Multi-Layer IBN in NFV ecosystem: functional architecture and practical experience

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CNIT

PNTLab
Photonic Networks&Technologies

Background

Background:

- SDN/NFV enable flexible slicing of network, computing and storage infrastructures customized to meet specific needs of vertical applications (VAs)
- ETSI NFV MANagement and Orchestration (MANO) is the reference framework for the orchestration and lifecycle management of physical and/or software resources supporting network slicing
- SDN can provide flexibility features to allow for programmable interconnection among Virtual Network Functions (VNFs) composing the network slices

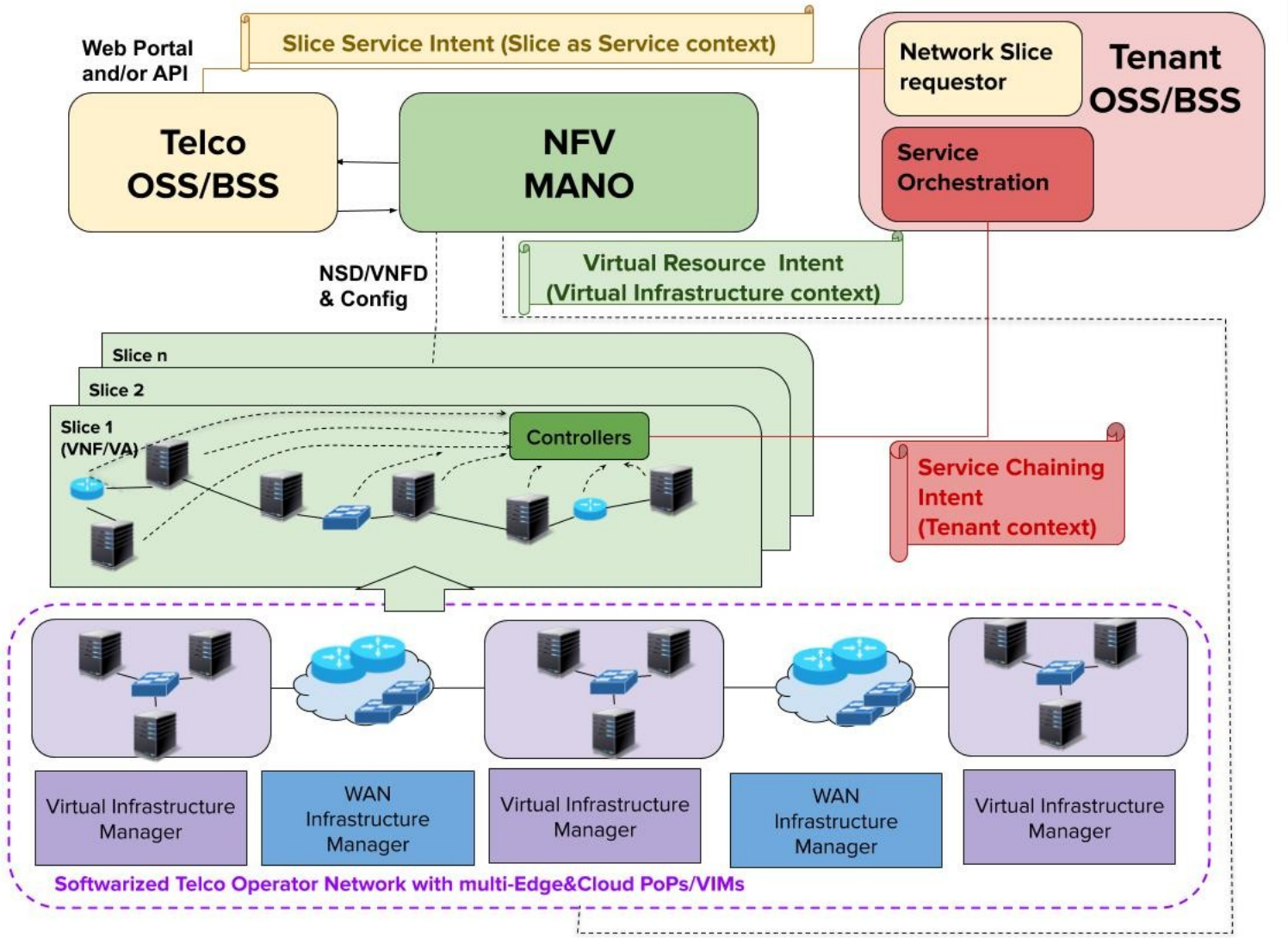
Challenge:

- SDN/NFV and MANO lead to increasingly network and service platforms flexibility and new business opportunities provided that an end-to-end vision is embraced and multi-layer orchestration functionalities are put in place.

Open question:

- Does multi-layer orchestration imply multi-layer intents?
- Does different involved stakeholders imply multi-layer intent?
- What is the role of SDN in this multi-layer vision?
- How SDN can be part of an intent specification?

Multi-layer Orchestration and Intents in NFV



Outline

- Intent-based service chain deployment
  - Scope: network slice
  - Perspective Tenant/Vertical
- Intent-based Virtual Link deployment
  - Scope: virtual infrastructure (WAN)
  - Perspective: Network service provider
- Intent-based SDN-capable slice deployment
  - Scope: slice as a service
  - Perspective: Tenant/Vertical

Intent-based service chain deployment

Fed4FIRE+ Open Call for Experimentation
«Latency-aware and self-Adaptive Service cHaining in reliable 5G/SDN/NFV infrastructures (LASH-5G)" (GA: 732638)

