Network Functions Virtualization (NFV) for Next Generation Networks (NGN)

Summary

Network Functions Virtualization (NFV) has drawn industry attention. Network Virtualization aims to transform mobile network infrastructure, from dedicated hardware and network equipment into a cloud based system built by general purpose equipment. It offers significant flexibility to provision the infrastructure with different services including 4G, WiFi, and next generation services. Also, it reduces capital expenditure (CapEx) and operational expenditure (OpEx). In this paper, several key technological concepts will be introduced: Network Functions Virtualization (NFV), Software Defined Networking (SDN), and orchestration. Technical challenges such as system/network architecture performance, and management will also be discussed.

Contact us:

Address: Rm 310-318, 3/F, Lakeside 2, 10 Science Park West Avenue, Hong Kong Science Park, Shatin, Hong Kong

Tel: (852) 3406 2469

Email: info_ct@astri.org

Acronym

ASTRI	Applied Science and Technology Research Institute
ATCA	Advanced Telecommunications Computing Architecture
DPACC	Data Plane Acceleration
DSC	Dynamic Service Chaining
EPC	Evolved Packet Core
GW	Gateway
HA	High Availability
IMS	IP Multimedia Subsystem
IPSec	Internet Protocol Security
LTE	Long Term Evolution
MANO	Management and Orchestration architectural framework
NFV	Network Functions Virtualization
NFVI	Network Functions Virtualization Infrastructure
OPNFV	Open Platform for NFV
SDN	Software-Defined Networking
SFC	Service Function Chaining
VM	Virtual Machine
VNF	Virtual Network Function

Concept of NFV and SDN

Some key technologies are driving the transition from today's network infrastructure into a cost-effective virtualized solution. The two most important technologies are NFV and SDN.

1) **Network Functions Virtualization** (NFV) is a network architecture concept that proposes using IT virtualization related technologies to virtualize entire classes of network node functions into building blocks that may be connected, or chained, to create communication services[1]. FIGURE 1 shows the vision for Network Functions Virtualization by ETSI[2].

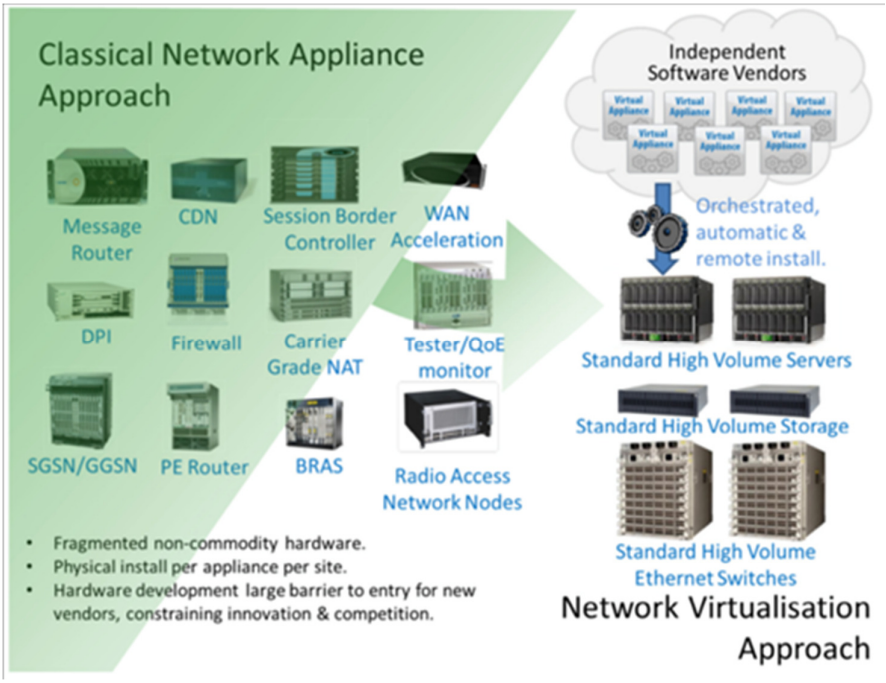


FIGURE 1 Vision for Network Functions Virtualization by ETSI[2]

NFV decouples network functions from underlying hardware. Instead of installing and operating a dedicated appliance to perform the network function, NFV allows operators to simply load the software image into a virtual machine (VM) on demand.

2) **Software-defined networking** (**SDN**) is an approach to computer networking that allows network administrators to manage network services through abstraction of lower-level functionality. This is done by decoupling the system that makes decisions about where traffic is sent (the control plane) from the underlying systems that forward traffic to the selected destination (the data plane). The inventors and vendors of these systems claim that this simplifies networking[3]. FIGURE 2 highlights the concept of SDN.

