

L'architettura di rete: NFV e SDN

Prof. Ing. Maurizio Casoni

(and many thanks to Prof. Callegati and Dr. Fiorani)



Dipartimento di Ingegneria “Enzo Ferrari”

Università degli Studi di Modena e Reggio Emilia

The software evolution of networks

- **Software** will play an unprecedented dominant role in upcoming communication environments

- A new buzzword:

Network Softwarization

  - Computing, storage, connectivity services, present and future application instance
  - will be deployed in the form of virtualized assets
  - within a software-defined infrastructure
  - running on top of general-purpose hardware



Everything under the *aaS paradigm

Software = Programmability = Flexibility

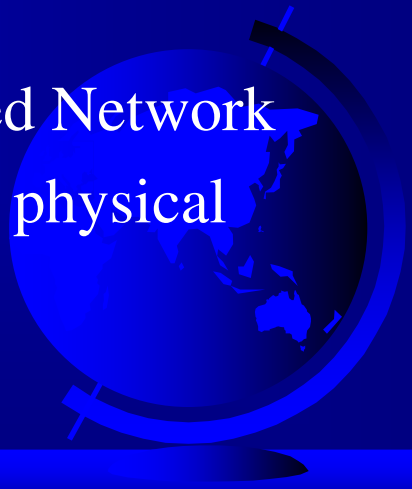
- Software = Programmability = Flexibility
- *aaS = General purpose hardware
  - Promise to improve Capex and Opex
- Not a new concept in communications
  - Active Networks
  - Software-Defined Radio
- Programmability does not answer all questions
  - heterogeneous resource management
  - full service abstraction
  - cross-layer, cross-domain functionalities

Software-Engineered Networking



Enabling technologies

- Devices → Virtualization
  - Embed any application into a Virtual Machine (VM) that can run in the cloud
- Infrastrucure → Cloud computing
  - Flexible VM placement and management
  - Tenants isolation
- Control and management → Software Defined Network
  - Design your own network topology on top of the physical network



Enabling Instruments

- Many vendor proprietary solutions but also
- Many opensource projects
  - Virtualization
    - KVM, VirtualBox, libvirt
    - Open vSwitch, linux bridges
  - Cloud Management
    - OpenStack
  - Cloud provisioning
    - Cloudify
  - SDN implementation
    - Pox, Ryu, OpenDayLight



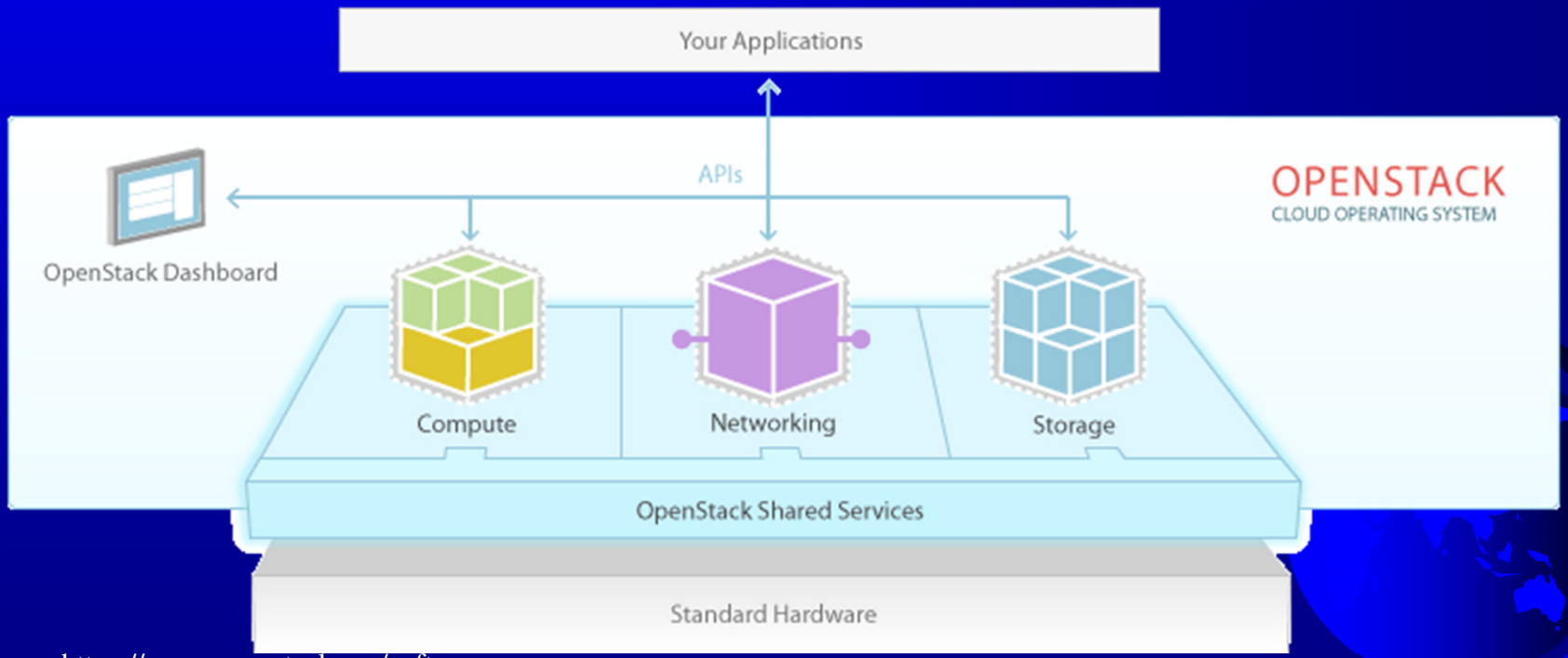
An example that fits all

- Cloud computing
  - OpenStack
- NFV
  - VMs over KVM
- Networking
  - OvS
- SDN
  - Pox, OpenDayLight



Cloud Operating System

openstack™
CLOUD SOFTWARE



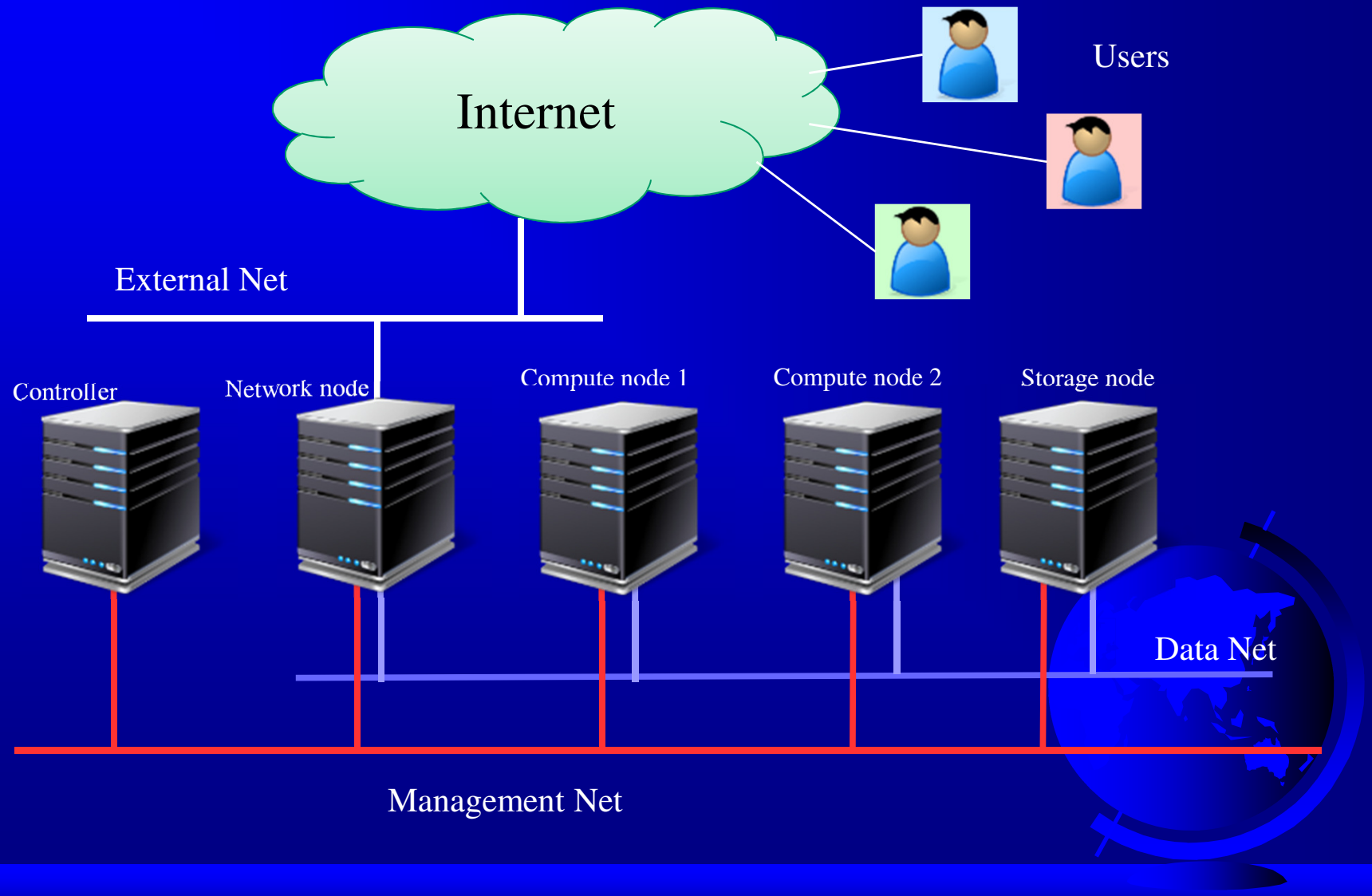
Source: https://www.openstack.org/software

Openstack: key physical components

- 4 physical components
  - Same hardware configuration
  - Minimize Capex and Opex
  - Controller
    - Management console
  - Compute node
    - Host virtual machines and related computing tasks
  - Network Node
    - Host shared network components
  - Storage node
    - Host shared storage devices



