Intent-based Abstractions for Network Service Specification

Walter Cerroni
University of Bologna, Italy

walter.cerroni@unibo.it

IRTF NMRG Virtual Meeting – Apr. 25, 2019

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Network services in the NFV era: Service Function Chaining (SFC)

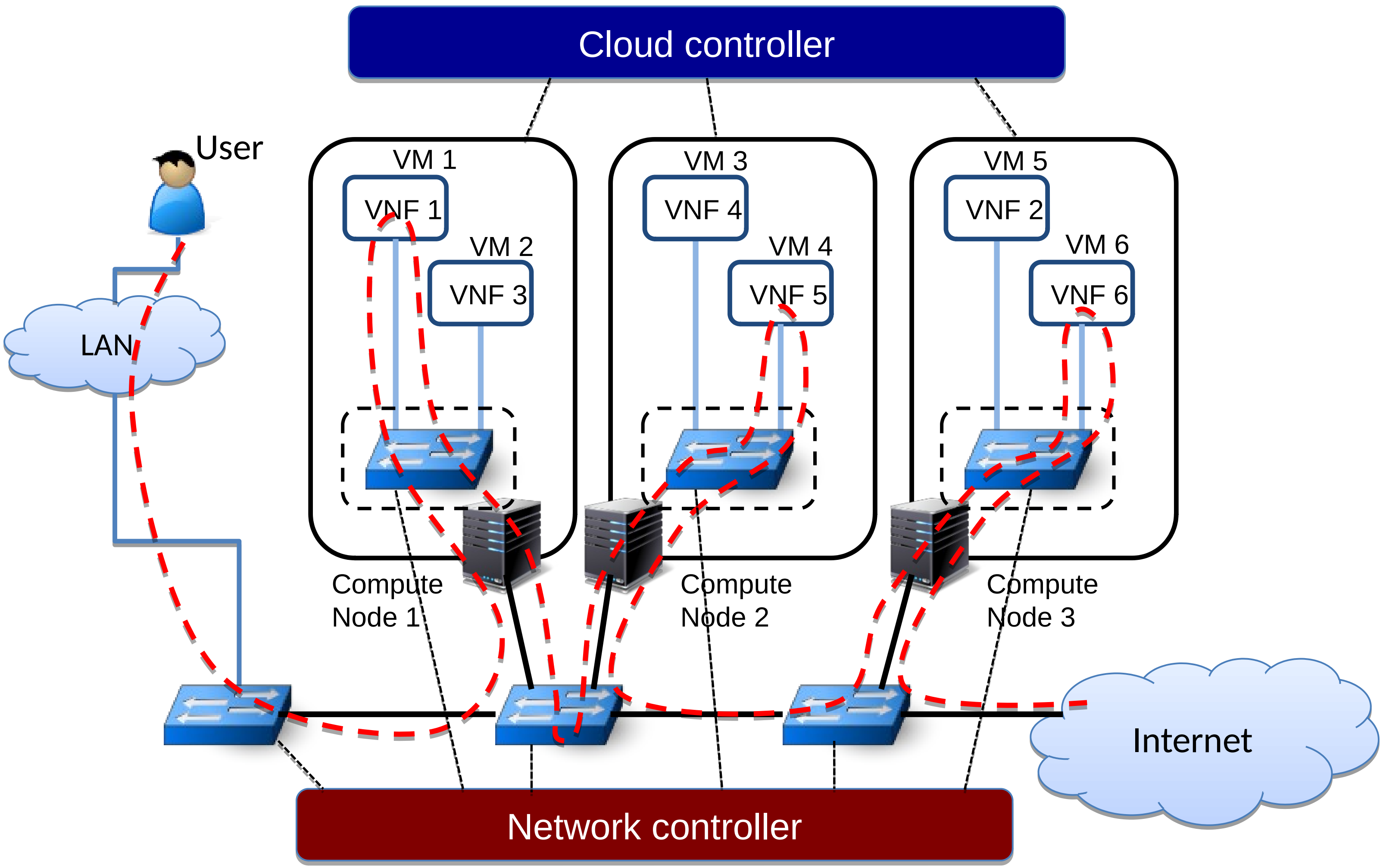
- End-to-end network service deployed on heterogeneous and distributed software-defined infrastructures
- Service composition as a “chain” of software-based virtual network functions (VNFs) over a unified programmable environment
- New challenges:
  - slicing / multi-tenancy
  - resource control/management across multiple domains
  - adaptive usage of multi-technology resources
  - fulfillment of end-to-end service performance requirements (e.g., latency)

Enablers for network programmability

- NFV
  - software-based network elements and/or functions
  - cloud-like (*aaS) approach to virtualized infrastructure
  - scalability, mobility, replicability, etc.
- SDN
  - (logically) centralized view of network infrastructure and resources
  - open, standardized interface to control network forwarding

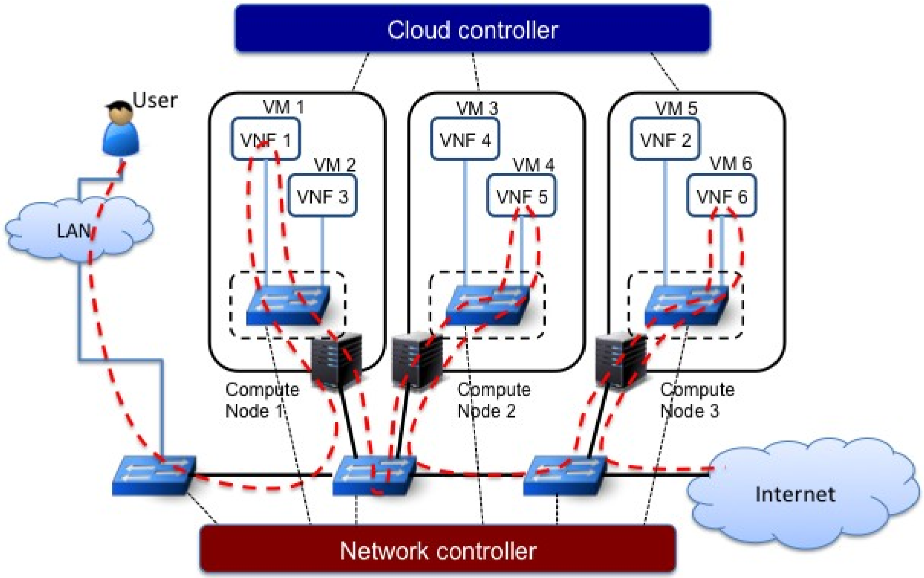
- Both contribute to enabling a programmatic approach to network management and service deployment
  - through controller's northbound interface
  - imperative vs. declarative

