Network Functions Virtualization

Overview

- Motivation for NFV
- What is NFV?
- NFV and SDN Relationship
- Concepts and Use cases

Motivation for NFV

- Operators' networks populated with large and increasing variety of proprietary hardware appliances[1]
  - New network service launch → often requires yet another variety and finding space and power to accommodate these boxes
- Increasing costs of energy in operators' networks
- Capital investment to evolve the network
- Rarity of skills to design, integrate, and operate increasingly complex hardware-based appliances

[1] A device or piece of equipment designed to perform a specific task

Source: Ken Gray, Thomas D. Nadeau, Network Function Virtualisation, Elsevier, ISBN: 978-0-12-802119-4, 2016.

Motivation for NFV

- Hardware-based appliances rapidly reach end of life
  - Requiring much of procure-design-integrate-deploy cycle to be repeated with little or no revenue benefit
- Hardware lifecycles becoming shorter
  - Technology and services innovation accelerating
  - Inhibiting roll out of new revenue earning network services
  - Constraining innovation in increasingly network-centric connected world

NFV Push

- Network **operators** and **vendors**
- ETSI NFV Industry Specification Group → starting point
- IETF Standards → NETMOD, NETCONF, SFC, and SPRING

Network Functions Virtualization – Definitions

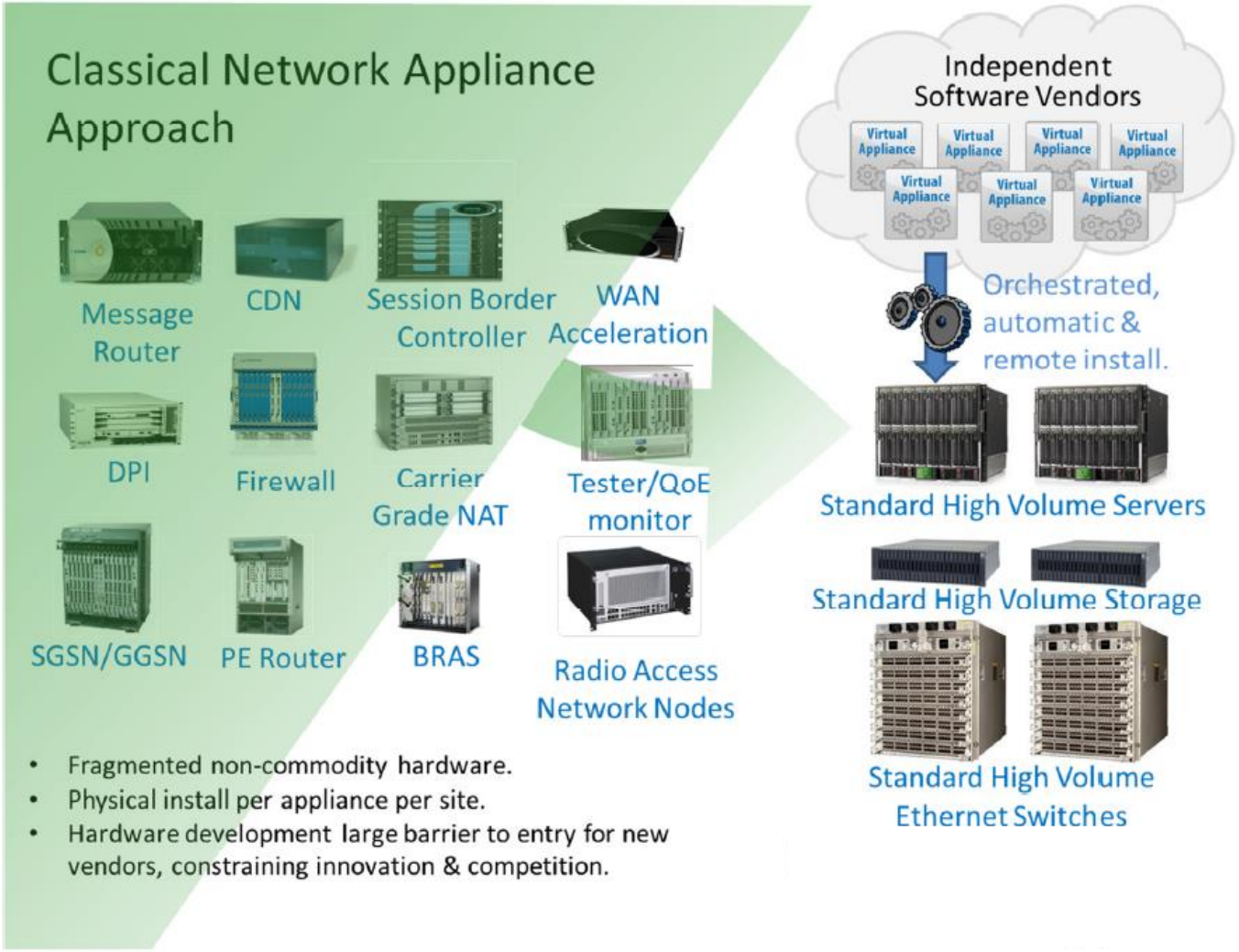
NFV describes and defines ***how network services are designed***, ***constructed***, *and* ***deployed*** *using* ***virtualized software components*** *and how these are* ***decoupled from the hardware*** *upon which they execute*

