Enabling 5G network slicing over heterogeneous optical networks

ONDM2017 Workshop

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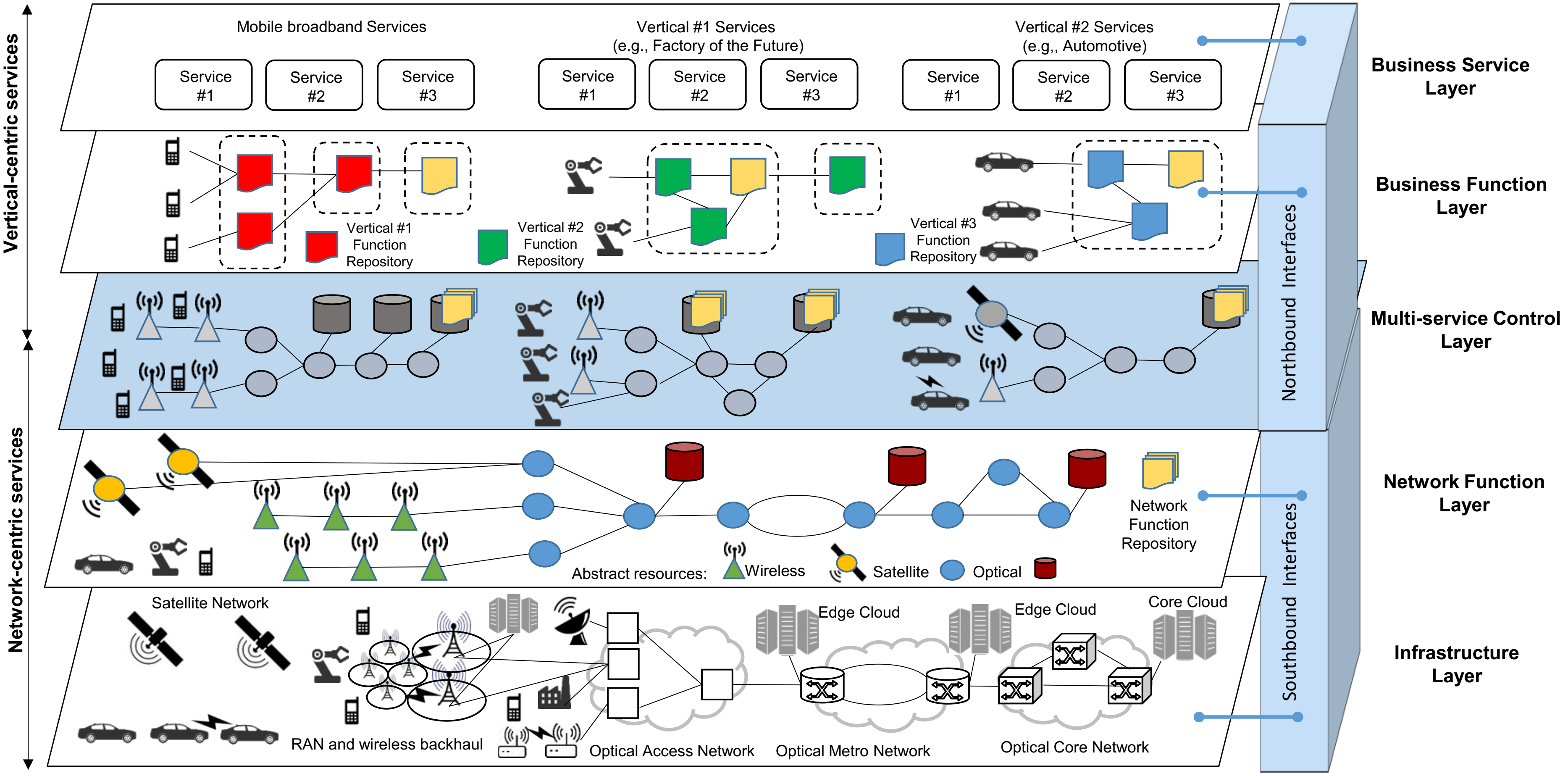
Introduction: slicing as an emerging requirement for 5G

- **Slicing Macroscopic Concept**: partition (slice) a single physical infrastructure into multiple *virtual X* optimized according to specific services, business models, etc.
  - X? Networks? Infrastructures? Functions?
  - Network virtualization? Virtual Private Network? ETSI NFV Network Service?
    - All can be seen as a particular cases.

- **Definitions**
  - Next Generation Mobile Networks (NGMN) White Paper
  - 3GPP TR 28.801 V1.0.0 (2017-03) Study on management and orchestration of network slicing for next generation network (Release 14)
    - a set of network functions and the resources for these network functions which are arranged and configured, forming a complete logical network to meet certain network characteristics.
    - May be composed of subnets of Physical Network Functions and/or Virtualized Network Functions.
    - Physical Network Functions and Virtualized Network Functions may belong to one or more network slice subnet(s).
  - Research papers, White papers…

A logical construct encompassing multiple interconnected functions, customized and optimized for a service (set) or vertical.

5GPPP White paper (MWC2016)



Source: 5GPPP White paper MWC2016: https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

Slicing as a Service

- **Goal** → To dynamically provide multiple, highly flexible, end-to-end dedicated network slices (considering virtual network, cloud and functions resources) over the same physical infrastructure in order to deliver vertical-specific requirements
  - Control, Management and Orchestration systems for slice life-cycle management.

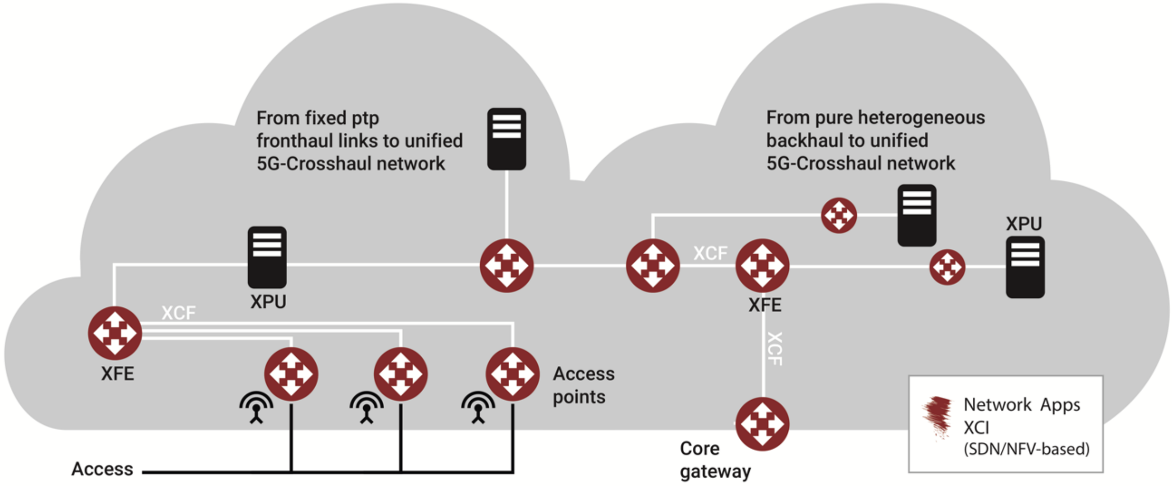
- Slices can be created and operated by the 5G network operator or enable new business models, e.g. “Slice-as-a-Service”.