SFC: VNF placement and traffic steering



SFC: VNF placement and traffic steering

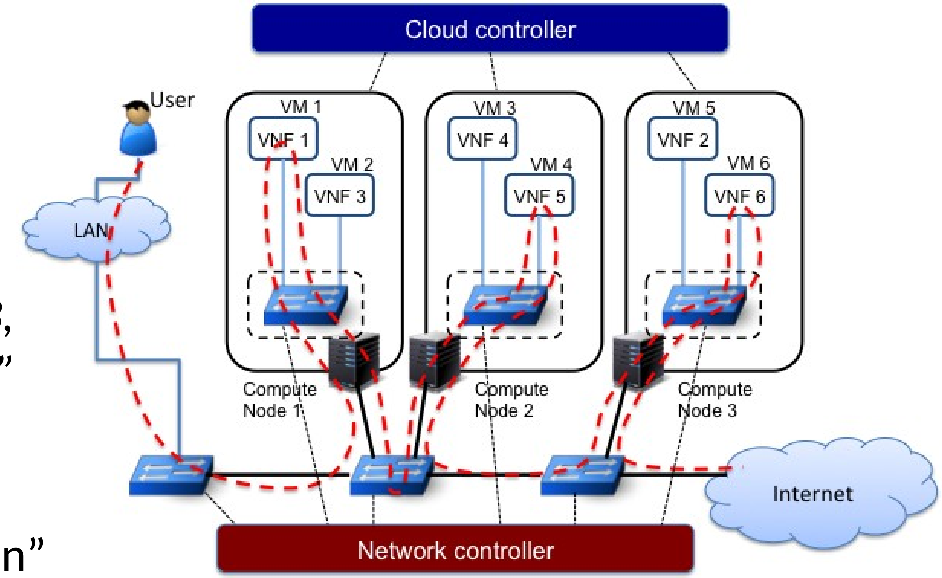
- Imperative network programming
  - specify step-by-step ***how*** the network must accomplish a given task
  - NFV
    - *“instantiate VM 1 on Compute Node 1 using VNF 1 image”*
    - *“instantiate VM 4 on Compute Node 2 using VNF 5 image”*
    - etc.
  - SDN
    - *“install flow F with matching rule R on physical switch PS 1 from port 3 to port 4”*
    - *“install flow F with matching rule R on virtual switch VS 2 from port 1 to port 2”*
    - etc.



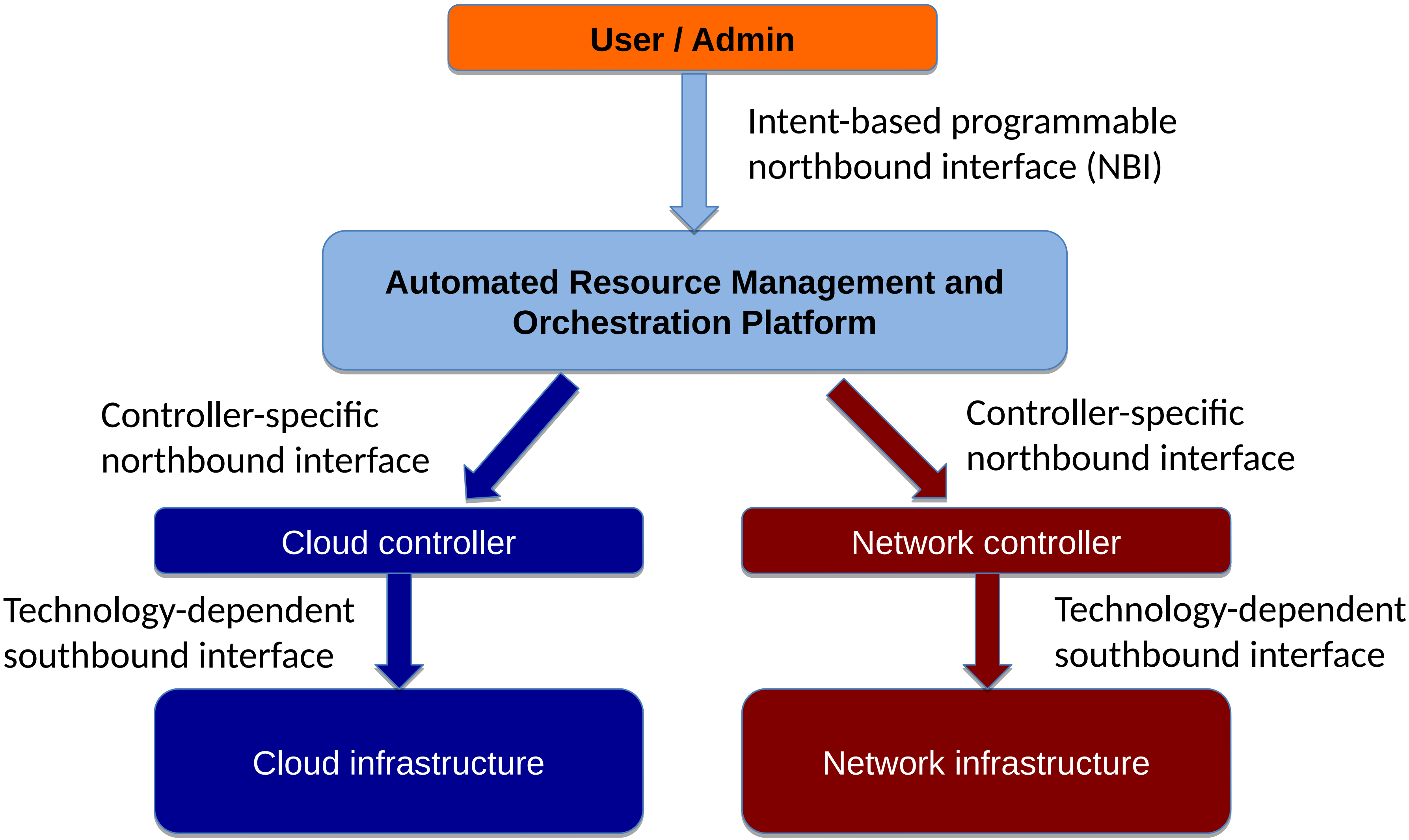
How about abstractions?

SFC: VNF placement and traffic steering

- Declarative network programming
  - specify ***what*** the network must accomplish (the ***intent***)
  - leave the details of how to do it to specific implementation
  - *“my service requires functions A, B, and C before entering the Internet”*
  - something else will take care of translating the intent into an infrastructure-specific “prescription” taking advantage of NFV and SDN technologies
    - function A ▭ VNF 1
    - function B ▭ VNF 5
    - function C ▭ VNF 6
    - instantiate VMs
    - steer traffic flow F accordingly