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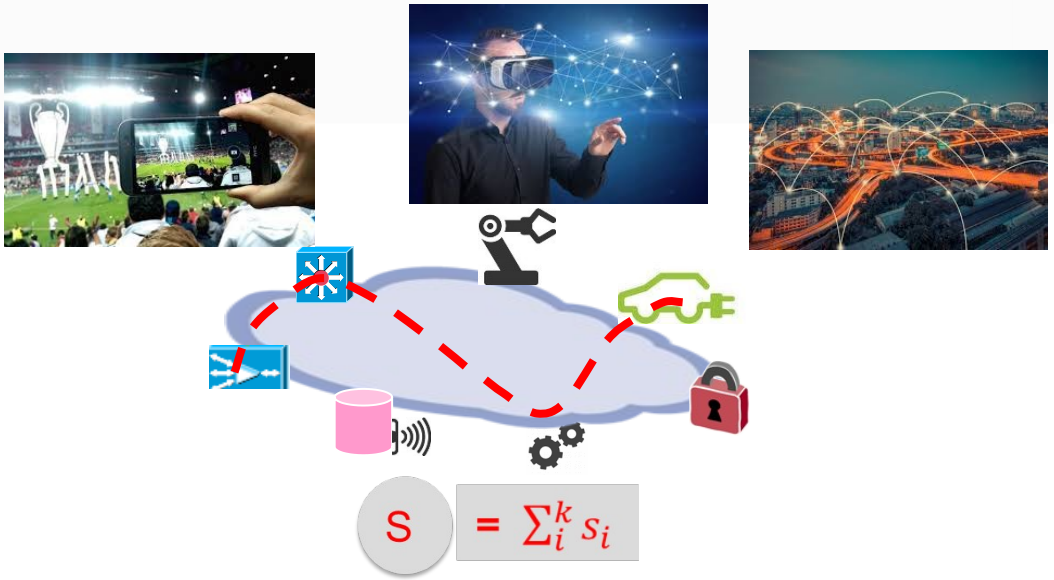
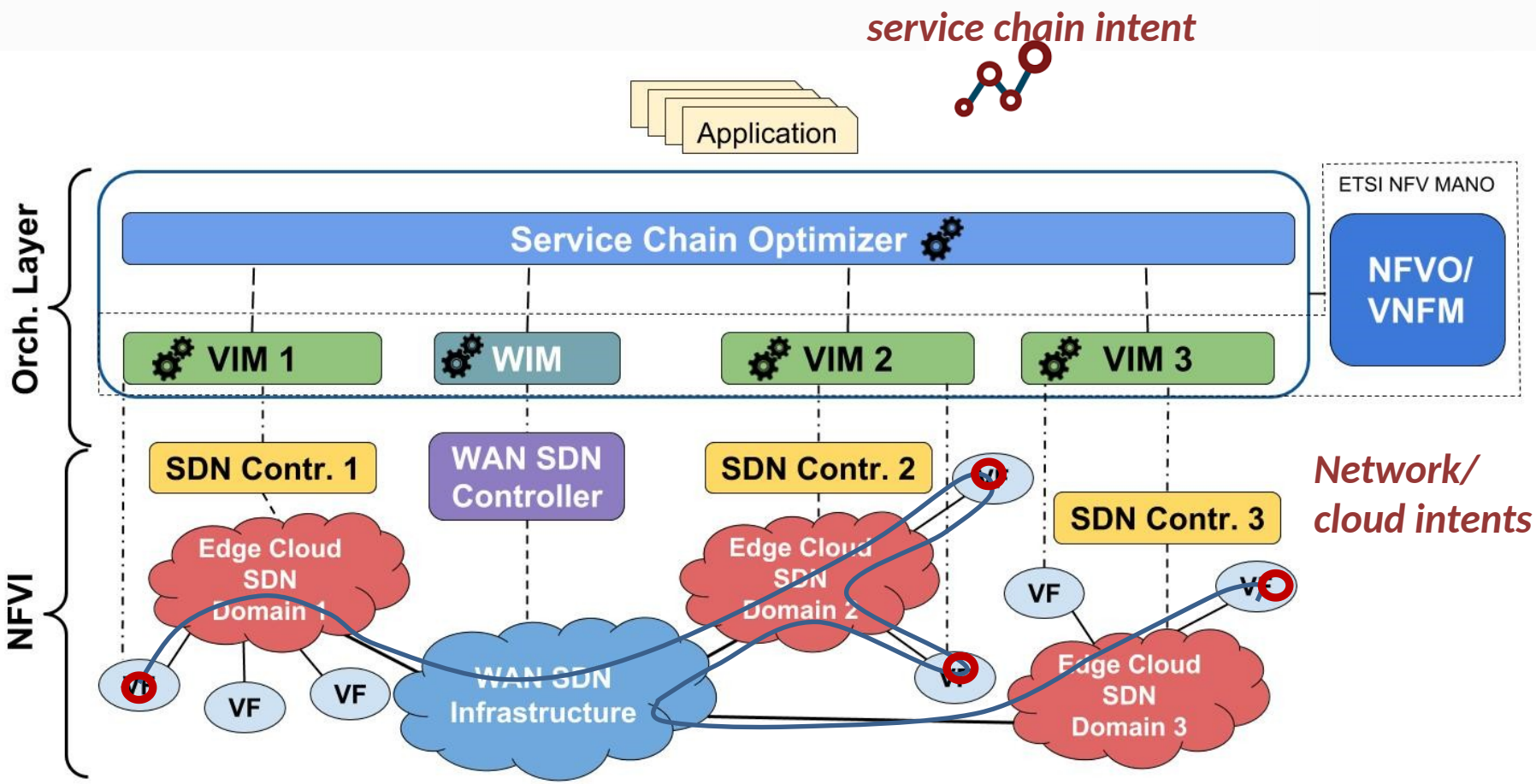
Overview

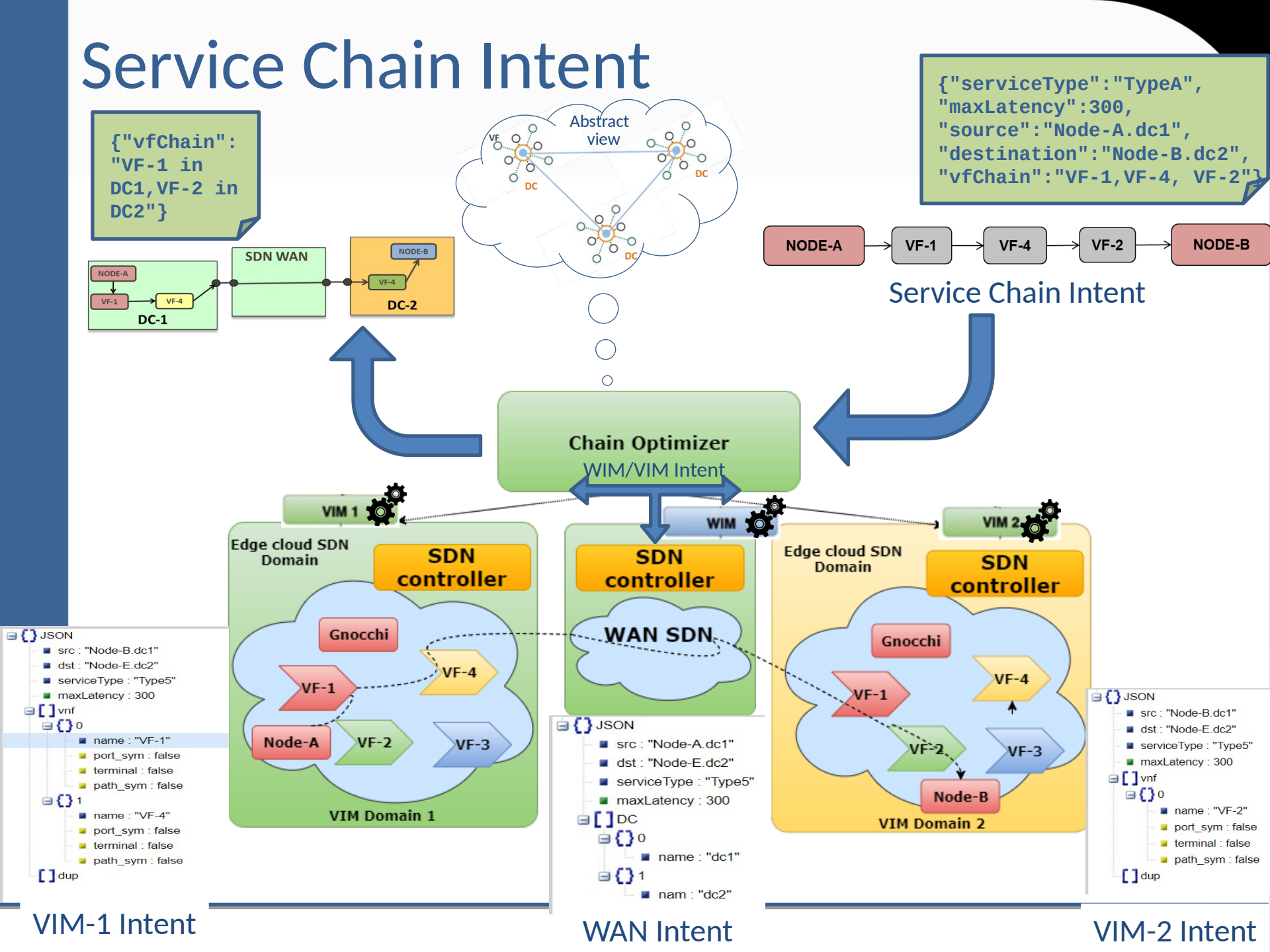


- 5G NR provides higher throughput and lower latency thereby enabling a unique smart environments and a new breed of vertical applications (e.g., connected cars, industry 4.0, e-health)
- network slicing enable tailored softwarized infrastructures to run those application mostly demanding for stringent end-to-end latency requirements
- traditionally vertical applications are delivered as chains of composite services (security, firewall, optimization) according to specified composition rules also based on context information (dynamic service composition)
- SDN network control capabilities to address an effective data delivery across dynamic (e.g., context-aware) chains of services

