NOKIA

Introducing virtualized service routing

Network functions virtualization and optimization for cloud-era networks

Strategic white paper

In the cloud era, network operators are adopting network functions virtualization (NFV) to improve efficiency, agility, openness and linear scaling capabilities. This white paper discusses an evolutionary NFV strategy for IP services that leverages existing network investments and operational practices using the Nokia Virtualized Service Routing portfolio.

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Scope and objective

This paper introduces a new portfolio of virtualized service routing functions for deployment on x86-based virtualization platforms either on standalone servers or in data center environments.

The objective is to make the benefits of network functions virtualization (NFV) available to the IP services edge without requiring network operators to first rethink and retool their operations support system (OSS) processes and infrastructure. This will enable network operators to adopt an evolutionary NFV strategy to virtualize service routing functions that leverages existing network investments and operational practices.

The paper assumes the reader has a basic knowledge of networking and compute virtualization.

Rationale for NFV

Widespread adoption of cloud and web-scale IT technologies have enabled NFV, a development approach that leverages general-purpose compute and server technologies to perform network functions that were previously only available on proprietary, chassis-based network appliances powered by custom application-specific integrated circuits (ASICs) such as Nokia FP3.

NFV and its cousin, software-defined networking (SDN), aim to create better cost and interworking synergies between the worlds of data networks, data centers and IT technology, and are driven by both web-scale operators such as Google, Facebook and Amazon, and network operators such as AT&T, Verizon and Telefónica.

Web-scale operators need to seamlessly interconnect their applications, data centers and clients they serve across WANs. Network operators aim to add value in the cloud era by operating and monetizing their network as a service and augmenting network services with cloud infrastructure, applications and content. Different vantage points lead to slightly different views on network implementation and cloud integration, but NFV and SDN are two key architectural concepts that feature prominently in both network- and cloud-centric business strategies.

Data communication networks and the applications using them traditionally operate in different planes of existence. A data communication network sees applications as just a number of TCP or UDP traffic flows between a set of IP addresses. For applications, the network is just a call to an input/output (I/O) library function in order to connect to a remote application process.

NFV essentially considers network functions such as IP routing as just another application that can run on a server, whether centralized in a data center or decentralized as part of the network. The potential benefits of NFV have been discussed in several publications, and chiefly relate to improving efficiency, agility, openness and linear scaling capabilities by decoupling and virtualizing network functions and deploying them on commodity server platforms based on Intel x86 processor technology.

However, to view NFV as merely the porting of network functions from proprietary, chassis-based appliances to server-based computing platforms would be an oversimplification that understates both the potential benefits and the challenges.

NFV deployment requirements

Most network functions are by nature distributed and must adhere to specific field deployment constraints such as available space and power, unattended operation and variable climate conditions. This is reflected in purpose-built appliances such as radio access nodes, broadband access multiplexors, optical transport systems, IP routers and Ethernet switches.

These appliances are often powered by custom ASICs, which are extremely energy efficient with high-density form factors and carrier-grade availability. Cloud applications, by contrast, are typically not location dependent and can be centralized at locations where power, cooling and space are available at a discount.

This focus on hardware optimization may obscure the fact that the vast majority of R&D spent on routing and switching equipment is software related, notably the network operating system. This number is even higher when considering the additional cost of developing the network management and OSS application software needed to support network operations. When virtualizing and deploying network functions and applications, it is important to consider some of the fundamental differences with mainstream IT and cloud applications.

IT applications typically run in some type of sandbox or container, in a trusted environment with massive redundancy that is inherently safe and walled off in a demilitarized network zone. If an application process or its server fails, it simply re-boots on another CPU and picks up where the previous process left off.

By contrast, network functions operate in open environments that are inherently untrusted and vulnerable to various security threats and forms of attack. Compromised network functions may cause network-wide performance degradation or loss of connectivity. Network functions operate in open, networked ecosystems and typically perform mission-critical tasks with real-time processing requirements. Network functions must comply with many different interworking and management standards and must support non-stop operation. When network functions perform slowly, they can inadvertently trigger alarms and restoration actions.