in Ken Gray, Thomas D. Nadeau, Network Function Virtualisation, Elsevier, ISBN: 978-0-12-802119-4, 2016.

(...) implementation of ***network functions in software*** *that can run on a range of industry* ***standard server hardware***, *and that can be* ***moved*** *to, or* ***instantiated*** *in,* ***various locations in the network*** *as required,* ***without the need for installation of new equipment****.*

in ETSI, Network Functions Virtualisation: An Introduction, Benefits, Enablers, Challenges & Call for Action, White Paper, Oct. 2012

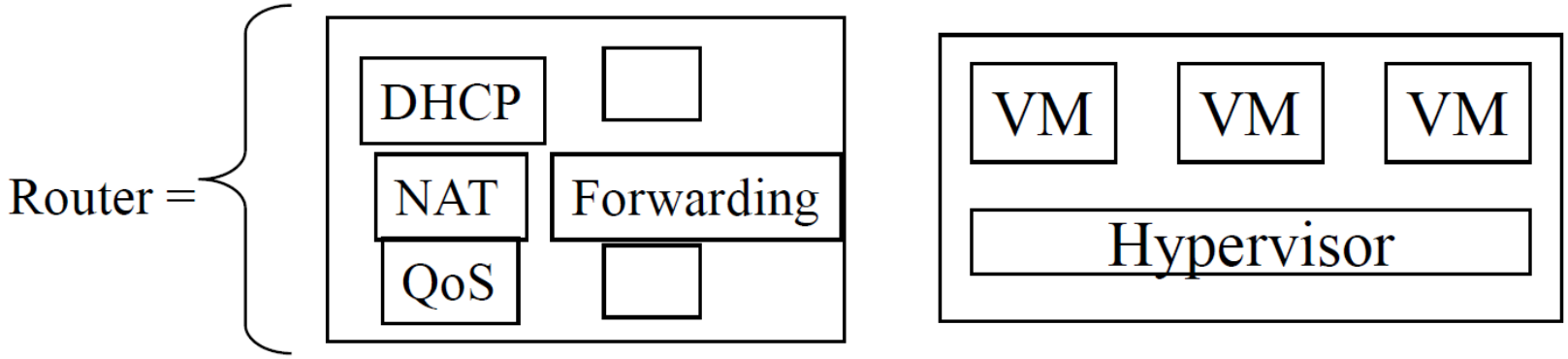
Network Functions Virtualization – Approach



Source: ETSI, Network Functions Virtualisation: An Introduction, Benefits, Enablers, Challenges & Call for Action, White Paper, Oct. 2012