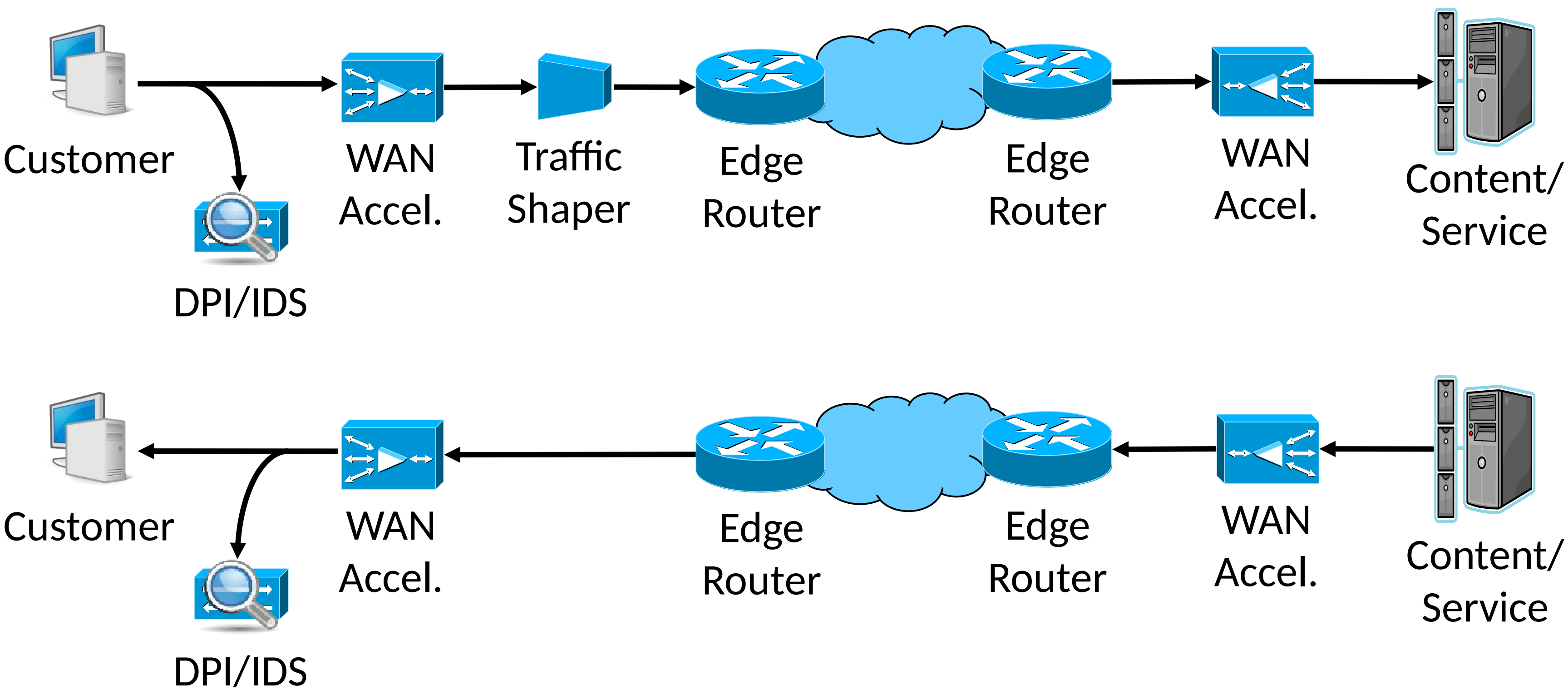
Intent-Based Networking (for SFC)



Intent-Based Networking (for SFC)

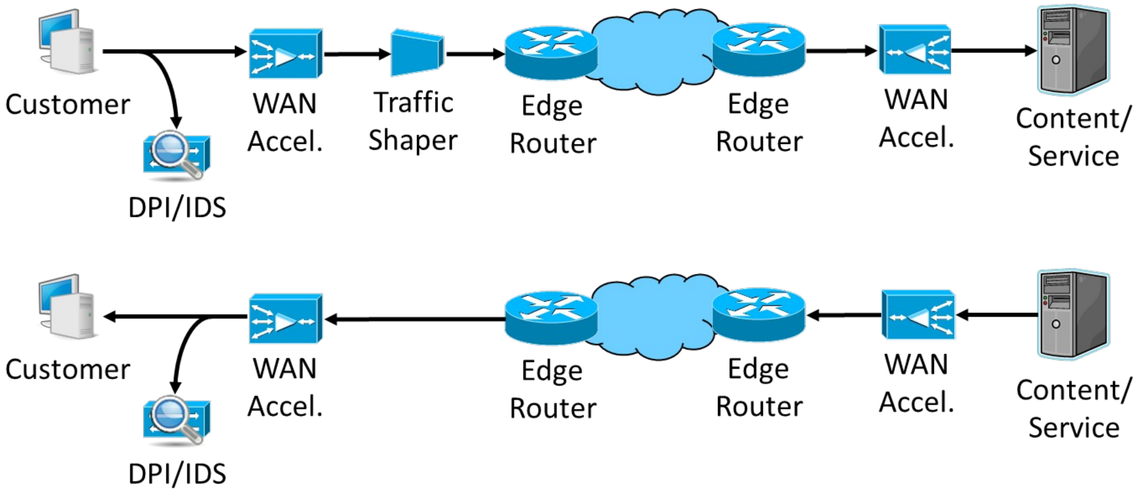
- Intent-based programmable NBI for SFC
  - open
  - vendor-agnostic
  - interoperable
  - should allow to specify not only the sequence but also the **nature** of the different network functions (NFs) to be traversed
  - nature of NFs is strictly related to the service component they implement

Network service specification: an example



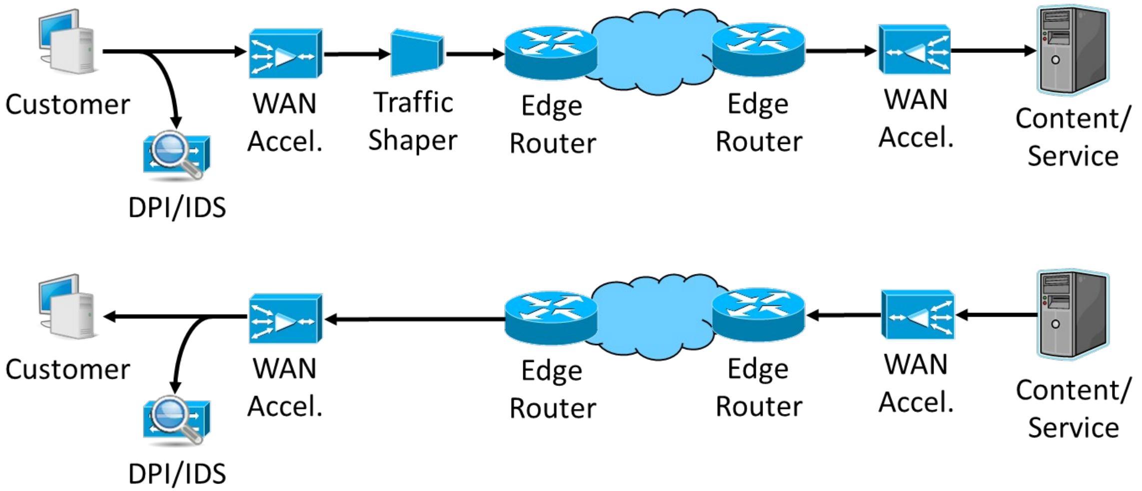
Topological abstractions of NFs (1/3)

- A NF can be **terminating** or **forwarding** a given traffic flow
  - in the example, DPI/IDS is terminating the flow, whereas traffic shaper and WAN accelerator are forwarding it



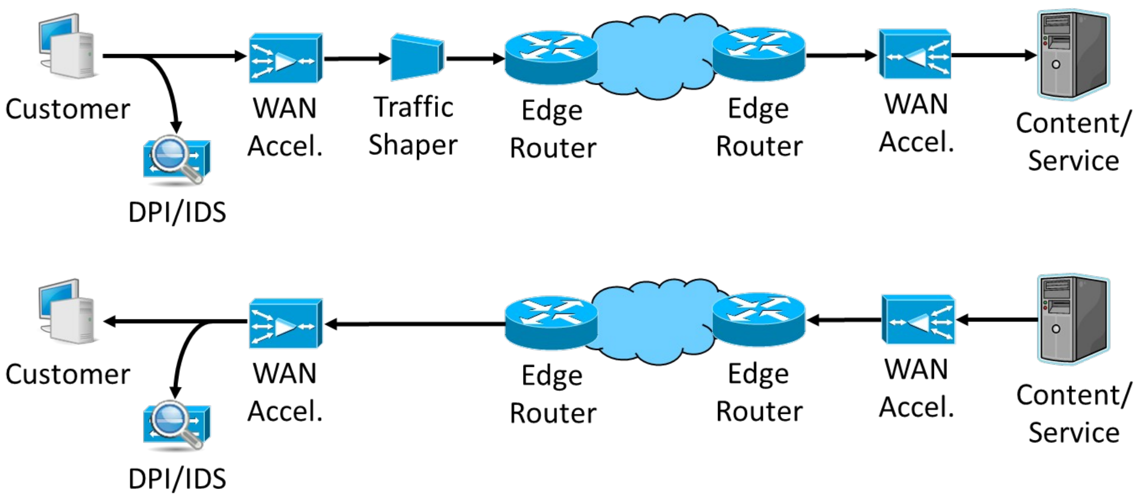
Topological abstractions of NFs (2/3)