Therefore, interworking, performance and regression testing plus threat analysis are paramount in developing and validating network functions that are reliable and secure. Many or most of the current requirements and application benefits remain valid; in addition, NFV also adds a number of new advantages:

- Enables a more elastic and on-demand deployment model in which hardware platform resources can be dynamically allocated and shared among a broad catalog of network functions. This improves investment protection, service scaling efficiency, velocity and, ultimately, revenues.
- Leverages proven software development principles and integration techniques to disaggregate networking applications into well-defined building blocks and software modules that can be combined into large-scale, distributed systems and solutions.
- Facilitates an open, IT-based integration environment in which multiple vendors can contribute compatible and interchangeable network functions that interwork in open cloud environments. Nokia participates in various work groups in the IETF, ITU, ETSI, ATIS and MEF, as well as industry forums such as ONOS, that are actively engaged to create the necessary APIs and integration frameworks required for multivendor cloud interoperability.
- Complements and enhances existing, chassis-based network infrastructure with virtualized deployment options and the flexibility to choose the most appropriate hardware platform (virtualized or purpose-built) to balance cost, performance and time-to-market objectives.

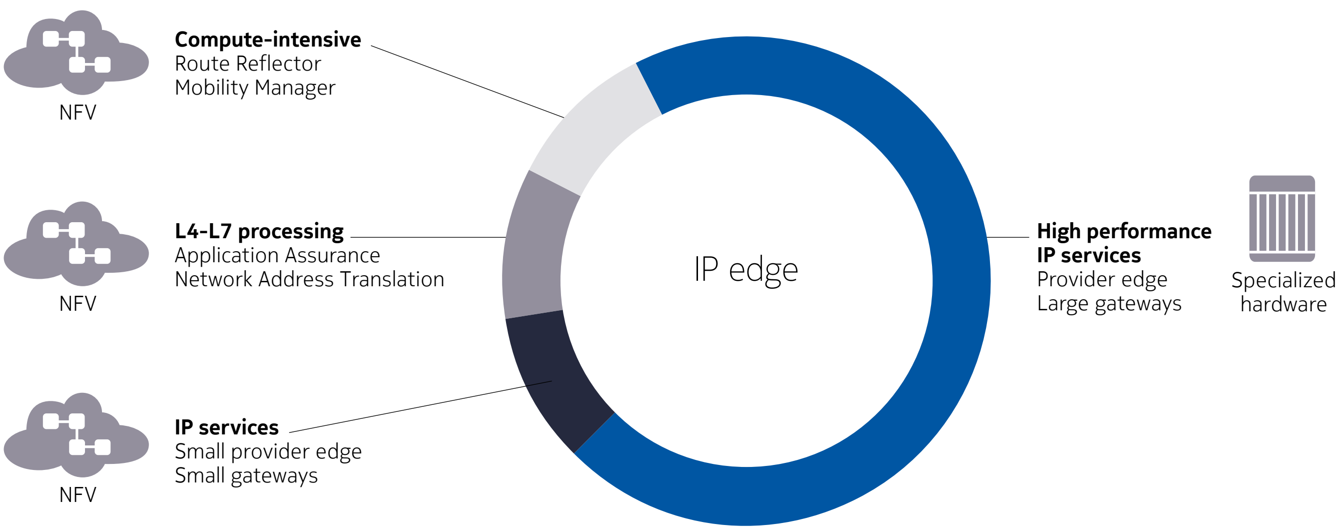
Nokia's approach makes the benefits of service routing available to cloud-based virtualization environments without network operators needing to first rethink and retool their OSS processes and infrastructure. This offers network operators the opportunity to adopt an NFV-based solution strategy in an evolutionary manner that leverages existing network investments and operational practices.

NFV deployment opportunities

NFV is primarily a task of adapting and optimizing network functions to virtualized server environments because the pre-existing requirements for networked operation, high availability, real-time performance and iron-clad security remain the same. As is common in chassis-based appliances, a virtualized router must also separate between control plane and data plane functions because they have different scaling requirements.

