

# A Pattern for Network Function Virtualization Infrastructure (NFVI)

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In Network Function Virtualization (NFV), different networking components such as firewalls, load balancers, and IDS are provided as a service and relying purely on support from the cloud, which makes expanding and upgrading the network an easy and fast process. Hardware-based Network Functions (NFs) normally require a tightly coupled infrastructure, where changes are hard to make; a Network Function Virtualization Infrastructure (NFVI) makes the process of enhancing and expanding the network much easier. This NFVI emulates the hardware functions using virtual functions to be provided as services. We present here a pattern to describe a NFVI.

## Keywords

Network Virtualization, architecture patterns, network functions, Network function virtualization infrastructure, Virtual infrastructure, cloud computing, telecommunications, NFV Services.

## 1.INTRODUCTION

Telecommunication Service Providers (TSPs) have to spend time and effort to deploy physical hardware and equipment for each network function, all this in addition to the need for highly skilled network designers and operators to deal with the complexity of setting up and administering large networks. Furthermore, the network life-cycle is becoming shorter due to the faster evolution of network hardware. As a result, this leads to an increase in the Operational Expense (OPEX) and Capital Expense (CAPEX) for TSPs [Haw14].

The European Telecommunications Standards Institute (ETSI) introduced NFV as a new concept to provide network functions (NFs) as a service to the consumers in a virtual manner as an alternative to the traditional legacy way of implementing NFs noting that this standard has been adopted world-wide by the leaders of networking solutions. The concept of NFV addresses the previously mentioned drawbacks of using the legacy network to provide networking solutions to the users. Moreover, NFV promises the following benefits [Car14] :

- Independence: software is no longer integrated with hardware in NFV. As a result, their evolution can be independent of each other.
- Flexibility: the decoupling of software from hardware helps to reassign and share the same infrastructure resources, which allows performing different functions at different times. As a result, the deployment of network functions and their connections becomes faster and more flexible.
- Scalability: decoupling software from hardware provides more flexibility to dynamically scale the actual performance of virtualized network functions with finer granularity.
- Reduced energy consumption: with the ability to scale resources up and down, TSPs will be able to reduce the OPEX needed to run network devices.
- Cost: Using NFV systems could significantly reduce the cost of having networking solutions.

The concept of providing network functions as virtual network functions can be achieved by converting hardware functions into virtual functions. In NFV, its Network Function Virtualization Infrastructure (NFVI) works as a backbone for the system by decoupling the functions from dedicated hardware and moving them into virtual servers. NFV should not be confused with Software Defined Networks (SDN), an architecture for networks that separates the control from the data in switches and routers [Kre15]; SDN controls the topology aspects of networks, not their functionality.

ETSI introduced the basic architecture for NFV systems [Ets14], Three different main components together create an NFV system (Figure1):