- *What about multi-tenancy?*
  - *Related to the concept of ownership and/or use.*
  - *Network Slicing is an enabler for flexible multi-tenancy.*
  - *Ultimately empowering tenant to control allocated slice (recursively)*

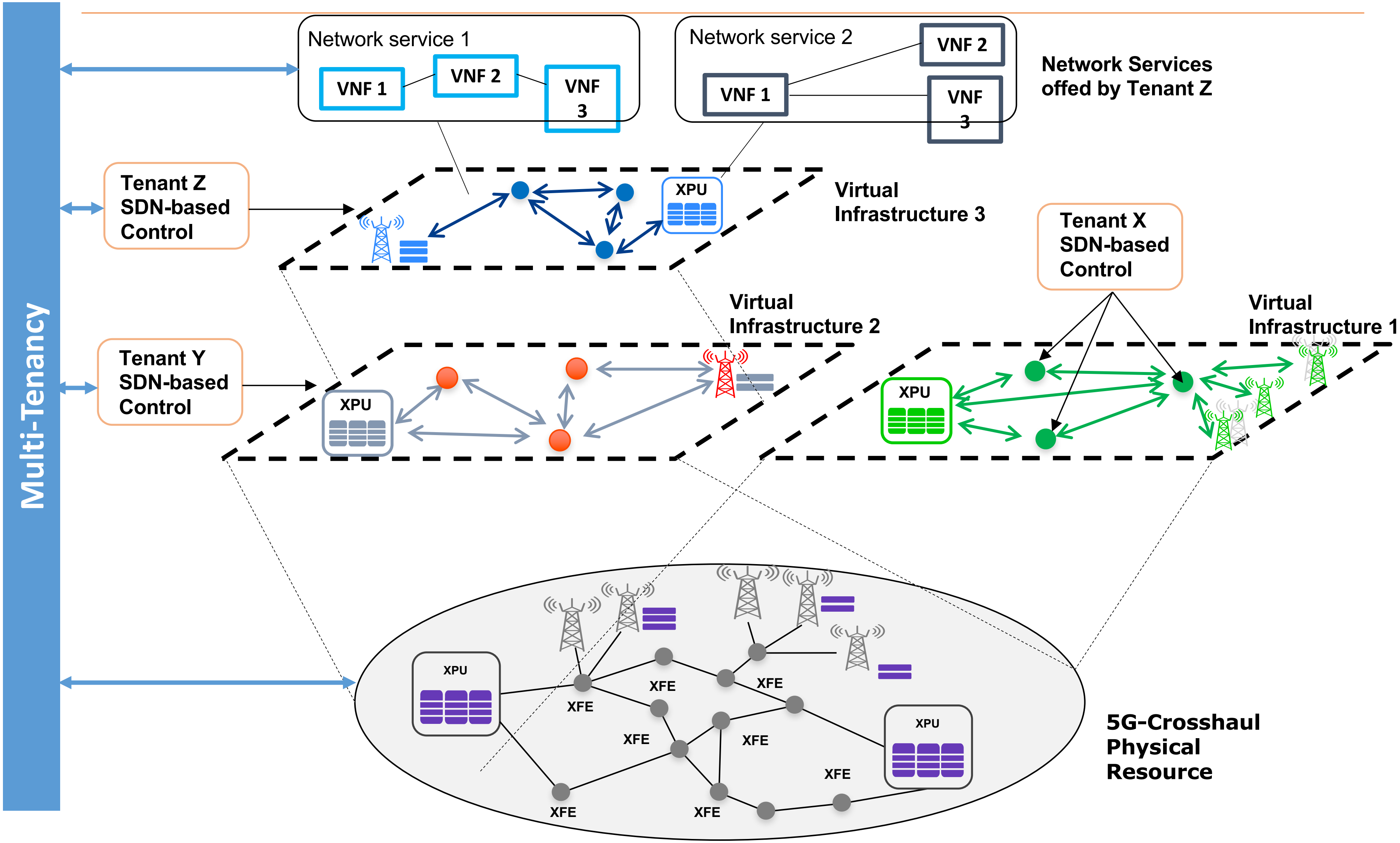
5G-Crosshaul project

- Defines a new generation of transport networks for 5G, integrating both fronthaul and backhaul segments into a common transport infrastructure.

- Converged Fronthaul and Backhaul under common SDN/NFV-based control, capable of supporting new 5G RAN architectures (vRAN) and performance requirements.
  - XCF – Common Frame capable of transporting the mixture of various Fronthaul and backhaul traffic
  - XFE – Forwarding Element for forwarding the Crosshaul traffic in the XCF format under the XCI control
  - XPU – Processing Unit for executing virtualized network functions and/or centralized access protocol functions
  - XCI – Control Infrastructure that is SDN-based and NFV-enabled for executing the orchestrator’s resource allocation decisions



5G-Crosshaul Slicing



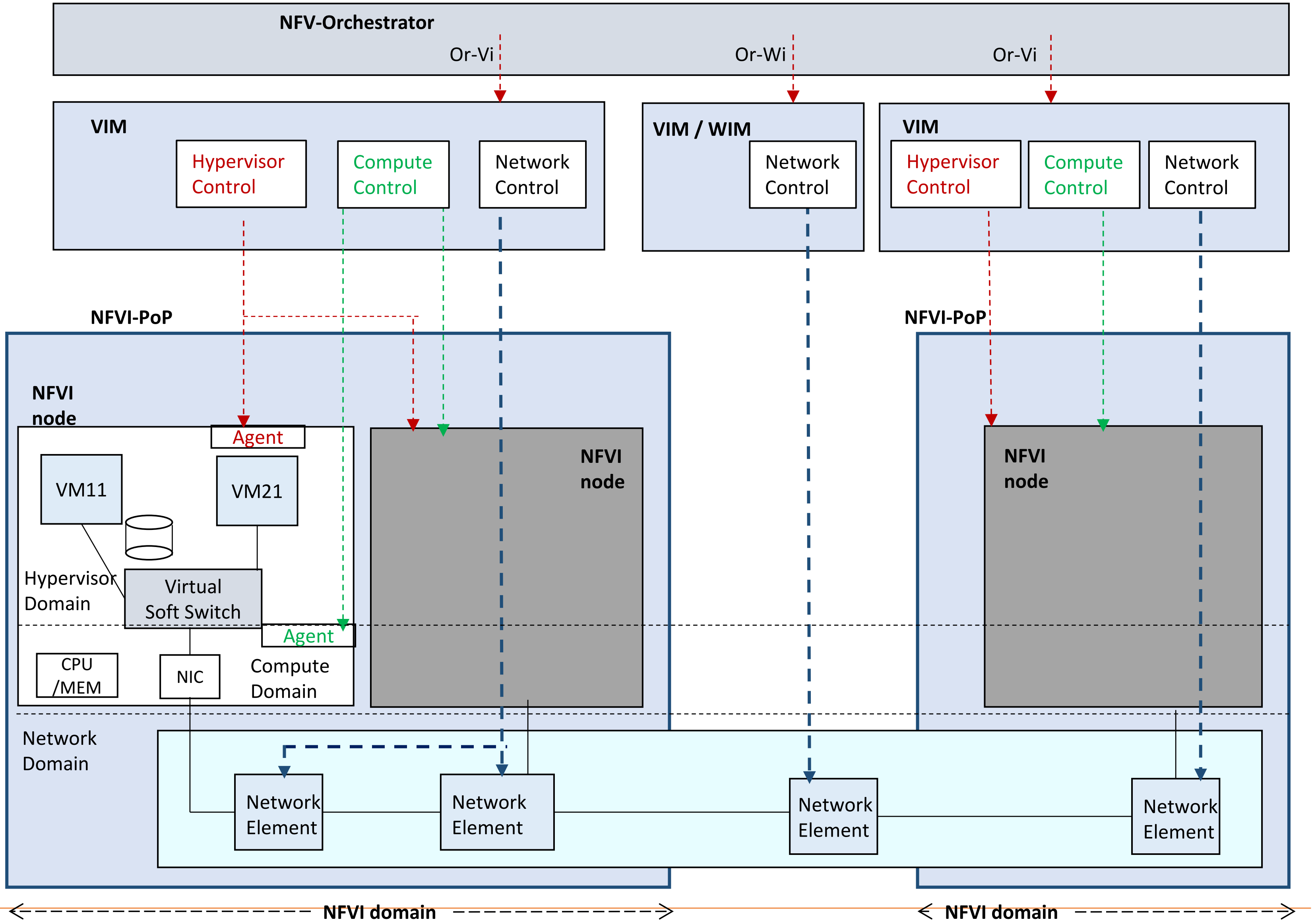
A potentially suitable framework for slicing: ETSI NFV

- What is Networks Function Virtualization (NFV)?
    - In simple terms → a deployment model and concept around the idea of replacing dedicated network appliances — such as routers and firewalls — with software (guests) running on hosts
    - Relies on the concept of host “virtualization”
        - E.g. Hypervisors