While compute-intensive control plane functions such as routing and path computation and L4-L7 flow processing functions lend themselves extremely well to virtualization using NFV approaches, the physical and logical data plane functions and IP forwarding services in broadband access, optical transport, and aggregation and core routing systems may continue to require specialized hardware (see Figure 1). Even network functions that are available on a virtualized platform may also be required on chassis-based appliances to meet location-specific system scaling and environmental requirements.

Figure 1. Candidate network functions for virtualization



As a result, conventional chassis-based network appliances and virtualized network functions (VNFs) will coexist and interwork for the foreseeable future. The need for coexistence follows from the inherent complementarity of these hardware platforms in addressing operational requirements. Most network operators will be unable to satisfy all networking needs using only one type of platform, and not all network functions will become virtualized in the same time frame.

Nokia's network functions virtualization-and-optimization approach enables operators to leverage prior investments in dedicated network infrastructure, services and operational support infrastructure as a launch platform for NFV applications and cloud-enabled services infrastructure.

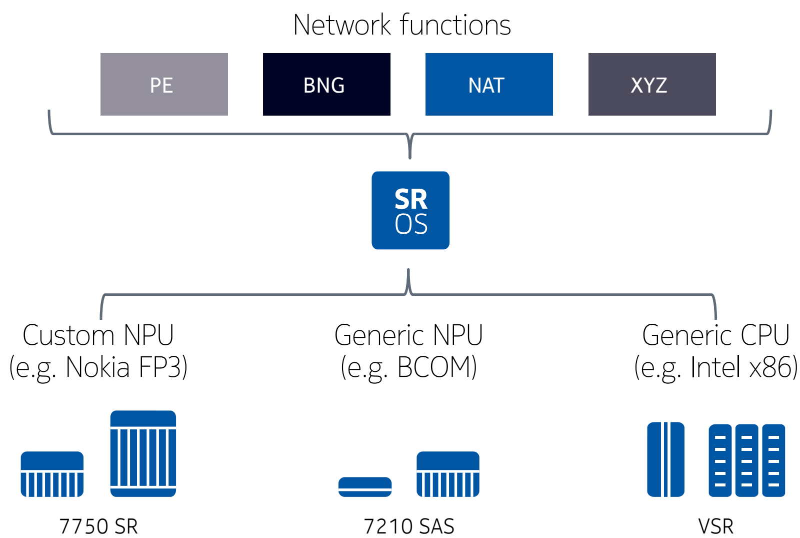
Hardware platform optimization

Like any other software, VNFs require an underlying hardware platform to run on. Optimizing NFV performance is a critical factor in determining the actual hardware cost of running the VNF. The difference between a great VNF implementation and a good one is like the difference between LED and incandescent bulbs—great VNFs deliver the same performance using a fraction of the compute and power used by good VNFs.[1]

1 Steve Vogelsang. "The crux of the matter: NFV unplugged", April 25, 2016.

From that perspective there is no fundamental difference between VNFs executing on an Intel server and non-virtualized network functions running on a dedicated hardware appliance. Although dedicated network appliances such as the Nokia 7750 Service Router (SR) use custom ASICs such as FP3 to optimize data path functions, the SR operating system (SR OS) and the network functions it supports already run on several other hardware platforms that are powered by merchant silicon and general-purpose CPUs (see Figure 2).

