# VNF Guidelines

## for

# Network Cloud

## and

# OpenECOMP

**Version 1.0**

**February 1, 2017**

# Document Revision History

| Date | Revision | Description |
|---|---|---|
| 2/1/2017 | 1.0 | Initial public release of VNF Guidelines for Network Cloud and OpenECOMP |

# Table of Contents

# 1 Abstract

This white paper and the accompanying reference documents set forth guidelines and requirements for Virtual Network Functions (VNFs) that run in Network Clouds[1] and are managed by OpenECOMP[2]. This document set is part of the OpenECOMP community and focuses on setting and evolving VNF standards that will facilitate industry discussion, participation, alignment and evolution toward comprehensive and actionable VNF best practices and standard interfaces. The goal is to accelerate adoption of VNF best practices which will increase innovation, minimize customization needed to onboard VNFs as well as reduce implementation complexity, time and cost for all impacted stakeholders. The intent is to drive harmonization of VNFs across VNF providers, Network Cloud Service Providers (NCSPs) and the overall Network Function Virtualization (NFV) ecosystem by providing both long term vision as well as short term focus and clarity where no current open source implementations exist today.

This first release of the guidelines and requirements, although applicable in many implementations, is targeted for those implementations that consist of Network Clouds based on OpenStack. Future versions of these guidelines are envisioned to include other targeted virtualization environments, such as Customer Premises or other single-tenant small scale cloud implementations.

In addition, given the relative maturity of key technologies involved, rapid innovation of NFV/SDN and virtualization technologies as well as the evolving OpenECOMP roadmap, this will be a living package that will evolve over time. These documents will become part of the OpenECOMP related requirements documents. The following enhancements are anticipated to be addressed in the next set of releases:

- Open source software and demos of simple reference VNFs;
- Automation of VNF onboarding and other aspects of VNF lifecycle as supported by OpenECOMP;
- Consistent VNF packaging for automated onboarding using OpenECOMP;
- Other implementation examples for targeted virtualization environments beyond OpenStack based Network Clouds;
- Incubation and certification environment to provide a self-service program to gauge maturity and readiness of VNFs.

[1] Network Clouds are built on a framework containing these essential elements: refactoring hardware elements into software functions running on commodity cloud computing infrastructure; aligning access, core, and edge networks with the traffic patterns created by IP based services; integrating the network and cloud technologies on a software platform that enables rapid, highly automated, deployment and management of services, and software defined control so that both infrastructure and functions can be optimized across change in service demand and infrastructure availability; and increasing competencies in software integration and a DevOps operations model.

[2] OpenECOMP is an open source initiative for ECOMP, www.openecomp.org.

# 2 Introduction

## 2.1 Motivation

The requirements and guidelines defined herein are intended to facilitate industry discussion, participation alignment and evolution toward comprehensive and actionable VNF best practices. Integration costs are a significant impediment to the development and deployment of new services. We envision developing open source industry processes and best practices leading eventually to VNF standards supporting commercial acquisition of VNFs with minimal integration costs. Traditional PNFs have all been unique like snowflakes and required expensive custom integration, whereas VNF products and services should be designed for easier integration just like Lego$^{TM}$ blocks. For example, by standardizing on common actions and related APIs supported by VNFs, plug and play integration is assured, jumpstarting automation with management frameworks. Onboarding VNFs would no longer require complex and protracted integration or development activities thus maximizing automation and minimizing integration cost. Creating VNF open source environments, best practices and standards provides additional benefits to the NFV ecosystems such as:

- Larger market for VNF providers
- Rapid introduction and integration of new capabilities into the services providers environment
- Reduced development times and costs for VNF providers
- Better availability of new capabilities to NCSPs
- Better distribution of new capabilities to end-user consumers
- Reduced integration cost (capex) for NCSPs
- Usage based software licensing for end-user consumers and NCSPs

## 2.2 Audience

The industry transformation associated with softwarization[3] results in a number of changes in traditional approaches for industry collaboration. Changes from hardware to software, from waterfall to agile processes and the emergence of industry supported open source communities imply corresponding changes in processes at many industry collaboration bodies. With limited operational experience and much more dynamic requirements, open source communities are expected to evolve these VNF guidelines further before final documentation of those aspects necessary for standardization. This white paper and accompanying reference documents provides VNF providers, NCSPs and other interested 3rd parties a set of guidelines and requirements for the design, build and overall lifecycle management of VNFs.

**VNF Providers**

Both suppliers transitioning from providing physical network functions (PNFs) to providing VNFs as well as new market entrants should find these VNF requirements and guidelines a useful introduction to the requirements to be able to develop VNFs for deployment into a Network Cloud. VNF Providers may also be interested to test their VNFs in the context of an open source implementation of the environment.

**Network Cloud Service Providers (NCSPs)**

A NCSP provides services based on Network Cloud infrastructure as well as services above the infrastructure layer, e.g., platform service, end-to-end services.

[3] Softwarization is the transformation of business processes to reflect characteristics of software centric products, services, lifecycles and methods.

