points defined in [13] and [14] that is depicted in the BBF reference model.

Table 3 – ETSI NFV Reference Points

Reference Point	Location	Description
Os-Ma-nfvo	Between the CFS/RFS Orchestration and Assurance and the NFVO	The Os-Ma-Nfvo reference point provides management of Network Service Descriptors and VNF packages; lifecycle management of Network Services and VNFs; Policy management and/or enforcement of Network Services, VNFs and NFVI resources. ETSI GS NFV-IFA013 describes the information exchanges across this reference point.
Or-Vnfm	Between the NFVO and VNFM	The Or-Vnfm reference point provides management of NFVI resources for a VNF including information needed for authorization, validation, reservation, allocation and release of NFVI resources. In addition lifecycle management of VNFs is

		provided. ETSI GS NFV-IFA007 describes the information exchanges across this reference point.
Ve-Vnfm-em	Between the EMS and the VNFM	The Ve-Vnfm-em reference point provides life cycle management of VNFs managed by the EMS and VNFM. ETSI GS NFV-IFA008 describes the information exchanges across this reference point.
Or-Vi	Between the NFVO and the VIM	The Or-Vi reference point provides management of NFVI resources including information needed for allocation and release of NFVI resources. ETSI GS NFV-IFA005 describes the information exchanges across this reference point.
Vi-Vnfm	Between the VIM and the VNFM	The Vi-Vnfm reference point provides management of NFVI resources including information needed for validation, reservation, allocation, update and release of NFVI resources. In addition software image management of VNFs is provided. ETSI GS NFV-IFA006 describes the information exchanges across this reference point.
Ve-Vnfm-vnf	Between the VNF and the VNFM	The Ve-Vnfm-vnf reference point provides lifecycle management of VNFs managed by the VNFM. ETSI GS NFV-IFA008 describes the information exchanges across this reference point.
[Nf-Vi]/N	Between the VIM and NFVI Layer	The NF-Vi reference point is comprised of sub-reference points for interfaces associated with requesting infrastructure connectivity services ([Nf-Vi]/N), hypervisor services ([Nf-Vi]/H) and compute services ([Nf-Vi]/C). The [Nf-Vi]/N reference point is described in clause 5.2 of ETSI GS NFV-INF 005 Clause 5.7.4 of ETSI GS NFV-MAN 001 describes the information exchanges across this reference point.
[Vn-Nf]/N	Between the NFVI Layer and the Network Service Layer	The [Vn-Nf]/N reference point provides transparent network services to VNFs as described in clause 5.1 of ETSI GS NFV-INF 005.
Ex-Nd	Between the NFVI Layer and the WAN Infrastructure Layer	The Ex-Nd reference point allows VNFs to connect to PNFs, other VNFs and external endpoints as described in clause 5.3.1 of ETSI GS NFV-INF 005. In BBF reference model the Ex-Nd reference point connects NFs located in NFVI POPs via the GWF.
Nd-Nd	Between NFVI-PoPs	The Nd-Nd reference point is comprised of the protocols that are exposed between NFVI-PoPs as described in clause 5.3.2 of ETSI GS NFV-INF 005.

4.4.7 Catalogs and Repositories

The following table describes the ETSI NFV repositories that support the NFVO function.

Table 4 – ETSI NFV Data Repositories

Reference Point	Primary Entities	Description
NS Catalog	NFVO	Represents the specifications of all of the on-boarded Network Services, VNFs and NFVI Resources. The NS Catalog is further described in clause 5.4.4 of ETSI GS NFV-MAN 001.
VNF Catalog	NFVO, VNFM	Represents the specifications of all of the on-boarded VNF Packages, supporting the creation and management of the VNF Package (VNF Descriptor (VNFD), software images, manifest files, etc.). The VNF Catalog is further described in clause 5.4.5 of ETSI GS NFV-MAN 001.
VNF Instance Repository	NFVO	The NFV Instances repository holds information of all VNF instances and Network Service instances. Each VNF instance is represented by a VNF record, and each NS instance is represented by an NS record. Those records are updated during the lifecycle of the respective instances, reflecting changes resulting from execution of NS lifecycle management operations and/or VNF lifecycle management operations. The VNF Instance Repository is further described in clause 5.4.6 of ETSI GS NFV-MAN 001.
NFVI Resource Repository	NFVO	Represents information about available/reserved/allocated NFVI resources as abstracted by the VIM across operator's Infrastructure Domains. The NFVI Resource Repository is further described in clause 5.4.7 of ETSI GS NFV-MAN 001.

4.5 Software Defined Networks (SDN)

This issue of the Technical Report does not address the integration of the entities and reference points associated with SDN.

4.6 Domain Management Coordination Function (DMCF)

4.6.1 Introduction

The DMCF, as a set of Customer and Resource Facing services, provides the management functions needed to maintain the “desired state” of functions within a specified domain. For example, the DMCF for the NERG provides the management functions (e.g., retrieve device topology, configure firewall) necessary to maintain functions within the residential domain.

The DMCF does this by providing an abstracted view of the resources and functions provided by the physical Network Element as well as the virtualized Network Element, hiding the deployment details of the FCAPS functions associated with the Network Element from the Service Provider's Service Orchestration and Assurance systems while providing a consistent management interface toward the Service Provider's system.

Within the reference model, the DMCF is deployed either as functions of a stand-alone system or as co-located functions with other management systems in the ITU TMN Service, Network or Element management layers.