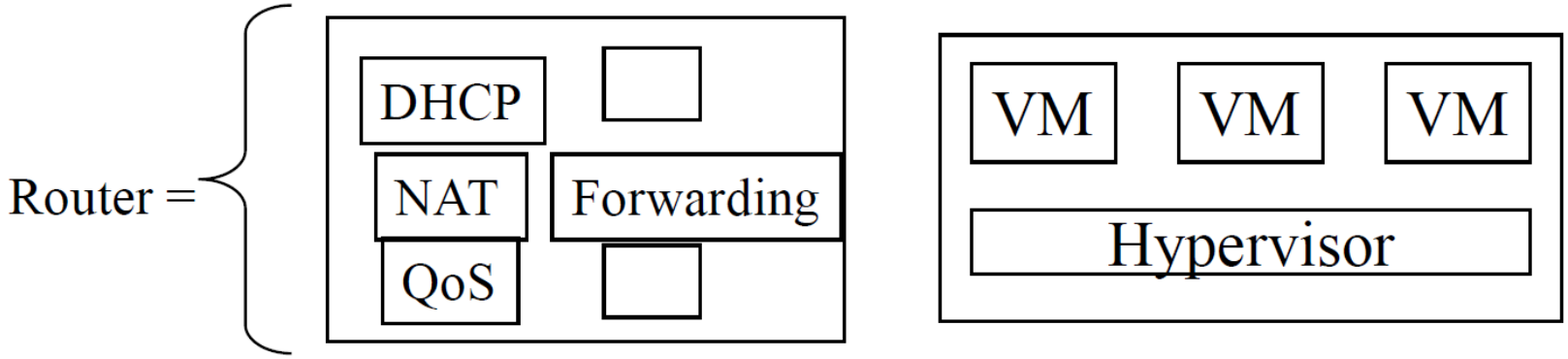
Network Functions Virtualization

- Fast standard hardware → **Software based Devices**
  - Virtual networking modules (switches, routers, DHCP, Firewall, NAT, …) running on standard processors
  - Also known as *white box* implementation
- Virtual Machine implementation → **Virtual Appliances**
  - All advantages of virtualization (quick provisioning, scalability, mobility, Reduced CapEx, Reduced OpEx, …)



Network Functions Virtualization

- Modules can be combined to create any combination of function for data privacy, access control, forwarding, …
  - Function Modules → both data plane and control plane
  - Network Service Function Chaining → service creation
- Standard APIs
  - New ISG (Industry Specification Group) in ETSI (European Telecom Standards Institute) set up in November 2012



Benefits of NFV

- **Reduced** equipment costs and power consumption
  - consolidating equipment
  - exploiting the economies of scale of the IT industry
- **Lower** Time to Market
  - Minimizing typical network operator cycle of innovation
  - Economies of scale required to cover investments in hardware-based functionalities no longer applicable for software-based development
- **Sharable** resources across services and different customers
  - Use single platform for different applications, users, and tenants

Source: ETSI, Network Functions Virtualisation: An Introduction, Benefits, Enablers, Challenges & Call for Action, White Paper, Oct. 2012

Benefits of NFV

- **Targeted service introduction** is possible
  - Based on geography or customer sets
  - Services can be rapidly scaled up/down as required
  - Service deployment velocity improved
    - Provisioning remotely in software → no site visits required to install new hardware
- **Opens virtual appliance market** to small players
  - Encouraging more innovation to bring new services and new revenue streams quickly at much lower risk

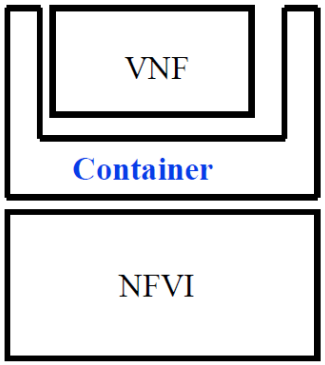
Source: ETSI, Network Functions Virtualisation: An Introduction, Benefits, Enablers, Challenges & Call for Action, White Paper, Oct. 2012