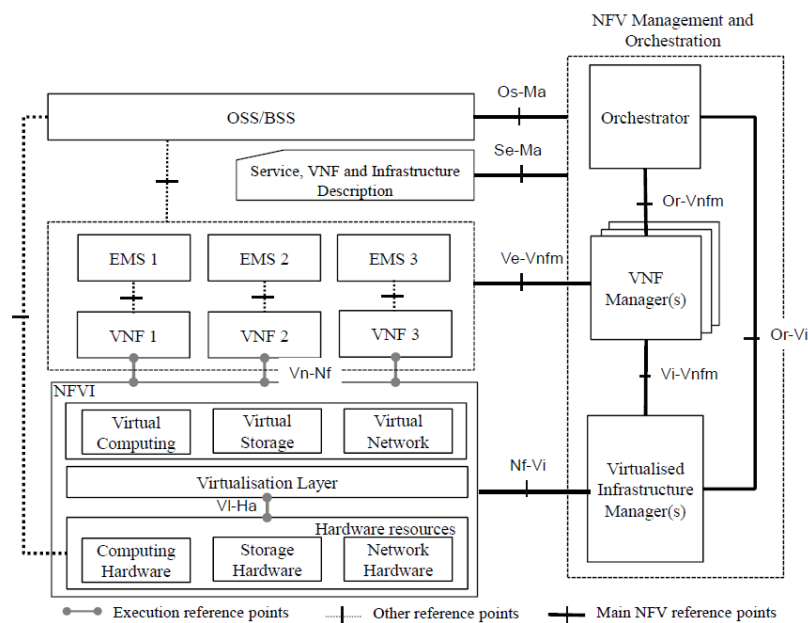


Figure 1. ETSI NFV architectural framework

1. Network Function Virtualization Infrastructure (NFVI)-- NFVI can be considered as a cloud data center that works as a foundation platform for NFV; it contains both hardware resources as well as the virtual resources which together build up the infrastructure on which Virtual Network Functions (VNFs) are executed, deployed and managed. NFVI contains three main components which are virtualized resources, virtualization layer, and hardware resources.
2. Virtualized Network Functions (VNFs) refer to the implementation of network functions in a virtual manner. In NFV systems all network functions are represented as software packages and combined into a network graph which represents the whole network. One single VNF is created from one or more VNF components (VNFC), noting that the entire service could be combined in a single VNF to reduce the complexity of deployment [Ets14]. However, VNF also could contain separate components which will increase the system reusability and scalability. Moreover, this will help in creating custom networks to support complex systems. Every VNF is connected to an Element Management System (EMS), which is responsible for the functional management of each VNF.
3. The NFV Management and Orchestration (MANO) unit could be considered as the heart of the NFV system. This unit takes care of the management and orchestration aspects of the entire set of VNFs. VNF management functions include traditional fault management as well as security management. Moreover, the MANO takes care of creating VNFs, scaling VNFs where more components could be added or removed from a single VNF which will lead to increasing or decreasing the capacity of the VNF, update or upgrade VNFs, and terminate VNFs. Also, it takes care of fault and performance management aspects of the system. On the other hand, orchestration differs from management in that its tasks register network services in the catalog, monitor the capacity of network services that the TSP provides to the consumer, and validates and verifies resource requests.

We present here a pattern for NFVI. Because the model of figure 1 is not sufficiently detailed, we found more details from the descriptions of these functions in several ETSI documents. Our audience includes

system designers, system architects, and designers of network systems in TSPs. A glossary in the Appendix describes the acronyms used in this paper.

## 2. Network Function Virtualization Infrastructure (NFVI)

### 2.1 Intent

The NFVI pattern describes an architectural layer that contains the actual physical components as well as the virtualization layer that performs the implementation of network functions as virtual functions.

### 2.2 Example

Dave works in a networking company that provides solutions to his customers. He is in charge of improving the efficiency and flexibility of the networks they provide. He is looking for a more cost-effective solution than using hardware functions as they do now, which they consider inflexible and costly.

### 2.3 Context

Telecommunication providers need to provide a variety of network services such as routers and firewalls to a variable number of customers.

### 2.4 Problem

Providing a variety of network functions in a flexible and cost-effective way is needed to be able to compete in the market. How can we achieve this objective?

The solution to this problem is affected by the following forces:

- Heterogeneity— We need to provide a variety of different types of network functions including some that do not have physical components.
- Availability— The network service should be available at most times.
- Scalability— The number and type of customers can change up or down along time. The number of functions they require also changes along time.
- Location— different physical components could be distributed in different locations which may introduce connectivity issues.
- Upgradability— When used together with physical components an upgrade should not introduce issues for virtual functions.
- Security— We need to provide a good level of security to our network functions.
- Performance— Virtual functions should provide a good level of performance with no latency or noticeable reduction in performance.
- Cost— Using VNFs should be cheaper than using legacy network systems.

### 2.5 Solution

Define an architectural unit (NFVI) that contains a virtualization layer which provides network functions using virtualization of hardware resources. The fundamental component of the NFVI is the hypervisor which

creates and manages virtual machines that can be used to create networks for NFV consumers. The hypervisor also provides isolation among the virtualized entities.