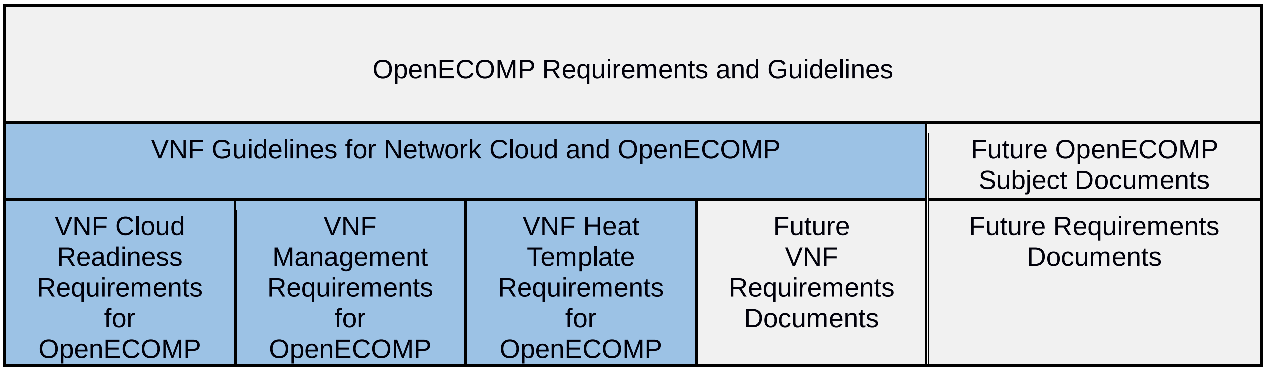
Common approaches to packaging of VNFs enable economies of scale in their development. As suitable infrastructure becomes deployed, NCSPs have a common interest in guidelines that support the ease of deployment of VNFs in each other's Network Cloud. After reading these VNF guidelines, NCSPs should be motivated to join AT&T in evolving these guidelines in the OpenECOMP open source community to meet the industry's collective needs.

**Other interested parties**

Other parties such as solution providers, open source community, industry standard bodies, students and researchers of network technologies, as well as enterprise customers may also be interested in the VNF Guidelines. Solution Providers focused on specific industry verticals may find these VNF guidelines useful in the development of specialized VNFs that can better address the needs of their industry through deployment of these VNFs in NCSP infrastructure. Open Source developers can use these VNF guidelines to facilitate the automation of VNF ingestion and deployment. The emergence of a market for VNFs enables NCSPs to more rapidly deliver increased functionality, for execution on white box hardware on customer's premises – such functionality may be of particular interest to enterprises supporting similar infrastructure.

## 2.3 Program and Document Structure

This document is part of a hierarchy of documents that describes the overall Requirements and Guidelines for OpenECOMP. The diagram below identifies where this document fits in the hierarchy.



OpenECOMP Requirements and Guidelines

VNF Guidelines for Network Cloud and OpenECOMP

Future OpenECOMP Subject Documents

VNF Cloud Readiness Requirements for OpenECOMP

VNF Management Requirements for OpenECOMP

VNF Heat Template Requirements for OpenECOMP

Future VNF Requirements Documents

Future Requirements Documents

Document summary:

***VNF Guidelines for Network Cloud and OpenECOMP***

- Describes VNF environment and overview of requirements

*VNF Cloud Readiness Requirements for OpenECOMP*

- Cloud readiness requirements for VNFs (Design, Resiliency, Security, and DevOps)

*VNF Management Requirements for OpenECOMP*

- Requirements for how VNFs interact and utilize OpenECOMP

*VNF Heat Template Requirements for OpenECOMP*

- Provides recommendations and standards for building Heat templates compatible with OpenECOMP– initial implementations of Network Cloud are assumed to be OpenStack based.

# 3 VNF Context

A technology trend towards softwarization is impacting the communications industry as it has already impacted a number of other industries. This trend is expected to have some significant impacts on the products and processes of this industry. The transformation from products primarily based on hardware to products primarily based on software has a number of impacts. The completeness of the software packages to ease integration, usage based licensing to reflect scaling properties, independence from hardware and location and software resilience in the presence of underlying hardware failure all gain in importance compared to prior solutions. The processes supporting software products and services are also expected to transform from traditional waterfall methodologies to agile methods. In agile processes, characteristics such as versioned APIs, rolling upgrades, automated testing and deployment support with incremental release schedules become important for these software products and services. Industry process related to software products and services also change with the rise of industrially supported open source communities. Engagement with these open source communities enables sharing of best practices and collaborative development of open source testing and integration regimes, open source APIs and open source code bases.

The term VNF is inspired by the work[4] of the ETSI[5] Network Functions Virtualization (NFV) Industry Specification Group (ISG). ETSI's VNF definition includes both historically network functions, such as Virtual Provider Edge (VPE), Virtual Customer Edge (VCE), and Session Border Controller (SBC), as well as historically non-network functions when used to support network services, such as network-supporting web servers and databases. The VNF discussion in these guidelines applies to all types of virtualized workloads, not just network appliance workloads. Having a consistent approach to virtualizing any workload provides more industry value than just virtualizing some workloads.[6]

VNFs are functions that are implemented in Network Clouds. Network Clouds must support end-to-end high-bandwidth low latency network flows through VNFs running in virtualization environments. For example, a Network Cloud is able to provide a firewall service to be created such that all Internet traffic to a customer premise passes through a virtual firewall running in the Network Cloud.

A data center may be the most common target for a virtualization environment, but it is not the only target. Virtualization environments are also supported by more constrained resources e.g., Enterprise Customer Premise Equipment (CPE). Virtualization environments are also expected to be available at more distributed network locations by architecting central offices as data centers, or virtualizing functions located at the edge of the operator infrastructure (e.g., virtualized Optical Line Termination (vOLT) or xRAN[7]) and in constrained resource Access Nodes. Expect detailed requirements to evolve with these additional virtualization environments. Some VNFs may scale across all these environments, but all VNFs should onboard through the same process before deployment to the targeted virtualization environment.

[4] " Virtual Network Functions Architecture" ETSI GS NFV-SWA 001 v1.1.1 (Dec 2012)

[5] European Telecommunications Standards Institute or ETSI (http://www.etsi.org) is a respected standards body providing standards for information and communications technologies.

[6] Full set of capabilities of Network Cloud and/or OpenECOMP might not be needed to support traditional IT like workloads.