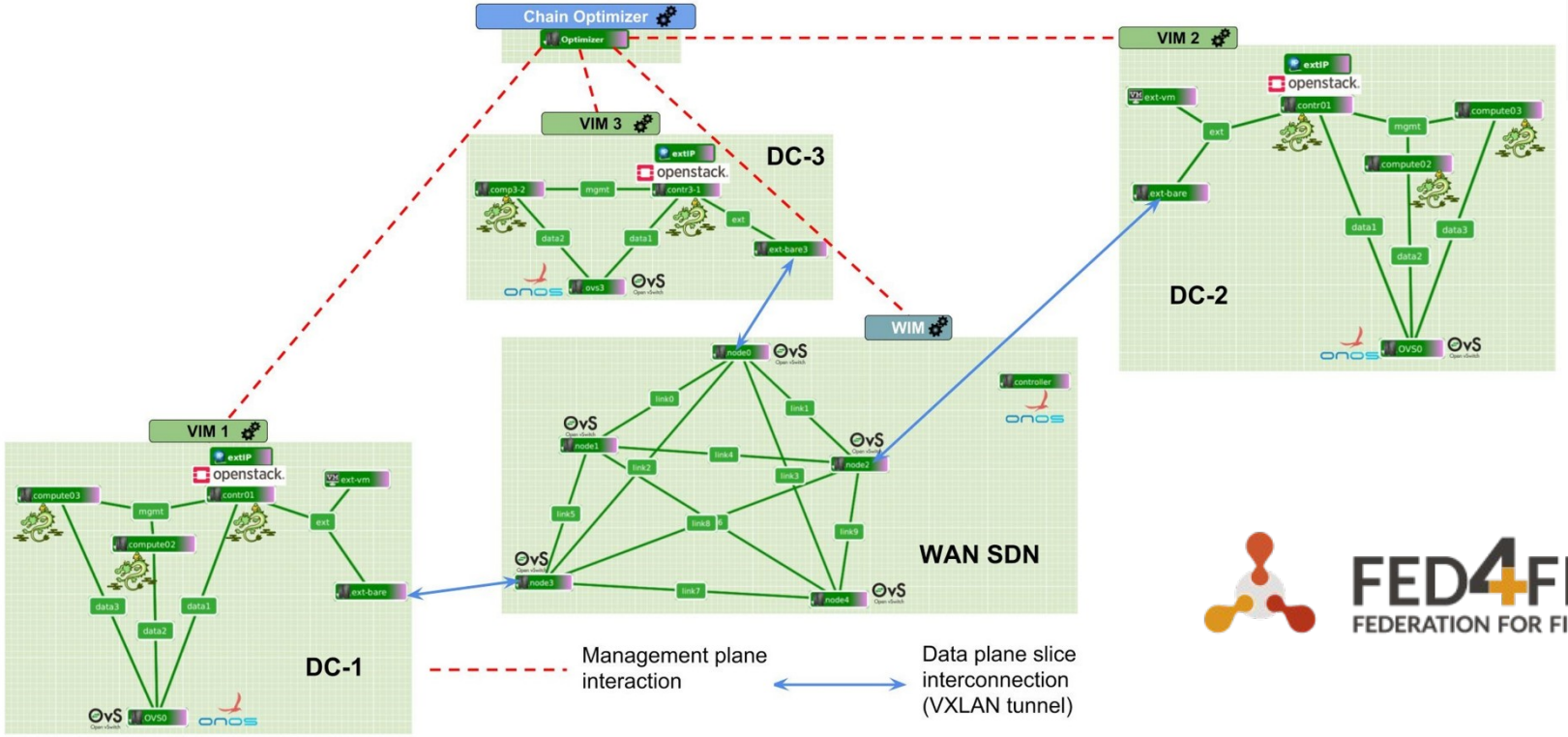
Reference architecture



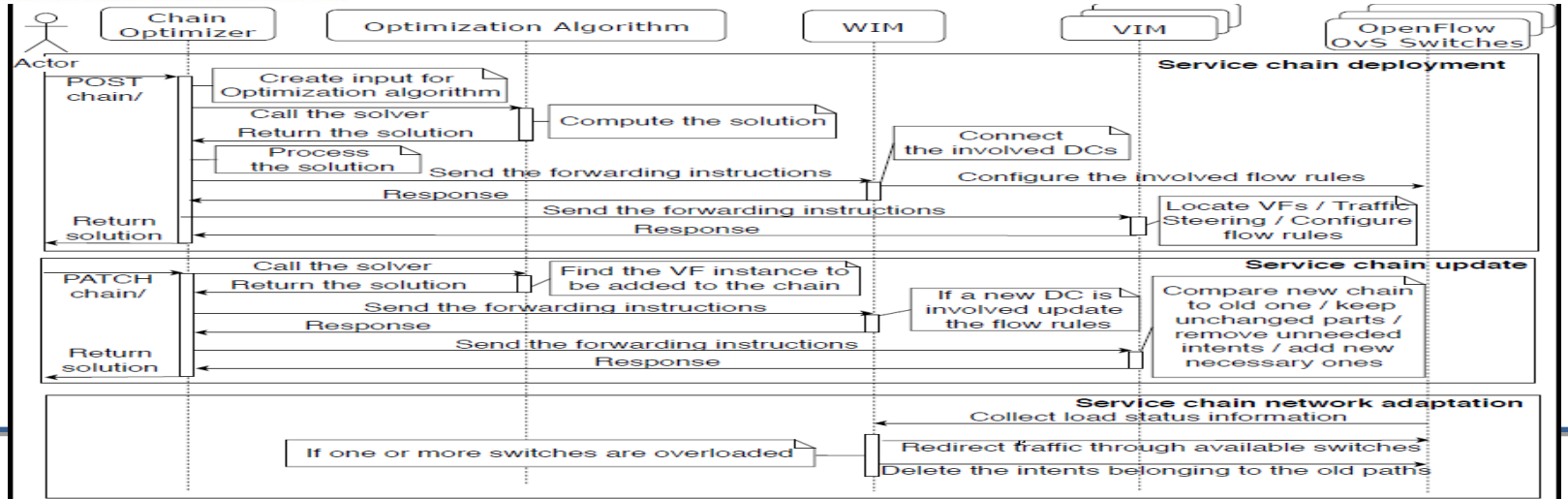
Service Chain Intent



Experimental set-up and workflow



FED4FIRE
FEDERATION FOR FIRE PLUS



Some results

PERFORMANCE OF THE ORCHESTRATION SYSTEM COMPONENTS.

Chain Length	CO Overall Resp. Time [s]	Resp. Time WIM [s]	Resp. Time VIMs [s]
2	64.34	40.84	1.41
3	69.34	36.29	1.50
4	74.96	35.98	1.48
5	82.75	40.5	1.52