Figure 2. Network function optimization for different hardware platforms



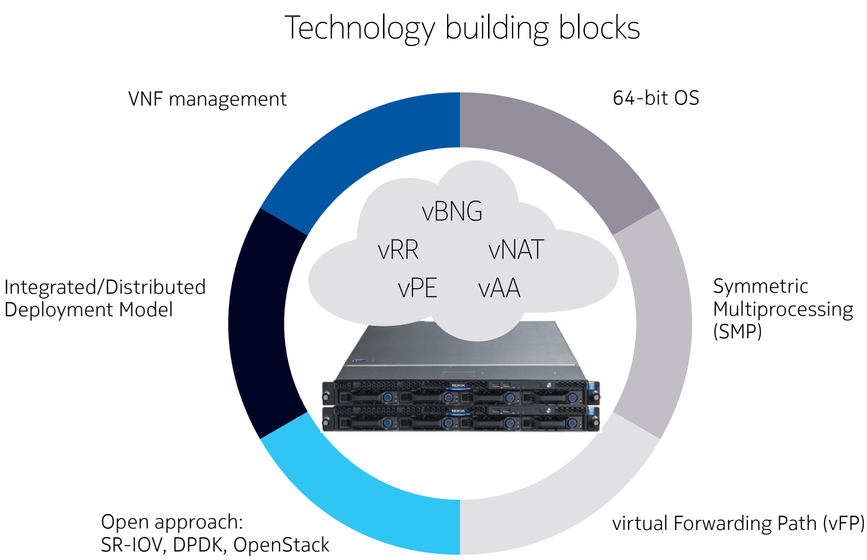
Also, like chassis-based network appliances, the Nokia Virtualized Service Router (VSR) runs SR OS and is managed by the Nokia 5620 Service Aware Manager (SAM) and the Nokia Network Services Platform (NSP).

The availability of network functions on multiple hardware platforms allows network operators to manage and optimize the virtualized and physical functions of their hybrid networks in a seamless manner. It provides a level of operational transparency and compatibility that eases the introduction of VNFs and aids the subsequent design, test, migration and evolution of new services that benefit from the sheer limitless scalability that web-scale computing platforms offer.

The Nokia SR OS has many innate capabilities that lend it well to compute virtualization (see Figure 3):

- Runs on a Linux 64-bit OS with multi-core symmetric multiprocessing (SMP)
- Virtualized chassis that supports both integrated and distributed deployment models
- Modular architecture with a clean separation of the control plane and forwarding path
- Complete set of network functions for residential, business and mobile applications.

Figure 3. Building blocks and enabling technologies for virtualization



The SR OS in the virtualized environment runs as a 64-bit guest OS of a wide variety of Linux distributions, including CentOS, Red Hat® Enterprise Linux® and Ubuntu. The VSR uses the KVM/QEMU hypervisor and is validated for use with the Red Hat Enterprise Linux Openstack Platform 7.

SR OS separates tasks that are allocated to the CPU into smaller tasks, called threads. These threads are then allocated to different CPUs or CPU cores. This process is called symmetric multiprocessing (SMP). This may take the form of splitting out tasks such as routing from the main OS and placing these tasks onto different CPU cores. Tasks can be subdivided over individual routing protocols, such as BGP, IS-IS and OSPF, and can even be further subdivided into individual tasks within each protocol.

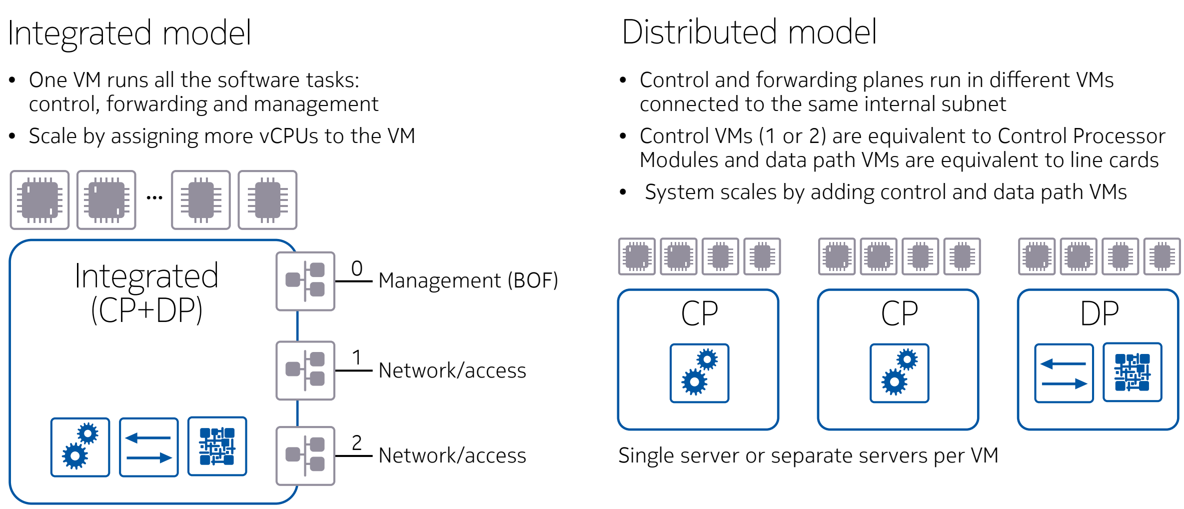
Each of these individual threads can be placed onto a separate CPU core and be processed in parallel, resulting in unrivaled performance. Because the number of CPU cores in a VNF environment is virtually unlimited, the application of SMP for virtualized SR OS applications provides outstanding processing capabilities.