[7] xRAN (http://www.xran.org/)

## 3.1 Business Process Impacts

Business process changes need to occur in order to realize full benefits of VNF characteristics: efficiency via automation, open source reliance, and improved cycle time through careful design.

**Efficiency via Automation**

Systems reliant on human labor for critical operational tasks don't scale. By aggressively automating all VNF operational procedures, VNFs have lower operational cost, are more rapidly deployed at scale and are more consistent in their operation. OpenECOMP provides the automation framework which VNFs can take advantage of simply by implementing OpenECOMP compatible interfaces and lifecycle models. This enables automation which drives operational efficiencies and delivers the corresponding benefits.

**Open Source**

VNFs are expected to run on infrastructure largely enabled by open source software. For example, OpenStack[8] is often used to provide the virtualized compute, network, and storage capabilities used to host VNFs. OpenDaylight (ODL)[9] can provide the network control plane. The OPNFV community[10] provides a reference platform through integration of ODL, OpenStack and other relevant open source projects. VNFs also run in open source operating systems like Linux. VNFs might also utilize open source software libraries to take advantage of required common but critical software capabilities where community support is available. Automation becomes easier, overall costs go down and time to market can decrease when VNFs can be developed and tested in an open source reference platform environment prior to on-boarding by the NCSP. All of these points contribute to a lower cost structure for both VNF providers and NCSPs.

**Improved Cycle Time through Careful Design**

Today's fast paced world requires businesses to evolve rapidly in order to stay relevant and competitive. To a large degree VNFs, when used with the same control, orchestration, management and policy framework (e.g., OpenECOMP), will improve service development and composition. VNFs should enable NCSPs to exploit recursive nesting of VNFs to acquire VNFs at the smallest appropriate granularity so that new VNFs and network services can be composed. The ETSI NFV Framework[11] envisages such recursive assembly of VNFs, but many current implementations fail to support such features. Designing for VNF reuse often requires that traditional appliance based PNFs be refactored into multiple individual VNFs where each does one thing particularly well. While the original appliance based PNF can be replicated virtually by the right combination and organization of lower level VNFs, the real advantage comes in creating new services composed of different combinations of lower level VNFs (possibly from many providers) organized in new ways. Easier and faster service creation often generates real value for businesses. As softwarization trends progress towards more agile processes, VNFs, OpenECOMP and Network Clouds are all expected to evolve towards continuous integration, testing and deployment of small incremental changes to de-risk the upgrade process.

## 3.2 ETSI Network Function Virtualization (NFV) comparison

ETSI defines a VNF as an implementation of a network function that can be deployed on a Network Function Virtualization Infrastructure (NFVI). Service instances may be composed of an assembly of VNFs.

[8] OpenStack (http://www.openstack.org)

[9] OpenDaylight (http://www.opendaylight.org)

[10] OPNFV (http://www.opnfv.org)

[11] See, e.g., Figure 3 of GS NFV 002, Architectural Framework

In turn, a VNF may also be assembled from VNF components (VNFCs) that each provide a reusable set of functionality. VNFs are expected to take advantage of platform provided common services.

VNF management and control under OpenECOMP is different than management and control exposed in the ETSI MANO model. With OpenECOMP, there is only a single management and control plane. In ETSI's Framework[12], architectural options exist for preserving legacy systems that increase integration costs e.g., different VNFs can be controlled by VNF Managers (VNFMs) and Element Management Systems (EMSs) provided by different software providers. OpenECOMP addresses the concern that multiple VNFMs in this space will hinder VNF reuse and increase VNF and service integration costs. Asking all VNF providers to take advantage of and interoperate with common control software mitigates related reuse and integration challenges. The common, SDN based, control platform (OpenECOMP) is being made available as an open source project to reduce friction for VNF providers and enable new network functions to get to market faster and with lower costs.

Also under OpenECOMP, VNF providers do not provide their own proprietary VNF Managers (VNFM) or Element Management Systems (EMS). Those capabilities are provided by OpenECOMP. Hence, VNFs are required to consume open interfaces to OpenECOMP in support of management and control. The VNF Package must include the appropriate data models for integration with OpenECOMP to enable management and control of the VNFCs.

**Figure *1*** shows a simplified OpenECOMP and Infrastructure view to highlight how individual Virtual Network Functions plug into the OpenECOMP control loops.

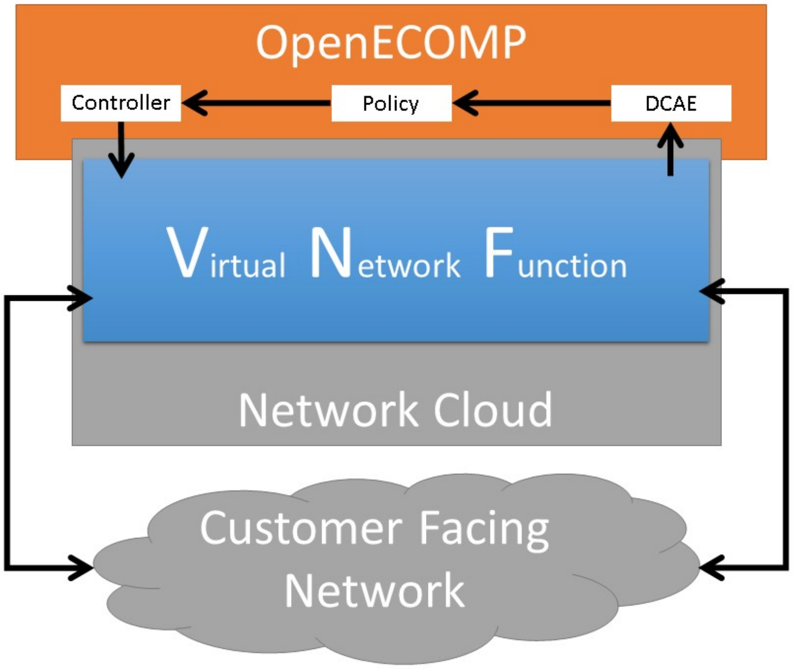


**Figure 1. Control Loop**

In the control loop view in **Figure *1***, the VNF provides an event data stream via an API to Data Collection, Analytics and Events (DCAE). DCAE analyzes and aggregates the data stream and when particular conditions are detected, uses policy to enable what, if any, action should be triggered. Some of the triggered actions may require a controller to make changes to the VNF through a VNF provided API.