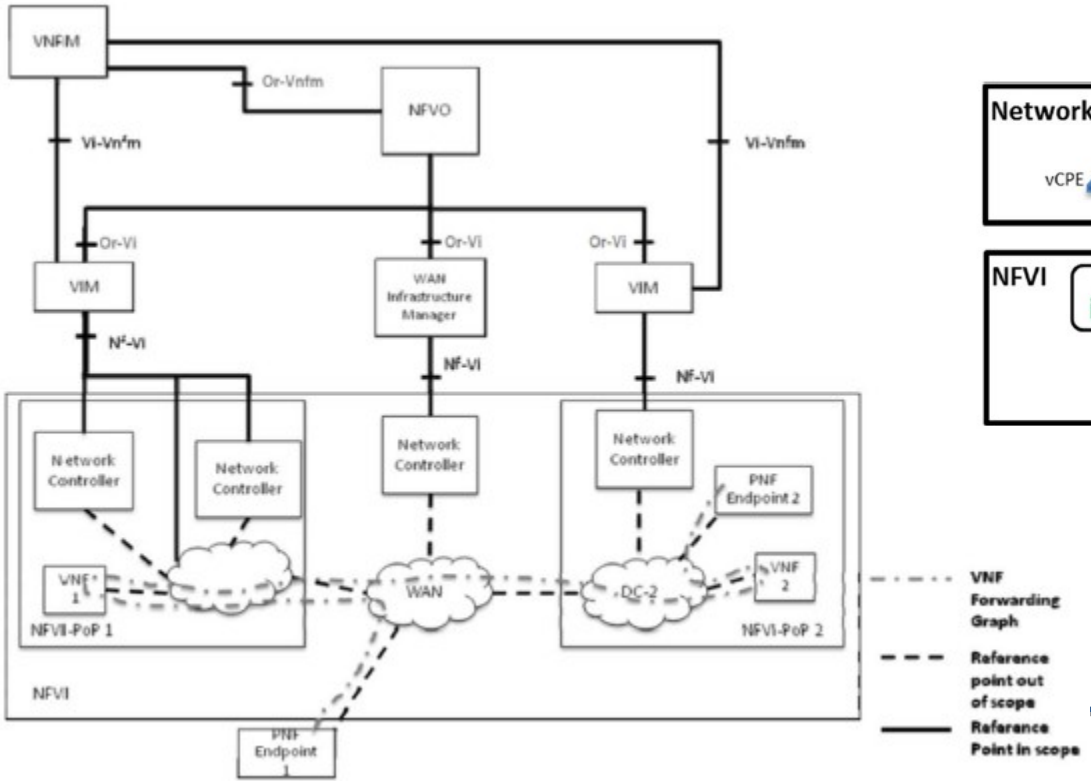
Video - Service Chain Deployment

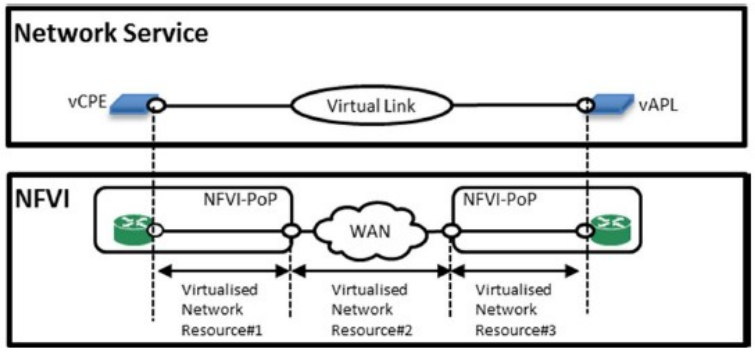
Deploy Service Chain: NODE-B@dc1 -VF4-VF5-VF9-VF10- NODE-D@dc2
Chain 4: NODE-B@dc1-VF4@dc1 -VF5@dc3-VF9@dc2-VF10@dc2- NODE-D@dc2

Intent-based Virtual Link deployment

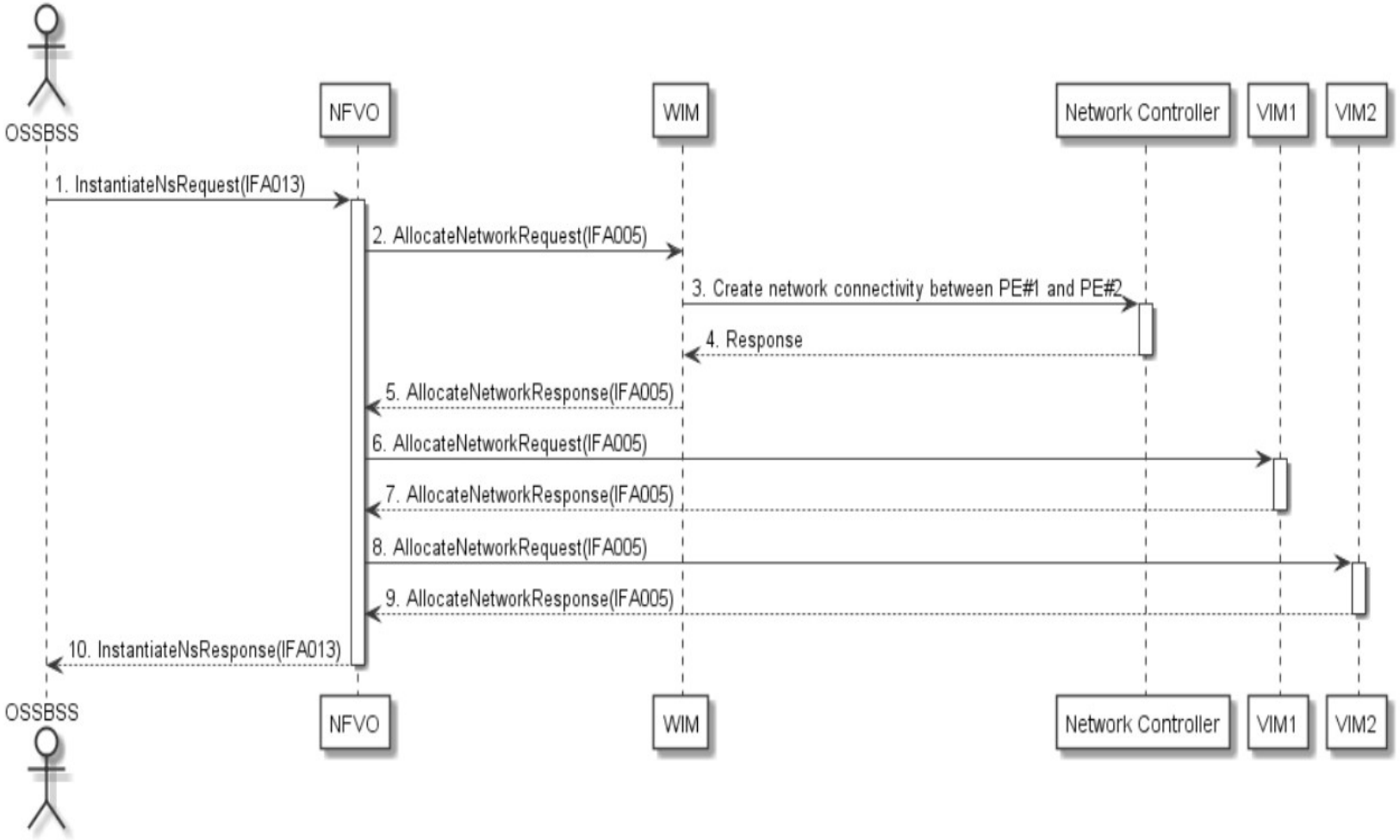
Overview (ETSI NFV)

- A unified Virtual Link connecting VNF is composed of 3 components:
  - *Virtualised network resource intra-PoP*: from the VNF to the network port attached to the WAN
  - *Virtualised network resource inter-PoP*
  - *Virtualised network resource intra-PoP*: from the VNF to the network port attached to the WAN
- Virtualised network resource inter-PoP: network connectivity between two sites across WAN
- Coordination among the VNFs deployments (including connectivity) at each site and the network connectivity between the two sites to set-up a Network Service (NS)/VNG-Forwarding Graph (NFV-FG)

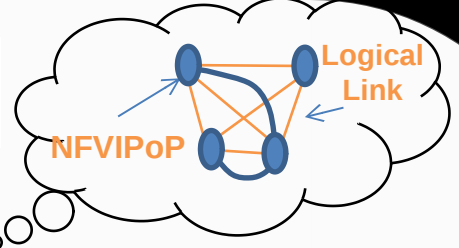




Sequence Diagram (ETSI IFA022/IFA005)



Reference architecture



NFVI DB

NFVIPoP topology:
- Logical Link
  - Id
  - NFVIPoP Id source
  - NFVIPoP Id dest
  - Gw IP Addr source
  - Gw IP Addr dest
  - *info…*
- NFVIPoP
  - *info…*

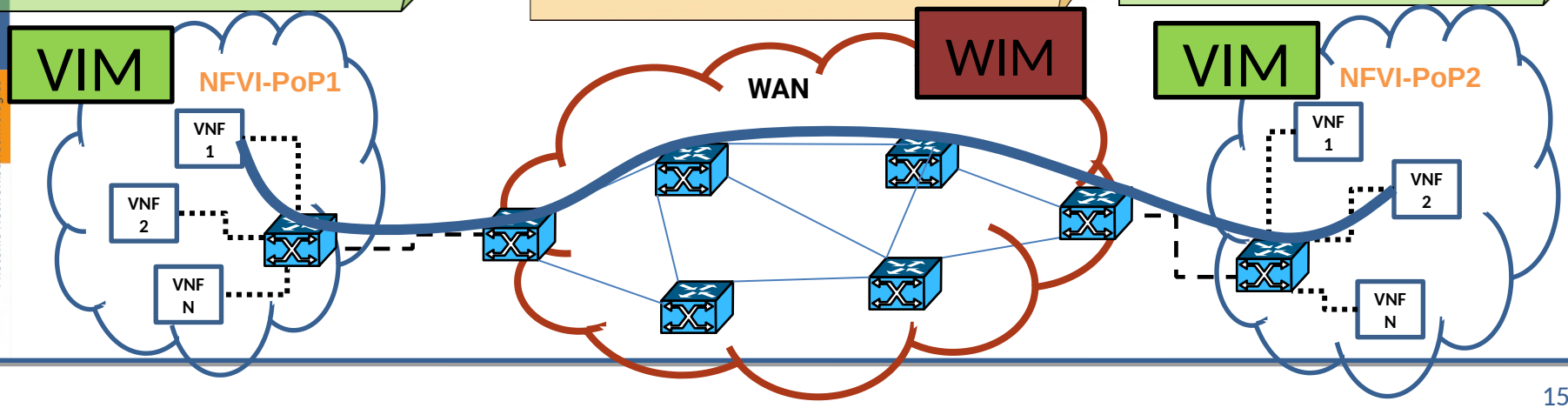
Service Orchestrator (SO)