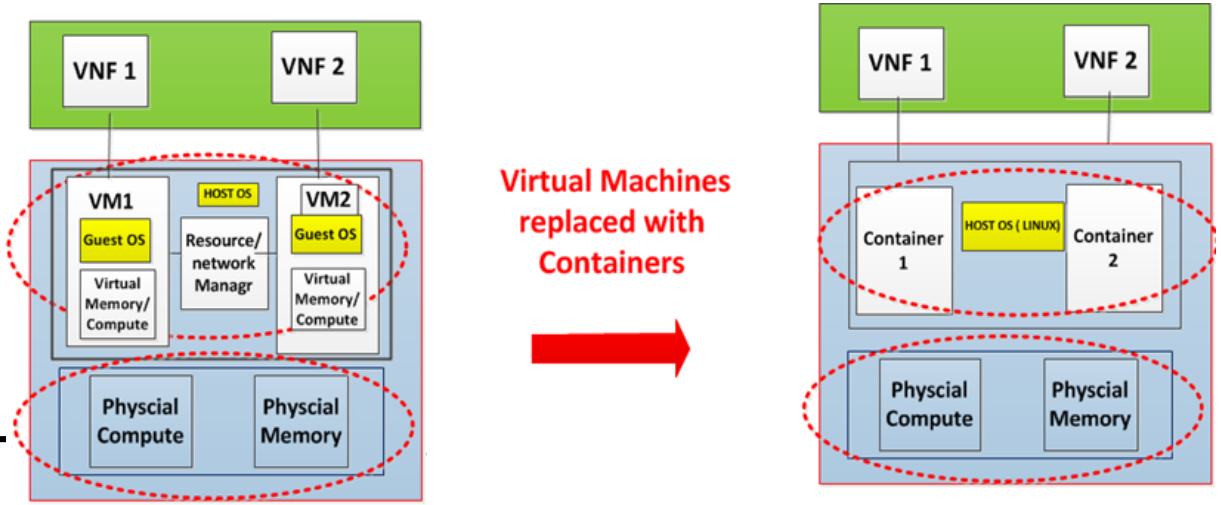
Benefits of NFV

- **Optimizing** network configuration and topology in near real-time
  - Based on actual traffic/mobility patterns and service demand
- **Reduced** energy consumption
  - Exploit power management features in standard servers and storage
  - Rely on virtualization to concentrate workload on smaller number of servers during off-peak hours – e.g., overnight
    - Other servers can be switched off or put into an energy saving mode

Virtual Network Function

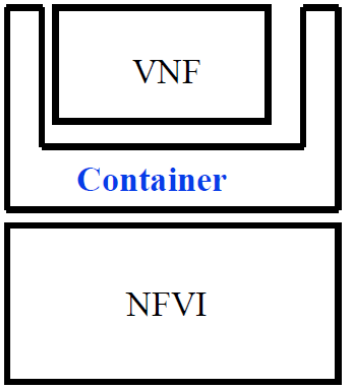
- **NFV Infrastructure (NFVI)**: Hardware and software required to deploy, manage, and execute VNFs
- **Network Function (NF):** Functional building block with well defined interfaces and well defined functional behavior
- **Virtualized Network Function (VNF)**: Software implementation of NF that can be deployed in a virtualized infrastructure
- **Container**: VNF is independent of NFVI but needs a VM/container software on NFVI to be able to run on different hardwares