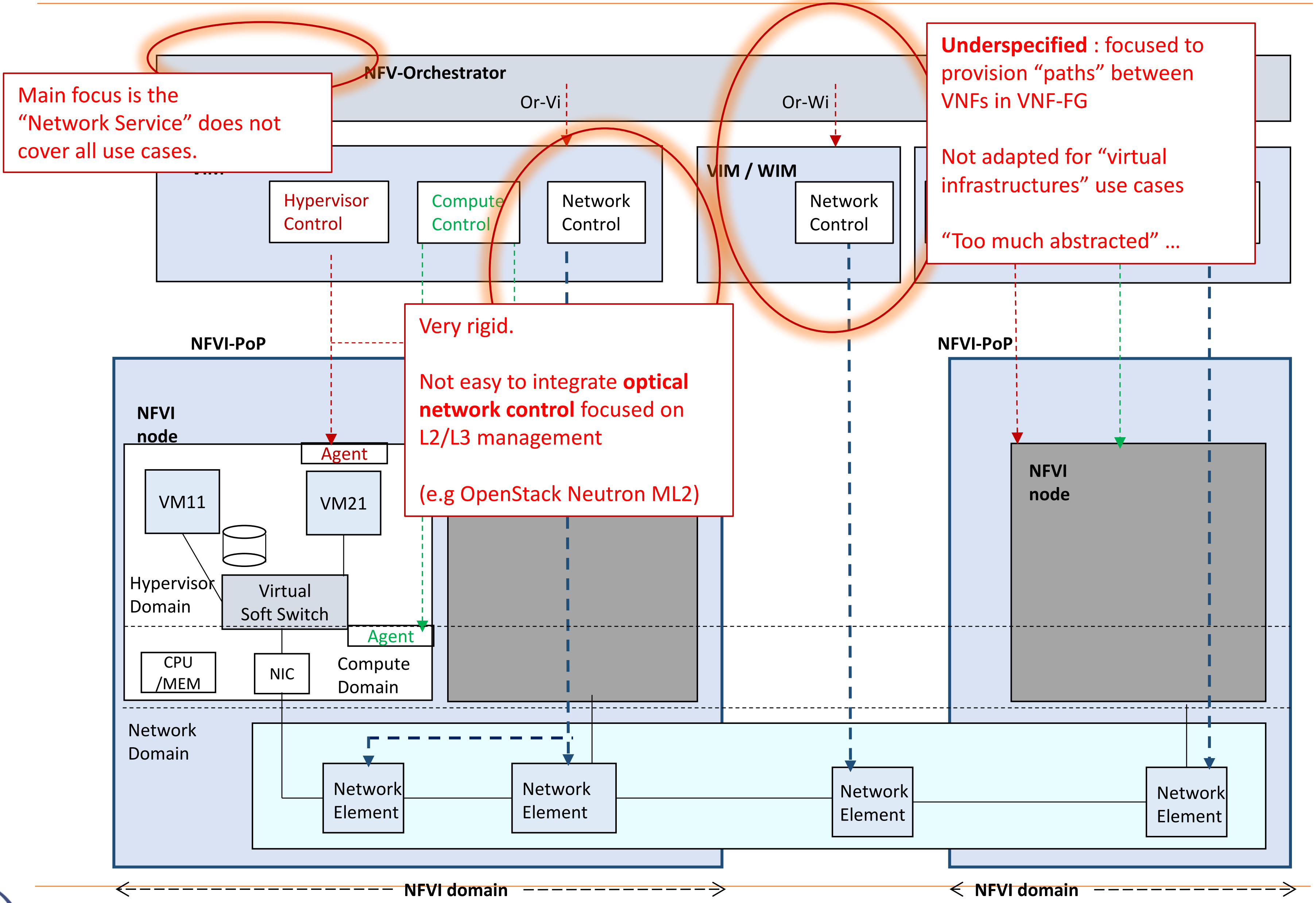
- *ETSI / NFVI architecture*
    - NFVI : NFV Infrastructure
        - Used to support the instantiation of Virtual Machines (VMs)
    - VIM: Virtualized Infrastructure Manager
        - Manages and provides access to storage, network and computer resources (NFVI)
    - MANO : Management and Orchestration
        - Deals with the orchestration of Virtualized Network Functions and how to deploy them (within the so called Network Services)

- **Benefits**
    - Lower costs : replacing dedicated appliances with shared servers. Efficient resource usage
    - Reduce operational costs with fewer appliances to deploy and maintain
    - Support on-demand pay-as-you go deployment models
    - Enable Innovation by making it easier to develop network functions
    - Deploy virtualized solutions on commercial, off-the-shelf (COTS) hardware

A potentially suitable framework for slicing: ETSI NFV



A potentially suitable framework for slicing: ETSI NFV



Main focus is the "Network Service" does not cover all use cases.

Underspecified : focused to provision "paths" between VNFs in VNF-FG

Not adapted for "virtual infrastructures" use cases

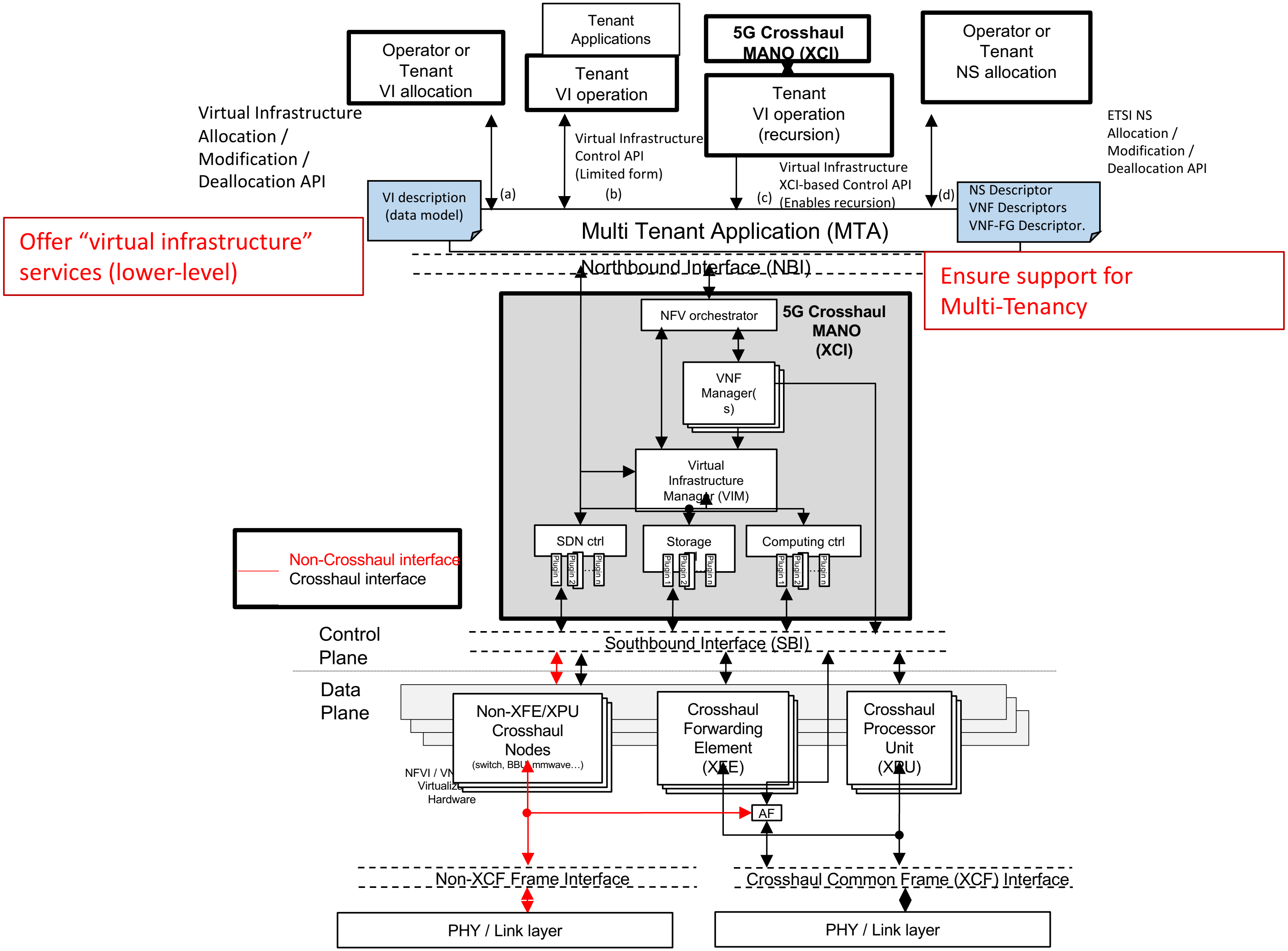
"Too much abstracted" …

Very rigid.

