Network Function Virtualization - A Survey

Shivam Pandit
Clemson University
pandit@clemson.edu

***Abstract*—Diverse network components lead to increased operational costs leading to problems in network maintenance and scalability. Network function virtualization is proposed to overcome this issue by rather than having hardware-based networking functions to software-based networking function which eases implementation and maintenance in long run while decreasing costs exponentially. NFV improves flexibility of the network by decoupling hardware from software implementation. Since, it is still in early phase leading to many issues that needs to be addressed like ensuring network performance. Integrated with SDN it leveraged full power of the network by separating control underlying hardware. In this survey paper, we will be discussing main techniques, issues and problem with future trends in the field of SDN.**

I. Introduction

Since legacy hardware components in networks is becoming larger and more complex leading to difficulty in adding or upgrading services, there was a need to have a simpler, robust and more flexible network. For the same, network function virtualization (NFV) was proposed with other supporting and similar technologies such as software defined networking (SDN) along with the cloud computing. NFV transformed the network by taking networking functions out from propriety hardware components to decoupled software units through virtualization. Best part of virtualization of network functions is that there is no need to install new equipments to handle new functions, but software virtualization techniques handles that which can be instantiated on demand. NFV architecture is shown in Fig.1 with virtualized network functions (VNF) deployed on Network Function Virtualization Infrastructure (NFVI) layer that decouples and partitions the hardware and software implementation. Hypervisor layer enables virtualization with every VNF mapped to VM in NFVI.

The deployment on any function on NFVI is handled by Management and Orchestration System which enables activation of functions remotely. NFV orchestrator controls network services while as VNF manager controls VNF. The software implementation of network functions helps in managing network easily while removing many additional costs associated with the addition of new devices to handle that. For example, in cellular networks NFV can make network functions to implement on legacy hardware thus giving a a low-cost agile network infrastructure. Moreover, it can bring other benefits to telecom operators like bringing capital and operational expenditures significantly down. Also, since network functions are not hardware dependent any innovation or upgradation will just need few changes on network function layer that can be remotely activated to give desired networking operation. NFV architechtural framework is shown in Fig. 1 with all its components. Though, we can see many advantages in NFV implementation there are still some bottlenecks like network performance that is very important factor for any network usability.

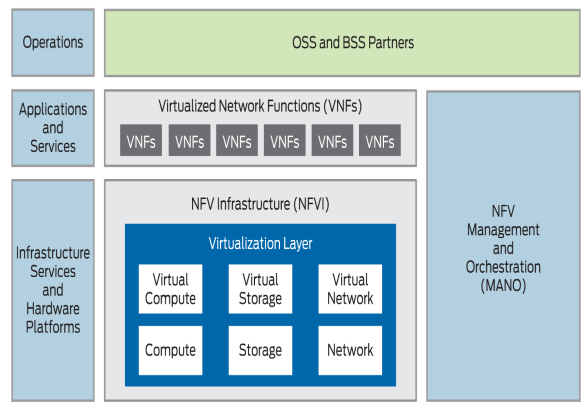

Fig. 1. NFV architectural framework

Network performance remains a critical point of concern while considering NFV since there are technical challenges when deploying virtual network functions and it adds to abnormal latency variations leading to poor network performance. One more concern is the migration of legacy systems to NFV systems without any downtime of the network. Since network is complex and large, migrations are not smooth and easy. The separation or decoupling of underlying hardware and software-based network function creates problems like dynamically instantiation on demand. Rise of acceptability of SDN has led to the foundations of NFV by adding more abstractions in the network architectures. Not only SDN and NFV made network flexible but also reduced costs of network exponentially. Control and management of network became way easier than earlier legacy network. SDN along with NFV can address resource management and intelligent service orchestration.

NFV also enable dynamic packet forwarding. Software defined network function virtualization utilizes centralized functions based on software units on top of hardware through hypervisors to minimize the operational and capital costs while maximizing network utilization. Since, centralized implementation of software functions on the top of hardware equipments eases network operations it opens roads for more innovation without worrying about underlying hardware. This also reduces any possibility of human error while installing services as a software than hardware. Any hardware implementation reduces much testing, validation and verification before deployment on production stage. Service chaining is one important area that simplifies service chain deployment with easier and cheaper services in the network. Earlier networks used to have separate hardware components offering different services like lad balancers, intrusion detection systems, etc. This not only made network inflexible to innovation but also increased costs manifold. This also leads to errors in deployment of new hardwares that should be avoided to decreases operational costs.