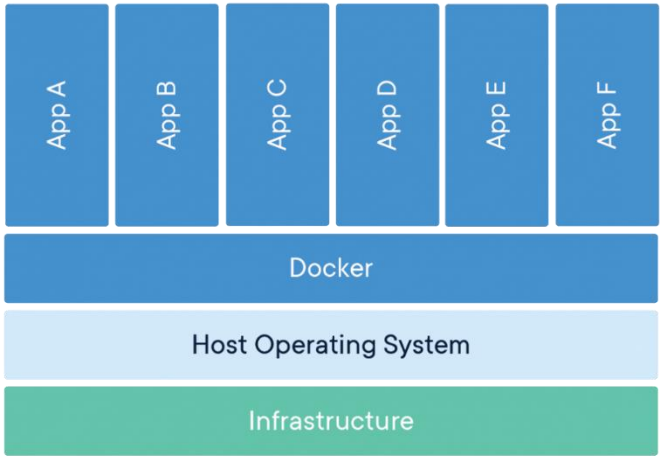




Containers

- Allow developer to package up an application with all parts it needs (e.g., libraries, other dependencies) and ship it as package
  - Contain applications in a way that keep them isolated from host system
- Containers behave like a Virtual Machine
  - But containers do not need to replicate entire operating system
    - Only individual components they need to operate → performance boost
    - Process essentially running natively on its host → operate much faster just with an additional layer of protection around it





Source: https://www.docker.com/resources/what-container [Accessed: 21st May 2021]

NFV and SDN Relationship

- Concept of NFV originated from SDN
- NFV and SDN are complementary
  - One does not strictly depend upon the other
  - It is possible to have SDN-only, NFV-only, or SDN and NFV
- With SDN virtualization of large networks becomes easier
- NFV requires moving network applications from dedicated hardware to virtual containers on commercial-off-the-shelf (COTS) hardware

NFV and SDN Relationship

- Core similarity between SDN and NFV – both use network abstraction
  - SDN → separates **control** functions from **forwarding** functions
  - NFV → **abstracts network functions** from hardware on which they run
- When SDN executes on NFV infrastructure
  - SDN → forwards data packets from one network device to another
    - Allows configuration and behavior to be programmatically defined
    - Networking control functions → run in VMs somewhere on the network
  - NFV → provides basic networking functions
  - SDN → controls and orchestrates network functions for specific uses

NFV and SDN Relationship

- SDN and NFV differ in how they separate functions and abstract resources
  - SDN abstracts physical networking resources – switches, routers and so on – and moves decision making to virtual network control plane
    - Control plane decides where to send traffic, while the hardware continues to direct and handle the traffic
  - NFV aims to virtualize physical network resources beneath a hypervisor
    - Allows network to grow without addition of more devices
- SDN and NFV make networking architectures **more flexible** and **dynamic**
  - But they perform different roles in defining those architectures and the infrastructure they support