Example of OpenStack platform architecture



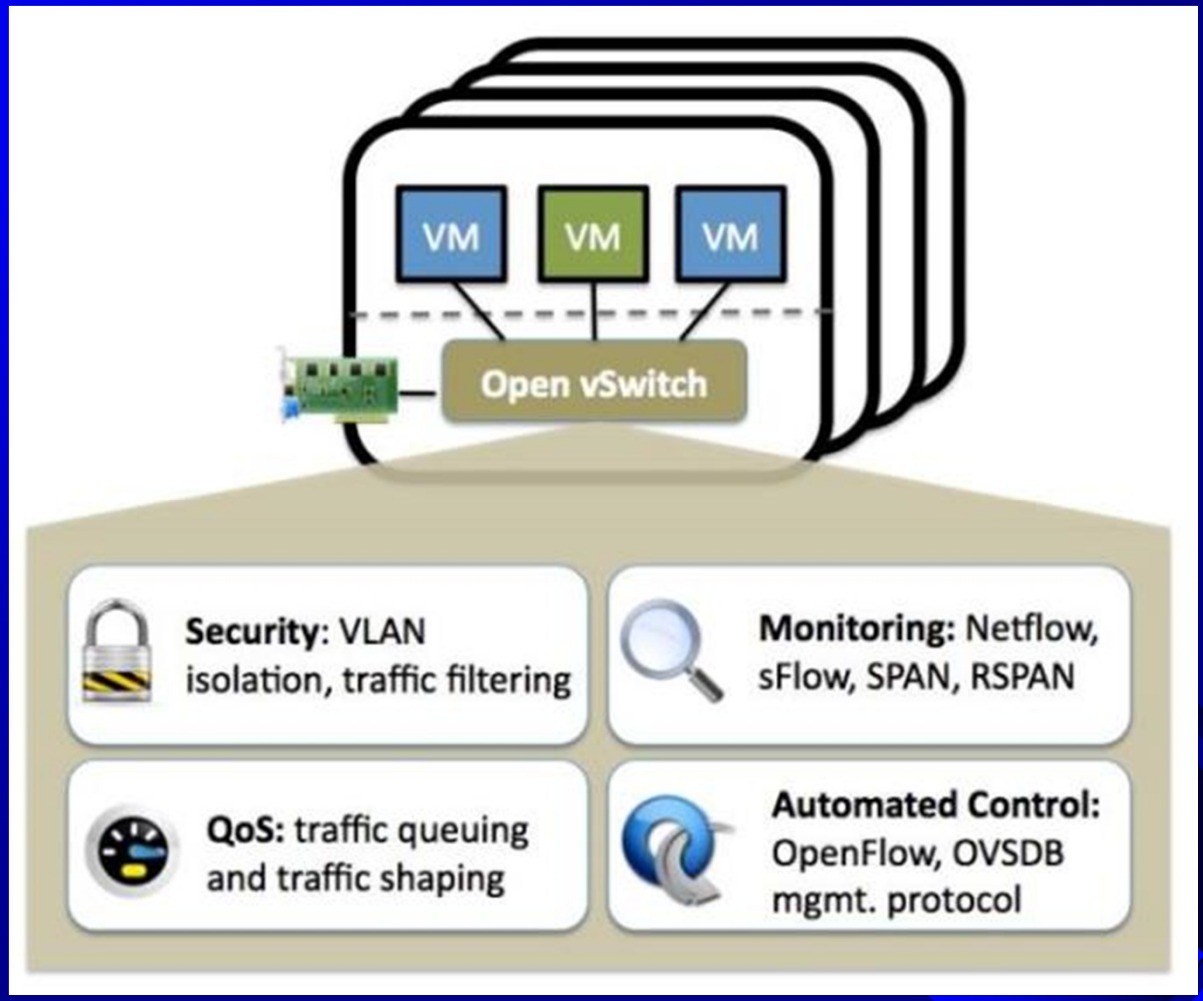
The Openstack virtual network

- Every tenant sees its own conventional LAN
  - LAN switch, DHCP and DNS servers, default gateway
- None of these exist as a real device
- It is a virtual network infrastructure VNI
- The VNI is
  - Distributed among compute, network and storage nodes
  - Made of several virtual building blocks

- What are the main components?
- Who manages the VNI?

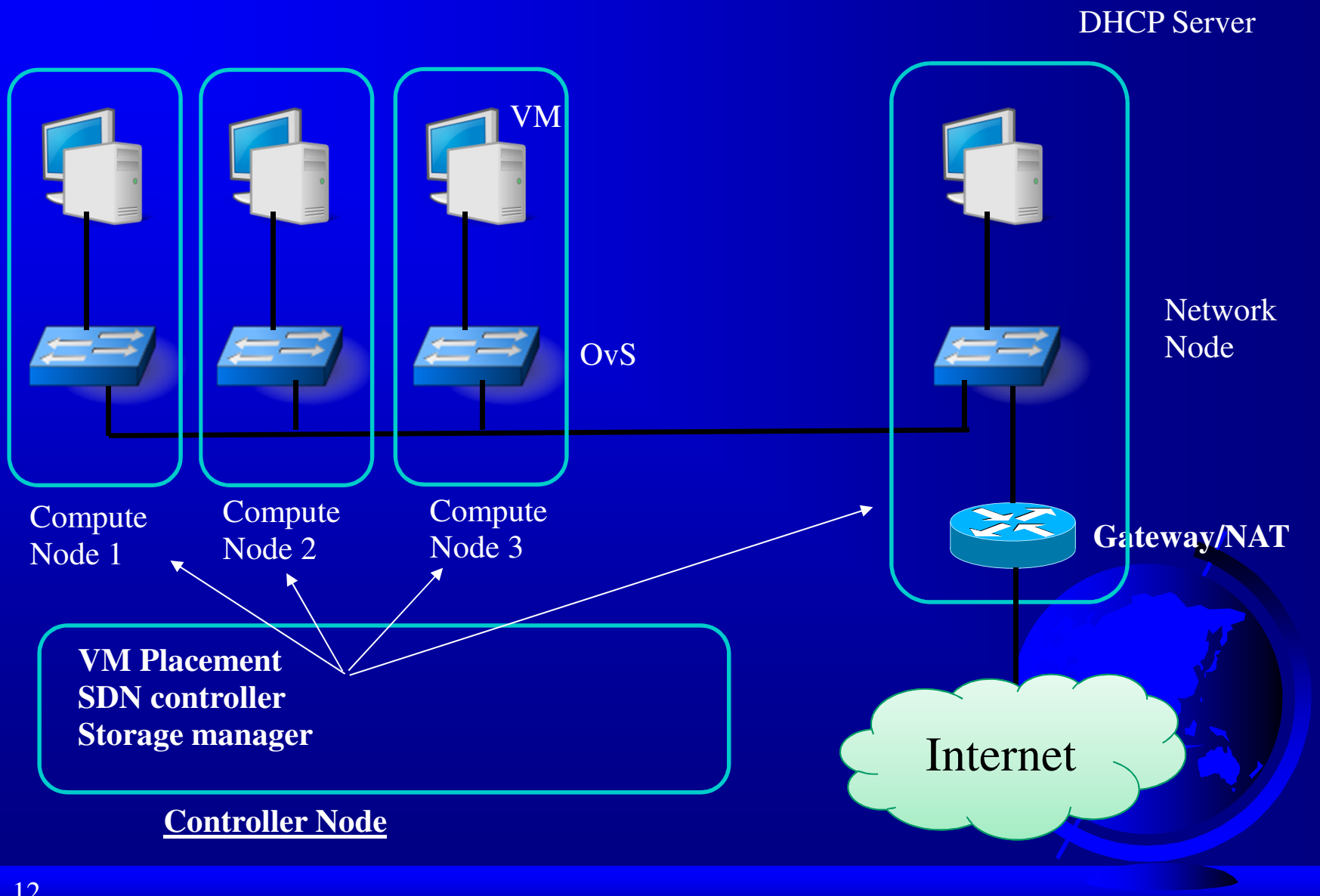


Virtual Ethernet/SDN Switch



Source: http://openvswitch.org

Location of VNI elements

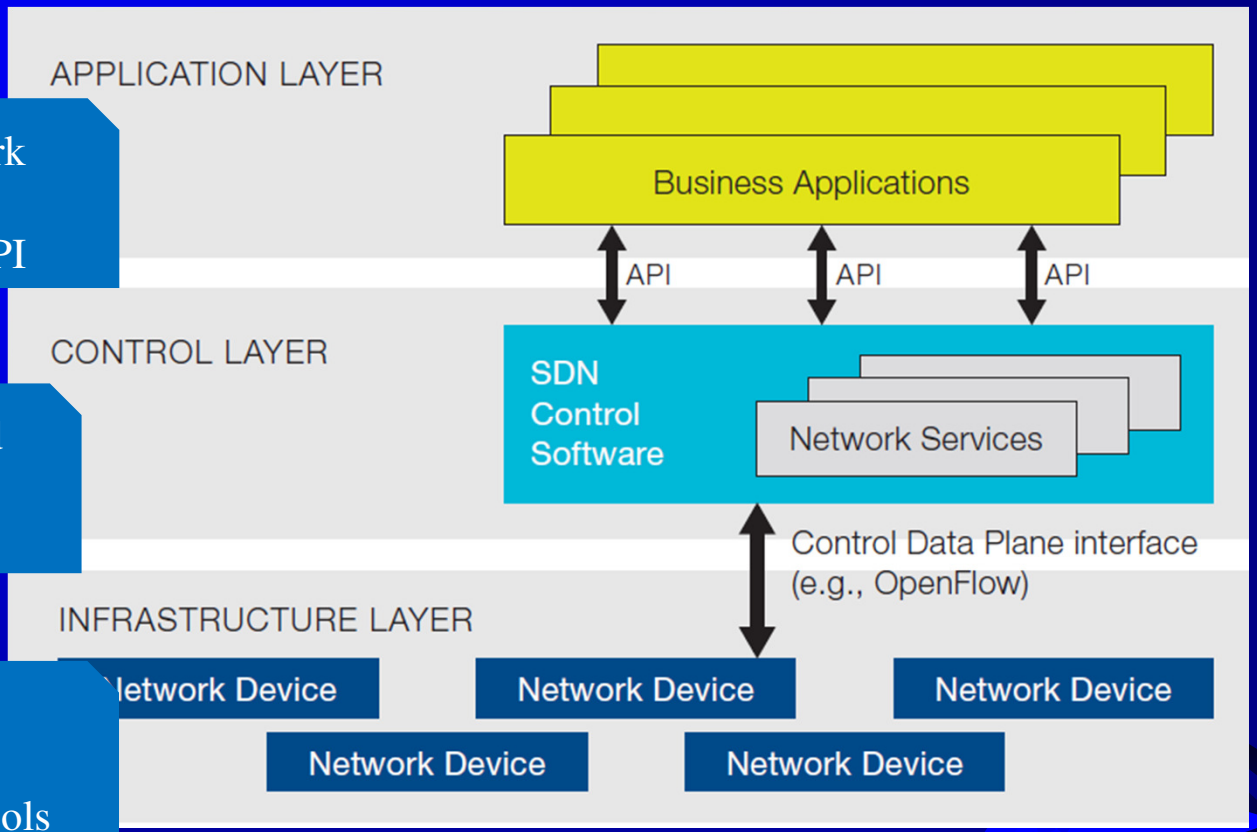


Software-Defined Networking (SDN)

Applications see the network as a single, logical switch controlled via abstracted API