II. Main Techniques

Virtualization enables flexible network leading to more scope more innovations in networks. Currently networks have these network functions implemented in a astatic way NFV enables use to use network functions dynamically through virtualization of network functions as a software running on current hardwares through hypervisors. As already discussed, service chaining plays a very important role by administering the services remotely without any complexity. We can also merge several VNFs to make one that provides many services reducing management complexity. This levels of abstractions of network also lays foundations for cloud-based computing. Compared to existing networks, NFV proposed 3 major additions in terms of services.

- Hardware and software separation: The concept of virtualization and virtual network functions decoupled hardware and software to evolve and innovate independent of the other.
- Flexible network function deployment: NFV enables to remotely deploy network function software through hypervisor which run on underlying hardware that may be in different data centers in different locations.
- Provisioning services dynamically: NFV helps to scale the network through dynamic resource allocation based on network topology and conditions. So, based on need network operator can scale network up or down without worrying about underlying architecture.

There are 4 major components in NFV architecture including VNF manager, network orchetstrator, virtualization layer and infrastructure manager as shown in Fig. 1. All these components are having important role in implementation of NFV. The network orchestrator manages and orchestrates network resources. VNF manager performs events associated with VNF like instantiation, termination or scaling of the services. The virtualization layer runs through hypervisor and abstracts the underlying resources acting as a bridge between network function and hardware components. It also ensures VNF is independent of underlying hardware.Lastly, the infrastructure manager is the component block in control of network including network functions, resources and storage resources through virtual machines. It is also responsible for managing network connectivity and fixing any root cause of issues related to network performance as well as optimization.

A. SDN based NFV system

NFV and SDN complement each other as both help each other in enabling required operations. NFV virtualizes SDN controller and act as SDN whereas SDN can connect VNFs providing connectivity which is programmable to act as NFV. Fig. 2 shows SDN based NFV system. Though, they share some similarity they have differences in system architectures. NFV implements network functions in software manner and SDN achieves centralized programmable network architectures. NFV aims at reducing costs of network operations and SDN aims at enabling abstractions for flexible network.

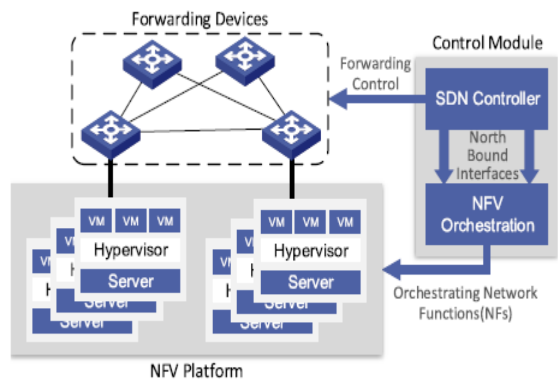

Fig. 2. SDN based NFV system

NFV separates network functions from underlying hardware whereas SDN decouples control plane from data plane for better control of the network and global view. Fig 2 shows SDN based NFV system. We can see control module, NFV platform and forwarding devices that make up the system. SDN controller manages packet forwarding and manages forwarding tables. OpenFlow is one of the efficient protocols commonly used in SDN implementation. NFV platform takes powers of existing servers to implement network functions through hypervisors at low cost. Middleboxes are also important component that runs network functions in programmable data plane includes IDSes, firewalls, etc. Network functions are more of a software that run and take services from hardware.

B. MiddlleBoxes:

MiddleBoxes are network appliances in the data plane of the network and has various functions like forwarding of the traffic, filtering of traffic, managing of traffic, etc. MiddleBoxes implement network services either through static hardware-based network functions or dynamic virtual network functions deployed through hypervisors. MiddleBoxes include

Network Address Translator (NAT), Firewalls, Intrusion Detection Systems, or Load Balancers. These are most common middle boxes in almost every network implementation.

1) Intrusion Detection System (IDS):: IDS is deployed to monitor traffic and raise alarm when it finds any anomaly that can be related to security or even sometimes false alarms. So, decision is required to see if anomaly is threat or normal data flow.

2) Load Balancer:: Load Balancer is very important to ensure traffic doesnt overload some server. These devices distribute traffic across servers to minimize response time and optimize network performance

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4) Flow Monitor:: This middle box is deployed to monitor network traffic flow and performs network troubleshooting. Data centers mostly have these components.