The SR OS separates the control plane and data plane to accommodate deployment on a wide range of chassis-based systems. Examples include the Nokia 7750 SR, merchant silicon such as the Nokia 7210 Service Access Switch (SAS) and Intel x86 (for the Nokia VSR). The VSR leverages various I/O virtualization approaches, including VirtIO, PCI passthrough and single root I/O virtualization (SR-IOV).

Nokia has partnered with Intel to optimize how virtualized control plane functions can optimally interact with a virtualized forwarding plane, including I/O and storage functions. We are leveraging tools such as the Intel® Data Plane Development Kit (DPDK) with the application of poll-mode drivers or SR-IOV to maximize data plane performance in x86 environments.

The Nokia VSR implementation allows combining control and data path functions in a single integrated virtual machine (VM) or dividing the functions over multiple VMs and servers in a distributed model (see Figure 4).

Figure 4. Deployment options for virtualized SR OS network functions



The integrated deployment model enables placing individual standalone servers quickly and easily throughout the network to perform specific network functions and also enables the ability to replicate a specific function multiple times to increase network performance and improve scalability.

The distributed model brings with it the full power and versatility of virtualization:

- High availability: Brings carrier-grade and mission-critical routing features such as Non-Stop Routing, Non-Stop Forwarding and Graceful Restart to the virtualized environment.
- Hardware and software resiliency and redundancy: Allow each VSR control plane or data plane instance to be created in a single VM that can reside on separate servers or racks.
- Scale up/scale down: VSR systems can be configured to meet the exact CPU and memory required, and available resources can be dynamically modified to adjust to evolving demand.
- Scale in/scale out: Enables deploying and provisioning new VSR systems remotely and rapidly without needing to send an engineer on site.

Nokia Virtualized Service Router

The NFV approach is applicable to a variety of network functions, and Nokia is actively engaged to make all options available for its VSR. The functional specifications of these VNFs are similar to the equivalent chassis-based implementation.

The key VSR properties are described in the following sections.

Elastic

A VSR can run in a single VM or be distributed over multiple VMs to scale out data path and control plane functions. A VSR can be dynamically enhanced in scalability and functionality by adding vCPUs or VMs and configuring appropriate network function user licenses.

Versatile

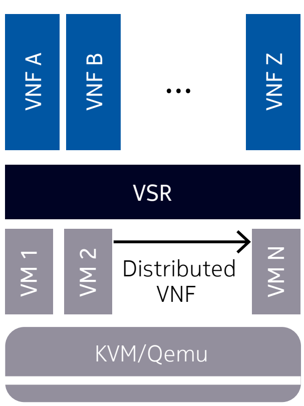
A VSR can be configured as a basic IP/MPLS provider edge (PE) or a full-fledged multiservice edge combining VNFs for residential, business and mobile services.

Flexible

Operators have the flexibility to combine one or several VNFs in a VSR system, and combine virtualized and physical service routers in the same network.

The VSR supports a broad catalog of network functions that can be configured for individual VSR system instances to perform a specific networking role for a specific networking application or for a selection of applications (see Figure 5).