Centralized intelligence and network state knowledge to configure the devices

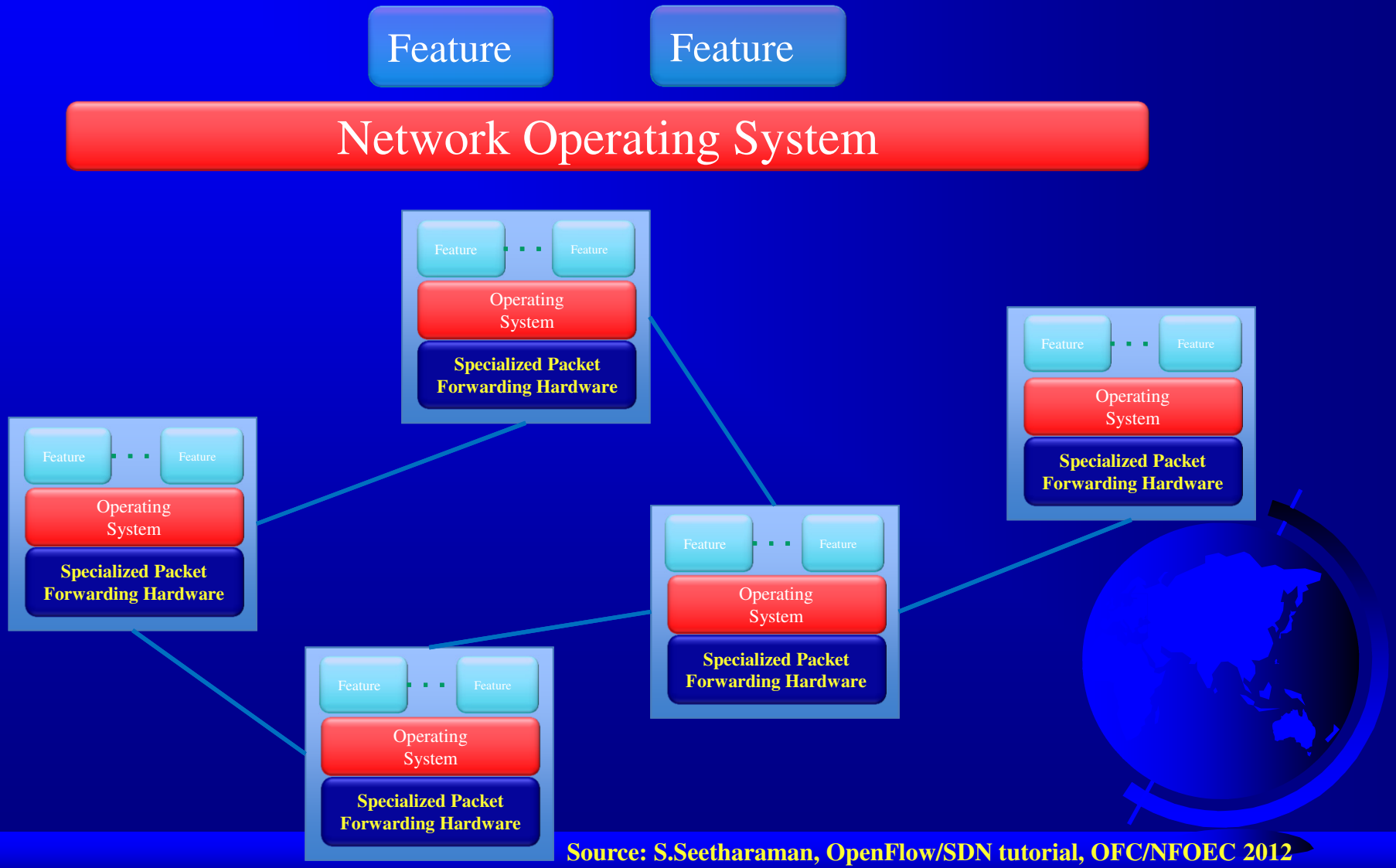
Simplified network devices do not need to process all routing/switching protocols



Enterprises and carriers gain **vendor-independent** control over the entire network from a **single logical point**, which greatly **simplifies the network design and operation**.

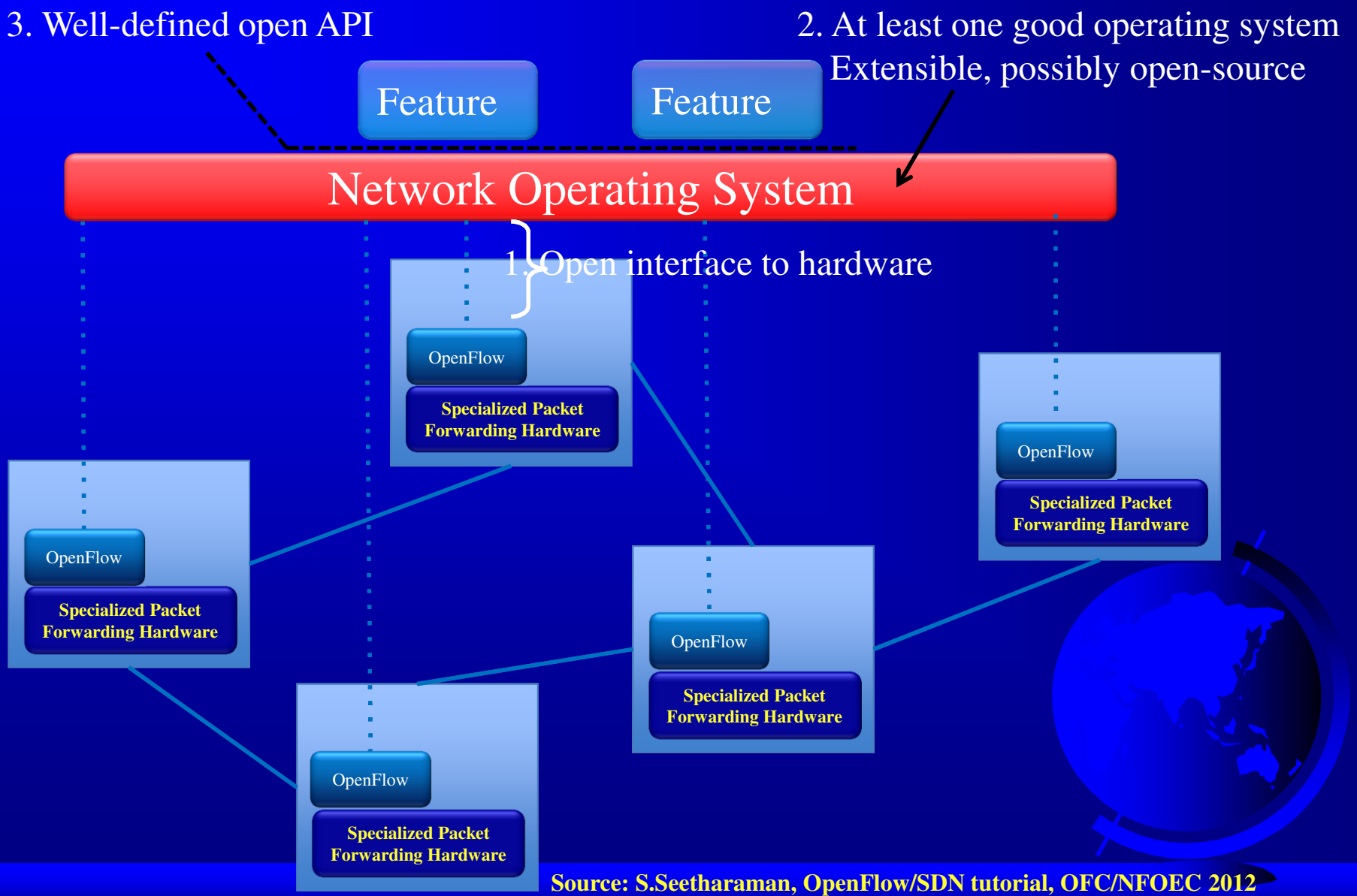
Source: ONF White Paper, https://www.opennetworking.org/

The OpenFlow Network Innovation



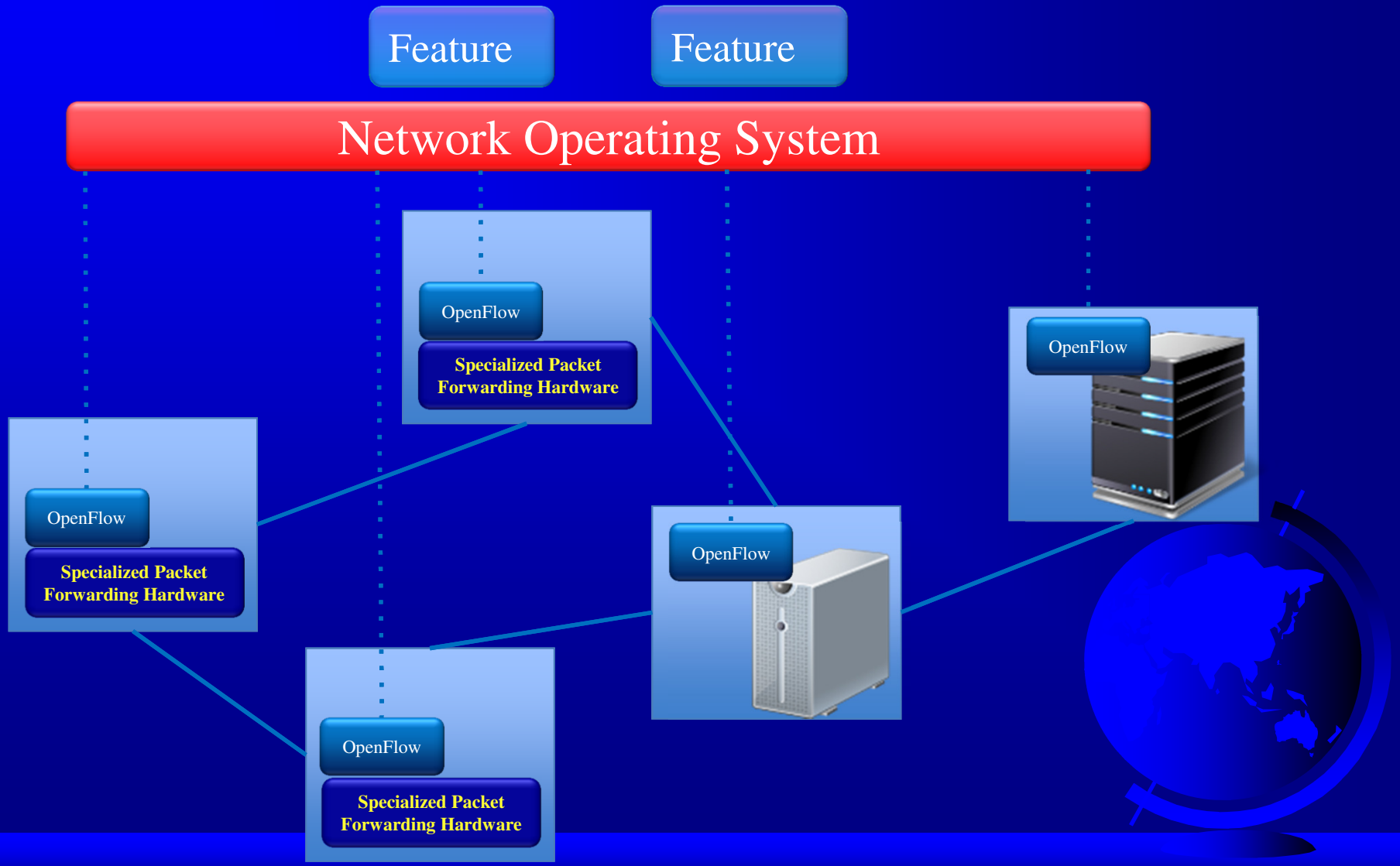
Source: S.Seetharaman, OpenFlow/SDN tutorial, OFC/NFOEC 2012