- A forwarding NF can be **port-symmetric** or **port-asymmetric**
  - depending on whether or not it can be traversed by a given traffic flow regardless of which port is used as input or output
  - in the example, WAN accelerator is port-asymmetric, because it compresses or decompresses traffic based on the input port used
  - traffic shaper can be considered port-symmetric, if we assume that the shaping function is applied to any output of the NF

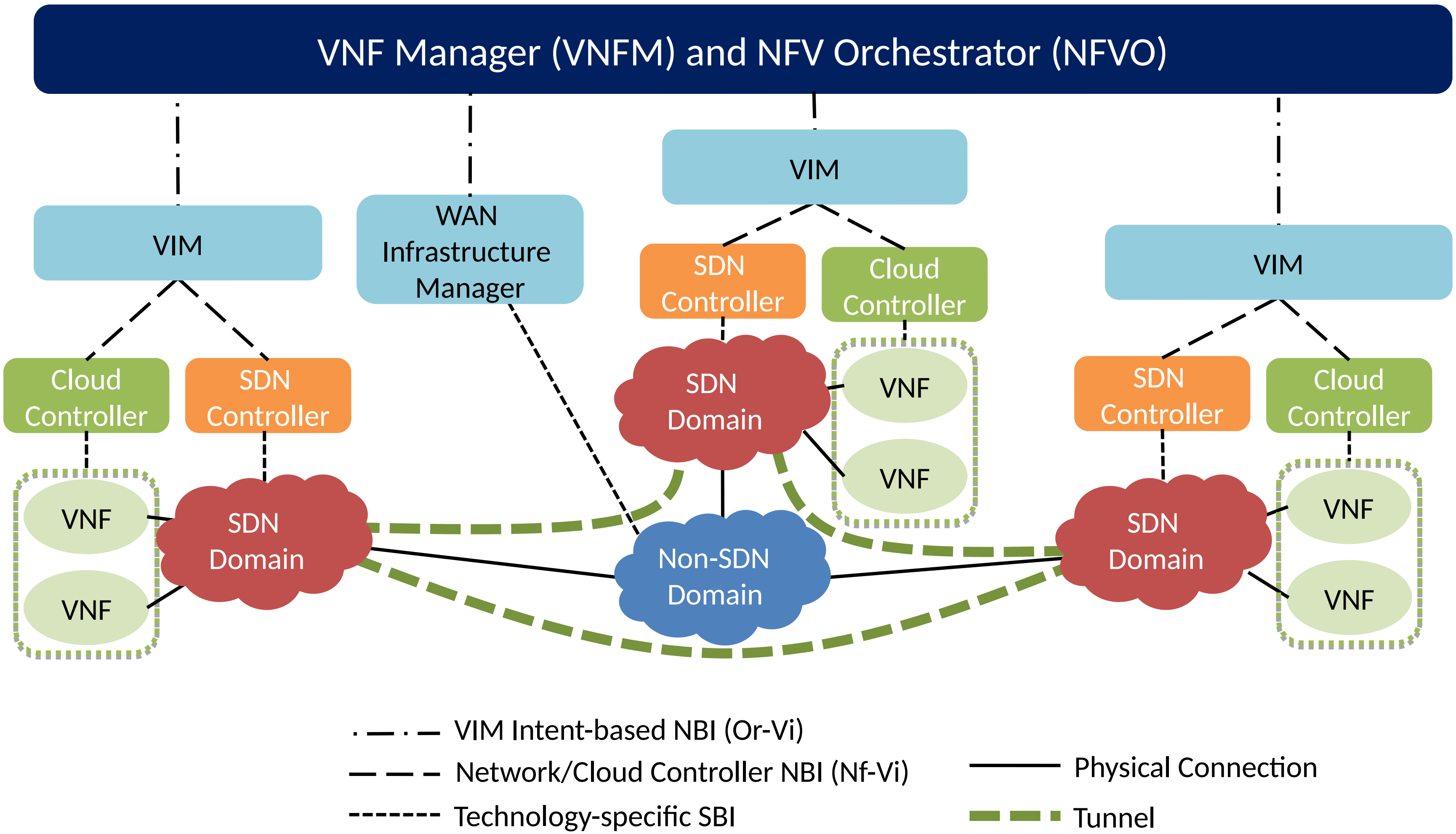


Topological abstractions of NFs (3/3)

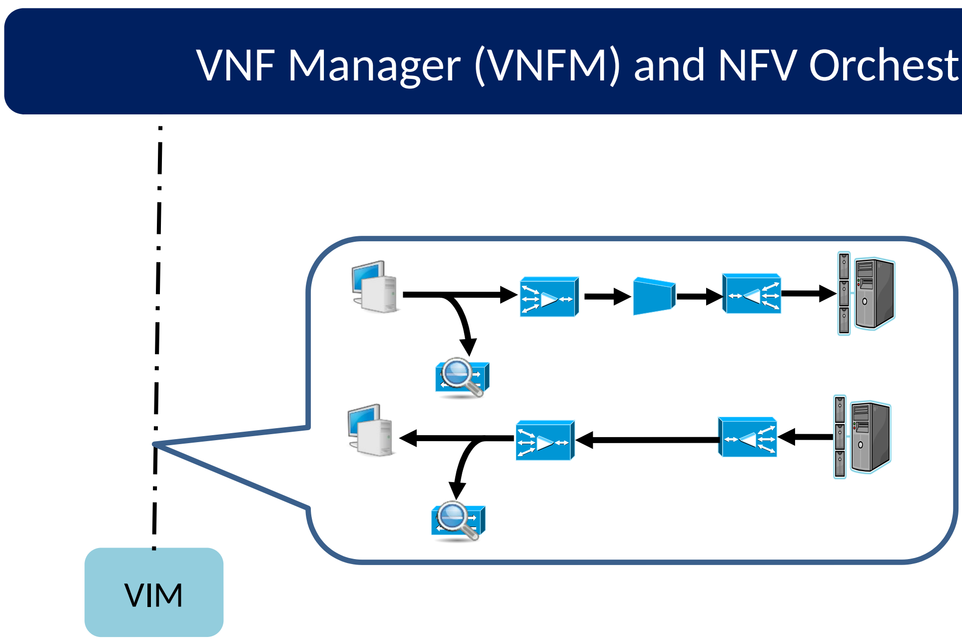
- A NF can be **path-symmetric** or **path-asymmetric**,
  - depending on whether or not it must be traversed by a given flow in both upstream and downstream directions
  - in the example, according to service specification, WAN accelerator and DPI/IDS are path symmetric, whereas traffic shaper is path asymmetric



Implemented on an "NFV-inspired" architecture



Intent-based network service specification




```
{
   "src": "Customer",
   "dst": "Content/Service",
   "vnfList": [DPI_IDS, WA_1, TS, WA_2]
   "dupList": [DPI_IDS]
}
```