Not easy to integrate **optical network control** focused on L2/L3 management

(e.g OpenStack Neutron ML2)

5G-Crosshaul Slicing: Extending the NFV framework



Offer “virtual infrastructure” services (lower-level)

Ensure support for Multi-Tenancy

Operator or Tenant VI allocation

Tenant Applications

Tenant VI operation

5G Crosshaul MANO (XCI)

Tenant VI operation (recursion)

Operator or Tenant NS allocation

Virtual Infrastructure Allocation / Modification / Deallocation API

VI description (data model)

(a)

Virtual Infrastructure Control API (Limited form)

(b)

(c)

Virtual Infrastructure XCI-based Control API (Enables recursion)

(d)

NS Descriptor
VNF Descriptors
VNF-FG Descriptor.

ETSI NS Allocation / Modification / Deallocation API

Multi Tenant Application (MTA)

Northbound Interface (NBI)

NFV orchestrator

5G Crosshaul MANO (XCI)

VNF Manager(s)

Virtual Infrastructure Manager (VIM)

SDN ctrl

Storage

Computing ctrl

Plugin 1, Plugin 2, … Plugin n

Non-Crosshaul interface
Crosshaul interface

Control Plane

Southbound Interface (SBI)

Data Plane

Non-XFE/XPU Crosshaul Nodes (switch, BBU, mmwave…)

NFVI / VN… Virtualiz… Hardware

Crosshaul Forwarding Element (XFE)

Crosshaul Processor Unit (XPU)