The OpenFlow Network Innovation

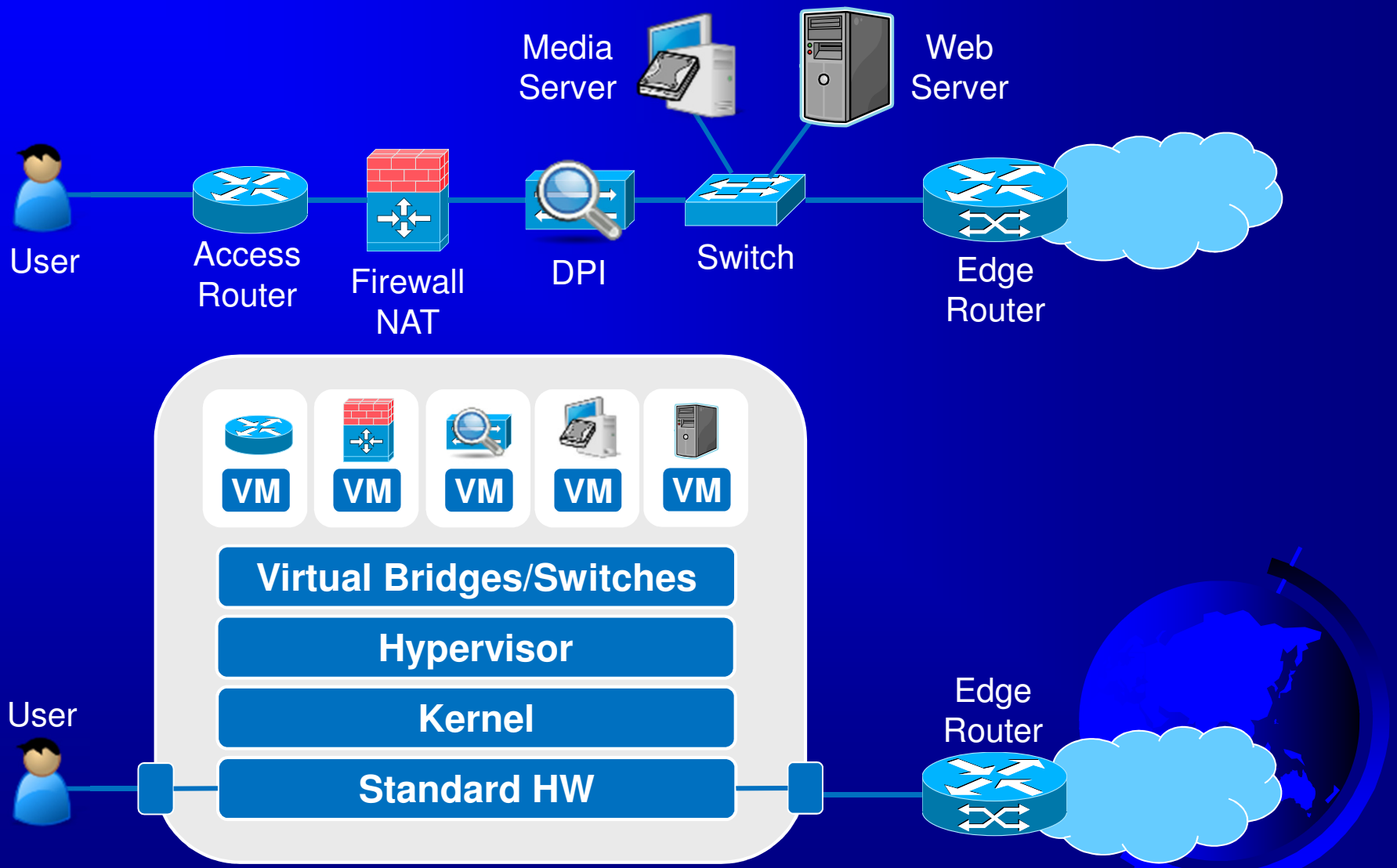


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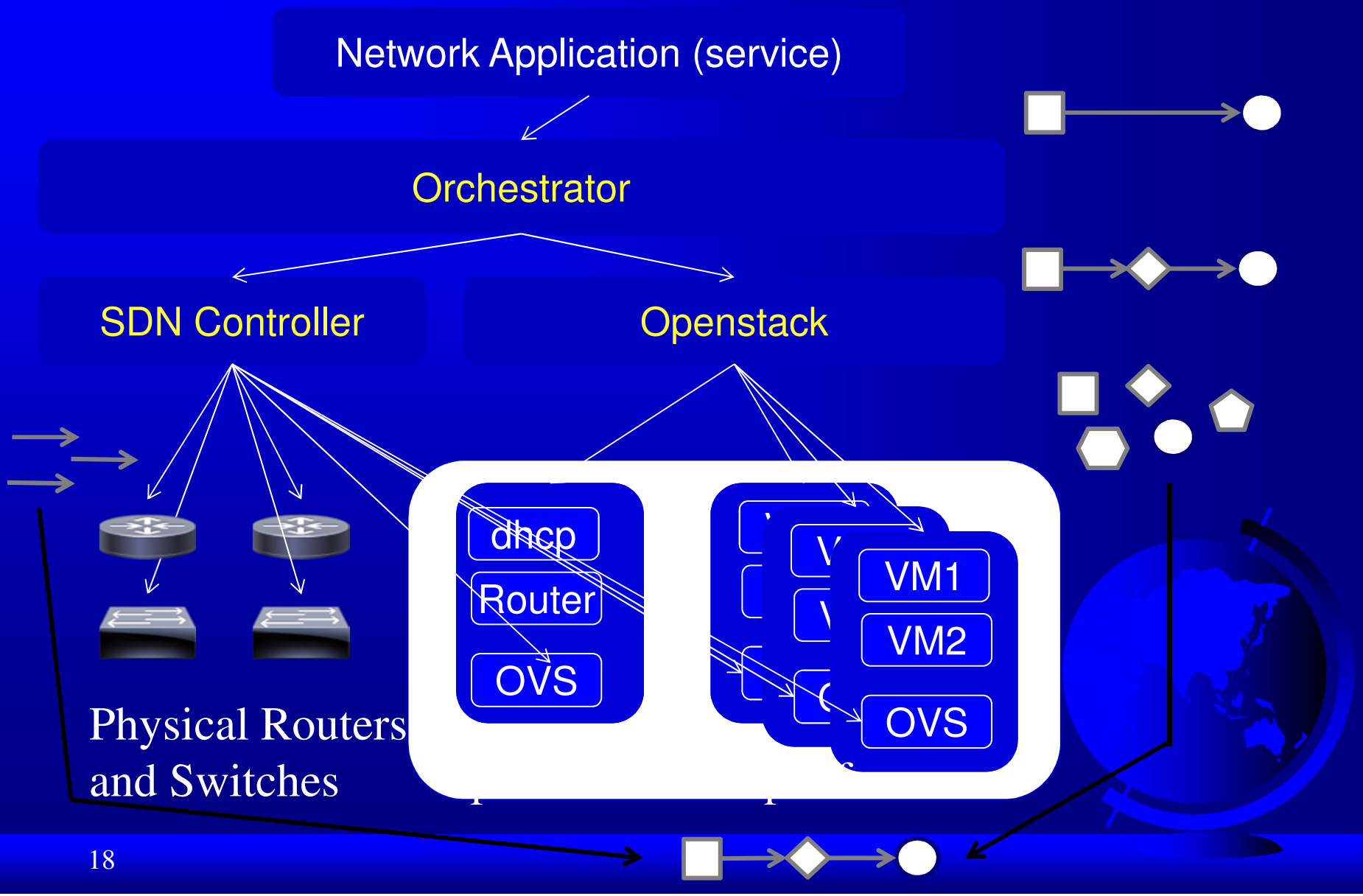
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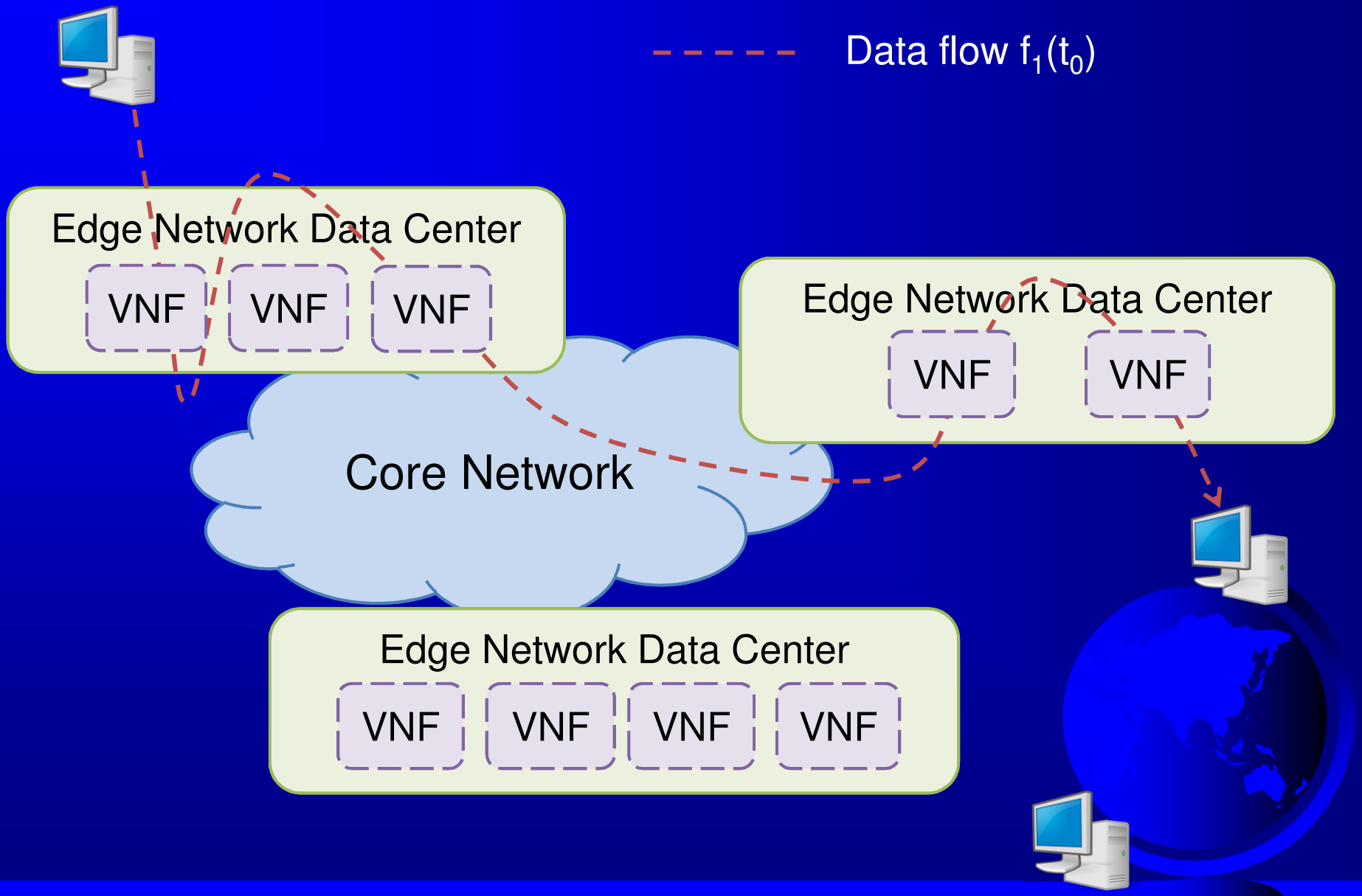
Network Function Virtualization (NFV):