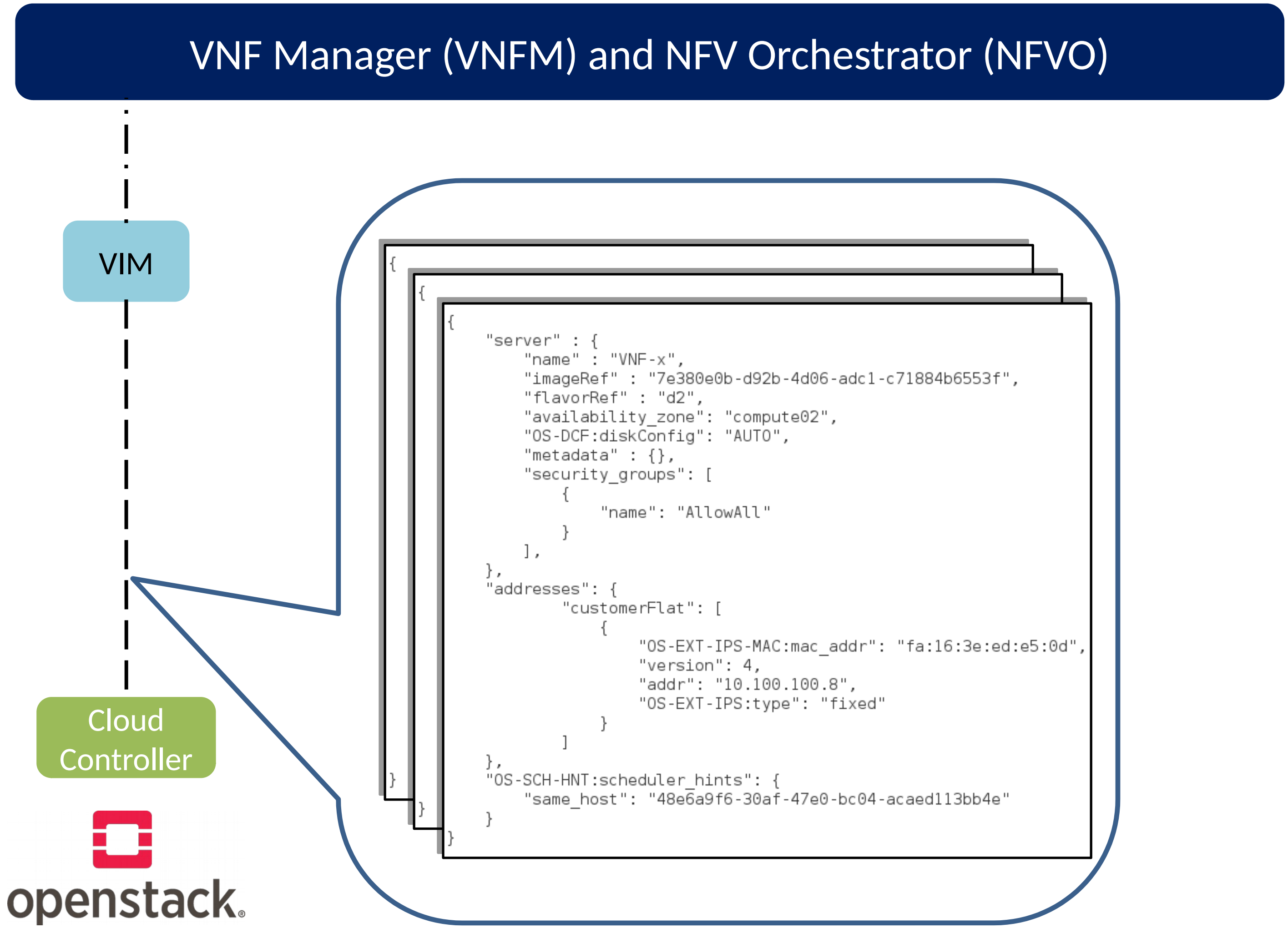
```
DPI_IDS ::= {
  "name": "DPI_IDS",
  "terminal": "true",
  "port_sym": "null",
  "path_sym": "true"
}

WA_1 ::= {
  "name": "WA_1",
  "terminal": "false",
  "port_sym": "false",
  "path_sym": "true"
}
```

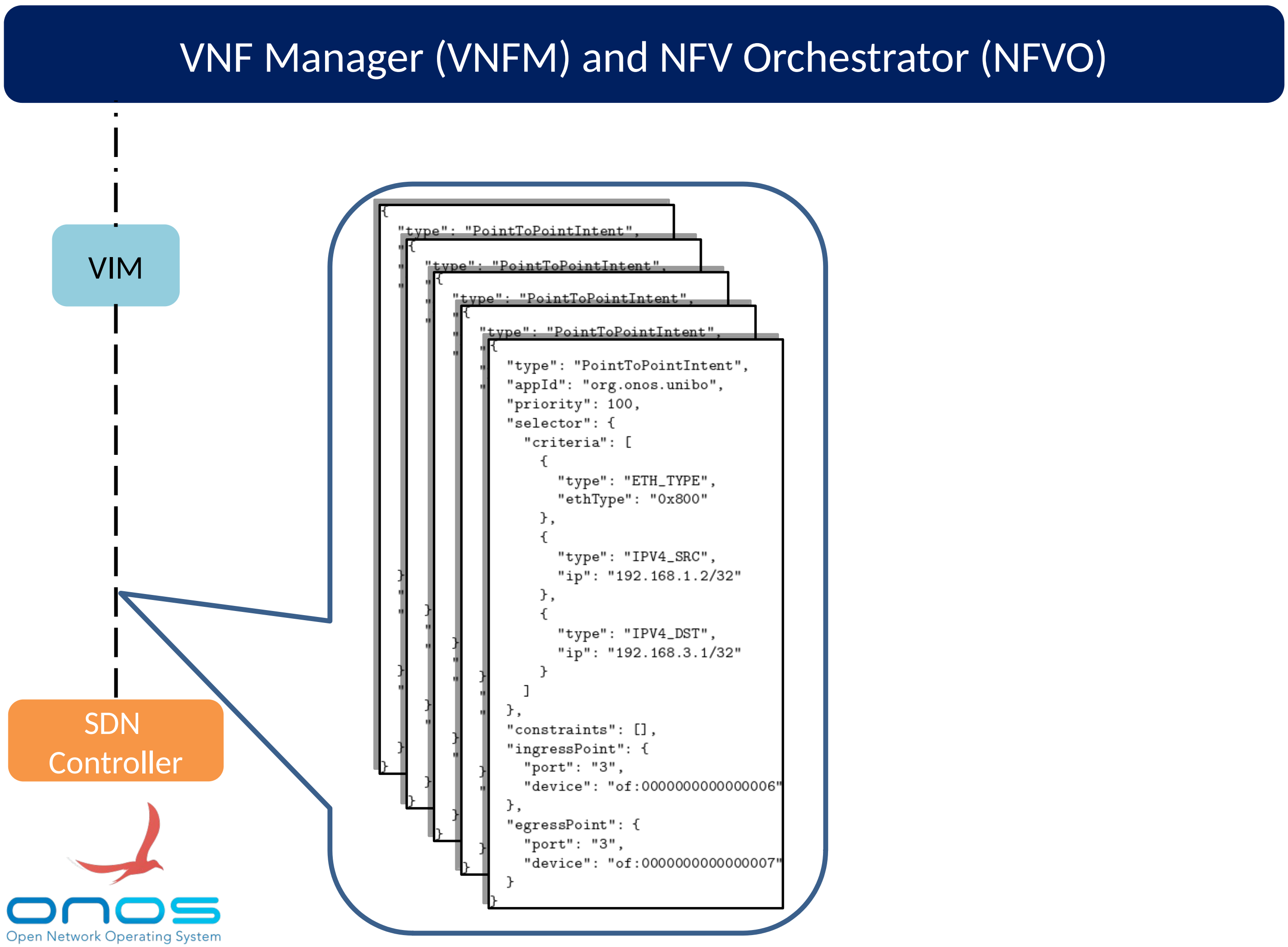
```
TS ::= {
  "name": "TS",
  "terminal": "false",
  "port_sym": "true",
  "path_sym": "false"
}

WA_2 ::= {
  "name": "WA_2",
  "terminal": "false",
  "port_sym": "false",
  "path_sym": "true"
}
```