[12] "Architectural Framework", ETSI GS NFV 002 (v1.1.1) Oct. 2013)

For a detailed comparison between ETSI NFV and OpenECOMP, refer to Appendix C - Comparison between VNF Guidelines and ETSI GS NFV-SWA 001.

## 3.3 Evolving VNF Related Industry Activities

Many existing industry collaboration bodies are structured around a particular service or segment of the network. VNFs are intended to operate across multiple services and execute on commodity targeted virtualization environments. With the NCSPs transformation to acquiring products and services based on location and hardware independent VNFs, the opportunity exists for instances of those VNFs to be deployed across multiple network locations and services where suitable virtualization infrastructure is available.

The rise of industry-supported open source communities has created new opportunities for collaboration and challenges for existing industry communities such as Standards Developing Organizations (SDOs). Collaboration in many SDOs defers intellectual property issues. Most industrially-supported open source communities resolve intellectual property issues between collaborators through explicit contribution licensing agreements. Common infrastructure software components (e.g., SDN Controllers, Cloud Management Systems) are expected to be available through industrially supported open source communities (e.g., Open Daylight and OpenStack). Whether VNFs are open or proprietary, they should use open APIs, test and integration capabilities developed in industrially supported open source communities (e.g., OpenECOMP, OPNFV).

The migration path for operator's existing processes and services to effectively utilize VNFs may be operator specific. The requirements for VNFs may be expected to evolve rapidly as the industry develops experience with operational and development best practices for VNFs. In particular, industry operations procedures are expected to evolve towards agile software methodologies, DevOps, continuous integration and continuous deployment (CI/CD). In this environment of changing and context-dependent VNF requirements, agile, pragmatic approaches focused on delivering functionality in the near term and evolving it towards targeted VNF characteristics are preferred over lengthy waterfall industry standardization processes. Demonstrating functionality and interoperability of appropriate VNF-related APIs in open source communities is considered a pre-requisite to starting industry specification work documenting stable interfaces.

While multiple open source communities exist supporting particular infrastructure software options, the market success of any particular option combination cannot be assured. Integration communities such as OPNFV provide an approach enabling VNF providers to test their products and services against a variety of expected configurations available in the industry.

## 3.4 Evolving towards VNFs

In order to deploy VNFs, a target virtualization environment must already be in place. The NCSPs scale necessitates a phased rollout of virtualization infrastructure and then of VNFs upon that infrastructure. Some VNF use cases may require greenfield infrastructure deployments, others may start brownfield deployments in centralized data centers and then scale deployment more widely as infrastructure becomes available. Some service providers have been very public and proactive in setting transformation targets associated with VNFs[13].

Because of the complexity of migration and integration issues, the requirements for VNFs in the short term may need to be contextualized to the specific service and transition planning.

Much of the existing VNF work has been based on corresponding network function definitions and requirements developed for PNFs. Many of the assumptions about PNFs do not apply to VNFs and the modularity of the functionality is expected to be significantly different. In addition, the increased service velocity objectives of NFV are based on new types of VNFs being developed to support new services

[13] AT&T, for instance, has announced that it seeks to virtualize and control 75% of its network functionality by 2020 and that 50% of AT&T's software be coming from open source. For AT&T, VNFs have already been placed in service in the Network Cloud and enterprise CPE whiteboxes.

being deployed in virtualized environments. Much of the functionality associated with 5G (e.g., IoT, augmented reality/virtual reality) is thus expected to be deployed as VNFs in targeted virtualization infrastructure towards the edge of the network.

# 4 VNF Characteristics

VNFs need to be constructed using a distributed systems architecture that we will call "Network Cloud Ready". They need to interact with the orchestration and control platform provided by OpenECOMP and address the new security challenges that come in this environment.

The main goal of a Network Cloud Ready VNF is to run 'well' on any Network Cloud (public or private) over any network (carrier or enterprise). In addition, for optimal performance and efficiency, VNFs will be designed to take advantage of Network Clouds. This requires careful engineering in both VNFs and candidate Network Cloud computing frameworks.

To ensure Network Cloud capabilities are leveraged and VNF resource consumption meets engineering and economic targets, VNF performance and efficiency will be benchmarked in a controlled lab environment. In line with the principles and practices laid out in ETSI GS NFV-PER 001, efficiency testing will consist of benchmarking VNF performance with a reference workload and associated performance metrics on a reference Network Cloud (or, when appropriate, additional benchmarking on a bare metal reference platform).

Network Cloud Ready VNF characteristics and design consideration can be grouped into three areas:

- Cloud Readiness
- OpenECOMP Ready
- Virtualization Environment Ready

Detailed requirements are contained in the reference documents that are listed in Appendix B - References.

## 4.1 Cloud Readiness

VNFs should be designed to operate within a cloud environment from the first stages of the development. The VNF provider should think clearly about how the VNF should be decomposed into various modules. Resiliency within a cloud environment is very different than in a physical environment and the developer should give early thought as to how the Network Cloud Service Provider will ensure the level of resiliency required by the VNF and then provide the capabilities needed within that VNF. Scaling and Security should also be well thought out at design time so that the VNF runs well in a virtualized environment. Finally, the VNF Provider also needs to think about how they will integrate and deploy new versions of the VNF. Since the cloud environment is very dynamic, the developer should utilize DevOps practices to deploy new software.