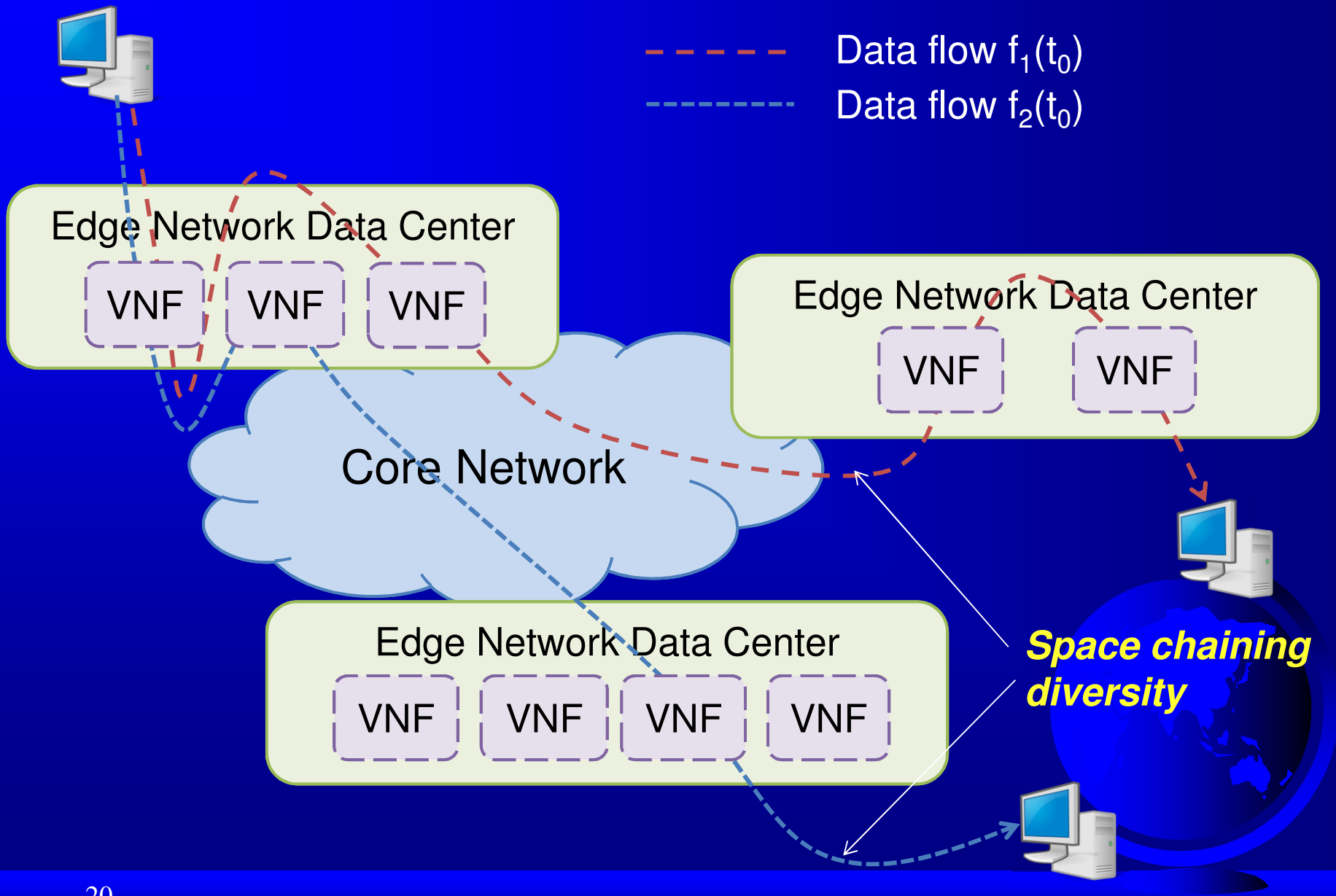
Implementing



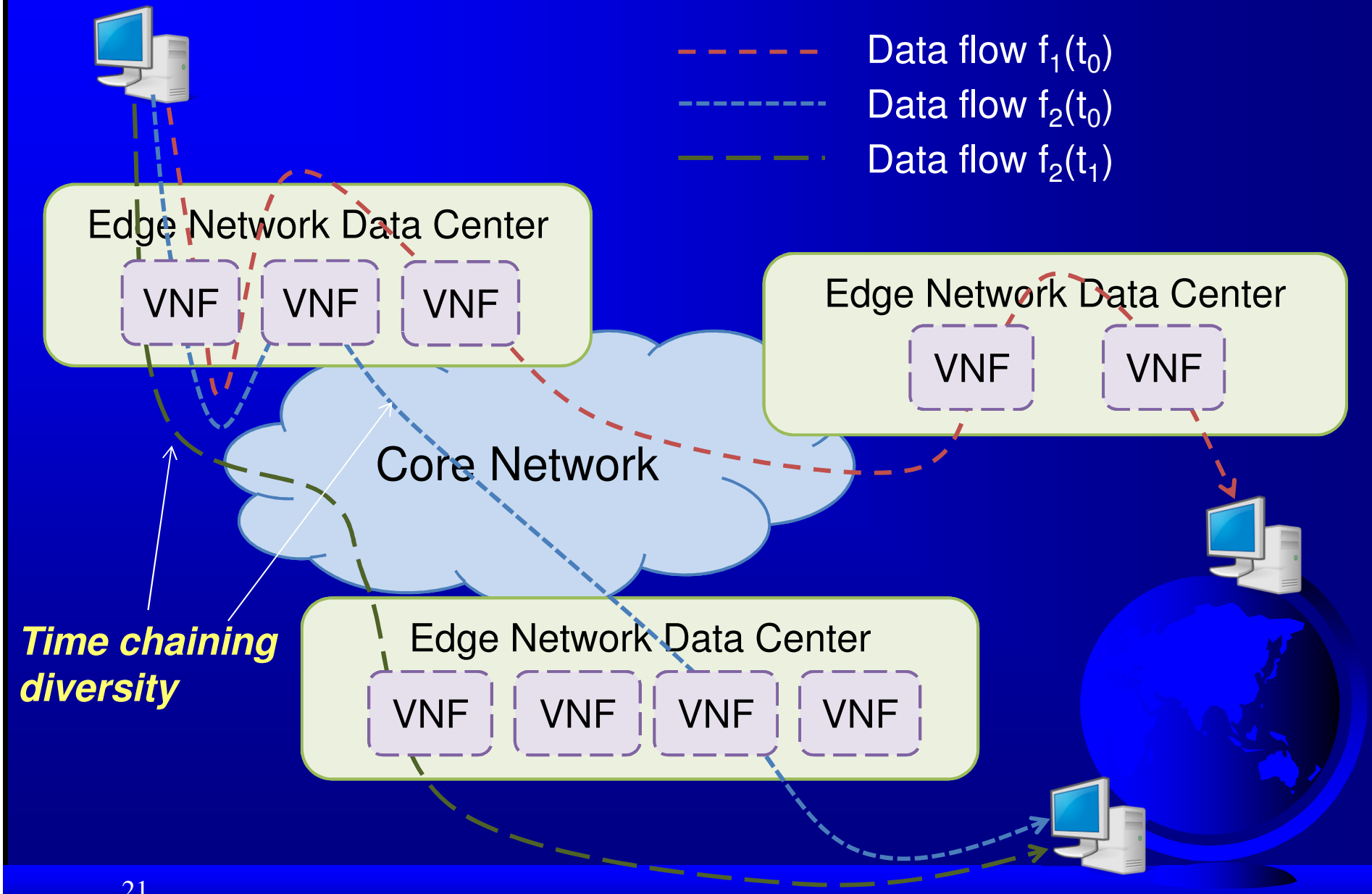
NFV Chaining & dynamic traffic steering



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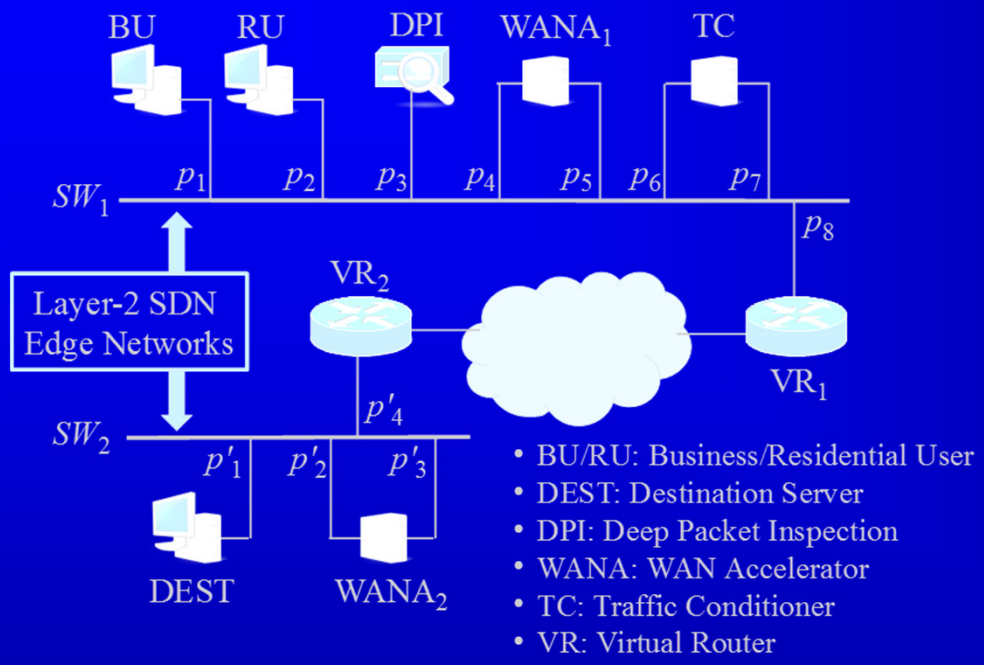


A simple use case

- QoS control and SLA enforcement
- 3 Virtual Network Functions
  - Deep Packet Inspection and traffic classification
  - Wireless accelleration (traffic squeezing)
  - Traffic control (traffic policing and packet dropping)
- Goal:
  - Safeguard the SLA with premium users
  - Exploit bandwidth accelleration
  - Allow best effort users in residual bandwidth



Proof of concept: SDN controller design



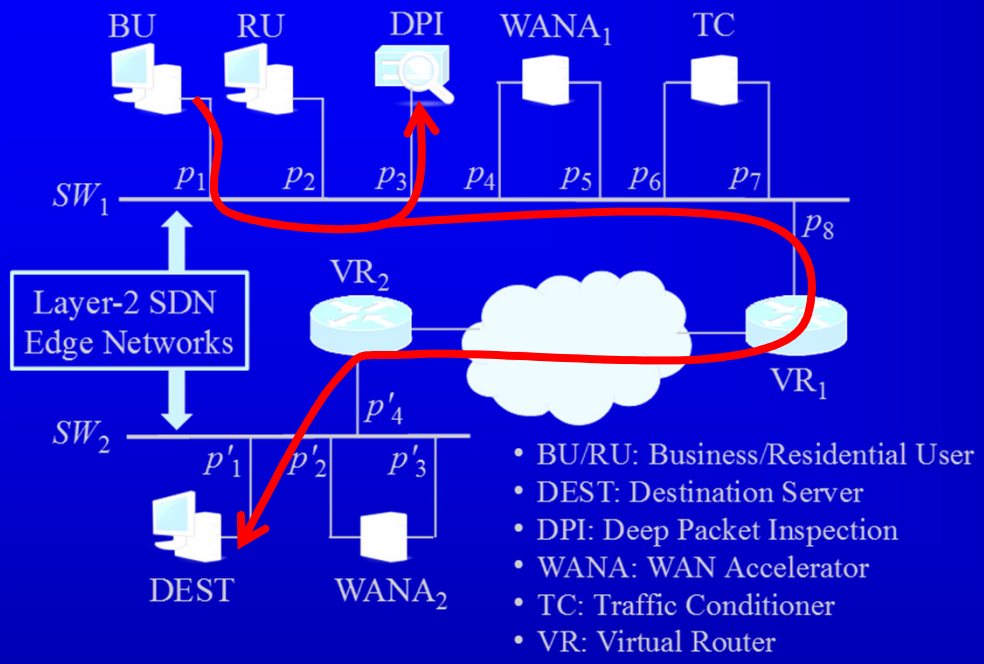
Hybrid SDN approach:

- ARP processed according to *NORMAL* action
- TCP and UDP flows processed dynamically according to SLA and network traffic conditions

Rules installed at ***startup phase***:

- Broadcast storm avoidance
  - ✓Prevents loops
- Any other rule not requiring flow by flow processing (e.g.: apply action NORMAL to ARP packets)
  - ✓Decrease load on controller

Proof of concept: SDN controller design

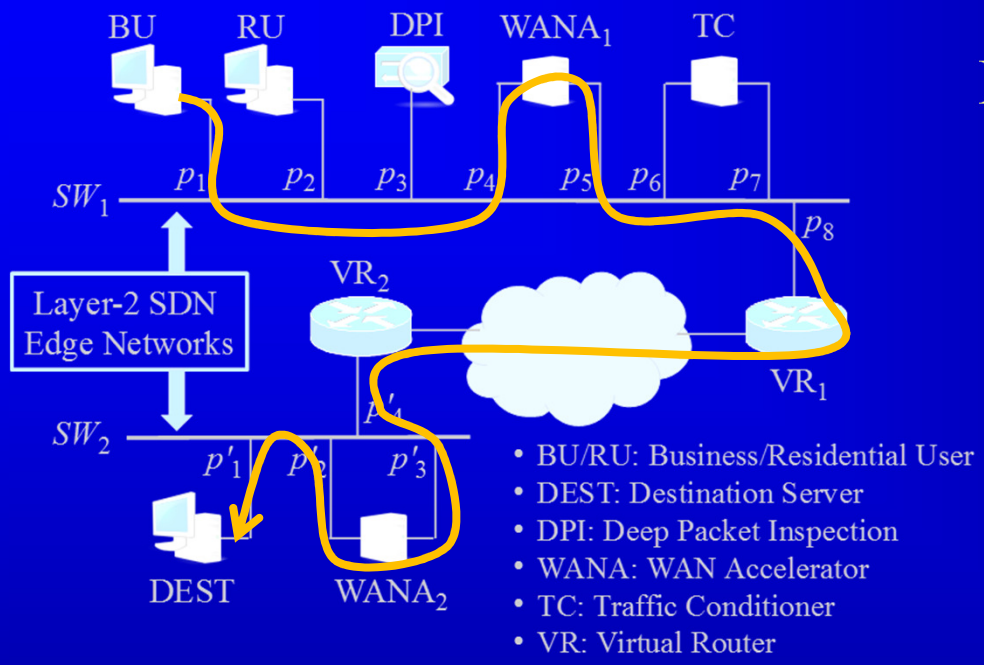


Phase 1: classification

Rules installed in SW1:

- Traffic from BU to DEST is forwarded both to VR1 and DPI
- Similarly for inbound packets

Proof of concept: SDN controller design

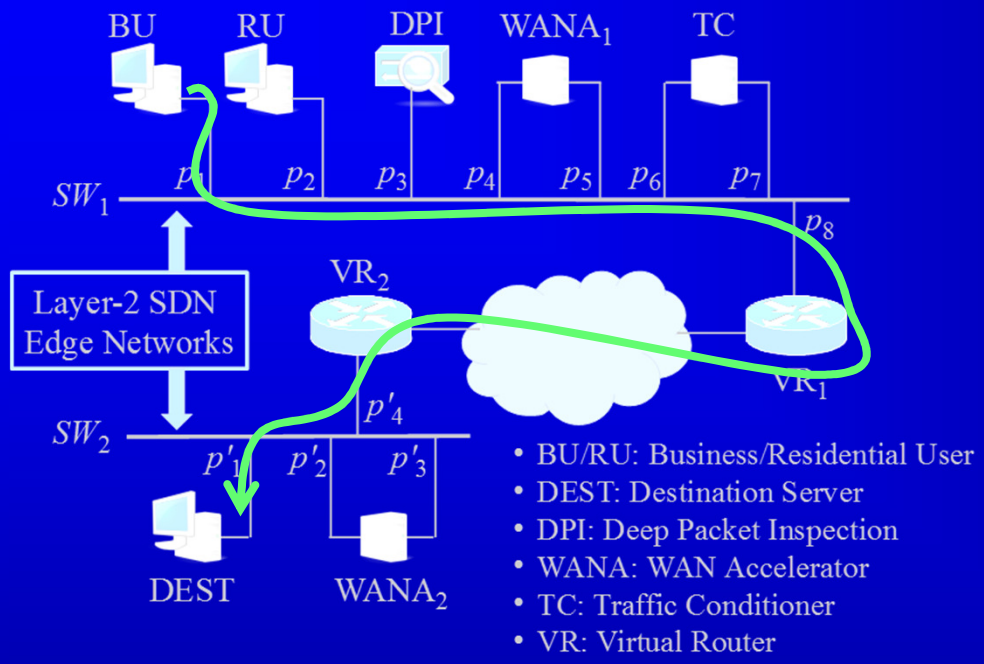


Phase 2: SLA compliance

Rules installed in SW1:

- Traffic from BU to DEST is forwarded to VR1 via WANA1
- Similarly for inbound packets

Proof of concept: SDN controller design

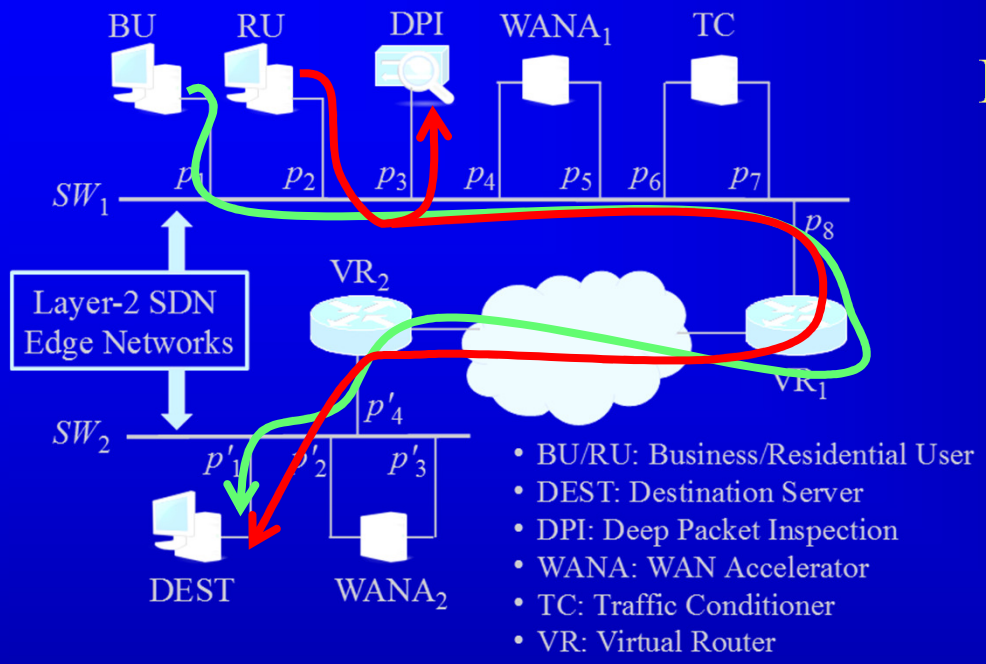


Phase 3: no congestion
→ SLA not enforced

Rules installed in SW1:

- Traffic from BU to DEST is forwarded directly to VR1
- Similarly for inbound packets

Proof of concept: SDN controller design

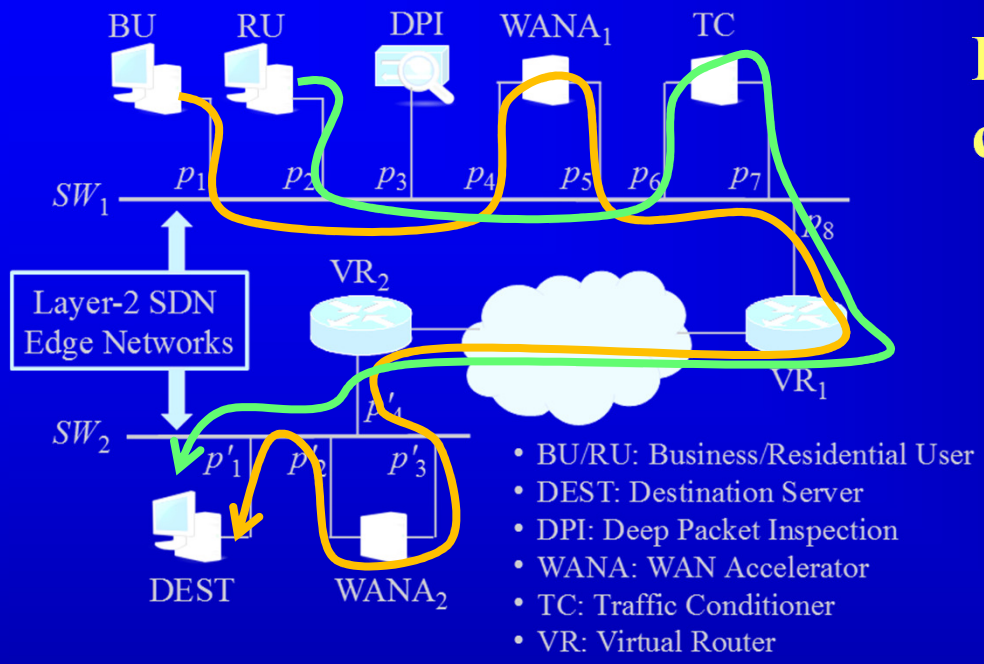


Phase 4: classification

Rules installed in SW1:

- Traffic from BU to DEST is forwarded directly to VR1
- Traffic from RU to DEST is forwarded both to VR1 and DPI
- Similarly for inbound packets