Domain-specific NBI – Cloud



Domain-specific NBI – Network



Implemented following ONF mapping approach

- ***Key-value stores***, used by providers to translate from the ("simple and intuitive") consumer intent to the detailed, specific provider terms

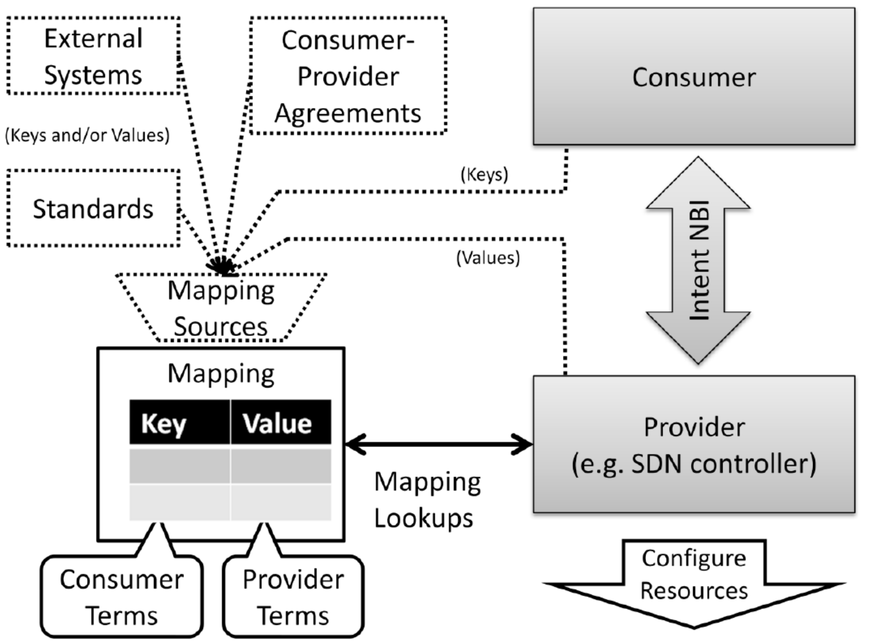
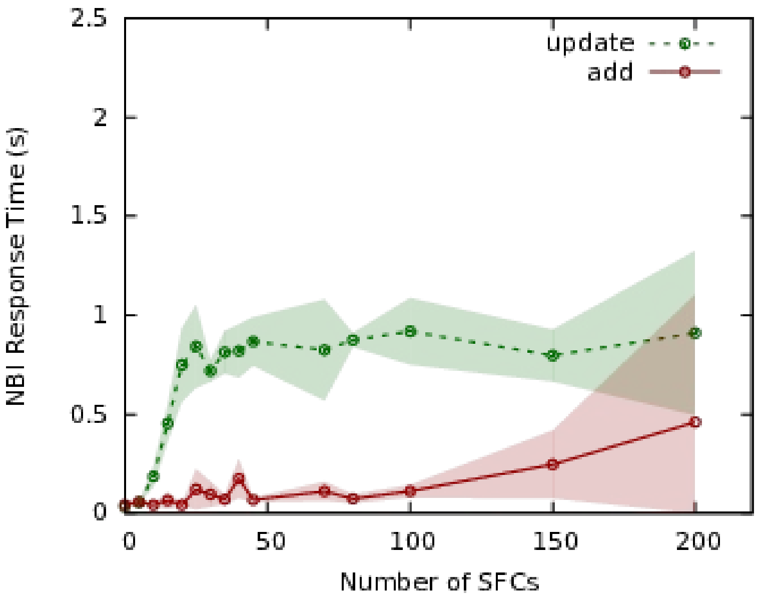
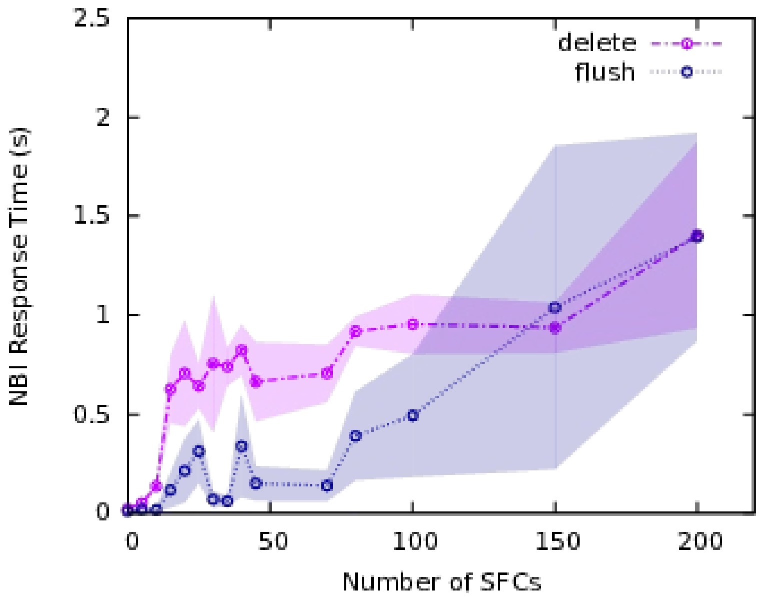


Figure 4 Architectural representation of Intent NBI, mapping and potential sources of mapping contents and/or their dynamic updates. The illustration of mappings as standing outside of provider systems is not prescriptive.