Mobile Transport and Computing Platform (MTP)

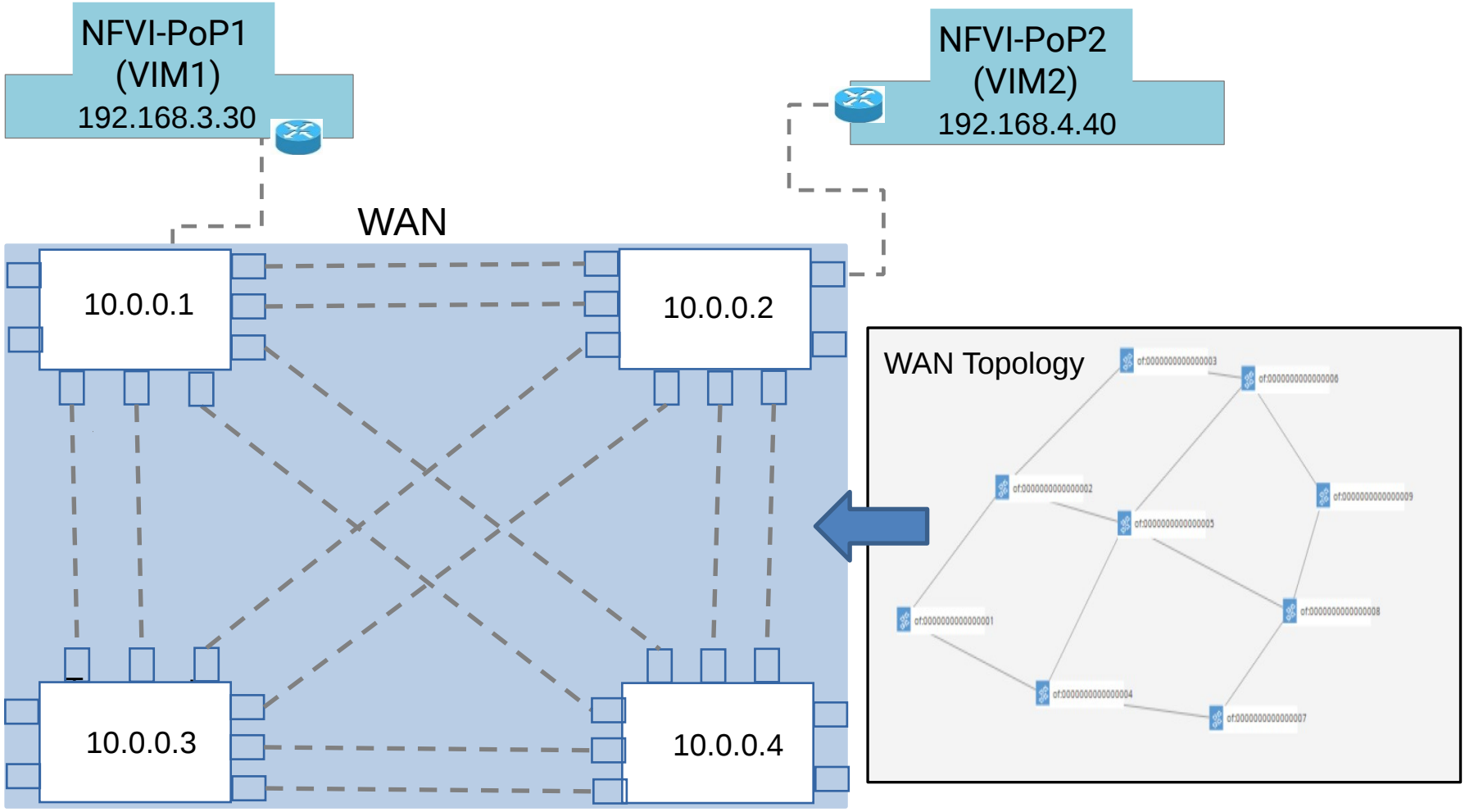
NFVIPoP Attributes:
- Id
- Location
- Gw IP addr
- CPU capacity / availability
- RAM capacity / availability
- STORAGE capacity / availability
- Link capacity
- Cost
- Failure rate

WAN Connectivity Attributes:
- Id (resource identifier used internally)
- Gw IP Addr(s) (Gw-a, Gw-b)
- *info for connecting to the WAN (IP address+VXLAN ID, MPLS+VPN Route Distinguisher)*
- Cost
- Total and Available bw
- Total delay

NFVIPoP Attributes:
- Id
- Location
- Gw IP addr
- CPU capacity / availability
- RAM capacity / availability
- STORAGE capacity / availability
- Link capacity
- Cost
- Failure rate



WIM abstraction (1/2)



WIM abstraction (2/2)

5G-SO

5G-MTP

WIM REST client

WIM REST server

WIM

REST client

REST ONOS APIs

ONOS SDN Controller

Open Network Operating System

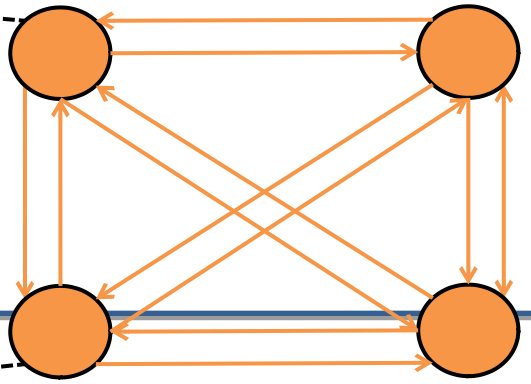
WAN Topology

SOInterface

GET	/abstract-resources	Retrieve aggregated Cloud NFVI-PoP and Inter-NFVI-PoP Connectivity
POST	/abstract-network-resources	Create inter-NFVI-PoP connectivity
DELETE	/abstract-network-resources	Delete inter-NFVI-PoP connectivity

GET	/abstract-network	Retrieve aggregated WAN Connectivity
DELETE	/network-resources/{networkId}	
GET	/network-resources	
POST	/network-resources	

Logical view



WAN Virtual Link Intent

- GET Abstract view
  - Request for the abstract view of the WAN
  - Response: json file containing list of gateways and list of virtual links

- POST request to allocate a virtual link
  - Request: json body containing info relative to the VL (id, bandwidth, delay, ingress/egress points)