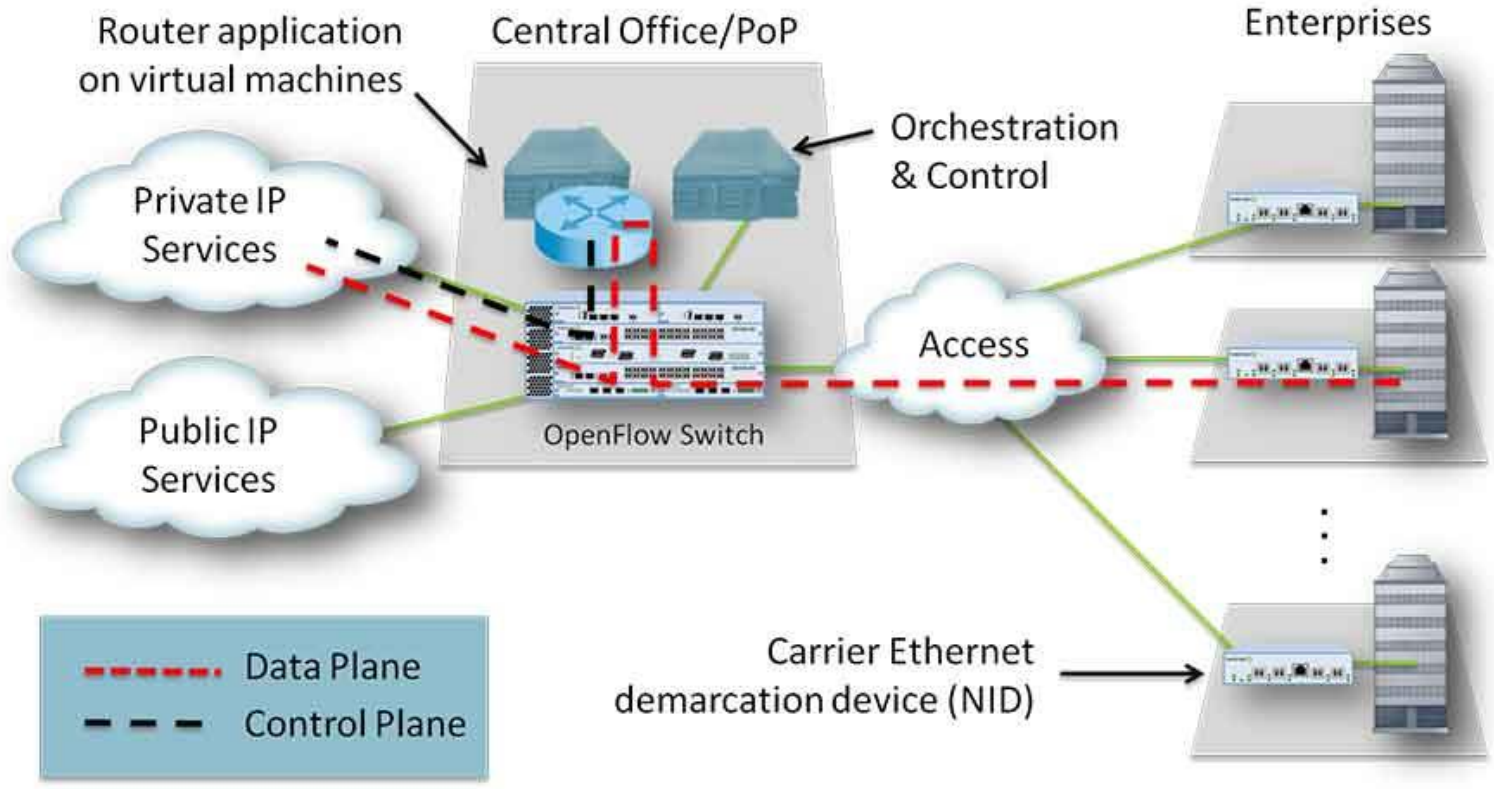
Source: https://www.cisco.com/c/en/us/solutions/software-defined-networking/sdn-vs-nfv.html [Accessed: 21st May 2021]

NFV and SDN Working Together

- SDN can benefit from NFV-introduced concepts such as virtualized infrastructure managers and the orchestrator
  - SDN controller may run on a VM/Container
  - SDN controller itself can be implemented as VNF to benefit from reliability and elasticity features brought by NFV
- Ultimately, NFV and SDN to become less distinguishable as independent topics → unified software-based networking paradigm

