FED4FIRE
Federation for FIRE Plus

Barbara Martini

CONTRIBUTORS

Federica Paganelli, Walter Cerroni, Molka Gharbaoui, Chiara Contoli, Gianluca Davoli, Giovanni Cuffaro

Review Open Call 1 *LASH-5G* experiment

FEC3

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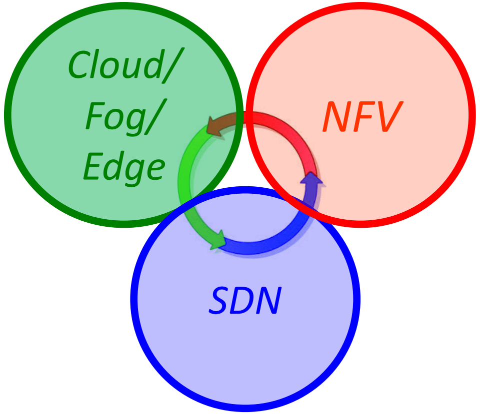
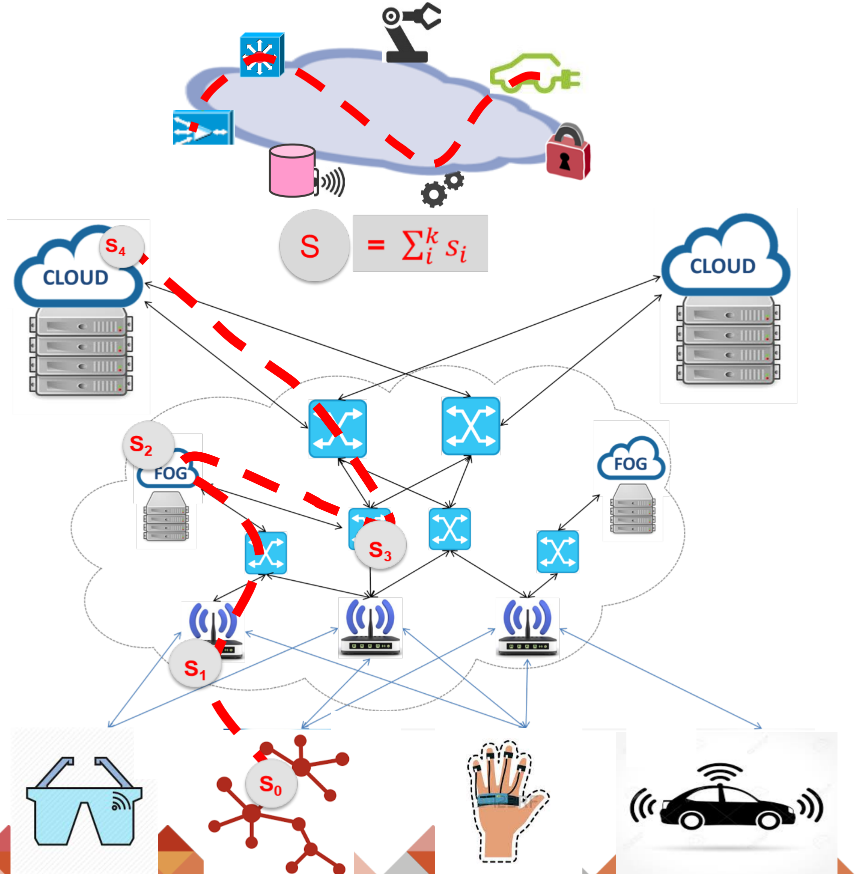
Outline

- Experiment description
  - Background and motivation
  - Concept and objectives
  - Experiment set-up
- Project results
  - Measurements
  - Lessons learned
- Business impact
  - Impact on our business
  - Value perceived
- Feedback
  - Used resources and tools
  - Added value of Fed4FIRE

Experiment Description

Background and Motivation





Scenario: cloudification of the network at the Edge; extension of cloud paradigm to the Edge (Fog); SDN fabric at the Edge and in the Coud/Fog for programmable network path set-up; applications delivered as chains of application and network services deployed as virtual functions (VFs) in micro-clouds distributed at the Edge of the network.