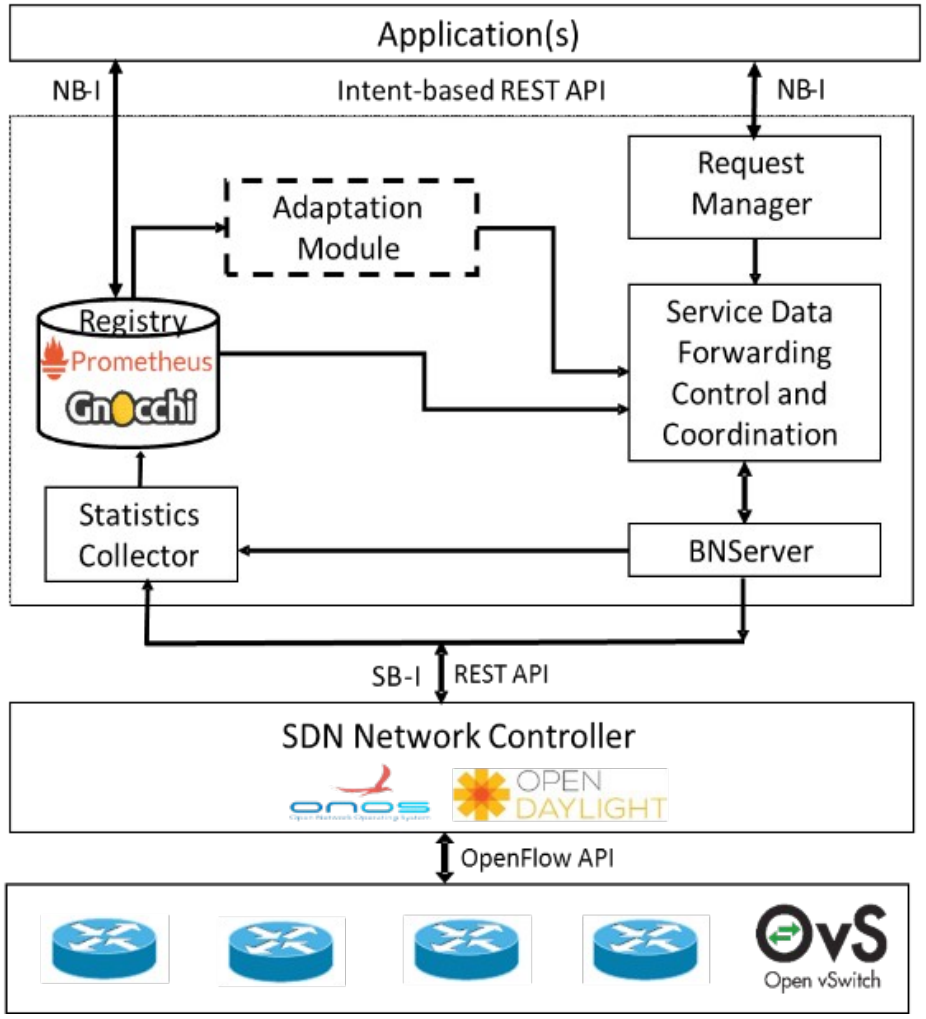
```
{
    "gateways": [
        {
            "gatewayAttributes": {
                "geographicalLocationInfo": "Pisa",
```

```
{
    "locationConstraints": "Pisa",
    "reservationId": "1234",
    "typeNetworkData": "L2VPN",
    "affinityOrAntiAffinityConstraints": "aff1",
    "typeNetworkPortData": "null",
    "resourceGroupId": "null",
    "metadata": "string",
    "networkResourceType": "data",
    "networkResourceName": "conn1",
    "typeSubnetData": "null",
    "bandwidth": 10000,
    "delay": "75",
    "networkType": "l3vpn",
    "segmentType": "l2vpn",
    "networkQoS": "1",
    "isShared": false,
    "sharingCriteria": "null",
    "layer3Attributes": "null",
    "portType": "null",
    "networkId": "10",
    "segmentId": "20",
    "ingressPointIPAddress": "192.168.1.10",
    "ingressPointPortAddress": "192.168.1.20",
    "egressPointIPAddress": "10",
    "egressPointPortAddress": "20",
    "wanLinkId": "101"
}
```

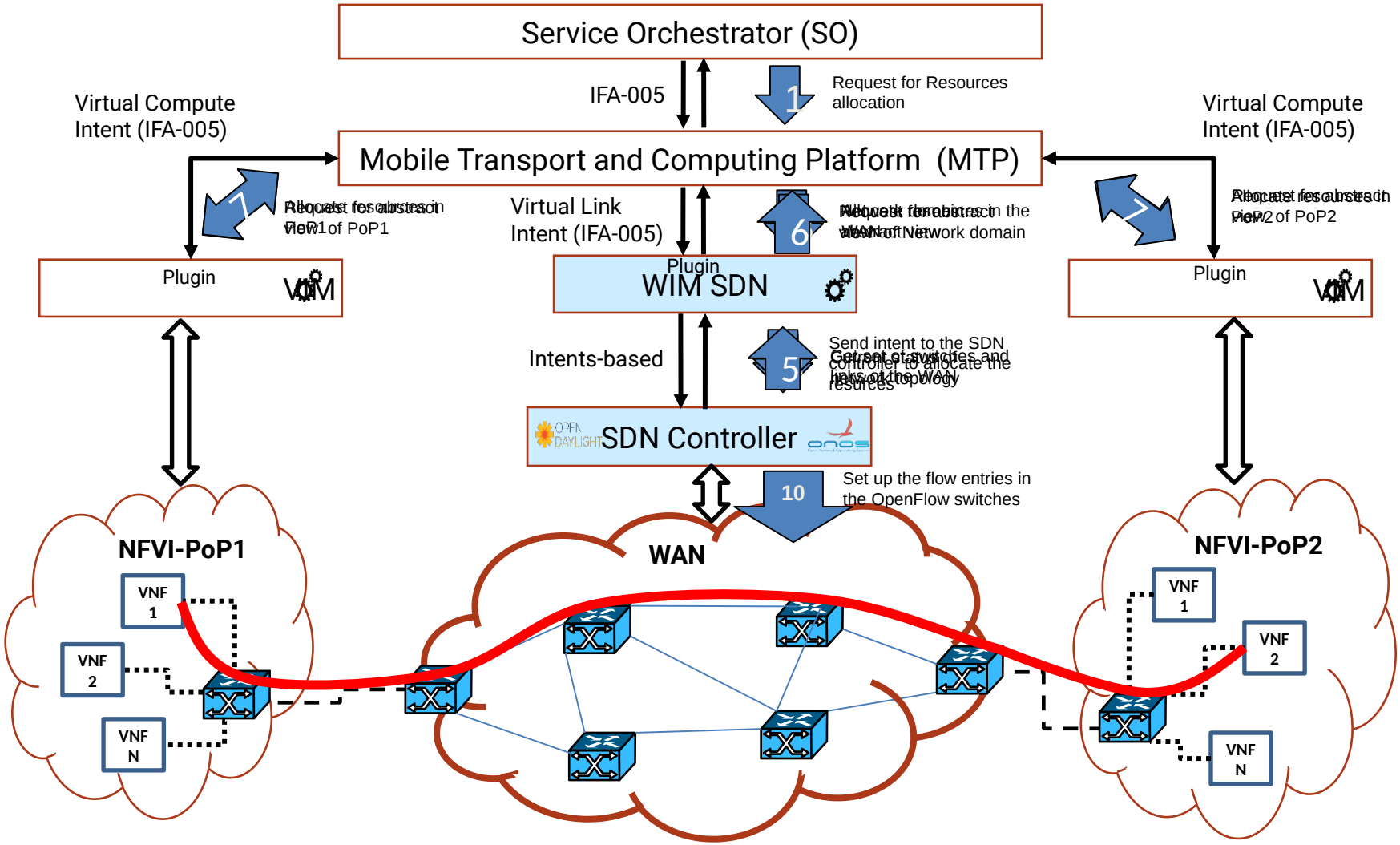
```
                "srcLinkId": 10,
                "dstGwId": "192.168.2.20",
                "dstLinkId": 20,
                "networkLayer": "vxlan"
            }
        }
    ]
}
```

CNIT SDN WIM

- Exposes an IFA-compliant Intent-based REST API for NFV deployments in inter-PoP scenarios (IFA005/IFA022)
- Advertises the abstract network topology
- Provisions end-to-end network paths (with and without explicit specification of the path hops)
- Exposes monitoring data related to the inter-PoP transport network:
  - topology characteristics: number of OF switches, number of virtual links, etc.
  - performance data: number of bytes per port/flow, throughput, etc.