AF

Non-XCF Frame Interface

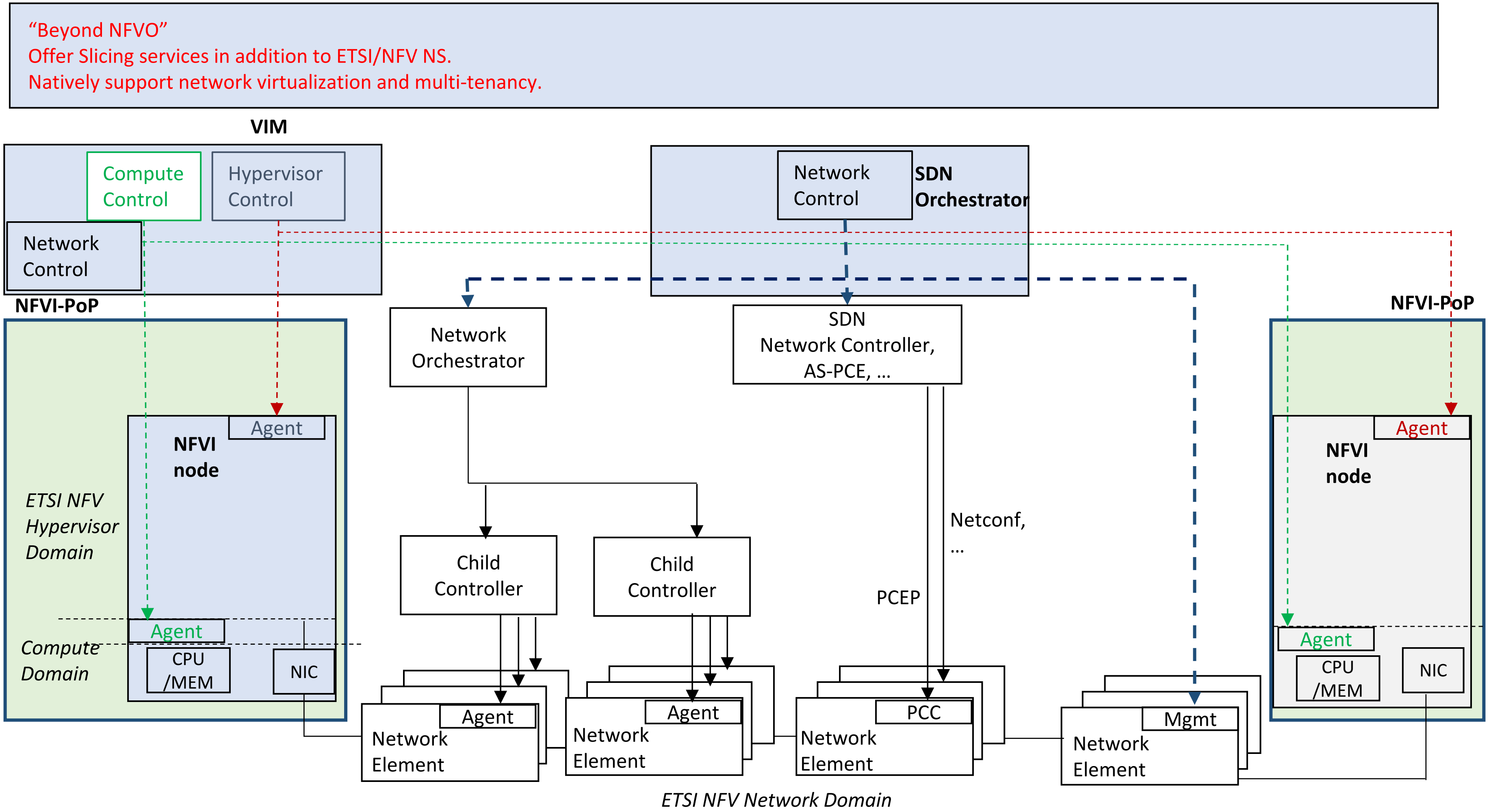
Crosshaul Common Frame (XCF) Interface

PHY / Link layer

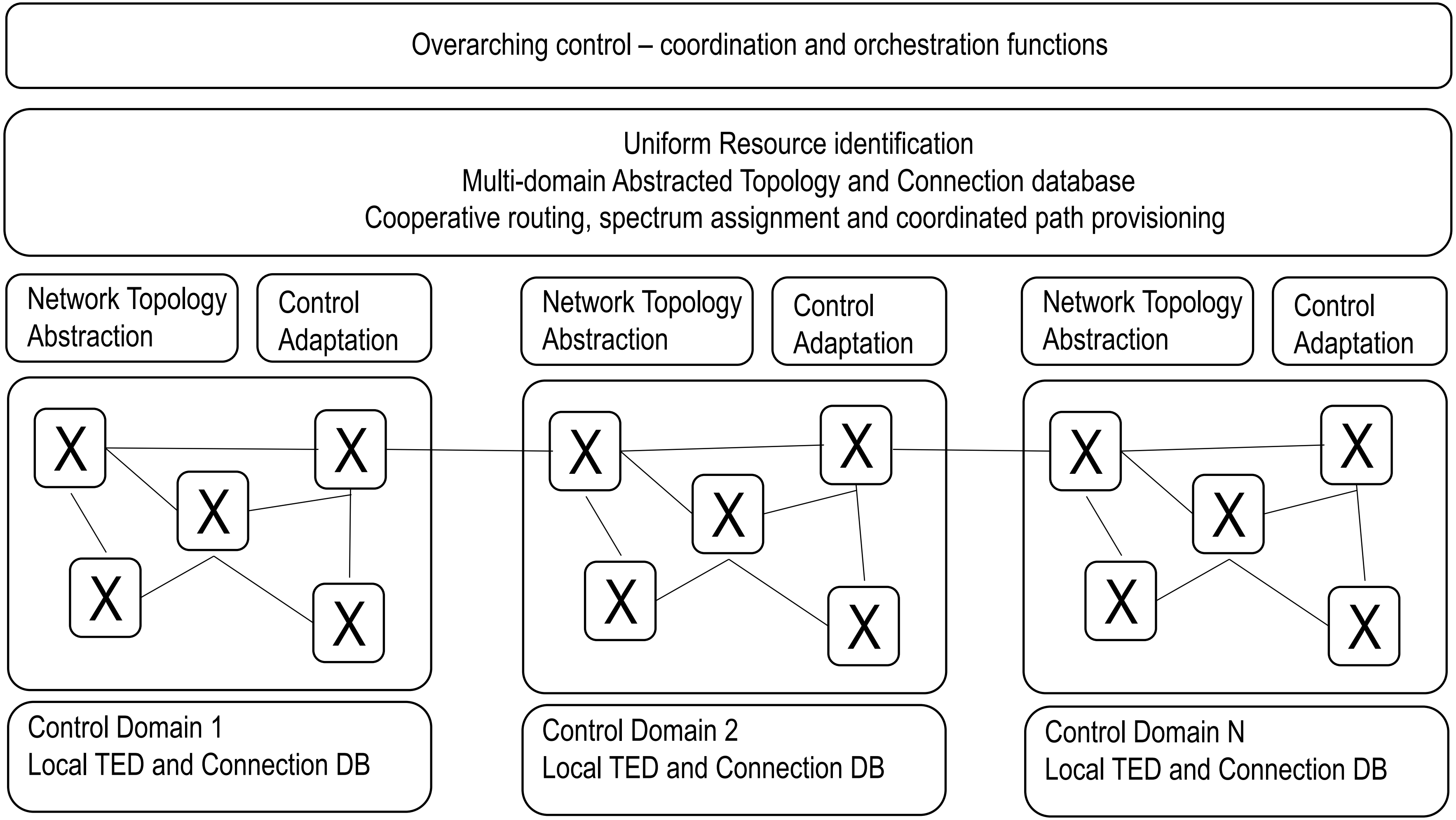
PHY / Link layer

X. Li, R. Casellas, G. Landi, A. de la Oliva, X. Costa-Pérez, A. Garcia-Saavedra,T. Deiß, L. Cominardi, R. Vilalta, “*5G-Crosshaul Network Slicing: Enabling Multi-Tenancy in Mobile Transport Networks*”, accepted for publication IEEE Communications Magazine, 2017

Realistic T-SDN/NFV integration



Network Orchestration and Overarching Control



Overarching control – coordination and orchestration functions

Uniform Resource identification
Multi-domain Abstracted Topology and Connection database
Cooperative routing, spectrum assignment and coordinated path provisioning

Network Topology Abstraction

Control Adaptation

Network Topology Abstraction

Control Adaptation

Network Topology Abstraction

Control Adaptation

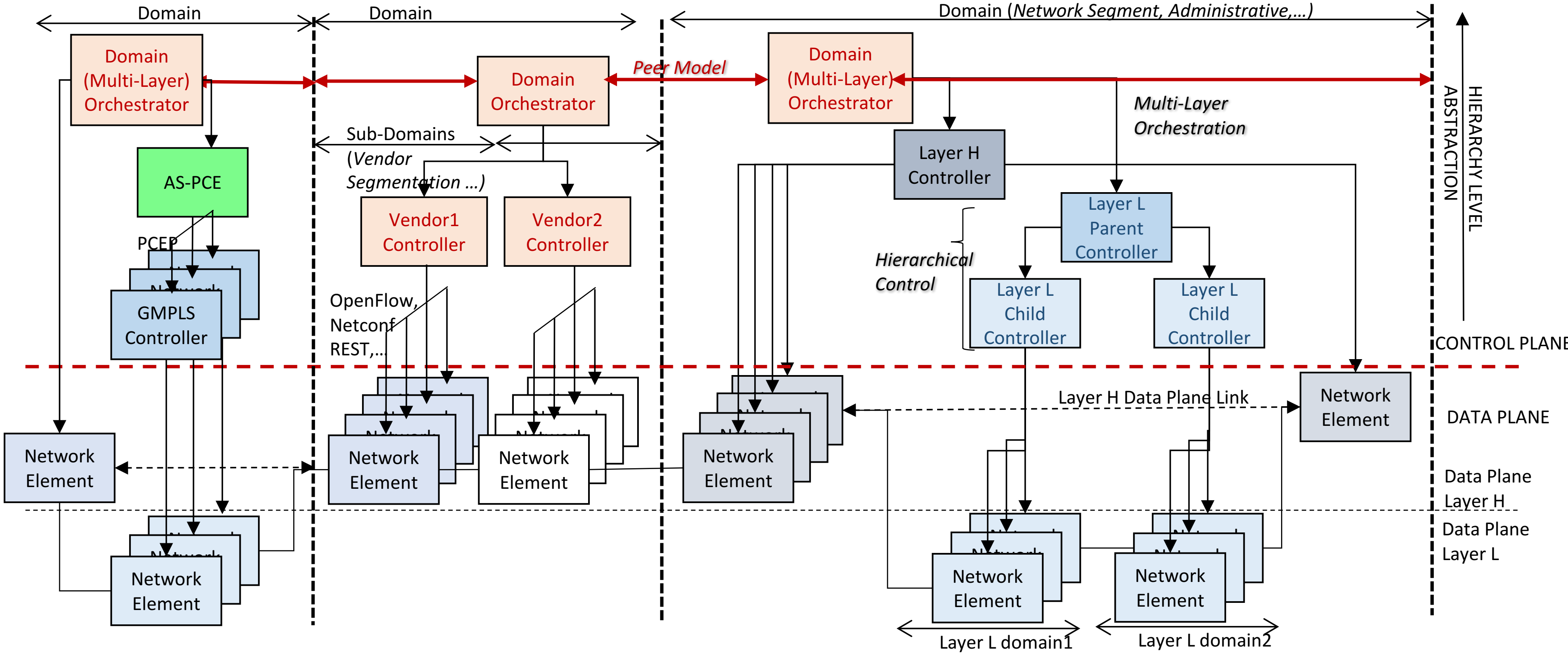
Control Domain 1
Local TED and Connection DB

Control Domain 2
Local TED and Connection DB

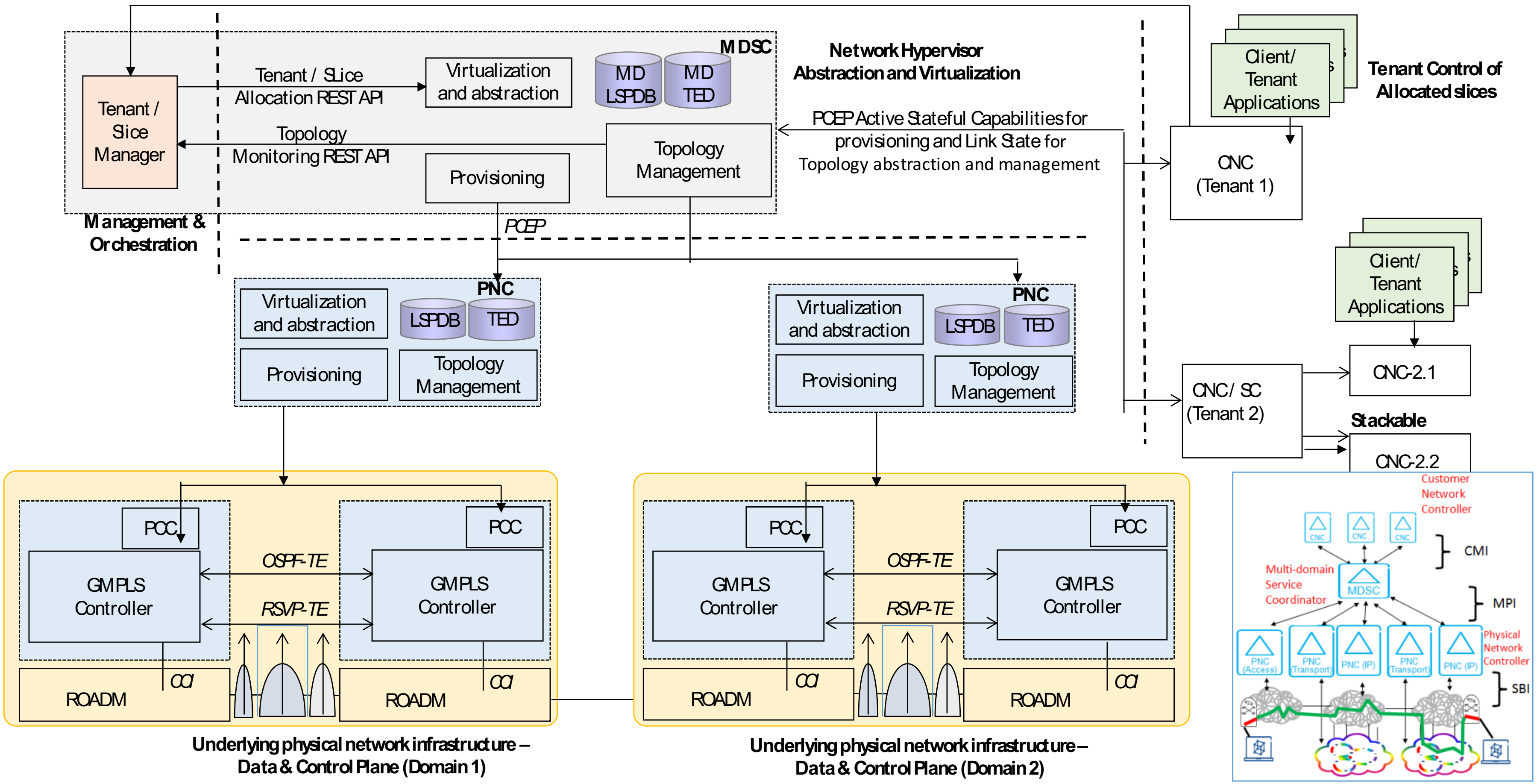
Control Domain N
Local TED and Connection DB