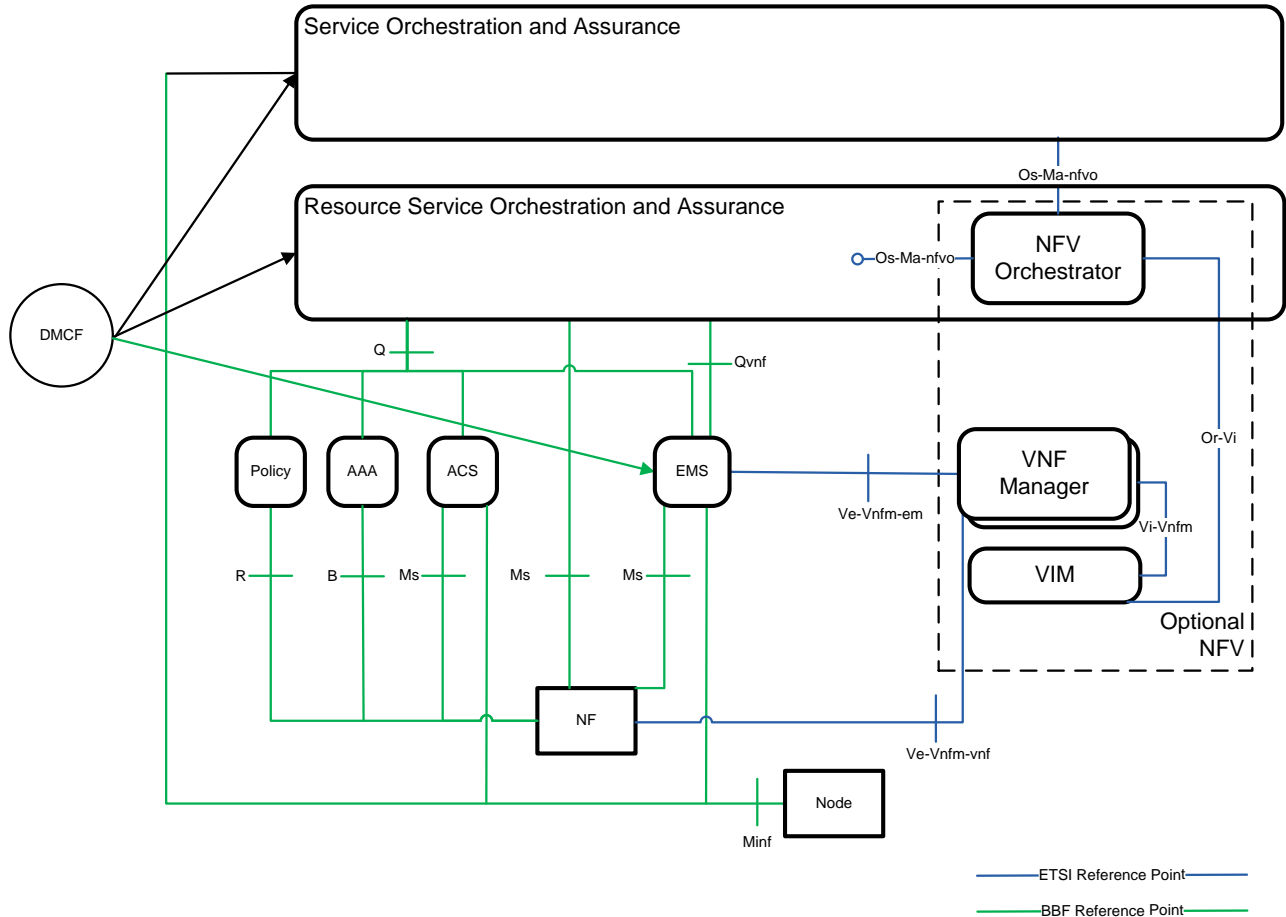


Figure 6: Domain Management Coordination Function

4.6.2 Coordination of Management Functions

The DMCF coordinates the set of management functions specific to the network or application technology to be managed (e.g., NERG, vBG, vAN).

For the DMCF, the set of management functions that should be considered are:

- Application Function Management: FCAPS management of the application layer functions associated with the PNFs and VNFs within the domain.
- Connectivity Management: FCAPS management of the underlying network connectivity (e.g., VPNs).
- Domain Specific Network Service Orchestration: Configuration and service assurance, in conjunction with the NFV and SDN frameworks, of Network Services specific to the domain.
- VNF EM management: Management support needed for the EM layer to manage VNFs through the Ve-Vnfm-em reference point.

FCAPS functions typically include:

- **Fault Management:** Alarm correlation and Troubleshooting (OAM) of the PNF and VNFs that constitute the Customer or Resource Facing Services as well as the underlying VNFI resources ascribed to the domain.
- **Performance Management:** Performance measurements of the PNF and VNFs that constitute the Customer or Resource Facing Services for the domain.
- **Configuration Management:** Coordination of configuration of the PNF and VNFs that constitute the Customer or Resource Facing Services for the domain.
- **Topology Management:** Management of the topology of the nodes and network functions for the domain.
- **Accounting:** Usage measurements of the network functions for the domain.
- **Security:** Security associated with the Application's Functions.
- **Software Management:** Management of software and associated artifacts (configuration files) associated with the PNFs and VNF packages in the domain.

Note: Software management of PNFs has different artifacts than what constitutes a VNF package.

Note: The DMCF is generally not involved in initial planning and configuration of the NFVI (e.g., Minf) but is involved in the activation and ongoing management of the Customer or Resource Facing Services for the specified domain.

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