Requirements for Cloud Readiness can be found in the *VNF Common Requirements for OpenECOMP* document.

### 4.1.1 VNF Design

A VNF may be a large construct and therefore when designing it, it is important to think about the components from which it will be composed. The ETSI SWA 001 document gives a good overview of the architecture of a VNF in Chapter 4 as well as some good examples of how to compose a VNF in its Annex B. When laying out the components of the VNF it is important to keep in mind the following principles: Single Capability, Independence, State and the APIs.

Many Network Clouds will use Heat to describe orchestration templates for instantiating VNFs and VNFCs. Heat has a useful abstraction called a "module" that can contain one or more VNFCs. A module can be thought of as a deployment unit. In general the goal should be for each module to contain a single VNFC.

#### 4.1.1.1 Single Capability

VNFs should be carefully decomposed into loosely coupled, granular, re-usable VNFCs that can be distributed and scaled on a Network Cloud. VNFCs should be responsible for a single capability.

The Network Cloud will define several flavors of VMs for a VNF designer to choose from for instantiating a VNFC. The best practice is to keep the VNFCs as lightweight as possible while still fulfilling the business requirements for the "single capability", however the VNFC should not be so small that the overhead of constructing, maintaining, and operating the service outweighs its utility.

#### 4.1.1.2 Independence

VNFCs should be independently deployed, configured, upgraded, scaled, monitored, and administered (by OpenECOMP). The VNFC must be a standalone executable process.

API versioning is one of the biggest enablers of independence. To be able to independently evolve a component, versioning must ensure existing clients of the component are not forced to flash-cut with each interface change. API versioning enables smoother evolution while preserving backward compatibility.

#### 4.1.1.3 Scaling

Each VNFC within a VNF must support independent horizontal scaling, by adding/removing instances, in response to demand loads on that VNFC. The Network Cloud is not expected to support adding/removing resources (compute, memory, storage) to an existing instance of a VNFC (vertical scaling). A VNF should be designed such that its components can scale independently of each other. Scaling one component should not require another component to be scaled at the same time. All scaling will be controlled by OpenECOMP.

#### 4.1.1.4 Managing State

VNFCs and their interfaces should isolate and manage state to allow for high-reliability, scalability, and performance in a Network Cloud environment. The use of state should be minimized as much as possible to facilitate the movement of traffic from one instance of a VNFC to another. Where state is required it should be maintained in a geographically redundant data store that may in fact be its own VNFC.

This concept of decoupling state data can be extended to all persistent data. Persistent data should be held in a loosely coupled database. These decoupled databases need to be engineered and placed correctly to still meet all the performance and resiliency requirements of the service.

#### 4.1.1.5 Lightweight and Open APIs

Key functions are accessible via open APIs, which align to Industry API Standards and supported by an open and extensible information/data model.

#### 4.1.1.6 Reusability

Properly (de)composing a VNF requires thinking about “reusability”. Components should be designed to be reusable within the VNF as well as by other VNFs. The “single capability” principle aids in this requirement. If a VNFC could be reusable by other VNFs then it should be designed as its own single component VNF that may then be chained with other VNFs. Likewise, a VNF provider should make use of other common platform VNFs such as firewalls and load balancers, instead of building their own.

### 4.1.2 Resiliency

The VNF is responsible for meeting its resiliency goals and must factor in expected availability of the targeted virtualization environment. This is likely to be much lower than found in a traditional data center. The VNF developer should design the function in such a way that if there is a platform problem the VNF will continue working as needed and meet the SLAs of that function. VNFs should be designed to survive single failure platform problems including: hypervisor, server, datacenter outages, etc. There will also be significant planned downtime for the Network Cloud as the infrastructure goes through hardware and software upgrades. The VNF should support tools for gracefully meeting the service needs such as methods for migrating traffic between instances and draining traffic from an instance. The VNF needs to rapidly respond to the changing conditions of the underlying infrastructure.

VNF resiliency can typically be met through redundancy often supported by distributed systems architectures. This is another reason for favoring smaller VNFCs. By having more instances of smaller VNFCs it is possible to spread the instance out across servers, racks, datacenters, and geographic regions. This level of redundancy can mitigate most failure scenarios and has the potential to provide a service with even greater availability than the old model. Careful consideration of VNFC modularity also minimizes the impact of failures when an instance does fail.

### 4.1.3 Security

Security must be integral to the VNF through its design, development, instantiation, operation, and retirement phases. VNF architectures deliver new security capabilities that make it easier to maximize responsiveness during a cyber-attack and minimize service interruption to the customers. SDN enables the environment to expand and adapt for additional traffic and incorporation of security solutions. Further, additional requirements will exist to support new security capabilities as well as provide checks during the development and production stages to assure the expected advantages are present and compensating controls exist to mitigate new risks.

New security requirements will evolve along with the new architecture. Initially, these requirements will fall into the following categories:

- VNF General Security Requirements
- VNF Identity and Access Management Requirements
- VNF API Security Requirements
- VNF Security Analytics Requirements
- VNF Data Protection Requirements

### 4.1.4 DevOps

The OpenECOMP software development and deployment methodology is evolving toward a DevOps model. VNF development and deployment should evolve in the same direction, enabling agile delivering of end-to-end services. Following these same principles better positions OpenECOMP and VNF development to coevolve in the same direction.