Figure 5. Virtualized service routing catalog



VNF catalog
Provider Edge
Broadband Network Gateway
L2TP Network Server
Virtualized Residential Gateway
Wi-Fi Gateway
Security Gateway
CG-NAT Gateway
DPI Gateway
Route Reflector

VSR base system

The VSR base system provides the basic feature set of an IP/MPLS edge router with IPv4 and IPv6 support for common routing protocols: RIP, OSPF, IS-IS and BGP. The VSR base system can be enhanced with a number of additional service options:

- Advanced QoS: Hierarchical QoS support on the I/O VMs.
- VPN services: Enable L2 and L3 VPN services such as VLL, VPLS and VPRN.
- IP tunneling: For example, Generic Route Encapsulation.
- Lawful Intercept: For selected traffic.
- Data center gateway/service chaining: BGP EVPN control plane for L2/L3 traffic steering.

Virtualized network functions

The virtualized network functions are complementary functions and feature licenses that enhance and tailor a VSR system to perform one or more specific network roles:

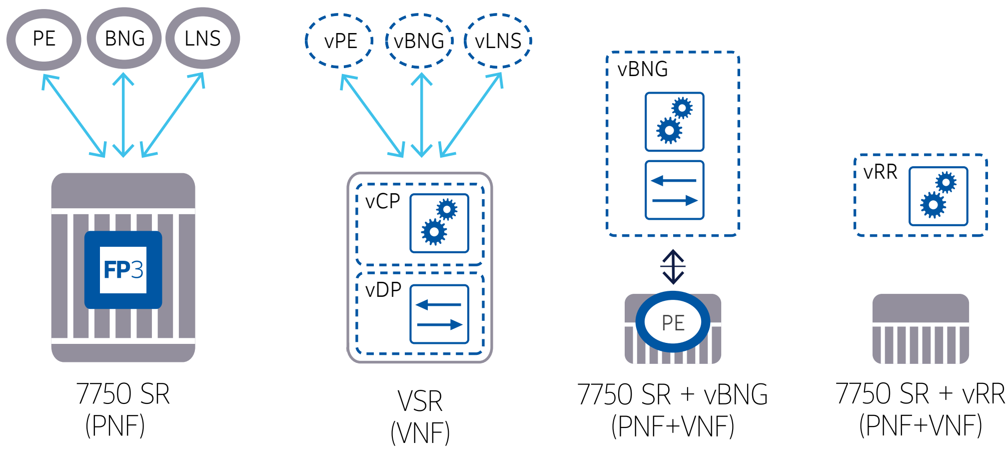
- Broadband Network Gateway (BNG) as defined in Broadband Forum TR-101.
- L2TP Network Server (LNS): PPP session termination L2TP tunnels for internet wholesale.
- Virtualized Residential Gateway as defined in Broadband Forum WT-317 NERG.
- Wireless LAN Gateway: Subscriber management for wireless LAN access points.
- Security Gateway: Secure IP tunneling based on IPsec.
- Application Assurance: Enables L4 to L7 visibility and intelligent, policy-driven control of IP applications.
- Network Address Translation (IPv4 private to public, to IPv6).
- Route Reflector (RR): Route Reflector for all BGP address families.

VSR deployment

The VSR uses the SR OS, which also powers the Nokia 7750 SR product family. This enables network operators to leverage the rich SR OS feature set that is field-proven in 700+ deployments and to manage VSR and 7x50 SR-based network functions using the same Operations, Administration and Maintenance (OAM) protocols and 5620 SAM management system.

Figure 6 shows how physical network functions (PNFs) and VNFs complement each other to optimize network deployment.

Figure 6. PNF and VNF use cases



The far left shows a traditional use case for a Nokia 7750 SR as a multiservice edge for residential, business and/or mobile services. This is a platform solution that is optimized for very high throughput and large subscriber and service scales.

To its right is the VSR, which provides the equivalent functionality on x86 server platforms with a virtualized control plane (vCP) and virtual Forwarding Path (vFP) functions. This solution enables decoupling specific network functions from physical network appliances and independently scaling individual network functions up or down as needed.