Proof of concept: SDN controller design

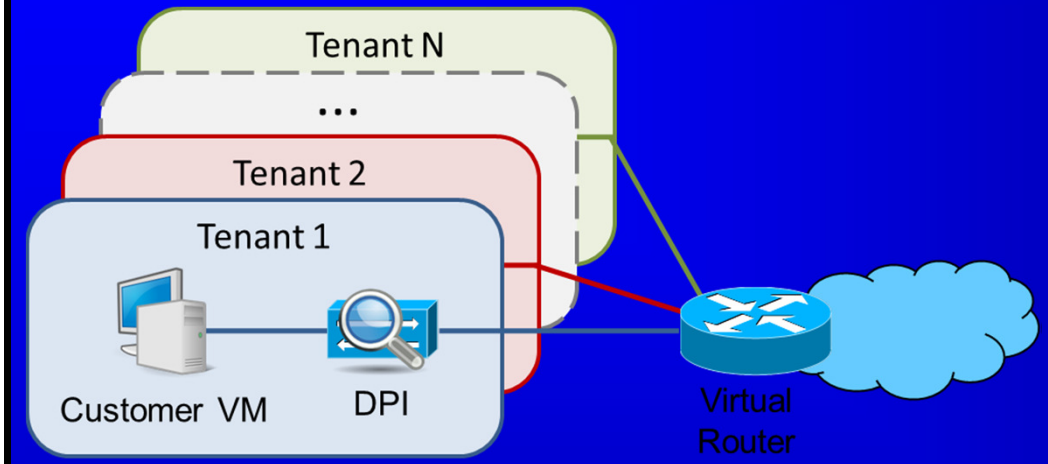


Phase 5: SLA compliance & congestion → SLA enforced

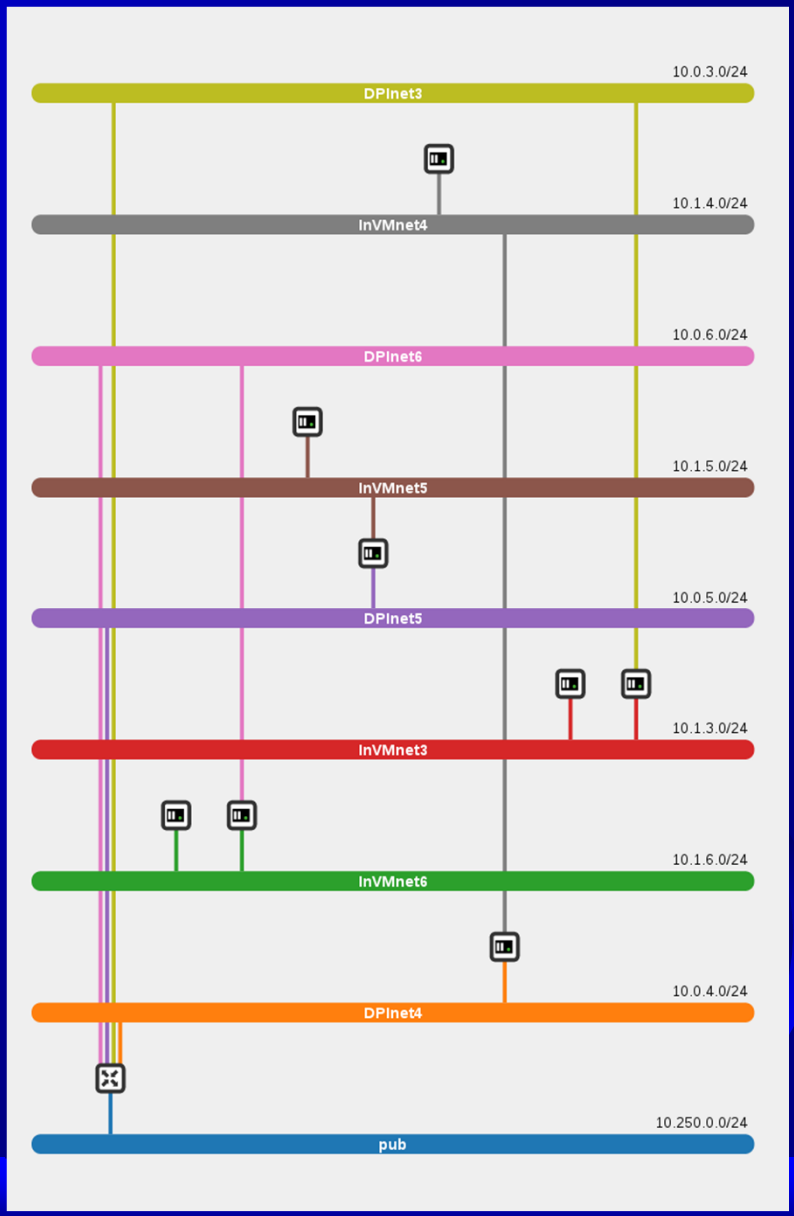
Rules installed in SW1:

- Traffic from BU to DEST is forwarded to VR1 via WANA1
- Traffic from RU to DEST is forwarded to VR1 via TC Similarly for inbound packets

Multi-tenant test scenario: NFV case study

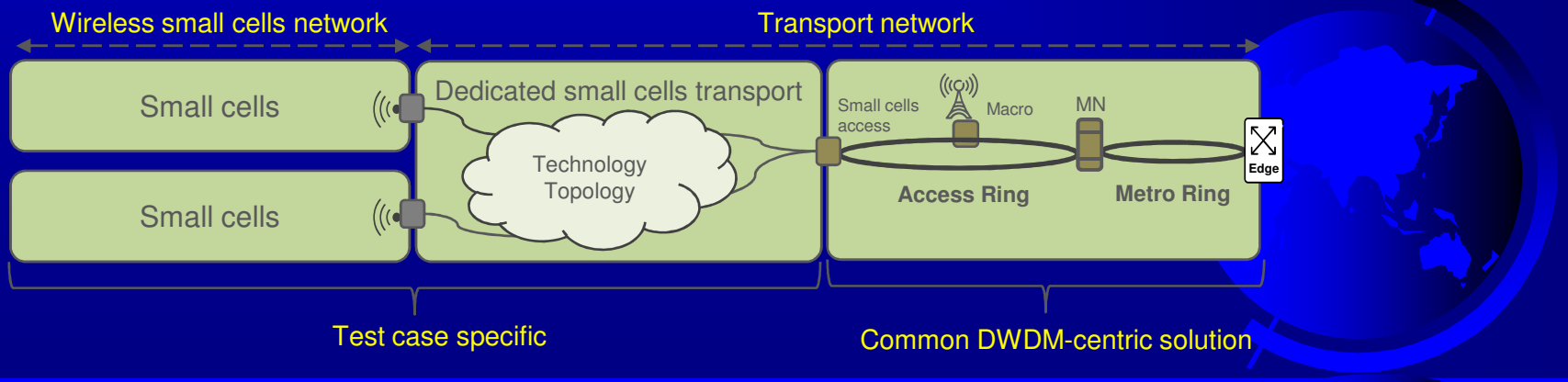


OpenStack dashboard view when N = 4



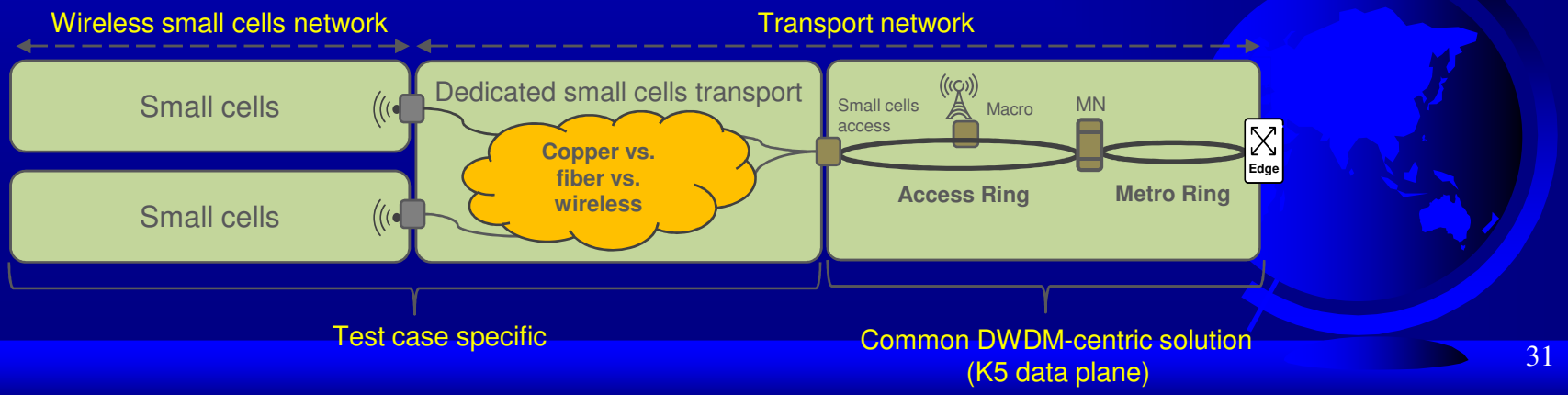
5G transport data plane

- A 5G transport network can be divided in two segments:
  - Small cells transport
    - Aggregates the traffic to/from the wireless small cells
    - Technology and topology are test case dependent
  - Metro/aggregation
    - Connects different site types (i.e., macro, small cells access and fixed access) among themselves and to the core network
    - Common DWDM-centric network



Small cells transport (1/2)

- The main technology options can be categorized as:
  - *Copper-based*
    - Rates in the order of a few Gbps over relatively short distances. Preferred in the areas where there is a large installed base of copper that can be reused
  - *Fiber-based*
    - Provide high data rates over long distances in an energy-efficient way. Good and long term candidate for 5G small cells transport networks
  - *Wireless-based*
    - High capacity using advanced radio technologies. Attractive where cost of deploying wired transport infrastructure is prohibitively high



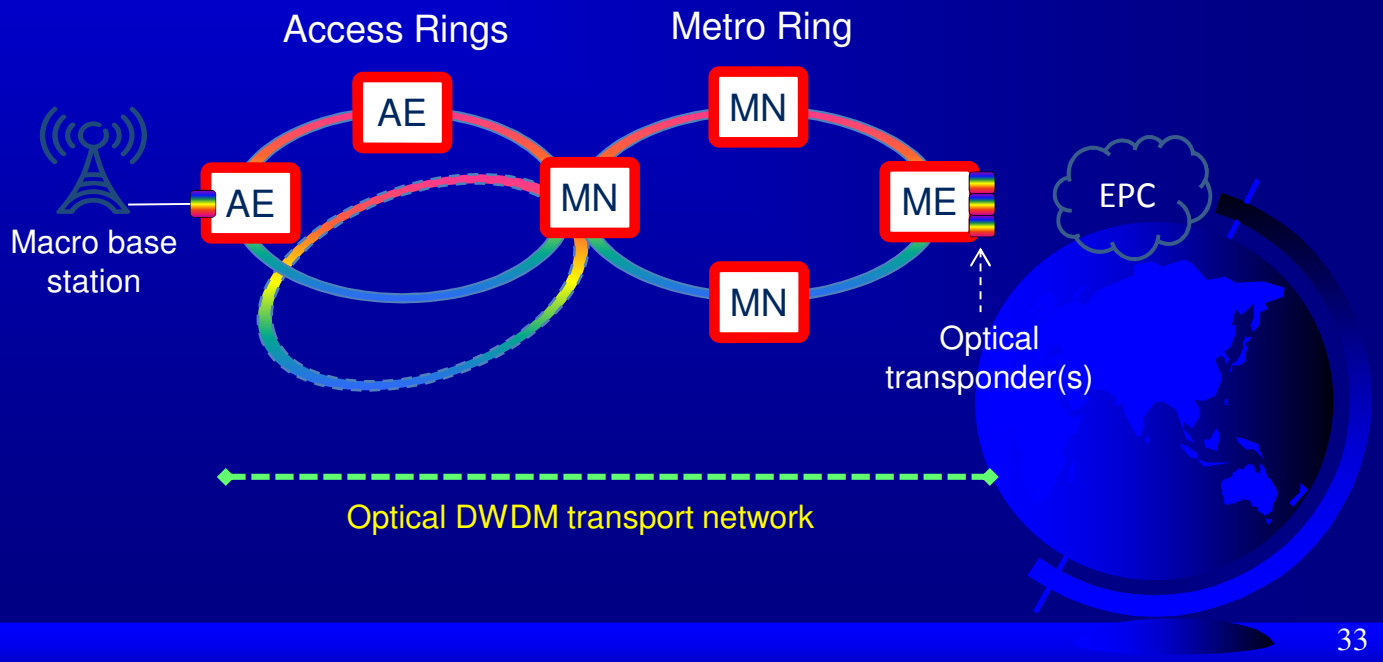
Small cells transport (2/2)