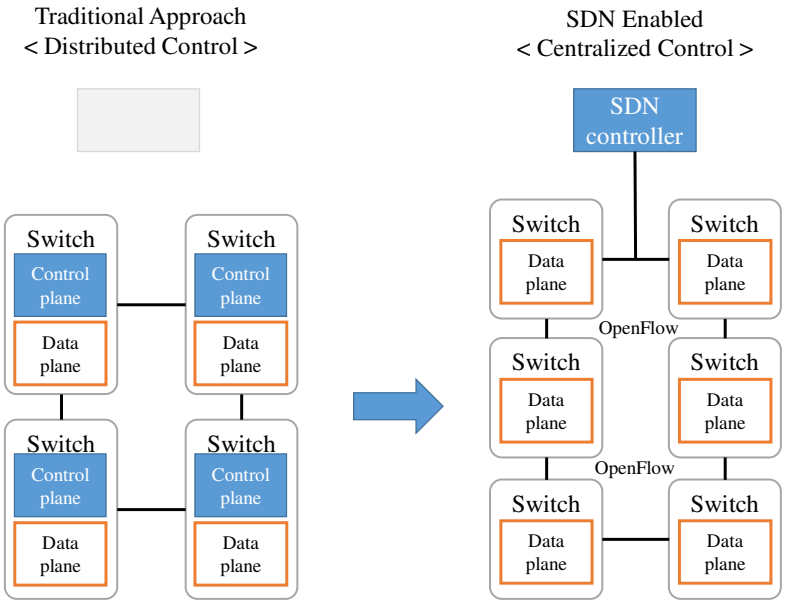


Figure 2 Concept of Software-Defined Networking

Software defined networking (SDN) has the following fundamental characteristics:

1. The separation of the control plane and data plane;
2. Centralized network controller. Since control of the network is decoupled from forwarding hardware, that allows a logically centralized software program to control the behavior of an entire network;
3. Another key to SDN's success, is that the network can be programmed so that SDN has a very flexible and dynamic traffic forwarding pattern.

NFV and SDN technologies are complementary. Both have similar goals but approaches are different. While SDN simplifies network infrastructure and giving flexible control, NFV works to improve service agility. Both lower the cost in deployment and operation.

- SDN needs new interfaces (e.g. OpenFlow[1]), and control modules.
- NFV requires moving network applications from dedicated hardware to virtual containers on commercial-off-the-shelf (COTS) hardware.

NFV Benefits

The demand of ever-increasing mobile traffic pushes operators to consider how can provide new services including scaling the network capacity more quickly with efficiency and low

[1] https://en.wikipedia.org/wiki/OpenFlow

cost. Operators must offer new and innovative services to drive revenue and stay competitive. Also they have to deliver these services quickly with cost under control.

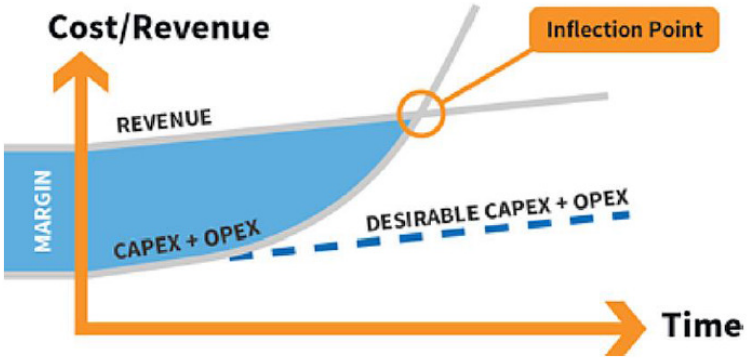


Figure 3 Projected revenue vs. cost structure of service providers (Intel)[5]

In telecom industry, each generation of operator's networks has its dedicated hardware and network infrastructure. Services are coupled to these hardware equipment and physical network topology. To launch a new service often requires another variety of dedicated hardware & changing the network topology. This is costly and complicated.

The concept of NFV is about to do network functions in software. It is one of the emerging technologies which leverage IT cloud computing and server virtualization techniques. NFV will enable operators to deploy network services dynamically in software without having to make changes to network at the hardware level. You can spin up a virtual network like you can spin up a virtual machine.

The virtual networks can reuse physical resources, and offer the flexibility of providing various virtual network functions, for example NAT, DHCP, load balance, and firewall, security appliance. That also greatly simplifies the underlying physical network as it only need to provide L2/3 connectivity.