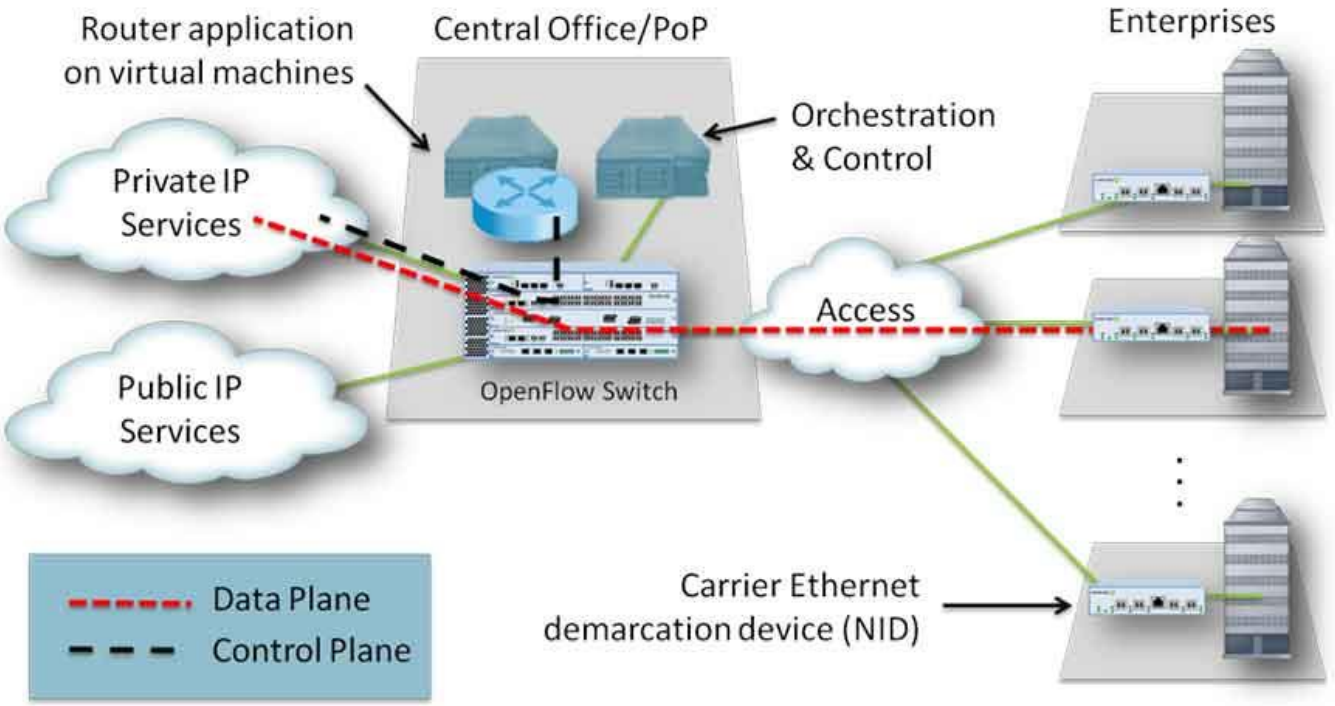
NFV and SDN Working Together – Example

- NFV → Virtualized router function
  - Routing (control plane) function running in virtual machine running in a rack mounted server



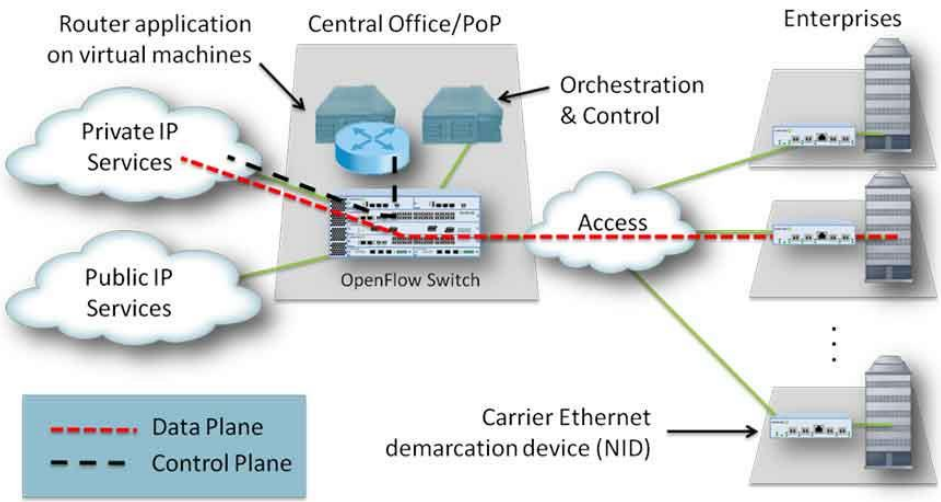
NFV and SDN Working Together – Example

- SDN → separation of control and data planes
  - Data packets forwarded by optimized data plane