To the far right are two hybrid deployment scenarios in which PNFs and VNFs complement each other. For example, a 7750 SR acting as a PE router can be deployed in conjunction with a virtualized Broadband Network Gateway (vBNG). A virtualized Route Reflector (vRR) is an example of deploying virtualized control plane functions in combination with physical network appliances (core/edge routers).

Management and orchestration

NFV will expose network operators to equivalent requirements with respect to life cycle management and OAM as they face with their existing network infrastructure and OSSs. There is no magic that will make these requirements go away in the virtualized world, but there is a risk of reinventing the wheel and forgetting lessons learned in the past. It has taken the networking industry several decades and countless effort to establish the requirements, frameworks and interworking standards that are being used today to operate, administrate and maintain their current networks.

Even larger is the effort and investments it took to build the tools, infrastructure and operational processes that implement these management interfaces and integration standards in operational networks today. While there probably aren't many network operators that are satisfied with the cost and effort to build and maintain their current OSSs, there surely aren't any that would like to repeat the same exercise for the sake of NFV and cloud-based applications. Indeed, there is a widespread concern that NFV will expose network operators to significant system integration challenges that didn't occur with traditional vertically integrated network appliances.

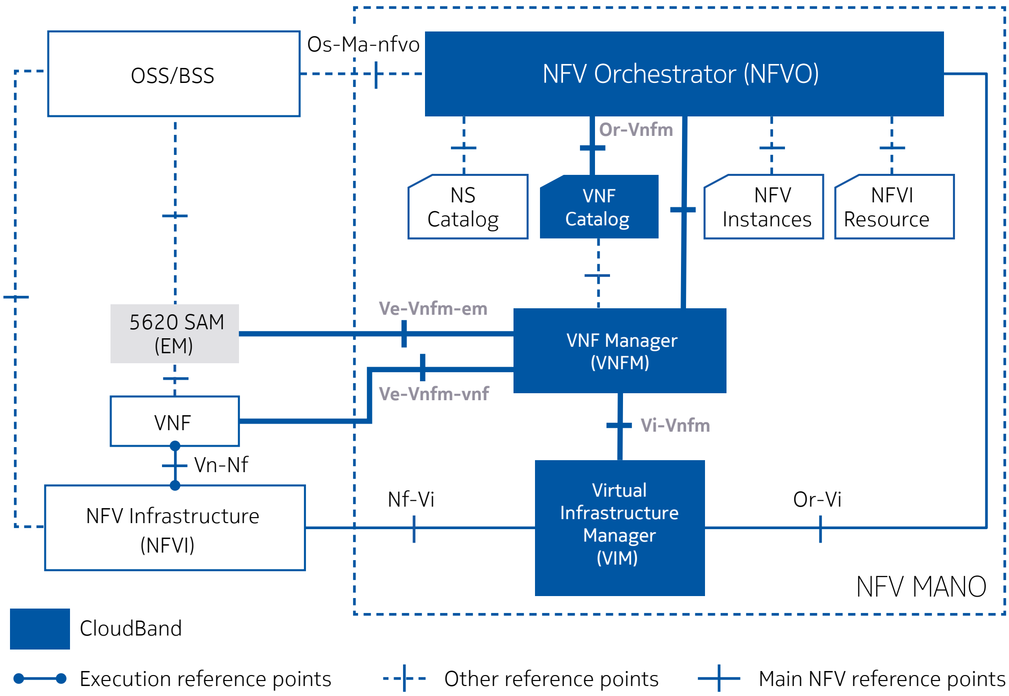
While new cloud- and NFV-specific management and operation tools are absolutely necessary, it is also mandatory to find an evolution path that preserves investments, avoids disruptive changes and provides continuity for existing customers and service revenues. Otherwise, the short-term and mid-term cost of NFV deployment will outweigh the potential benefits for all but the largest network operators.