Entertainment PoC: Set-up and Workflow



Intent-based SDN-capable slice deployment

5GINFIRE

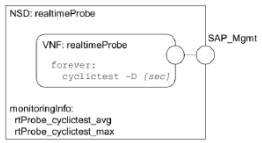
EVOLVING FUTURE INTERNET RESEARCH AND EXPERIMENTATION INTO A 5G-ORIENTED EXPERIMENTAL PLAYGROUND FOR VERTICAL INDUSTRIES

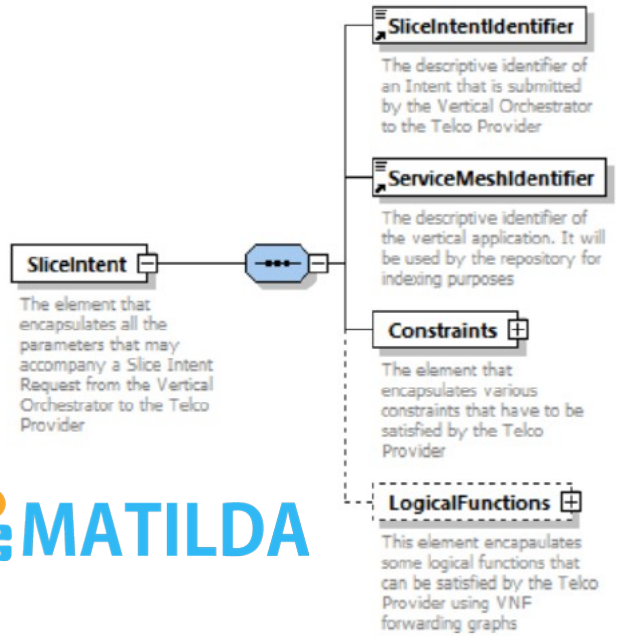
5GINFIRE Open Call for for additional functionalities and infrastructures for experimentation
«Slice SDN-based Network Management in 5G (SLICENET-5G)" GA: 732497

Overview

Network slice intents express the high-level requirements and constraints for the network service set-up hosting the vertical components:

- Vertical components and relevant service graph
- Requirements (e.g., CPU/memory/storage, link bandwidth)
- Constraints (e.g., delay, packet loss, throughput, location)
- Network functions and communication services (e.g., security, DPI, firewall, VPN, …)

Atomic functional components involved	stdLinux (see Table 74)
Service sequence	VNFFG in textual notation (ETSI NFV IFA 014) of 
Connectivity service	n/a
External interconnection	sapMgmt
Internal interconnection	n/a
SST	n/a (see the field SLA instead)
Service constraints	Geographical area: n/a Security: low Priority: medium Cost: n/a Synchronization: low Etc.
Management and control capabilities for the tenant	Provider managed
SLA	n/a
Monitoring	rtprobe_cyclictest_avg rtprobe_cyclictest_max
Lifetime	On-demand, 1h
Charging	n/a



SDN-enabled Network Slice Intent

- SDN-based connectivity in the slice to programmatically support:
  - internal L3/L2 forwarding functions across other slice components (L4-L7 network functions, vertical applications)
  - dynamic activation of data delivery services to recover from failure, traffic engineering
  - exposition of a control interface for interworking with external networks
- vertical may want to specify if SDN-related network capabilities are desired:
  - "*I want to connect VNF-1, VNF-2, VA-a, VA-b through SDN switches and to program the flows among them*"
- network slice intent should allow to request SDN capabilities in terms of:
  - which vertical applications or VNF to attach (id, type, network port)
  - SDN network interfaces and interconnections among VNFs/Vapp

Deploying SDN capabilities in a slice

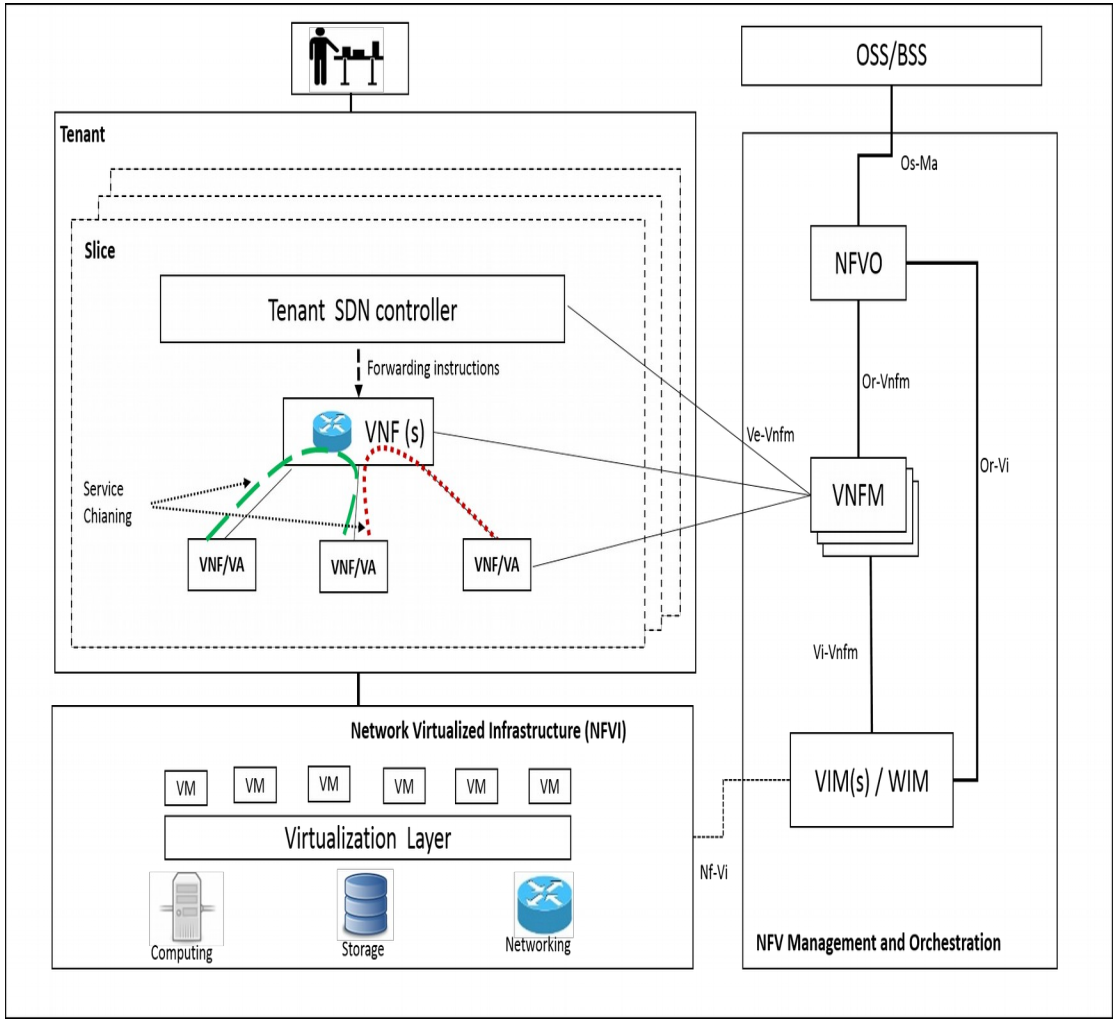
Slice composed of:

- SDN virtual switches and controller as VNFs
- Set of Vertical Applications (VAs) or VNFs

SDN components are configured to automatically start once the SDN-based VNFs are up:

- SDN controller
- SDN topology (OVS, emulated)

VAs configured to be attached to the SDN network



Blueprint example

```
name:
description:
deployment-details:
     min_applicative_instances_number:
     type: integer
     default: 1

     max_applicative_instances_number:
     type: integer
     default: 50

      instance_config:       #for each instance
            id:
            vCPU:
            RAM:
            storage-gb:
            image:
            management-IP:
            data-plane-IP
 connectivity-details:       #virtual links connecting VAs to the SDN slice
           virtual-link-1:
           virtual-link-2:
constraints:
     location
     instances_max_load
```