› Overview of fiber-based technologies for small cells transport:

Technology	Compatible services	Capacity	Costs (CAPEX)	Costs (OPEX)	Technology maturity	Open challenges
Active Ethernet (CAT 5/6 and/or grey optics + packet switching)	Ethernet	1-10G (drop) 10G-100G (feeder)	Equipment (low) Deployment (low)	General (high) Energy (high)	Mature	Control and management of active resources (switches/links)
PtP grey optical links	• Ethernet • CPRI • RoF	1-100G	Equipment (low) Deployment (high)	General (high) Energy (low/med)	Mature	Fiber deployment/handling
TWDM-PON	• Ethernet • WDM overlay with CPRI/RoF over same fiber infrastructure	≤40G (drop)	Equipment (med) Deployment (low)	General (low) Energy (med)	Standardized	• Handling of clients with stringent service requirements • Low cost components (tunable TRx)
DWDM-PON	• Ethernet • CPRI • RoF	1-10G (drop) ≤380 WL per fiber (feeder)	Equipment (med) Deployment (med)	General (low) Energy (low)	Products available for less cost sensitive segments Low cost technologies (3-5 years)	Low cost components (tunable TRx, integrated TRx arrays)
UD-WDM-PON	• Ethernet • CPRI • RoF	1-10G (drop) ≤1000 WL per fiber (feeder)	Equipment (very high) Deployment (very low)	General (low) Energy (med)	Concept/demo stage Low cost technologies (5+ years)	Low cost components (coherent TRx)

Metro/aggregation network

- The (D)WDM transport technology provides extremely high capacity for the metro/aggregation network:
  - Hierarchy of interconnected optical rings
  - Different options for metro node design
  - Different options for the placement of the BBU functions



AE: Access Edge
MN: Metro Node
ME: Metro Edge

Data plane design strategies

- Two main design strategies for 5G transport networks:
  - **Overprovisioning**

    The challenge of providing high capacity on-demand with (possibly) fast resource reconfiguration is satisfied thanks to the ubiquitous availability of ultra-high capacity transport

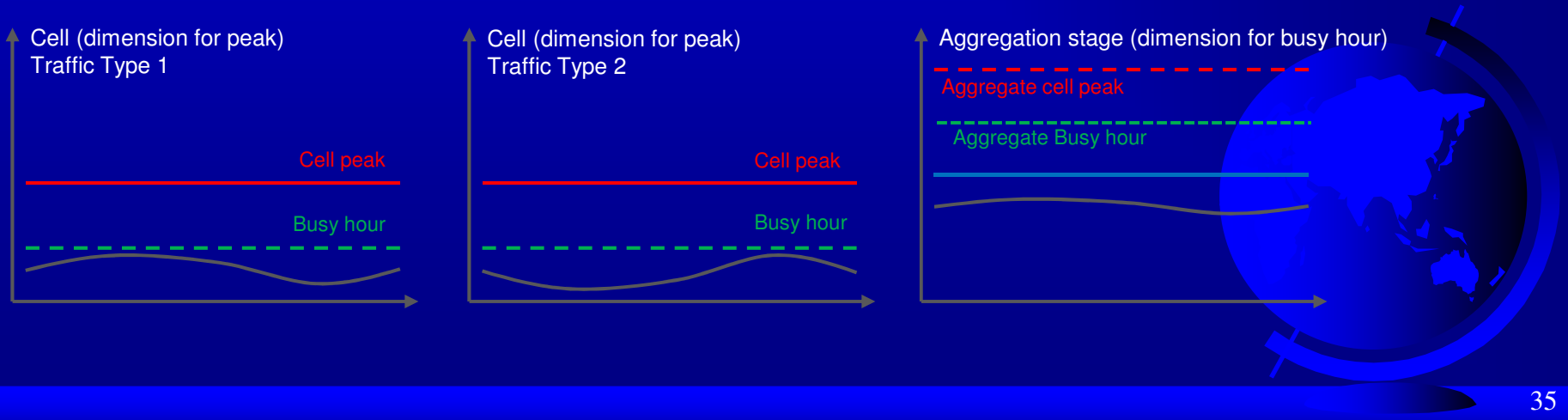
    - Pros: relatively low complexity at the control plane
    - Cons: potentially high cost because of inefficient use of network resources
  - **Smart transport networks**

    1. *Dynamic resource sharing*
       - Re-configurable systems for dynamically sharing limited transport resources
    2. *Network functions virtualization*
       - Dynamically push network functions to different locations, such as closer to the users so that a portion of the traffic requests can be served locally



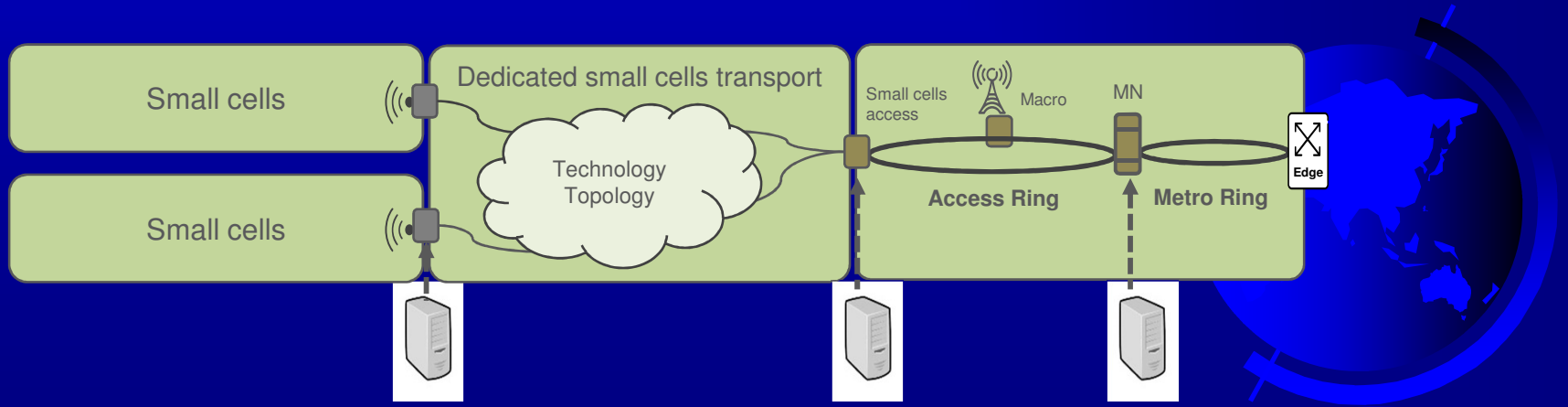
Dynamic resource sharing

- The type of resources and how they can be shared depends on:
  - Radio deployment solution/architecture
  - Transport technology
  - User traffic dynamicity
- Resources that can be shared:
  - Packet switching: traffic engineering to allocate switching capacity
  - Fiber: wavelength division multiplexing (WDM)
  - Wavelength: time division multiplexing (TDM) or dynamic wavelength allocation
  - Spectrum: time, frequency or code multiple access
- Example of dynamic resource sharing by exploiting temporal traffic patterns:



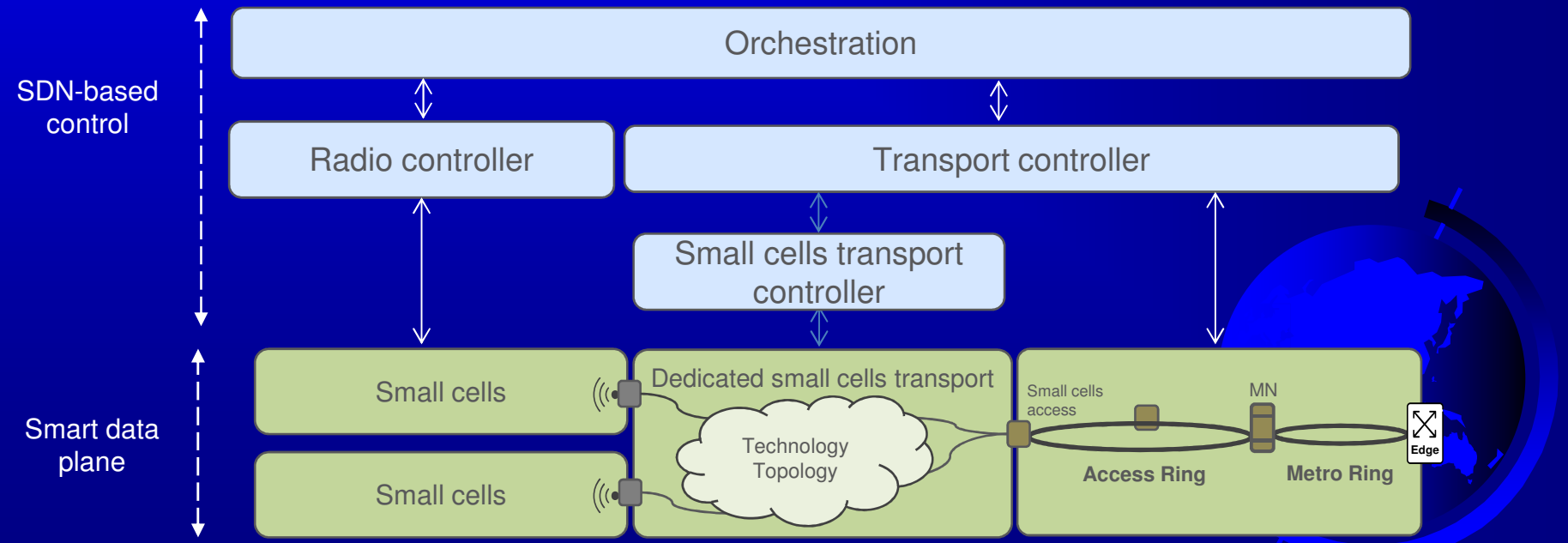
Network Functions Virtualization

- The type of resources that can be dynamically virtualized depends on:
  - User traffic type
  - Business model (agreement between wireless and transport providers)
- Example of resources that can be virtualized:
  - Wireless network functions
    - BB processing
    - Evolved packet core (EPC)
  - Transport network functions
    - Packet aggregation
  - Cloud resources
    - Cache/storage
- Servers needs to be available in different network locations:



Control plane design (1/2)

- The use of dynamic resource sharing and NFV puts requirements on the control plane
- A software-defined networking (SDN) based control plane with programmable control of network resources and end-to-end orchestration could provide a framework for such a scenario
- Possible control plane architecture:



Control plane design (2/2)

- Demonstration video …
- https://www.youtube.com/watch?v=1BA0qW14MAU



Open issues

- Performance may be an issue
  - Smart network and traffic engineering
- Orchestration
  - Description tools and languages
  - Application building tools
- Multi-domain
  - Coordinate different orchestration logics
  - VNF standardization