Generic Network Orchestration

- Hybrid models, very heterogeneous in terms of protocols and interfaces



Slicing over Multi-domain flexi-grid networks: ACTN



MDSC

Tenant / Slice Manager

Tenant / Slice Allocation REST API

Topology Monitoring REST API

Virtualization and abstraction

MD LSPDB

MD TED

Provisioning

Topology Management

Management & Orchestration

Network Hypervisor Abstraction and Virtualization

PCEP Active Stateful Capabilities for provisioning and Link State for Topology abstraction and management

PCEP

Tenant Control of Allocated slices

Client/ Tenant Applications

CNC (Tenant 1)

Client/ Tenant Applications

CNC-2.1

CNC/ SC (Tenant 2)

Stackable

CNC-2.2

PNC

Virtualization and abstraction

LSPDB

TED

Provisioning

Topology Management

PNC

Virtualization and abstraction

LSPDB

TED

Provisioning

Topology Management

PCC

GMPLS Controller

OSPF-TE

RSVP-TE

CCI

ROADM

PCC

GMPLS Controller

CCI

ROADM

Underlying physical network infrastructure – Data & Control Plane (Domain 1)

PCC

GMPLS Controller

OSPF-TE

RSVP-TE

CCI

ROADM

PCC

GMPLS Controller

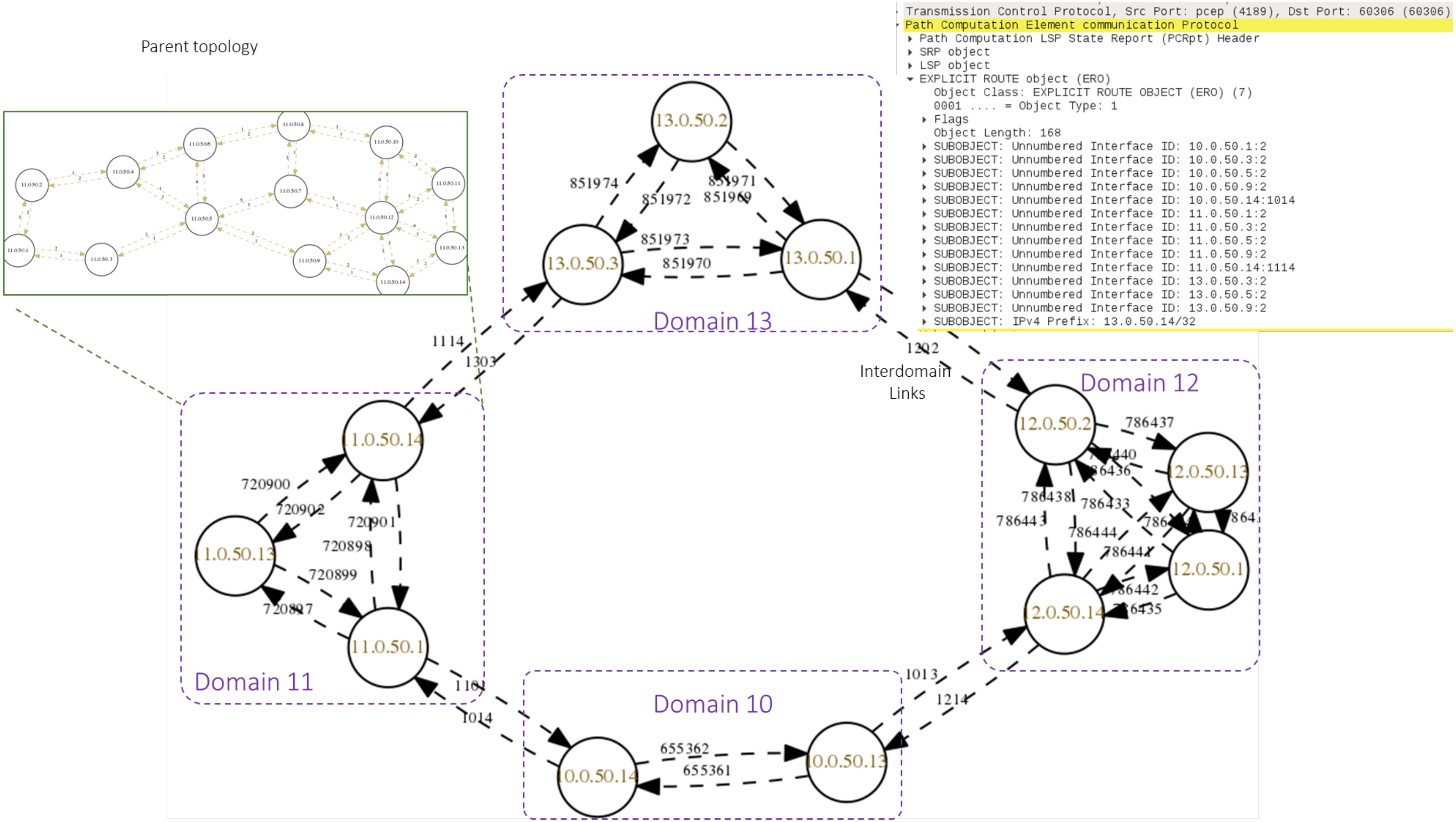
CCI

ROADM

Underlying physical network infrastructure – Data & Control Plane (Domain 2)

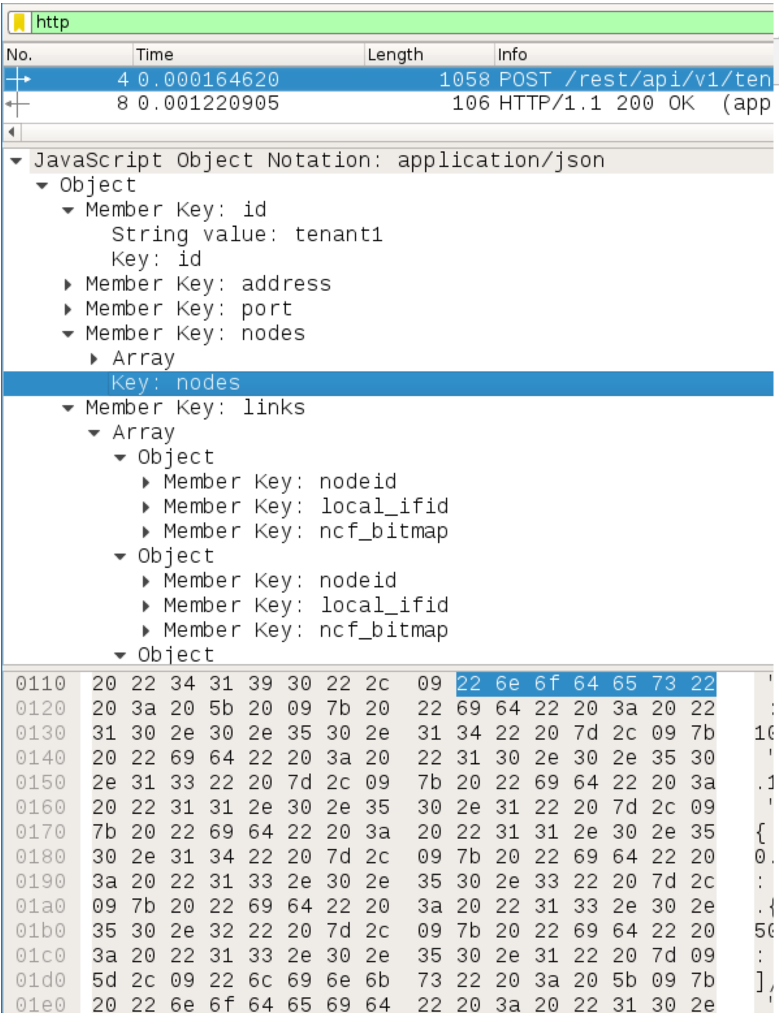
Customer Network Controller
CNC
CNC
CNC
CMI
Multi-domain Service Coordinator
MDSC
MPI
PNC (Access)
PNC (Transport)
PNC (IP)
PNC (Transport)
PNC (IP)
Physical Network Controller
SBI