5) Network Address Translator (NAT):: NAT is deployed to enable private devices to connect to public devices on internet by replacing the IP addresses of the packets traversing through it. It is used when same IP address is used by multiple devices like many hosts connected to a router that assigns them a private IP address and later replaces that IP address for connection.

6) Firewall:: Firewall enforces security policies by allowing and rejevting packets based on the firewall rules. These rules can be checked in session or application layer.

7) Network Optimizer:: Network Optimizer shorten network transmission latency and are normally deployed at network end points to send and receive data at optimized network usage.

III. Issues and Problems

Though NFV has immense benefits for network as it enables innovation for network operators, it still has some issues and problems which will be discussed now.

A. Function Virtualization:

The virtualized function needs to be optimized for the best network performance since hypervisors are not actually network performance friendly since they add abstractions which reduces performance of the middleboxes. Also, these middleboxes should support multiple hosts running their services concurrently.

B. Portability:

The NFV should be portable in the sense that VNFs can be deployed across different servers in diverse environments. High performance is required at middleboxes and ensuring VNFs are not hardware dependent.

C. Reliability:

Reliability is always most important factor that determines the usability of any service. Network should be reliable with minimum failure rate and backup and troubleshoot mechanism in case of failure. Migration to NFV shouldnt cause any network downtime since moving from hardware based static implementation to dynamic virtualized implementation can be error prone.

D. Service Chaining:

NFV based on SDN has immense potential to monitor traffic as well as ensure flexible network implementation while minimizing implementation and operational costs. Services are deployed and service chaining plays important rule in configuring services as network functions via network controllers. Fig 3 shows service chaining process where user policies as are inputs, and efficient routing is selected via network functions while ensuring resources constraints. These network functions are chained and invoked on demand. Physically moving network across locations has high costs associated with it but SDN based NFV can do the same through creation of new chains called service chaining without changing hardware that is error prone.

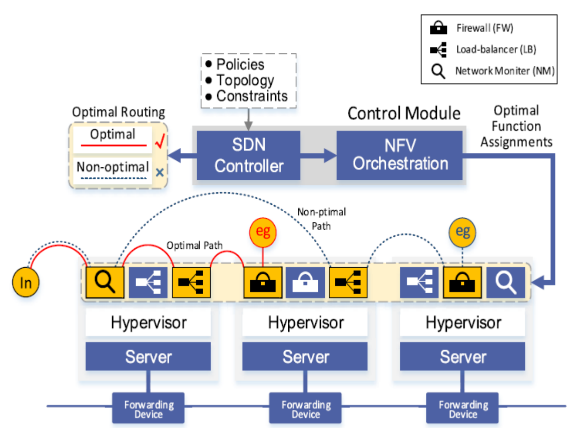

Fig. 3. Service chaining in SDN based NFV system

E. Stability:

This is related to reliability only but focuses more on continuity of the network like network components or network functions should execute in a stable way even after moving from different network components. This also means to ensure specific network feature indicators to there optimum values.

F. Manageability:

NFV should ensure networks are manageable in the sense that they can be instantiated from control locations without any issues. Since network can comprise of many different network components from different vendors that are not equivalent. The management functionality of middleboxes ensure that despite multi-vendor network components and network functions, there should be optimized network performance. Also, network loads of different volumes shouldnt affect the network availability.

G. Traffic Forwarding:

SDN based NFV though simplifies network control by decoupling data and control layer. There is a centralized forwarding policy with rules that control that. Many research and work is being done towards having efficient traffic forwarding in SDN based NFV system. Though, these systems usually are scaled up by adding new networking components, that makes it tricky to solve the optimization problem since the policies need to change for accommodating new hardware components.

H. Performance:

Network performance is very important for any network and since in NFV based networks, virtualizations are introduced that are normally found to decrease performance has to be addressed first. The connections tend to be unstable for virtual appliances based on virtualization. There is one polling based approach that disables interrupts during high network load.

IV. Future Trends

NFV is seen as future of network implementation though lot of things needs to be addressed before it is seen as reliable enough to replace conventional network. It is still in dormant stage and many things including network performance, efficient scalability and interoperability among multi-vendor network components needs to be addressed before it become a success. Though concept wise it looks wonderful but there are still bottlenecks and new innovations that may need further refinement of the implementation. One popular service that NFV simplifies is cloud computing that focuses on having centralized computing infrastructure with all services virtualized that can be accessed by the client on demand. This makes it necessary to ensure it is free from failure as lot of business may be affected if cloud services get affected.

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