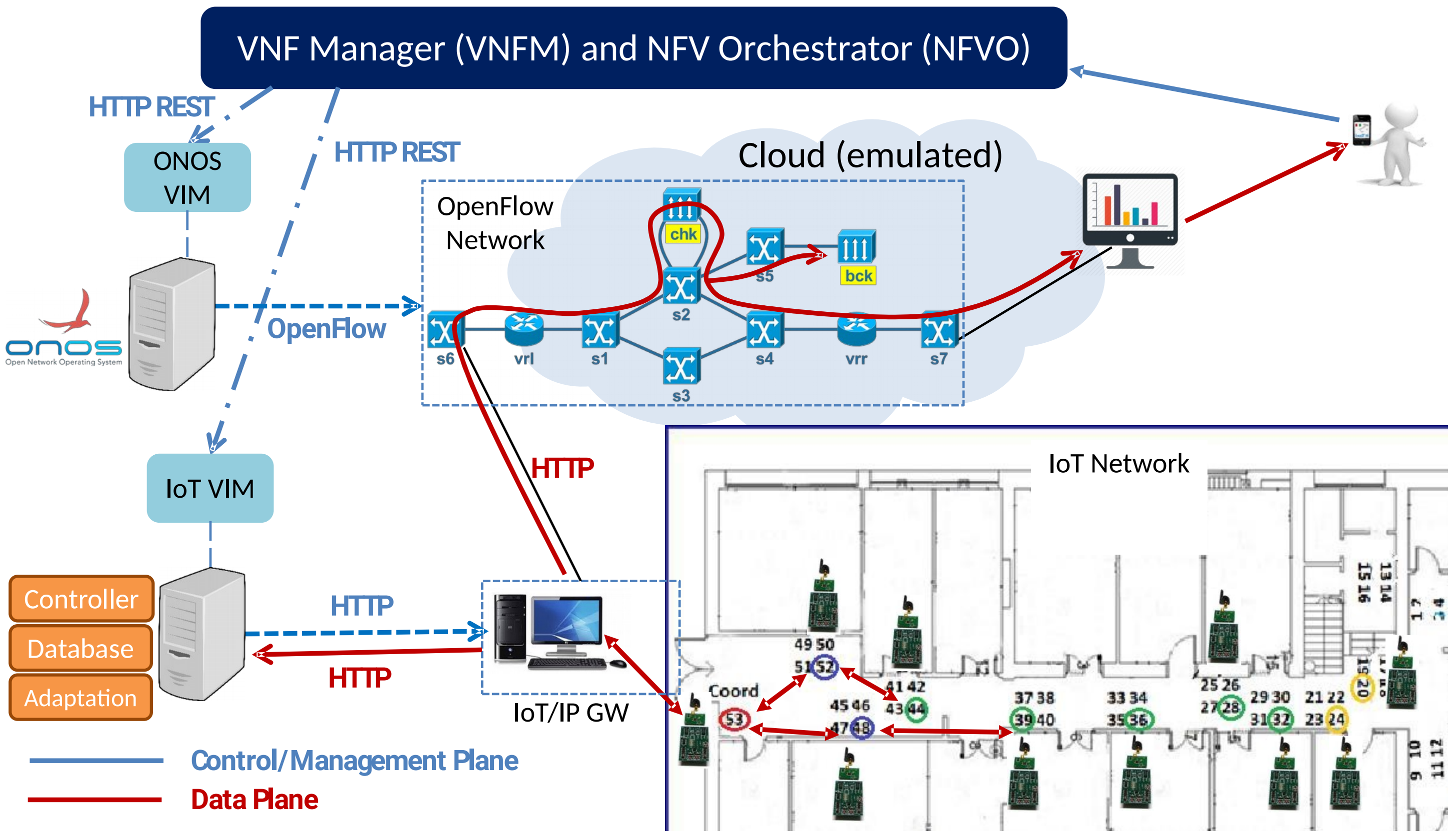
ONF, *Intent NBI – Definition and Principles*, ONF TR-523 , Oct. 2016