### 2.5.1 Structure

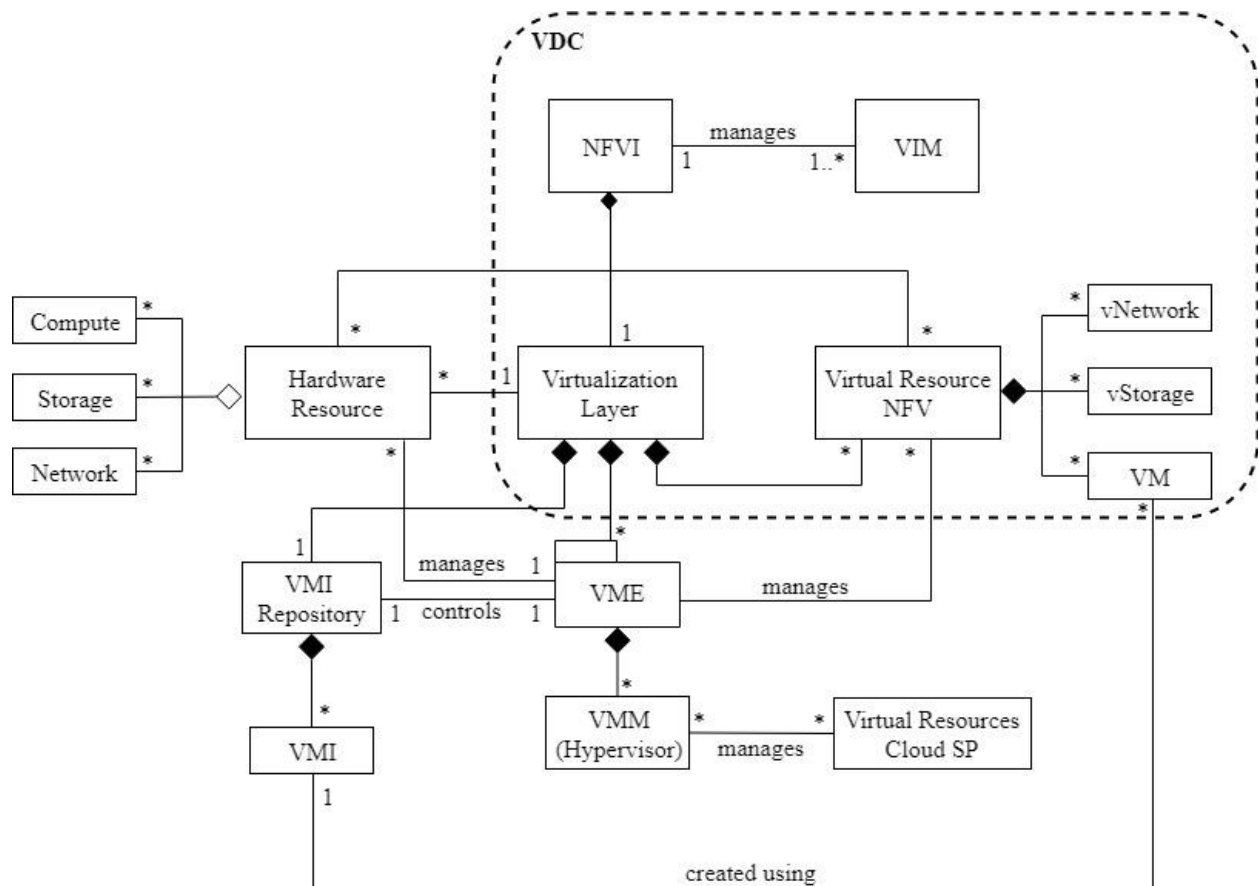


Figure 2. structure of NFVI pattern

Figure 2 shows the class diagram of the NFVI pattern which contains the hardware resources (compute, storage, network), Virtual Machine Image (VMI), which is a template used to create new machines and may contain an operating system, data files and applications; VMI Repository that contains VMIs, the Virtual Machine Environment (VME) that contains the VMM (Virtual Machine Monitor or hypervisor), which in turn manages the resources for the cloud service provider, and the VIM that manages the hypervisor within the VME. The VME is a pattern and described in more detail in [Aln19]. Also, the diagram shows the boundary of the Virtual Data Center (VDC) that is dedicated to the NFV service. The VDC contains the VIM and the virtual resources of the NFVI.

### 2.5.2 Dynamics

NFVI includes several use cases including “Create a set of Virtual Network Functions”, “Assign virtual resources to user accounts”, and “Modify virtual resources”. In this subsection, we discuss two use cases in detail: “Create a set of Virtual Network Functions”, and “Stop NFV Service”.

UC1: Create a set of Virtual Network Functions

Actor: VIM.

Precondition: The customer has an active account.

Description:

VIM receives external request to create service.

1. VIM sends a create service request with details about the needed resources for the service.
2. Hardware unit handles the request and checks for available resources.
3. Hardware resource details get forwarded to the virtualization layer.
4. Virtualization layer creates the virtual function based on the available hardware resources.

Postcondition: A set of VNF has been created.