SDN and NFV have been viewed as the technological trends for Telecom industry. SNS Research predicts that "the SDN, NFV and network virtualization market will account for nearly $4 Billion in 2014 alone. …further growth at a CAGR of nearly 60% over the next 6 years. By 2020, SDN and NFV technologies can enable service providers (both wireline and wireless) to save up to $32 Billion in annual CAPX investments".**Error! Reference source not found.** Maravedis Rethink forecasts that "the combination of these two platforms (NFV, SDN) will transform the carriers' networks, cost bases and service delivery …, and by 2018, over 72% will have implemented NFV in some elements of their commercial networks".**Error! Reference source not found.**

NFV Architecture and Use Cases in Mobile Network

The European Telecommunications Standards Institute (ETSI) has defined the NFV framework which consists of three main components:

1. **Network function virtualization infrastructure (NFVI)** is the totality of all hardware and software components which build up the environment in which VNFs are deployed. The NFV-Infrastructure can span across several locations. The network providing connectivity between these locations is regarded to be part of the NFV-Infrastructure.
2. **Virtual network functions (VNF)** are software implementations of network functions that can be deployed on a NFVI.
3. **Network functions virtualization management and orchestration architectural framework (NFV-MANO Architectural Framework)** is the collection of all functional blocks, data repositories used by these functional blocks, and reference points and interfaces through which these functional blocks exchange information for the purpose of managing and orchestrating NFVI and VNFs.

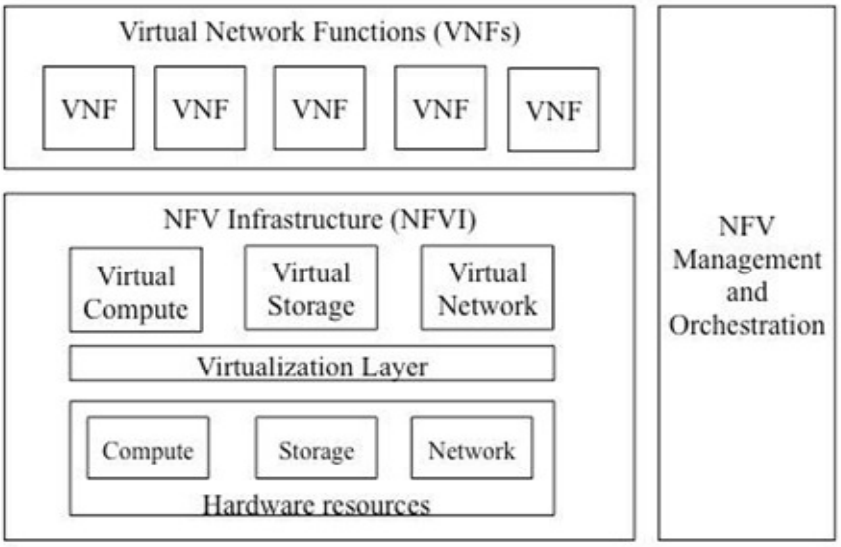


Figure 4 Simplified ETSI ISG defined NFV framework[6]

In summary, the building blocks for both the NFVI and the NFV-MANO is the NFV platform. In the NFVI role, it consists of both virtual and physical processing and storage resources, and virtualization software. In its NFV-MANO role it consists of VNF and NFVI managers and virtualization software operating on a hardware controller. The NFV platform implements carrier-grade features used to manage and monitor the platform components, recover from failures and provide effective security - all required for the public carrier network.

Examples of VNFs in mobile network include: Security (IPsec) Gateway, LTE Small Cell Gateway, EPC, IMS, baseband function of mobile base station, etc.