#### 4.1.4.1 Testing

VNF packages should provide comprehensive automated regression, performance and reliability testing with VNFs based on open industry standard testing tools and methodologies. VNF packages should provide acceptance and diagnostic tests and in-service instrumentation to be used in production to validate VNF operation.

#### 4.1.4.2 Build and Deployment Processes

VNF packages should include continuous integration and continuous deployment (CI/CD) software artifacts that utilize automated open industry standard system and container build tools. The VNF package should include parameterized configuration variables to enable automated build customization. Don’t create unique (snowflake) VNFs requiring any manual work or human attention to deploy. Do create standardized (Lego™) VNFs that can be deployed in a fully automated way.

OpenECOMP will orchestrate updates and upgrades of VNFs. The target method for updates and upgrades is to onboard and validate the new version, then build a new instance with the new version of software, transfer traffic to that instance and kill the old instance. There should be no need for the VNF or its components to provide an update/upgrade mechanism.

#### 4.1.4.3 Automation

Increased automation is enabled by VNFs and VNF design and composition. VNF and VNFCs should provide the following automation capabilities, as triggered or managed via OpenECOMP:

- Events and alarms
- Lifecycle events
- Zero-Touch rolling upgrades and downgrades
- Configuration

## 4.2 OpenECOMP Ready

OpenECOMP is the “brain” providing the lifecycle management and control of software-centric network resources, infrastructure and services. OpenECOMP is critical in achieving the objectives to increase the value of the Network Cloud to customers by rapidly on-boarding new services, enabling the creation of a new ecosystem of consumer and enterprise services, reducing capital and operational expenditures, and providing operations efficiencies. It delivers enhanced customer experience by allowing them in near real-time to reconfigure their network, services, and capacity.

For more details, refer to the *ECOMP Architecture White Paper*[14].

One of the main OpenECOMP responsibilities is to rapidly onboard and enrich VNFs to be cataloged as resources to allow composition and deployment of services in a multi-vendor plug and play environment. It is also extremely important to be able to automatically manage the VNF run-time lifecycle to fully realize benefits of NFV. The VNF run-time lifecycle includes aspects such as instantiation, configuration, elastic scaling, automatic recovery from resource failures, and resource allocation. It is therefore imperative to provide VNFs that are equipped with well-defined capabilities that comply with OpenECOMP standards to allow rapid onboarding and automatic lifecycle management of these resources when deploying services as depicted in **Figure *2***.

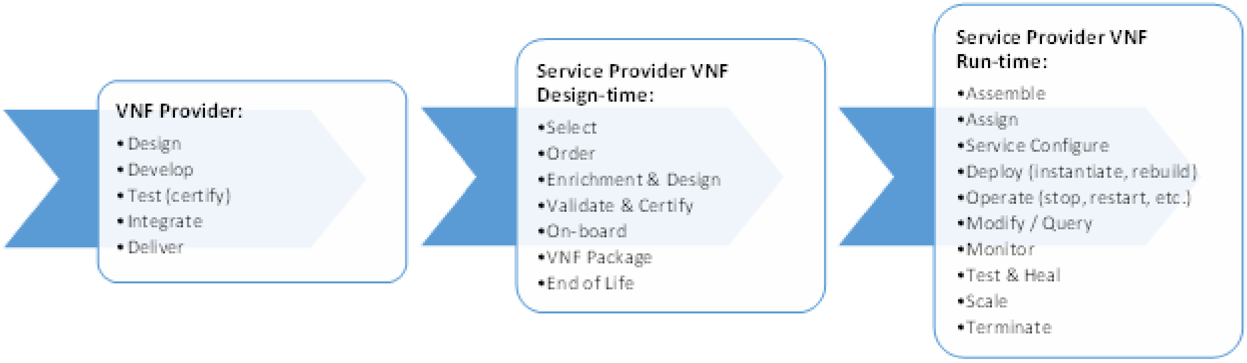


**Figure 2. VNF Complete Lifecycle Stages**

In order to realize these capabilities within the OpenECOMP platform, it is important to adhere to a set of key principles (listed below) for VNFs to integrate into OpenECOMP.

[14] ECOMP (Enhanced Control Orchestration, Management & Policy) Architecture White Paper (http://about.att.com/content/dam/snrdocs/ecomp.pdf)

Requirements for OpenECOMP Ready can be found in the *VNF Management Requirements for OpenECOMP* document.

### 4.2.1 Design Definition

Onboarding automation will be facilitated by applying standards-based approaches to VNF packaging to describe the VNF’s infrastructure resource requirements, topology, licensing model, design constraints, and other dependencies to enable successful VNF deployment and management of VNF configuration and operational behavior.

The current VNF Package Requirement is based on a subset of the Requirements contained in the ETSI Document: ETSI GS NFV-MAN 001 v1.1.1 and GS NFV IFA011 V0.3.0 (2015-10) - Network Functions Virtualization (NFV), Management and Orchestration, VNF Packaging Specification.

### 4.2.2 Configuration Management

OpenECOMP must be able to orchestrate and manage the VNF configuration to provide fully automated environment for rapid service provisioning and modification. VNF configuration/reconfiguration must be allowed directly through standardized APIs without the need for an EMS.

### 4.2.3 Monitoring and Management

The end-to-end service reliability and availability in a virtualized environment will greatly depend on the ability to monitor and manage the behavior of Virtual Network Functions in real-time. OpenECOMP platform must be able to monitor the health of the network and VNFs through collection of event and performance data directly from network resources utilizing standardized APIs without the need for an EMS. The VNF provider must provide visibility into VNF performance and fault at the VNFC level (VNFC is the smallest granularity of functionality in our architecture) to allow OpenECOMP to proactively monitor, test, diagnose and trouble shoot the health and behavior of VNFs at their source.