Nokia is addressing these concerns in a number of ways. The Nokia VSR and supported VNF catalog leverages the proven technology, features and OAM capabilities of the SR OS and applicable cloud orchestration and NFV MANO standards, and is available on popular NFV hardware and software reference platforms. Nokia actively participates in various industry forums and consortiums to help create standards where needed.

The SR OS has been equipped with open SDN interfaces such as OpenFlow, NETCONF/YANG, PCEP and BGP/LS in combination with the Nokia NSP and the Nuage Networks™ Virtualized Services Platform to provide carrier SDN solutions for the WAN and data centers. Both SR OS-based appliances and VNFs can be seamlessly orchestrated using existing management tools such as the Nokia 5620 SAM. New state-of-the-art tools such as Nokia CloudBand™ complement the solution for NFV management and network operation (see Figure 7).

It will take some time before VNFs are as compatible and interchangeable as IP routers and Ethernet switches are today. The end-goal of NFV goes much further and aims to disaggregate network functions in virtual containers with a much finer level of granularity, and programmability through micro services and service chaining.

Figure 7. Nokia CoudBand and NFV MANO



Conclusion

NFV is a strategic architecture concept that leverages compute virtualization techniques to decouple network functions from underlying hardware platforms. In doing so, network operators can leverage generic x86 generalized compute hardware across their various network functions for elastic scaling of network functions and greater agility in deploying and operating new functions than conventional network appliances provide.

Nokia is a leader in NFV and SDN applications, and has virtualized and optimized its industry-leading Service Routing portfolio and broad catalog of virtualized network functions. This gives network operators more flexibility and freedom of choice than ever before in selecting deployment options that best meet cost and performance objectives, whether the option chosen is dedicated network appliances, VNFs or a combination of both.

The Nokia Virtualized Service Routing portfolio is compatible with our flagship 7750 SR portfolio. The VSR portfolio delivers class-leading performance and runs on Linux-based, open-source hypervisors and standard compute virtualization platforms. It is supported by comprehensive management and orchestration solutions in the form of Nokia CloudBand.

For more information about the Nokia VSR, please visit:

http://networks.nokia.com/products/virtualized-service-router

Acronyms

AA	Application Assurance
ACL	access control list
API	application programming interface
ASIC	application-specific integrated circuits
ATIS	Alliance for Telecommunications Industry Solutions
BGP	Border Gateway Protocol
BNG	Broadband Network Gateway
BSS	business support system
CPU	Central Processing Unit
DHCP	Dynamic Host Configuration Protocol
DPDK	Data Plane Development Kit
DPI	deep packet inspection
EANTC	European Advanced Networking Test Center
ETSI	European Telecommunications Standards Institute
EVPN	Ethernet virtual private network
IETF	Internet Engineering Task Force
I/O	input/output
IP	Internet Protocol
IoT	Internet of Things
IS-IS	Intermediate System-to-Intermediate System
ITU	International Telecommunication Union
KVM	Kernel-based virtual machine
L2TP	Layer-2 Tunneling Protocol
LAN	local area network
MANO	Management & Orchestration
MEF	Metro Ethernet Forum
MGW	mobile gateway
MPLS	Multiprotocol Label Switching
NFV	network functions virtualization
NPU	Network Processing Unit
ONOS	Open Network Operating System
OSPF	Open Shortest Path First
OSS	operations support system
PCE-P	Path Computation Element Communication Protocol
PCIe	Peripheral Component Interconnect Express
PE	provider edge
PIM	Protocol Independent Multicast
PNF	physical network function
PPPoE	Point-to-Point Protocol over Ethernet
QEMU	Quick Emulator
QoS	Quality of Service
RGW	residential gateway
RIP	Routing Information Protocol
RR	Route Reflector
SDN	software-defined networking
SMP	symmetric multiprocessing
SR-IOV	single-root I/O virtualization
SR OS	Nokia Service Router Operating System
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
VCF	virtual control function
vFP	virtual Forwarding Path
VLL	virtual leased line
VM	virtual machine
VNF	virtualized network function
VPLS	Virtual Private LAN Service
VPN	virtual private network
WAN	wide area network

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