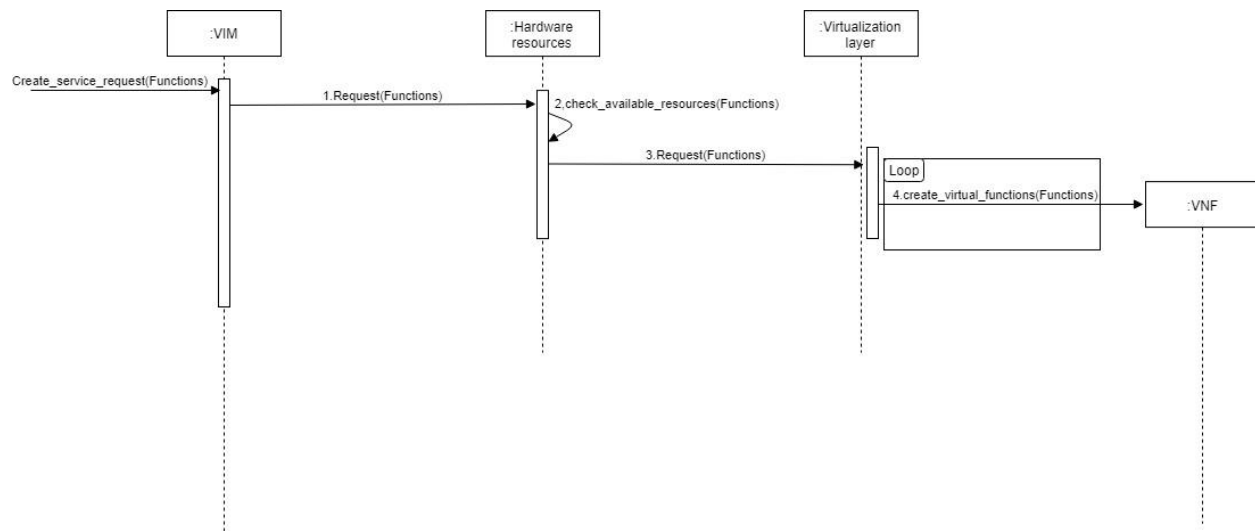


Figure 3. Sequence diagram for use case 1 "Create a Virtual Function".

UC2: Stop Service

Actor: VIM.

Precondition: the customer has an active set of NFVs

Description:

- 1.VIM receives external request to stop VF.
- 2.VIM forwards the request to NFVI to handle the request.
- 3.NFVI sends stop request to the virtual resources.
- 4.once received Virtual resources pause the VF.
- 5.after successfully pausing the VF, it stops the service.

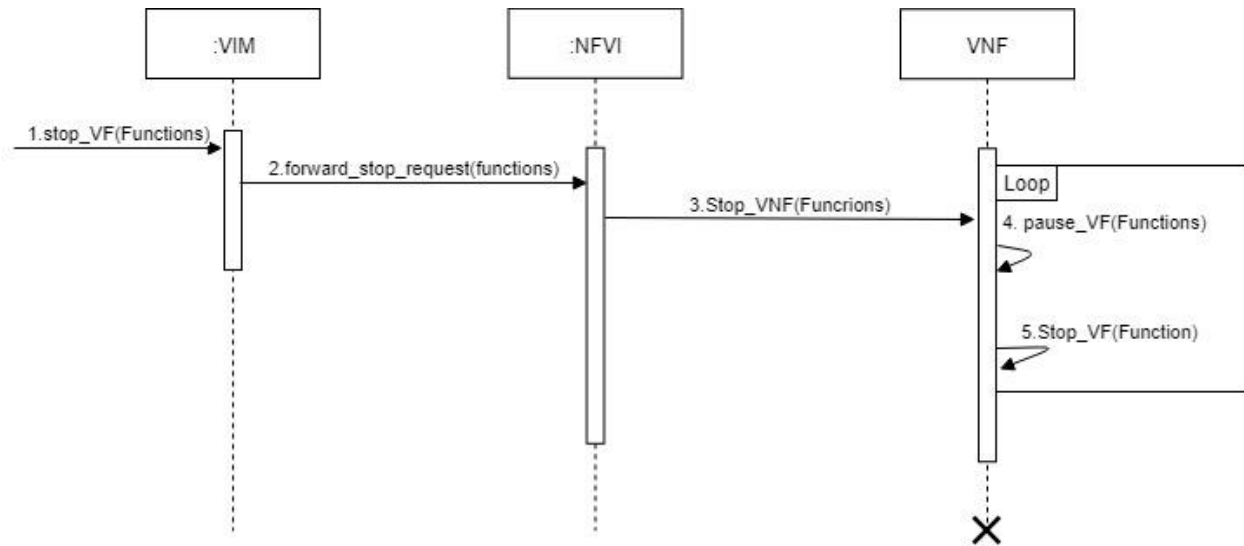


Figure 4. Sequence diagram for Use Case 2: “Stop Service”

## 2.6 Implementation

NFV providers must have different hardware equipment ready based on the services they plan to provide to their users base. They need a virtual machine environment as a base for this software in the form of virtual machines created by a hypervisor. Each created service must be registered in a services repository where the Management and Orchestration unit (MANO) can assign it to specific users; this process is explained in detail in the MANO pattern [Alw19].