## 4.3 Virtualization Environment Ready

Every Network Cloud Service Provider will have a different set of resources and capabilities for their Network Cloud, but there are some common resources and capabilities that nearly every NCSP will offer.

### 4.3.1 Network Cloud

VNFCs should be agnostic to the details of the Network Cloud (such as hardware, host OS, Hypervisor or container technology) and must run on the Network Cloud with acknowledgement to the paradigm that the Network Cloud will continue to rapidly evolve and the underlying components of the platform will change regularly. VNFs should be prepared to move VNFCs across VMs, hosts, locations or datacenters, or Network Clouds.

### 4.3.2 Overlay Network

VNFs should be compliant with the Network Cloud network virtualization platform including the specific set of characteristics and features.

The Network Cloud is expected to be tuned to support VNF performance requirements. Initially, specifics may differ per Network Cloud implementation and are expected to evolve over time, especially as the technology matures.

### 4.3.3 Guest Operating Systems

VNFs should use the NCSP’s standard set of OS images to enable compliance with security, audit, regulatory and other needs.

### 4.3.4 Compute Flavors

VNFs should take advantage of the standard Network Cloud capabilities in terms of VM characteristics (often referred to as VM Flavors), VM sizes and cloud acceleration capabilities aimed at VNFs such as Intel’s Data Plane Development Kit (DPDK).

# 5 Summary

The intent of these guidelines and requirements is to provide long term vision as well as short term focus and clarity where no current open source implementation exists today. The goal is to accelerate the adoption of VNFs which will increase innovation, minimize customization to onboard VNFs, reduce implementation time and complexity as well as lower overall costs for all stakeholders. It is critical for the Industry to align on a set of standards and interfaces to quickly realize the benefits of NFV. AT&T is contributing these guidelines to the OpenECOMP open source community as a step in moving toward standards. These guidelines are based on our experience with large scale deployment and operations of VNFs over the past several years.

This VNF guidelines document provides a general overview and points to more detailed requirements documents. The subtending documents provide more detailed requirements and are listed in Appendix B - References. All documents are expected to evolve.

Some of these VNF guidelines may be more broadly applicable in the industry, e.g., in other open source communities or standards bodies. The art of VNF architecture and development is expected to mature rapidly with practical deployment and operations experience from a broader ecosystem of types of VNFs and different VNF providers. Individual operators may also choose to provide their own extensions and enhancements to support their particular operational processes, but these guidelines are expected to remain broadly applicable across a number of service providers interested in acquiring VNFs.

We invite feedback on these VNF Guidelines in the context of the OpenECOMP Project. We anticipate an ongoing project within the OpenECOMP Community to maintain similar guidance for VNF developers to enable them to more easily develop VNFs which are compatible with the evolving releases of OpenECOMP. Comments on these guidelines should be discussed there.

# Appendix A - Glossary

**Heat** Heat is a service to orchestrate composite cloud applications using a declarative template format through an OpenStack-native REST API.

**Network Clouds** Network Clouds are built on a framework containing these essential elements: refactoring hardware elements into software functions running on commodity cloud computing infrastructure; aligning access, core, and edge networks with the traffic patterns created by IP based services; integrating the network and cloud technologies on a software platform that enables rapid, highly automated, deployment and management of services, and software defined control so that both infrastructure and functions can be optimized across change in service demand and infrastructure availability; and increasing competencies in software integration and a DevOps operations model.

**Network Cloud Service Provider** Network Cloud Service Provider (NCSP) is a company or organization, making use of a communications network to provide Network Cloud services on a commercial basis to third parties.

**SDOs** Standards Developing Organizations are organizations which are active in the development of standards intended to address the needs of a group of affected adopters.

**Softwarization** Softwarization is the transformation of business processes to reflect characteristics of software centric products, services, lifecycles and methods.

**Targeted Virtualization Environment** Targeted Virtualization Environment is the execution environment for VNFs. While Network Clouds located in datacenters are a common execution environment, VNFs can and will be deployed in various locations (e.g., non-datacenter environments) and form factors (e.g., enterprise Customer Premise Equipment). Non-datacenter environments are expected to be available at more distributed network locations including central offices and at the edge of the NCSP’s infrastructure.

**VM** Virtual Machine (VM) is a virtualized computation environment that behaves very much like a physical computer/server. A VM has all its ingredients (processor, memory/storage, interfaces/ports) of a physical computer/server and is generated by a hypervisor, which partitions the underlying physical resources and allocates them to VMs. Virtual Machines are capable of hosting a virtual network function component (VNFC).

**VNF** Virtual Network Function (VNF) is the software implementation of a function that can be deployed on a Network Cloud. It includes network functions that provide transport and forwarding. It also includes other functions when used to support network services, such as network-supporting web servers and database.

**VNFC** Virtual Network Function Component (VNFC) are the sub-components of a VNF providing a VNF Provider a defined sub-set of that VNF's functionality, with the main characteristic that a single instance of this component maps 1:1 against a single Virtualization Container. See **Figure *3*** for the relationship between VNFC and VNFs.