Slicing over Multi-domain flexi-grid networks: experimental



```
▸ Transmission Control Protocol, Src Port: pcep (4189), Dst Port: 60306 (60306)
▾ Path Computation Element communication Protocol
  ▸ Path Computation LSP State Report (PCRpt) Header
  ▸ SRP object
  ▸ LSP object
  ▾ EXPLICIT ROUTE object (ERO)
      Object Class: EXPLICIT ROUTE OBJECT (ERO) (7)
      0001 .... = Object Type: 1
    ▸ Flags
      Object Length: 168
    ▸ SUBOBJECT: Unnumbered Interface ID: 10.0.50.1:2
    ▸ SUBOBJECT: Unnumbered Interface ID: 10.0.50.3:2
    ▸ SUBOBJECT: Unnumbered Interface ID: 10.0.50.5:2
    ▸ SUBOBJECT: Unnumbered Interface ID: 10.0.50.9:2
    ▸ SUBOBJECT: Unnumbered Interface ID: 10.0.50.14:1014
    ▸ SUBOBJECT: Unnumbered Interface ID: 11.0.50.1:2
    ▸ SUBOBJECT: Unnumbered Interface ID: 11.0.50.3:2
    ▸ SUBOBJECT: Unnumbered Interface ID: 11.0.50.5:2
    ▸ SUBOBJECT: Unnumbered Interface ID: 11.0.50.9:2
    ▸ SUBOBJECT: Unnumbered Interface ID: 11.0.50.14:1114
    ▸ SUBOBJECT: Unnumbered Interface ID: 13.0.50.3:2
    ▸ SUBOBJECT: Unnumbered Interface ID: 13.0.50.5:2
    ▸ SUBOBJECT: Unnumbered Interface ID: 13.0.50.9:2
    ▸ SUBOBJECT: IPv4 Prefix: 13.0.50.14/32
```

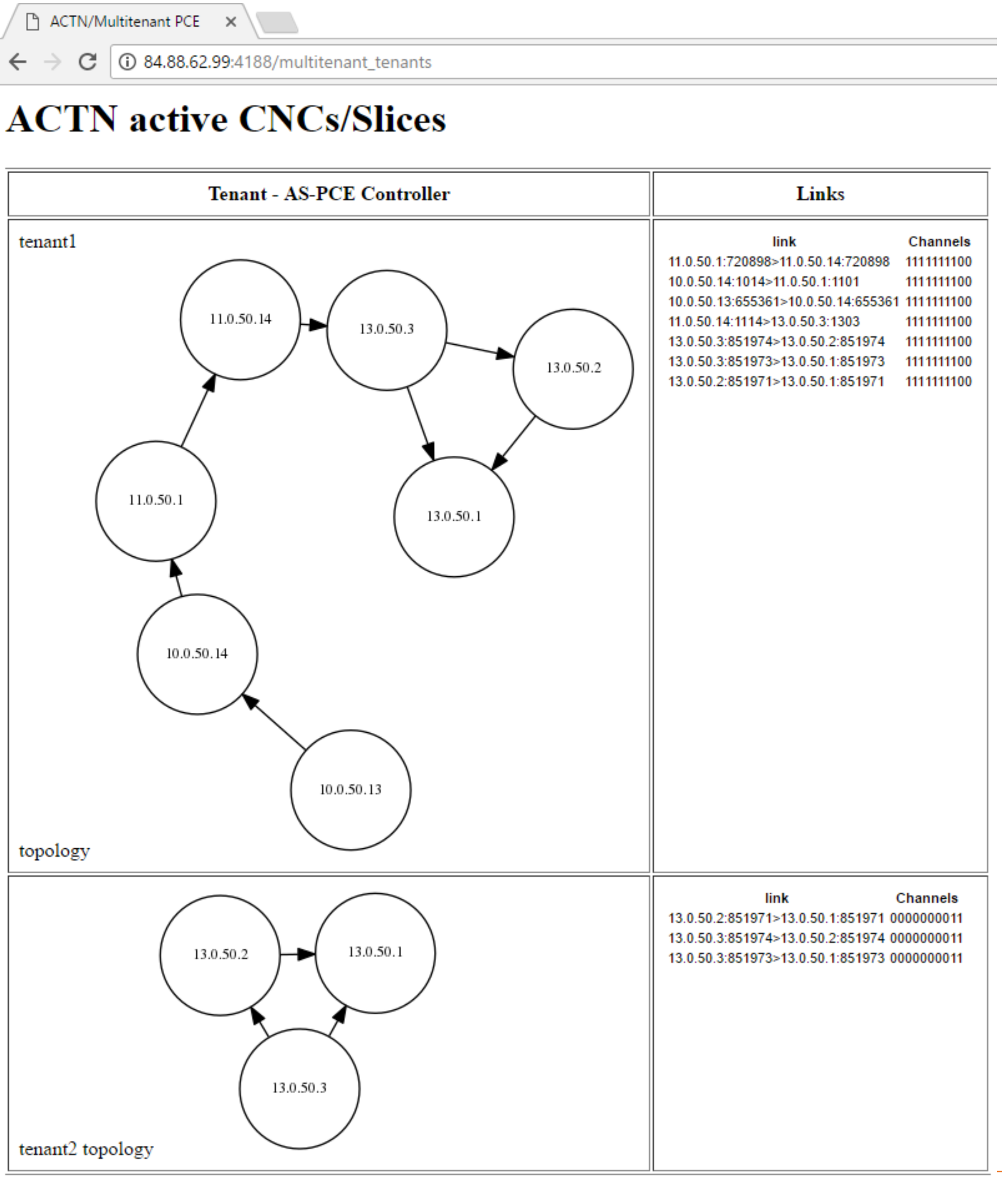
Example with 2 tenants/slices.



```
No.   Time          Length  Info
   4 0.000164620      1058 POST /rest/api/v1/ten
   8 0.001220905       106 HTTP/1.1 200 OK  (app
```

```
▼ JavaScript Object Notation: application/json
  ▼ Object
    ▼ Member Key: id
        String value: tenant1
        Key: id
    ▶ Member Key: address
    ▶ Member Key: port
    ▼ Member Key: nodes
      ▶ Array
        Key: nodes
    ▼ Member Key: links
      ▼ Array
        ▼ Object
          ▶ Member Key: nodeid
          ▶ Member Key: local_ifid
          ▶ Member Key: ncf_bitmap
        ▼ Object
          ▶ Member Key: nodeid
          ▶ Member Key: local_ifid
          ▶ Member Key: ncf_bitmap
        ▼ Object
```

```
0110  20 22 34 31 39 30 22 2c  09 22 6e 6f 64 65 73 22   '
0120  20 3a 20 5b 20 09 7b 20  22 69 64 22 20 3a 20 22   :
0130  31 30 2e 30 2e 35 30 2e  31 34 22 20 7d 2c 09 7b  10
0140  20 22 69 64 22 20 3a 20  22 31 30 2e 30 2e 35 30   '
0150  2e 31 33 22 20 7d 2c 09  7b 20 22 69 64 22 20 3a  .1
0160  20 22 31 31 2e 30 2e 35  30 2e 31 22 20 7d 2c 09   '
0170  7b 20 22 69 64 22 20 3a  20 22 31 31 2e 30 2e 35  {
0180  30 2e 31 34 22 20 7d 2c  09 7b 20 22 69 64 22 20  0.
0190  3a 20 22 31 33 2e 30 2e  35 30 2e 33 22 20 7d 2c  :
01a0  09 7b 20 22 69 64 22 20  3a 20 22 31 33 2e 30 2e  .{
01b0  35 30 2e 32 22 20 7d 2c  09 7b 20 22 69 64 22 20  50
01c0  3a 20 22 31 33 2e 30 2e  35 30 2e 31 22 20 7d 09  :
01d0  5d 2c 09 22 6c 69 6e 6b  73 22 20 3a 20 5b 09 7b  ],
01e0  20 22 6e 6f 64 65 69 64  22 20 3a 20 22 31 30 2e   '
```