. The VMs in the VDC are used only to deploy NFV services; the VM should have only one VMI installed on it

## 2.7 Known uses

- Ericsson NFVI solution enables operators to deploy virtual function, OSS, BSS, IT [Erc17]. Ericsson uses the standard provided by ETSI to implement NFVI. Moreover, their solution includes an automated MANO to have better overall performance.
- Cisco Network Function Virtualization Infrastructure (NFVI) provides the virtual layer and hardware environment in which virtual network functions (VNFs) can operate [Cis16].
- Cloudband by Nokia uses an OpenStack Platform to deliver NFVI [Alc17].
- Huawei has released its 100 Gigabit Ethernet-capable NFVI solution that provides high bandwidth and low latency performance [Haw17].

## 2.8 Consequences

. The NFVI pattern presents the following advantages:

- Heterogeneity—Since the networking functions are all virtual they can all be easily made compatible.
- Availability— NFV services can be running at all times if the TSP includes some redundant implementation of VNFs.

- Scalability— Since the service will be provided in virtualized manner the TSP just needs to allocate more cloud resources when the number of customers increases.
- Location— NFV infrastructure is part of a TSP and it can use any of the locations of a cloud service.
- Upgrades— New Functions can be added to the existing VNFs without affecting old functions.
- Security— the NNF can build secure networks by including appropriate controls in them; for example, authorization to use some VNFs.
- Performance— The TSP can allocate more VMs to a network to increase its performance.
- Cost— The NFVI provides a cost-effective network to its customers because creating new functions does not require actual hardware costs.

### Liabilities

- Problems may occur when trying to combine old hardware functions with VNFs due to integration and compatibility issues.
- Security is a concern in NFV systems. Every network function is now provided as software which increases its attack surface.

## 2.9 Example Resolved

Dave decided to use an NFV system rented from a public cloud, where physical components are emulated by virtual functions with the help of an NFVI. This allows Dave's company to deliver network functions to the user without the complexity of deploying and installing new equipment.

## 2.10 Related patterns

- A pattern for Network Function Virtualization [Fer15] presented the NFV architecture that shows how to create network services using Software-as-a-Service (SaaS) of the cloud. This is a general pattern than contain NFVI as a class in it. This pattern refines the details of that pattern.
- Cloud ecosystem-- [Fer16] shows how the NFV pattern interacts with the different parts of the cloud ecosystem as well as with other external systems.
- A pattern for an NFV Virtual Machine Environment [Aln19] shows this environment and how it is related to NFV, as well as describing how the NFV architecture interacts with the virtual environment.
- A pattern for NFV Management and orchestration (MANO) is given in [Alw19]. This pattern shows how NFVI is managed and controlled by the MANO unit.
- A Reference Architecture model for NFV is provided in [Aln19B], which shows all the components of the architecture.

### 3. Conclusions

NFV is a new technology under development that could be considered as the future of networks. NFVI is a critical component of an NFV system because it is the unit responsible for converting functions provided by hardware into virtual functions provided as software.

We presented here a pattern for NFVI which complements our previous work on describing precisely the units of an NFV system. As indicated, the ETSI model is too high level and imprecise to be useful to users and developers of NFV systems.

### Acknowledgment

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## Glossary

Acronym	Definition
TSP	A telecommunications service provider is a type of communication service provider that provides networking solutions
NFV	Network Function Virtualization is the service to be provided to the user in the form of virtual functions.
NFVI	Network Function Virtualization Infrastructure is where the physical resources are used to build virtual services.
NF	Network Function: each function includes a set of network-related operations
MANO	The Management and Orchestration unit takes care of controlling and managing the NFV system.
VM	Virtual Machine is an emulation of a computer system and its functionality.
VIM	Virtual Infrastructure Manager manages and controls the infrastructure in NFV systems.
VNF	Virtual Network Functions are virtual implementations of network functions.
VDC	Virtual Data Center is a pool of cloud infrastructure resources specifically designed for enterprise business needs
VME	Virtual Machine Environment is the environment where VMs are created.
VNFC	Virtual Network Function Component: a set of these components together create a VNF. Every VNF in any NFV system should contain one or more VNFCs.