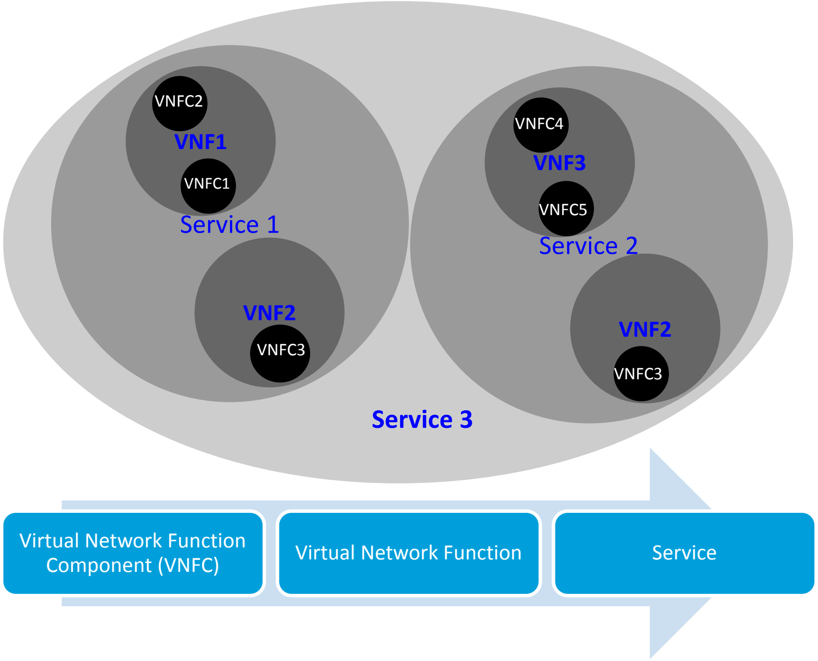


**Figure 3. Virtual Network Function Entity Relationship**

# Appendix B - References

1. VNF Cloud Readiness Requirements for OpenECOMP
2. VNF Management Requirements for OpenECOMP
3. VNF Heat Template Requirements for OpenECOMP

# Appendix C - Comparison between VNF Guidelines and ETSI GS NFV-SWA 001

The VNF guidelines presented in this document (VNF Guidelines) overlap with the ETSI GS NFV-SWA 001 (Network Functions Virtualization (NFV); Virtual Network Function Architecture) document. For convenience we will just refer to this document as SWA 001.

The SWA 001 document is a survey of the landscape for architecting a VNF. It includes many different options for building a VNF that take advantage of the ETSI MANO architecture.

The Network Cloud and OpenECOMP have similarities to ETSI's MANO, but also have differences described in earlier sections. The result is differences in the VNF requirements. Since these VNF Guidelines are for a specific implementation of an architecture they are narrower in scope than what is specified in the SWA 001 document.

The VNF Guidelines primarily overlaps the SWA 001 in Sections 4 and 5. The other sections of the SWA 001 document lie outside the scope of the VNF Guidelines.

This appendix will describe the differences between these two documents indexed on the SWA 001 sections

## Section 4 Overview of VNF in the NFV Architecture

This section provides an overview of the ETSI NFVI architecture and how it interfaces with the VNF architecture. Because of the differences between infrastructure architectures there will naturally be some differences in how it interfaces with the VNF.

A high level view of the differences in architecture can be found in the main body of this document and a more detailed analysis can be found in the *ECOMP Architecture White Paper*[15].

### Section 4.3 Interfaces

Since OpenECOMP provides the VNFM and EMS functionality for all VNFs the SWA-3 and SWA-4 interfaces are OpenECOMP interfaces. All OpenECOMP interfaces are described in this package of documents.

## Section 5 VNF Design Patterns and Properties

This section of the SWA 001 document gives a broad view of all the possible design patterns of VNFs. The VNF Guidelines do not generally differ from this section. The VNF Guidelines address a more specific scope than what is allowed in the SWA 001 document.

### Section 5.1 VNF Design Patterns

The following are differences between the VNF Guidelines and SWA-001:

- 5.1.2 - The Network Cloud does not recognize the distinction between "parallelizable" and "non-parallelizable" VNFCs, where parallelizable means that there can be multiple instances of the VNFC. In the VNF Guidelines, all VNFCs should support multiple instances and therefore be parallelizable.
- 5.1.3 - The VNF Guidelines encourages the use of stateless VNFCs. However, where state is needed it should be kept external to the VNFC to enable easier failover
- 5.1.5 - The VNF Guidelines only accepts horizontal scaling (scale out/in) by VNFC. Vertical scaling (scale up/down) is not supported by OpenECOMP.

[15] ECOMP (Enhanced Control Orchestration, Management & Policy) Architecture White Paper (http://about.att.com/content/dam/snrdocs/ecomp.pdf)

- 5.1.5 - Since OpenECOMP provides all EMS and VNFM functionality On-Demand scaling is accomplished through OpenECOMP and not directly by the VNF

### Section 5.2 VNF Update and Upgrade

- 5.2.2 - OpenECOMP will orchestrate updates and upgrades. The preferred method for updates and upgrades is to build a new instance with the new version of software, transfer traffic to that instance and kill the old instance

### Section 5.3 VNF Properties

The following are differences between the VNF Guidelines and SWA-001:

- 5.3.1 - In a Network Cloud all VNFs must be only “COTS-Ready”. The VNF Guidelines does not support “Partly COTS-READY” or “Hardware Dependent”.
- 5.3.2 – The only virtualization environment currently supported by OpenECOMP is “Virtual Machines”. The VNF Guidelines state that all VNFs should be hypervisor agnostic. Other virtualized environment options such as containers are not currently supported. However, container technology is targeted to be supported in the future.
- 5.3.3 - All VNFs must scale horizontally (scale out/in) within the Network Cloud. Vertical (scale up/down) is not supported.
- 5.3.5 - The VNF Guidelines state that OpenECOMP will provide full policy management for all VNFs. The VNF will not provide its own policy management for provisioning and management.
- 5.3.7 - The VNF Guidelines recognizes both stateless and stateful VNFCs but it encourages the minimization of stateful VNFCs.
- 5.3.11 - The VNF Guidelines only allows for OpenECOMP management of the VNF. It does not allow a proprietary management interface for use with a 3rd party EMS

### Section 5.4 Attributes describing VNF Requirements

Attributes described in the VNF Guidelines and reference documents include those attributes defined in this section of the SWA 001 document but also include additional attributes.