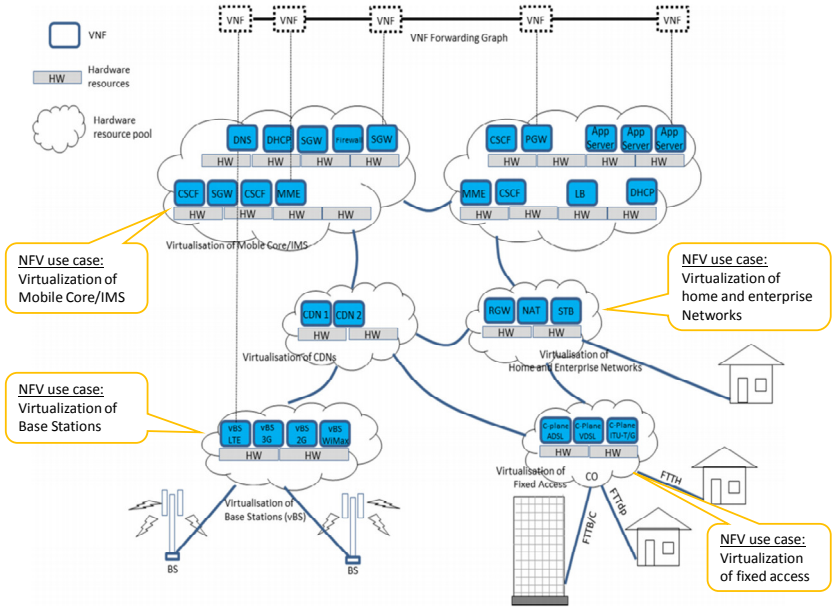


Figure 5 Overview of NFV use cases[7]

Challenges

While the market potential looks very good, network virtualization introduces new challenges. In this section, we will describe two key challenges for implementation of virtual network function (VNF) in NFV architecture: (1) Performance in NFV platform, and (2) Dynamic Service Chaining (DSC).

(1) Performance in Virtual Platform

Performance is a big challenge in NFV environment due to immature technology in NFV. The performance of virtual network functions (VNFs) is not yet equivalent to today's built-for-purpose products, or even sufficiently close to it.

Network Functions Virtualization inherently introduces overheads that lead to some level of application performance degradation compared to a non-virtualized environment.

Since the NFV approach aims to use general purpose server which is typically low-cost, the implementation of virtual network functions may fail to provide the required performance due to additional overhead required in a virtual infrastructure. For example, data packets traveling in the

network may be delayed by unnecessary routing through the OS, and hypervisor etc., resulting performance degradation of the VNFs.

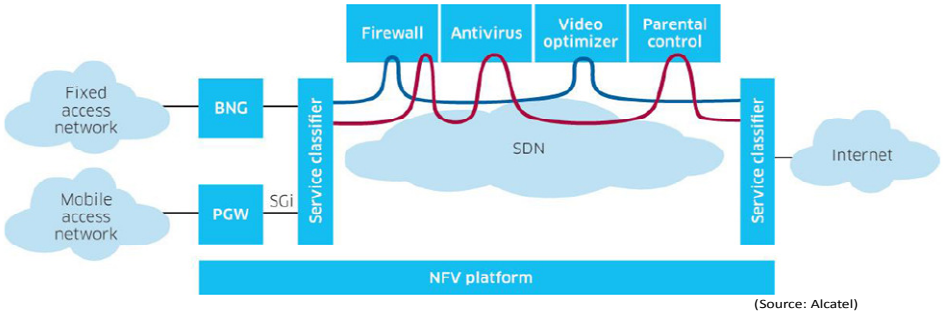
Reliability is also an unknown quantity and must be approached with a fundamentally different mindset.

(2) Dynamic Service Provisioning

As dynamic service provisioning is a requirement in NFV, one of the challenges is how to seamlessly coordinate between service manager, orchestrator, service application and network infrastructure to provide dynamic service provisioning.

Service Function Chaining (SFC), as a networking technology in NFVI, aims to provide the dynamic service provisioning. SFC provides the ability to define an ordered list of a network services (e.g. firewalls, load balancers). These service are then "stitched" together in the network to create a service chain[8].

As an example, the figure below provides an example of two different SFCs: the blue service chain includes two functions (firewall and video optimizer), and the red service chain includes three functions (firewall, anti-virus and parental control). As the number of SFCs increase, it will require more sophisticated orchestration among network services, network functions and the underlying infrastructure. Thus, while network virtualization promises to streamline operations, the short-term effect actually could increase the overall system complexity.



An end-to-end network service can be defined as a service chain (a sequence of VNFs)

- Virtual Appliances are not in a fixed physical location
- Packets may need to traverse some links multiple times
- Need to be able to distinguish between “before” and “after” a service
- What the logical packet flow should be and how to determine the service path

Figure 6 Service Function Chaining (SFC) for dynamic service provisioning

(3) NFV Network Operation and Management

With the approach of NFV and SDN, service providers can assemble service function chains through software configuration without physically installing appliances and without rewiring or manually-reconfiguring network connectivity.

However, services now become applications running on virtual machines. This raises several challenges. Firstly, since all virtual appliances are in the cloud (not in a fixed physical location) and may be dynamically located, mechanisms are required to locate (dynamically) the VMs carrying on the service tasks. Secondly, there is a lack of mechanism to distinguish between "before" and "after" a service. In addition, packets may need to traverse some links multiple times. How a service path of a logical packet flow can be determined?