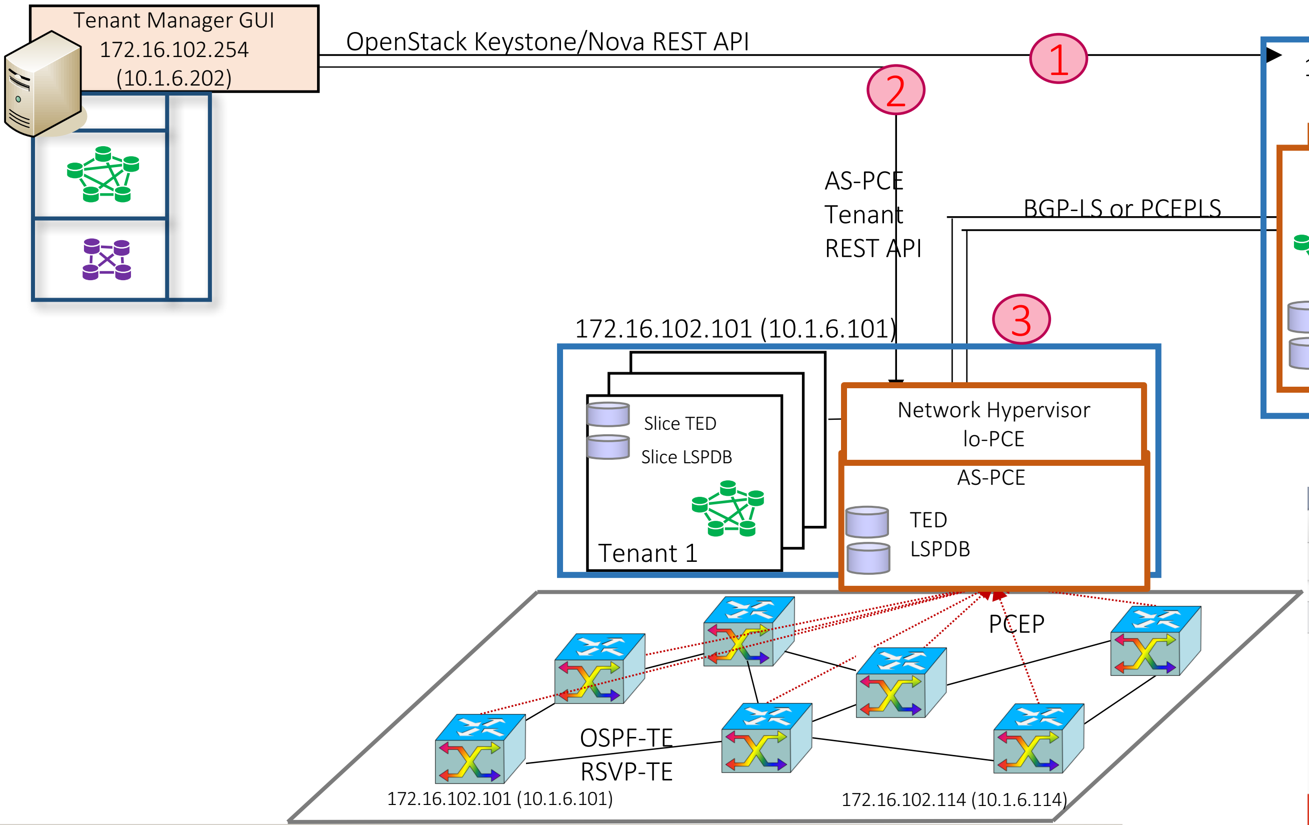
ACTN active CNCs/Slices

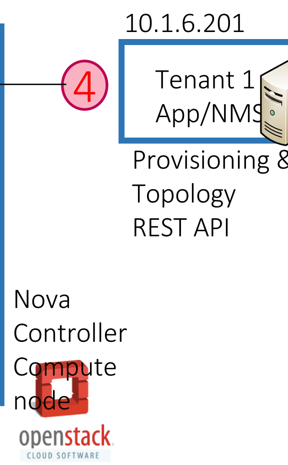
Tenant - AS-PCE Controller | **Links**

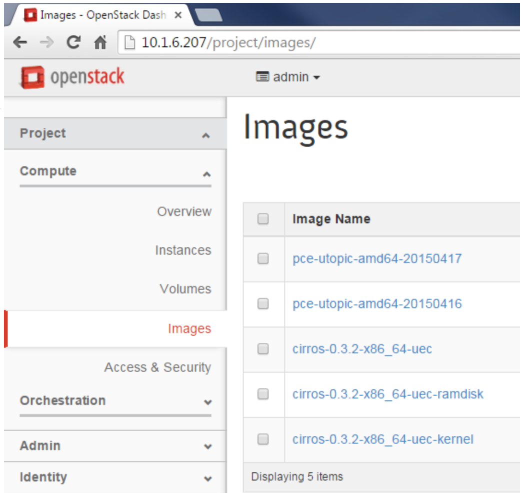
link	Channels
11.0.50.1:720898>11.0.50.14:720898	1111111100
10.0.50.14:1014>11.0.50.1:1101	1111111100
10.0.50.13:655361>10.0.50.14:655361	1111111100
11.0.50.14:1114>13.0.50.3:1303	1111111100
13.0.50.3:851974>13.0.50.2:851974	1111111100
13.0.50.3:851973>13.0.50.1:851973	1111111100
13.0.50.2:851971>13.0.50.1:851971	1111111100

link	Channels
13.0.50.2:851971>13.0.50.1:851971	0000000011
13.0.50.3:851974>13.0.50.2:851974	0000000011
13.0.50.3:851973>13.0.50.1:851973	0000000011

Example: dynamic instantiation of CNC



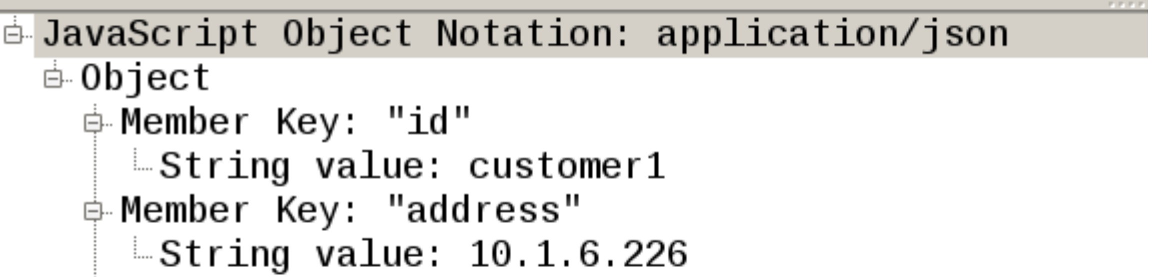




Images

☐	Image Name
☐	pce-utopic-amd64-20150417
☐	pce-utopic-amd64-20150416
☐	cirros-0.3.2-x86_64-uec
☐	cirros-0.3.2-x86_64-uec-ramdisk
☐	cirros-0.3.2-x86_64-uec-kernel

Displaying 5 items



```
JavaScript Object Notation: application/json
  Object
    Member Key: "id"
      String value: customer1
    Member Key: "address"
      String value: 10.1.6.226
```

Conclusions

- Slicing as an emerging requirement for 5G networks; a slice is a *logical construct involving functions and their interconnection, tailored for services and verticals*. The concept somehow generalizes ETSI Network services, virtual networks, VPNs, etc.

- The ETSI NFV framework, allowing the instantiation of *Network Services,* provides a platform to support network slicing, complemented with a “Slice Manager” or “Multi-Tenancy Application”
  - ☐ Does not fully cover all use cases, specially when partitioning the physical network, allowing ultimate SDN control over the virtual infrastructure

- Integrating optical transport networks and generalizing the slicing concept requires a finer joint orchestration of network and IT resources, with improved visibility of the optical network and its control and management.

- In particular, we considered the actual partitioning of a multi-domain flexi-grid optical network and how the IETF ACTN and hierarchical Active-Stateful PCE support the concept.

Thank you! Questions?

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