VNF/NS Descriptors

```
vnfd:vnfd-catalog:
  vnfd:
    - id: sdn_vnfd
      name: sdn_vnfd
      short-name: sdn_vnfd
      description: SDN-based VNF
      logo: 5GinFIRE.png
      vendor: 5GinFIRE
      version: '1.2'
      connection-point:
        - id: eth0
          name: eth0
          short-name: eth0
          type: VPORT
      mgmt-interface:
        cp: eth0
      vdu:
        - id: custom
          name: custom VDU
          image: custom
          count: 1
          cloud-init-file: cloud-config.yml
          vm-flavor:
            vcpu-count: 2
            memory-mb: 3072
            storage-gb: 5
          interface:
            - name: eth0
              position: 1
              type: EXTERNAL
              virtual-interface:
                type: VIRTIO
              external-connection-point-ref: eth0
      vnf-configuration:
        initial-config-primitive:
          - seq: '1'
            name: config
            parameter:
              - name: ssh-hostname
                value: <rw_mgmt_ip>
              - name: ssh-username
                value: ubuntu
              - name: ssh-password
                value: osm
```

```
nsd:nsd-catalog:
    nsd:
    -   id: SFC_nsd
        name: SFC_ns
        short-name: SFC_ns
        description: Chain of a 3 VNFs
        vendor: OSM
        version: '1.0'

        # Place the logo as png in icons directory and provide the name here
        logo: osm_2x.png

        # Specify the VNFDs that are part of this NSD
        constituent-vnfd:
            # The member-vnf-index needs to be unique, starting from 1
            # vnfd-id-ref is the id of the VNFD
            # Multiple constituent VNFDs can be specified
        -   member-vnf-index: 1
            vnfd-id-ref: simple1_vnfd
        -   member-vnf-index: 2
            vnfd-id-ref: sdn_vnfd
        -   member-vnf-index: 3
            vnfd-id-ref: simple2_vnfd
        vld:
        # Networks for the VNFs
            -   id: management_vld1
                name: management_vld1
                short-name: management_vld1
                type: ELAN
                mgmt-network: 'true'
                vim-network-name: shared
                vnfd-connection-point-ref:
                -   member-vnf-index-ref: 1
                    vnfd-id-ref: simple1_vnfd
                    vnfd-connection-point-ref: eth0
                -   member-vnf-index-ref: 2
                    vnfd-id-ref: sdn_vnfd
                    vnfd-connection-point-ref: eth0
            -   id: management_vld2
                name: management_vld2
                short-name: management_vld2
                type: ELAN
                mgmt-network: 'true'
                vim-network-name: shared
                vnfd-connection-point-ref:
                -   member-vnf-index-ref: 2
                    vnfd-id-ref: sdn_vnfd
                    vnfd-connection-point-ref: eth0
                -   member-vnf-index-ref: 3
                    vnfd-id-ref: simple2_vnfd
                    vnfd-connection-point-ref: eth0
```

Video Demo

Thank you!

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Approaches for Network Slice Intents

- **Provider-oriented approach** (5G-TRANSFORMER project):
  - The provider supports the Vertical Service Descriptors (VSDs) filled up with high-level requirements and constraints by the vertical
  - VSDs meant as abstractions of Network Service Descriptors (e.g., service sequence as VNF-FG, components as VNFD)
  - Additional components specified to support the service from the provider perspective (e.g., firewall, load balancer) transparent to the vertical.
  - Possibility to specify vertical service chains
- **Tenant-oriented approach** (MATILDA project):
  - The tenant requests the slice with specified requirements and constraints to set-up Vertical Applications in a service graph
  - A metamodel (i.e., Slice Intent) specified for the request
  - Vertical service chain natively supported (i.e., service mesh)
  - Possibility to specify logical components (e.g., firewall, VPN, IDS_IPS) required by the vertical to the telco operator

Operations

- GET Astract view
  - http://localhost:53000/wimsdnplugin/abstract-network
  - Request for the abstract view of the WAN
  - Response: json file containing list of gateways and list of virtual links

- POST request to allocate a virtual link
  - http://localhost:53000/wimsdnplugin/network-resources
  - Request: json body containing info relative to the VL (id, bandwidth, delay, ingress/egress points)
  - Steps:
    - Check if the requested parameters are available
    - Prepare an intent that corresppnds to the requested parameters
    - Send the intent to the SDN controller (ONOS) to setup the flowentries in the OpenFlow switches of the WAN (network connectivity)
    - If the intent is correctly installed, update the network resource with the new values of Free bw and Allocated bw
    - Update the intents DB

- DELETE request to delete a virtual link
  - http://localhost:53000/wimsdnplugin/network-resources/reqId
  - Steps:
    - Check if the network service already exists
    - Send a delete request to the SDN controller to delete the flowentries
    - Update the bandwidth status after the release of the resources
    - Update the intents DB

GET json


```
{
    "gateways": [
        {
            "gatewayAttributes": {
                "geographicalLocationInfo": "Pisa",
                "wimId": "3",
                "networkConnectivityEndpoint": [
                    {
                        "netGwIpAddress": "192.168.1.10",
                        "netGwInterfceId": null
                    }
                ],
                "gatewayId": "192.168.1.10"
            }
        },
        {
            "gatewayAttributes": {
                "geographicalLocationInfo": "Pisa",
                "wimId": "3",
                "networkConnectivityEndpoint": [
                    {
                        "netGwIpAddress": "192.168.2.20",
                        "netGwInterfceId": null
                    }
                ],
                "gatewayId": "192.168.2.20"
            }
        }
    ],
    "virtualLinks": [
        {
            "virtualLink": {
                "virtualLinkId": "101",
                "totalBandwidth": 1000000,
                "availableBandwidth": 1000000,
                "networkQoS": {
                    "linkCostValue": 1,
                    "linkDelayValue": 50,
                    "packetLossRate": 0
                },
                "srcGwId": "192.168.1.10",
                "srcLinkId": 10,
                "dstGwId": "192.168.2.20",
                "dstLinkId": 20,
                "networkLayer": "vxlan"
            }
        }
    ]
}
```

VS yaml

```
name:
description:
deployment-details:
     min_applicative_instances_number:
     type: integer
     default: 1

     max_applicative_instances_number:
     type: integer
     default: 50

      instance_config:       #for each instance
            id:
            vCPU:
            RAM:
            storage-gb:
            image:
            management-IP:
            data-plane-IP
 connectivity-details:       #virtual links connecting VAs to the SDN slice
           virtual-link-1:
           virtual-link-2:
constraints:
     location
     instances_max_load
```

NSD

```
nsd:nsd-catalog:
    nsd:
    -   id: SFC_nsd
        name: SFC_ns
        short-name: SFC_ns
        description: Chain of a 3 VNFs
        vendor: OSM
        version: '1.0'

        # Place the logo as png in icons directory and provide the name here
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        # Specify the VNFDs that are part of this NSD
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        -   member-vnf-index: 2
            vnfd-id-ref: sdn_vnfd
        -   member-vnf-index: 3
            vnfd-id-ref: simple2_vnfd
        vld:
        # Networks for the VNFs
            -   id: management_vld1
                name: management_vld1
                short-name: management_vld1
                type: ELAN
                mgmt-network: 'true'
                vim-network-name: shared
                vnfd-connection-point-ref:
                -   member-vnf-index-ref: 1
                    vnfd-id-ref: simple1_vnfd
                    vnfd-connection-point-ref: eth0
                -   member-vnf-index-ref: 2
                    vnfd-id-ref: sdn_vnfd
                    vnfd-connection-point-ref: eth0
            -   id: management_vld2
                name: management_vld2
                short-name: management_vld2
                type: ELAN
                mgmt-network: 'true'
                vim-network-name: shared
                vnfd-connection-point-ref:
                -   member-vnf-index-ref: 2
                    vnfd-id-ref: sdn_vnfd
                    vnfd-connection-point-ref: eth0
                -   member-vnf-index-ref: 3
                    vnfd-id-ref: simple2_vnfd
                    vnfd-connection-point-ref: eth0
```

VNFD - SDN

```
vnfd:vnfd-catalog:
  vnfd:
    - id: sdn_vnfd
      name: sdn_vnfd
      short-name: sdn_vnfd
      description: SDN-based VNF
      logo: 5GinFIRE.png
      vendor: 5GinFIRE
      version: '1.2'
      connection-point:
        - id: eth0
          name: eth0
          short-name: eth0
          type: VPORT
      mgmt-interface:
        cp: eth0
      vdu:
        - id: custom
          name: custom VDU
          image: custom
          count: 1
          cloud-init-file: cloud-config.yml
          vm-flavor:
            vcpu-count: 2
            memory-mb: 3072
            storage-gb: 5
          interface:
            - name: eth0
              position: 1
              type: EXTERNAL
              virtual-interface:
                type: VIRTIO
              external-connection-point-ref: eth0
      vnf-configuration:
        initial-config-primitive:
          - seq: '1'
            name: config
            parameter:
              - name: ssh-hostname
                value: <rw_mgmt_ip>
              - name: ssh-username
                value: ubuntu
              - name: ssh-password
                value: osm
```