Performance of intent-based NBI

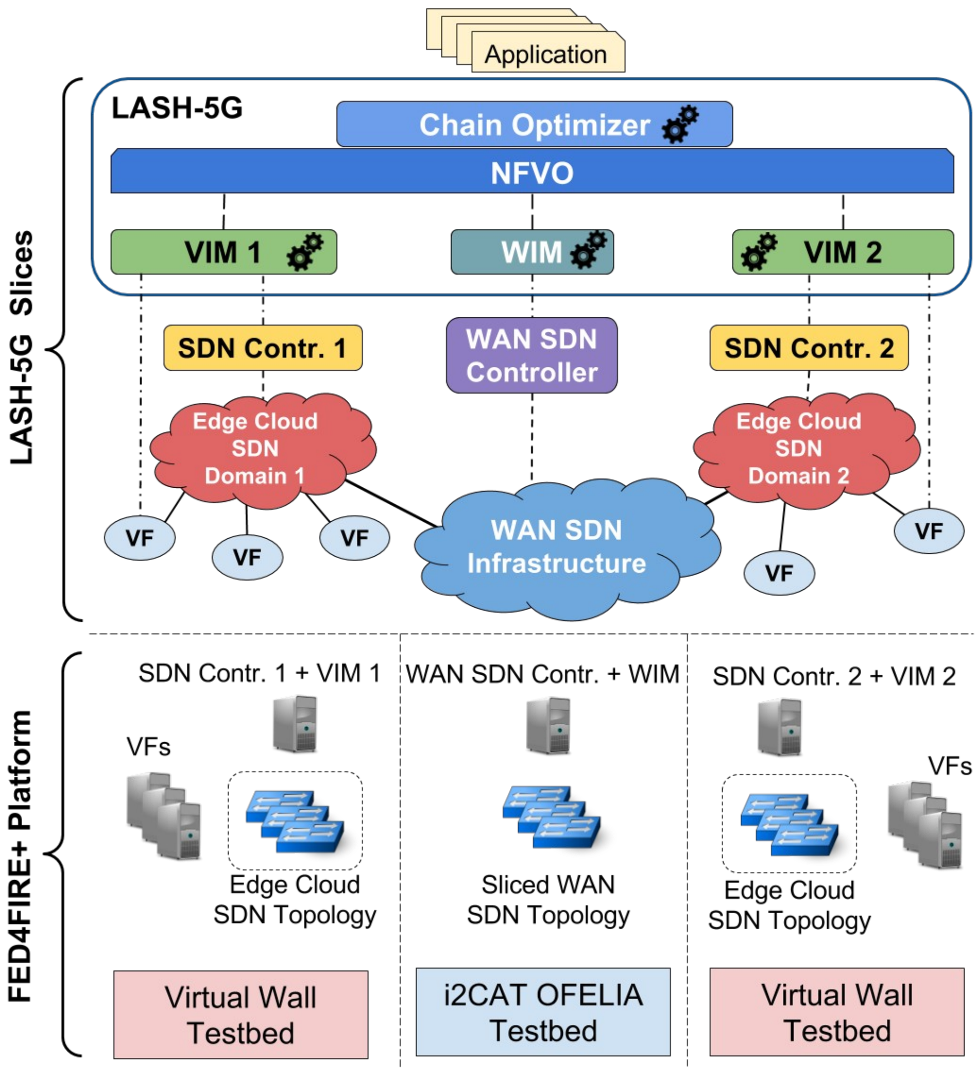




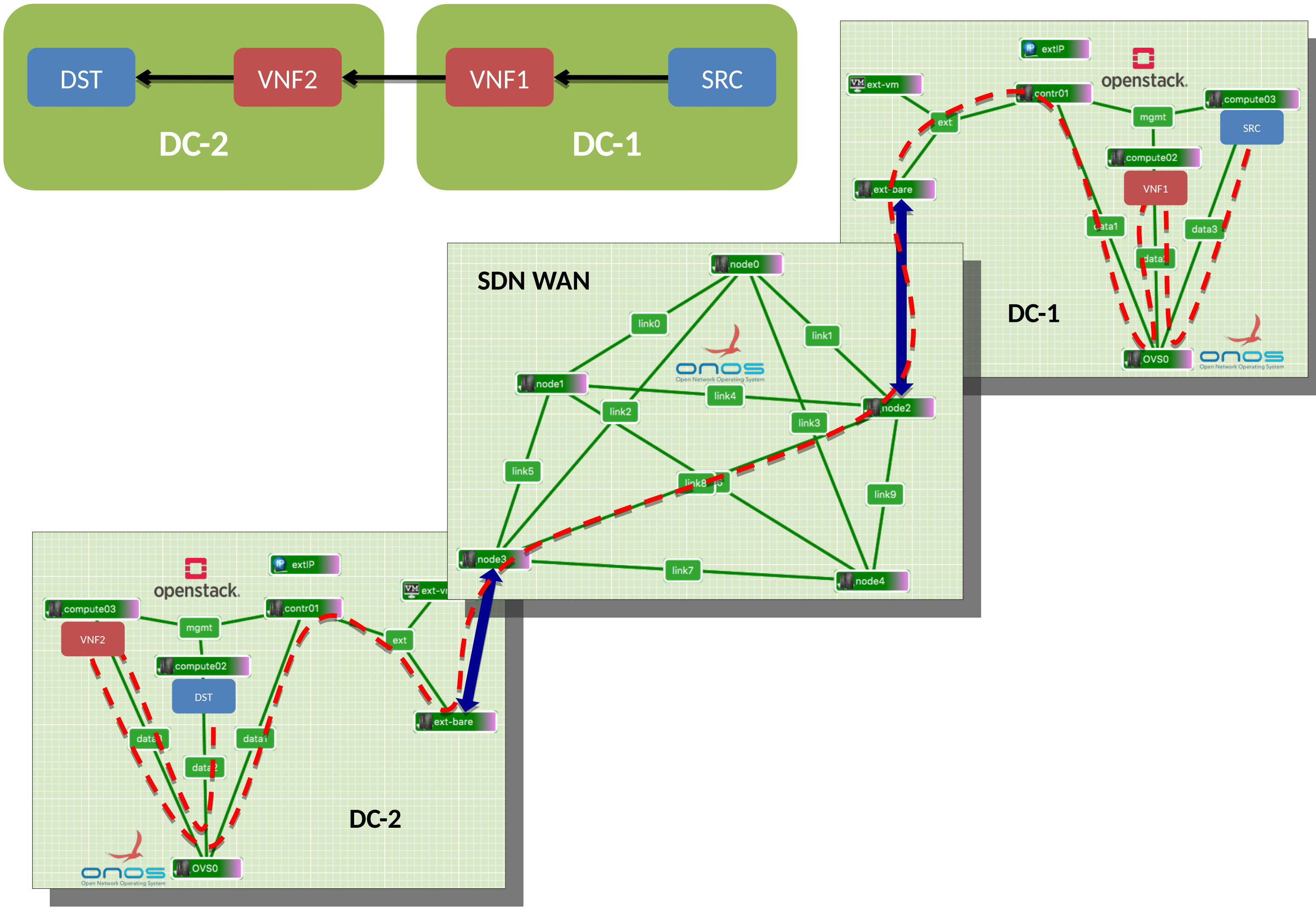
Heterogeneous OpenFlow/IoT SDN Domains



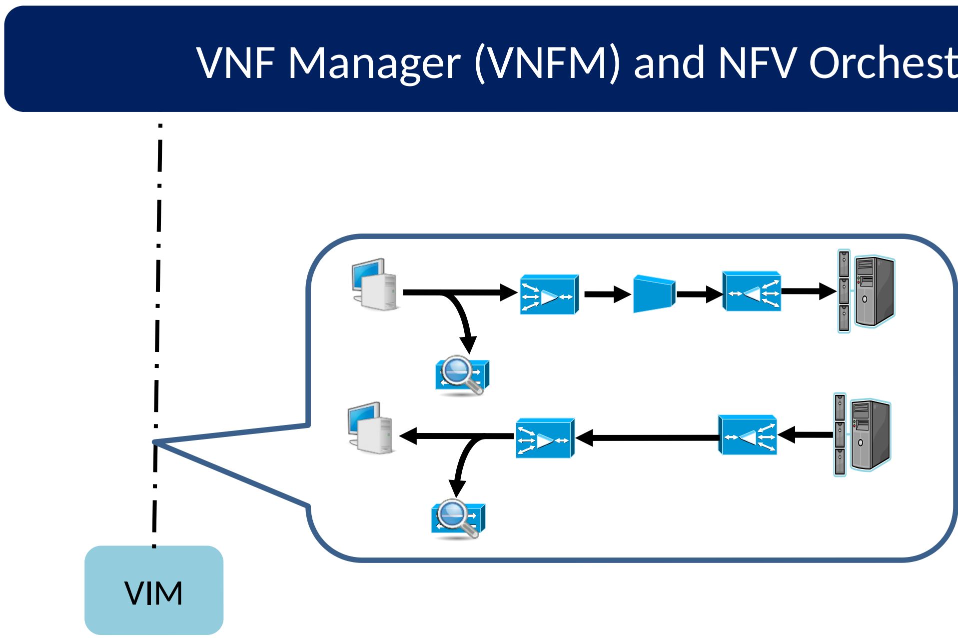
Multi-slice experiment on Fed4Fire+



Multi-slice experiment on Fed4Fire+



Question: can this still be considered “what” and not “how”?




```
{
  "src": "Customer",
  "dst": "Content/Service",
  "vnfList": [DPI_IDS, WA_1, TS, WA_2]
  "dupList": [DPI_IDS]
}
```

```
DPI_IDS ::= {
  "name": "DPI_IDS",
  "terminal": "true",
  "port_sym": "null",
  "path_sym": "true"
}

WA_1 ::= {
  "name": "WA_1",
  "terminal": "false",
  "port_sym": "false",
  "path_sym": "true"
}
```

```
TS ::= {
  "name": "TS",
  "terminal": "false",
  "port_sym": "true",
  "path_sym": "false"
}

WA_2 ::= {
  "name": "WA_2",
  "terminal": "false",
  "port_sym": "false",
  "path_sym": "true"
}
```

References

1. G. Davoli, W. Cerroni, S. Tomovic, C. Buratti, C. Contoli, F. Callegati, *Intent-Based Service Management for Heterogeneous Software-Defined Infrastructure Domains*, International Journal of Network Management, Wiley, Vol. 29, No. 1, January 2019.
2. T. Liu, F. Callegati, W. Cerroni, C. Contoli, M. Gabbrielli, S. Giallorenzo, *Constraint programming for flexible Service Function Chaining deployment*, Proc. of 52nd Hawaii International Conference on System Sciences (HiCSS 2019), Grand Wailea, Maui, HI, January 2019.
3. M. Gharbaoui, C. Contoli, G. Davoli, G. Cuffaro, B. Martini, F. Paganelli, W. Cerroni, P. Cappanera, P. Castoldi, *Demonstration of Latency-Aware and Self-Adaptive Service Chaining in 5G/SDN/NFV infrastructures*, Proc. of 4th IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN 2018), Verona, Italy, November 2018.
4. M. Gharbaoui, C. Contoli, G. Davoli, G. Cuffaro, B. Martini, F. Paganelli, W. Cerroni, P. Cappanera, P. Castoldi, *Experimenting latency-aware and reliable service chaining in Next Generation Internet testbed facility*, Proc. of 4th IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN 2018), Verona, Italy, November 2018.
5. F. Esposito, J. Wang, C. Contoli, G. Davoli, W. Cerroni, F. Callegati, *A Behavior-Driven Approach to Intent Specification for Software-Defined Infrastructure Management*, Proc. of 4th IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN 2018), Verona, Italy, November 2018.
6. W. Cerroni, C. Buratti, S. Cerboni, G. Davoli, C. Contoli, F. Foresta, F. Callegati, R. Verdone, *Intent-Based Management and Orchestration of Heterogeneous OpenFlow/IoT SDN Domains*, Proc. of 3rd IEEE Conference on Network Softwarization (NetSoft 2017), Bologna, Italy, July 2017.
7. F. Callegati, W. Cerroni, C. Contoli, F. Foresta, *Performance of Intent-based Virtualized Network Infrastructure Management*, Proc. of 2017 IEEE International Conference on Communications (ICC 2017), Paris, France, May 2017.

Thank you

walter.cerroni@unibo.it