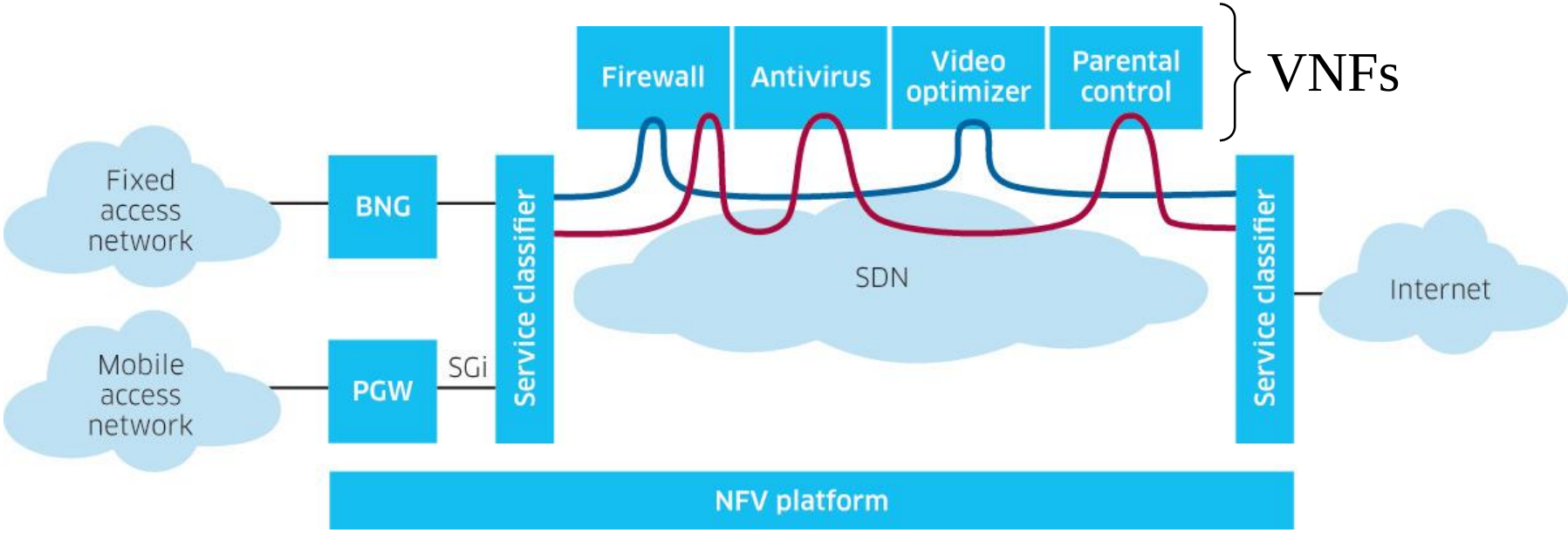
NFV and SDN Working Together

- The combination of SDN and NFV provides optimum solution
  - Expensive and dedicated appliance replaced by generic hardware and advanced software
  - Software control plane moved from expensive location (in a dedicated platform) to an optimized location (e.g., server in a data center)
- Control of data plane abstracted and standardized
  - Allows network and application evolution without need for upgrades of network devices



(Network) Service Function Chaining – SFC

- Virtual chain resulting from composition of VNFs
- SFC automates what traditional network administrators do
  - Chain series of physical L4-7 devices to process incoming and outcoming network traffic → may require a number of manual steps



Source: https://www.sdxcentral.com/networking/virtualization/definitions/what-is-network-service-chaining [Accessed: 21st May 2021]

NFV Use Cases

- Forwarding elements
  - Switches and routers
- Mobile network nodes
  - Home Location Register (HLR)
  - Radio Network Controller (RNC)
  - Packet Data Network Gateway (PGW)
  - Mobility Management Entity (MME)
  - Virtual CPE (vCPE)
- Security functions
  - Firewalls, virus scanners, intrusion detection systems, spam protection
- Functions contained in home routers and set top boxes

Source: https://www.sdxcentral.com/networking/virtualization/definitions/what-is-network-service-chaining [Accessed: 21st May 2021]

Summary

- NFV aims to reduce OpEx
  - Automation and scalability provided by implementing network functions as virtual appliances
- NFV allows all benefits of virtualization and cloud computing including orchestration, scaling, automation, hardware independence, pay-per-use, fault-tolerance, etc.
- NFV and SDN are independent and complementary
  - You can do either or both
- NFV can be done now
  - Several of virtual functions have already been demonstrated by carriers
  - 5G Networks use it by design