ASTRI's NFV Technologies

ASTRI has developed production-ready mobile core network solution

1. Evolved Packet Core (EPC)
2. LTE Small Cell Gateway
3. Security (IPSec) Gateway
4. WiFi Access Controller (AC)
5. WiFi/4G Convergence Gateway
6. FastGate - ASTRI's multicore packet process software (gateways enabling module)
7. Network Management System

Moving forward, ASTRI's technology roadmap will focus on the following aspects:

- to enhance virtualization layer networking performance to meet Telecom needs,
- to provide VNFs of EPC, Small cell GW, Security gateway, and WiFi AC etc.,
- to support orchestration for dynamic provisioning.

ASTRI is working on providing virtual network functions including EPC, Security (IPSec) Gateway, WiFi AC, and Network Management Functions. We are also supporting NFV open standards, for example ASTRI is a contributor in the OPNFV DPACC project.

Figure 7 highlights ASTRI's existing wireless core network software solution and the roadmap.

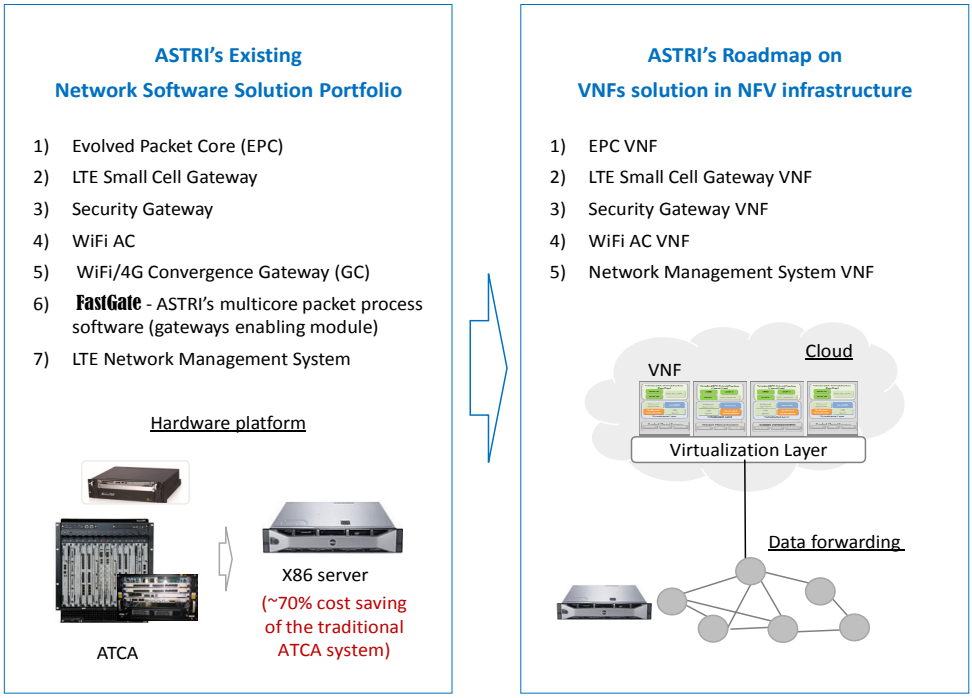


Figure 7 ASTRI's wireless Core Network Solution and Roadmap

We have developed VNFs of both LTE security gateway and small cell gateway with high performance and High Availability (HA).

Moving forward, our technology roadmap will cover the following areas:

- To implement NFV/SDN infrastructure platform
- To enhance virtualization layer networking performance to meet Telecom needs.
- To provide VNFs of EPC, Small cell gateway, Security gateway, and WiFi AC, etc.
- support orchestration for dynamic service provisioning

We are actively cooperating with mobile operators, hardware/software vendors, and platform providers to provide commercial NFV solution for mobile networks.

Please refer to our website (http://www.astri.org/) for more information about ASTRI's SDN/NFV technologies.

Reference

[1] http://en.wikipedia.org/wiki/Network_Functions_Virtualization

[2] https://portal.etsi.org/nfv/nfv_white_paper.pdf

[3] http://en.wikipedia.org/wiki/Software-defined_networking

[4] SDN control plane idea from the Metis Files

[5] Intel: End-to-End NFV - vEPC Service Orchestration

[6] "Inside NFV, SDN & the Emerging Network", http://www.eetimes.com/author.asp?section_id=36&doc_id=1320009

[7] NFV White Paper2, ETSI, https://portal.etsi.org/NFV/NFV_White_Paper2.pdf

[8] https://wiki.opendaylight.org/view/Service_Function_Chaining:Main