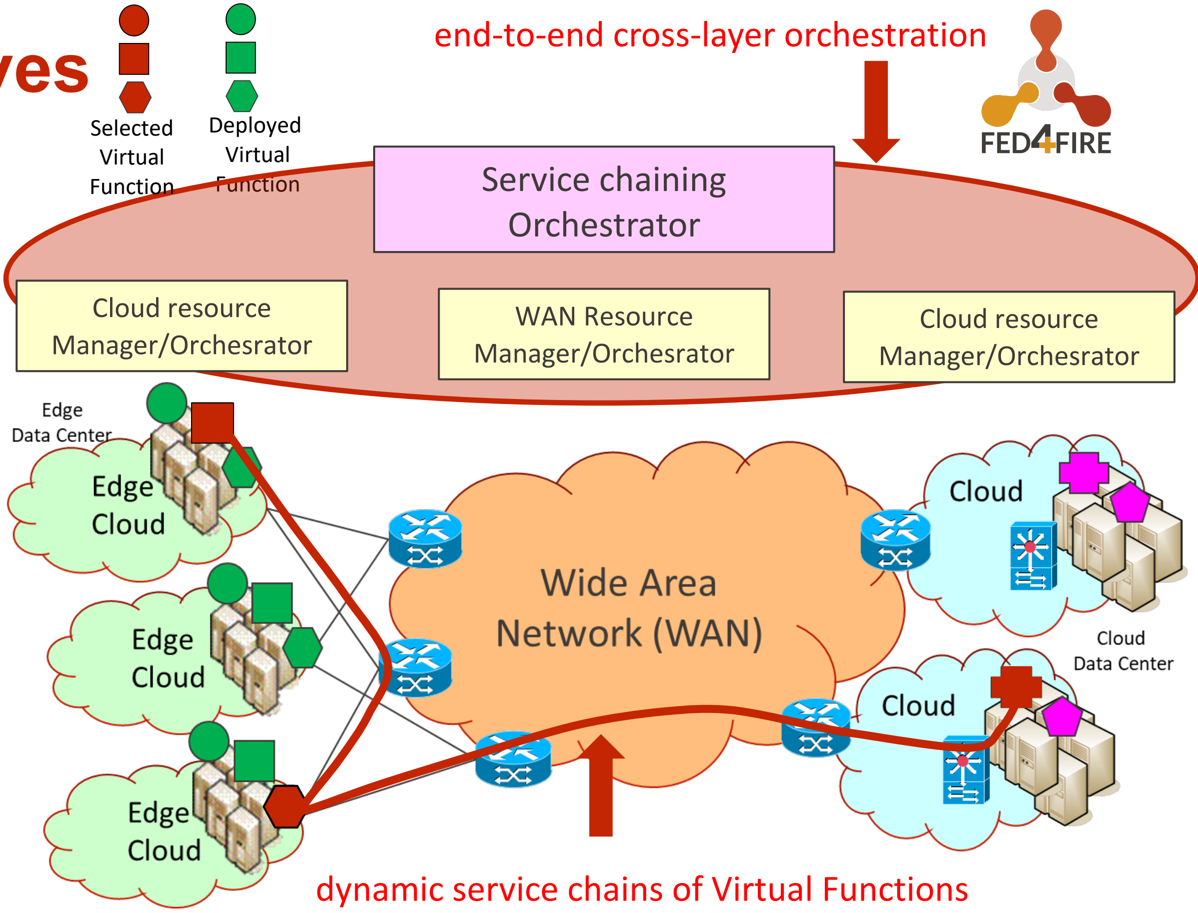
Challenges: dynamic selection and composition of services in a highly dynamic 5G service scenarios; allocation of heterogenous and distributed resources controlled by different managers/controllers; fulfilment of stringent end-to-end latency and high-availability requirements

Concept and Objectives

<u>Approach:</u> orchestration of resources over geographically distributed Edge clouds interconnected through SDN; adaptive service selection strategies to minimize overall latency along service chains

<u>Goals</u>: evaluate an end-to-end cross-layer orchestration system running on top multi-technology resource domains

- encompassing the following orchestration levels: service chaining orchestration – intra-DC resource orchestration – inter-DC WAN resource orchestration
- aiming at addressing latency, adaptability and availability requirements of 5G applications.



Experimental Set-up

OVERVIEW

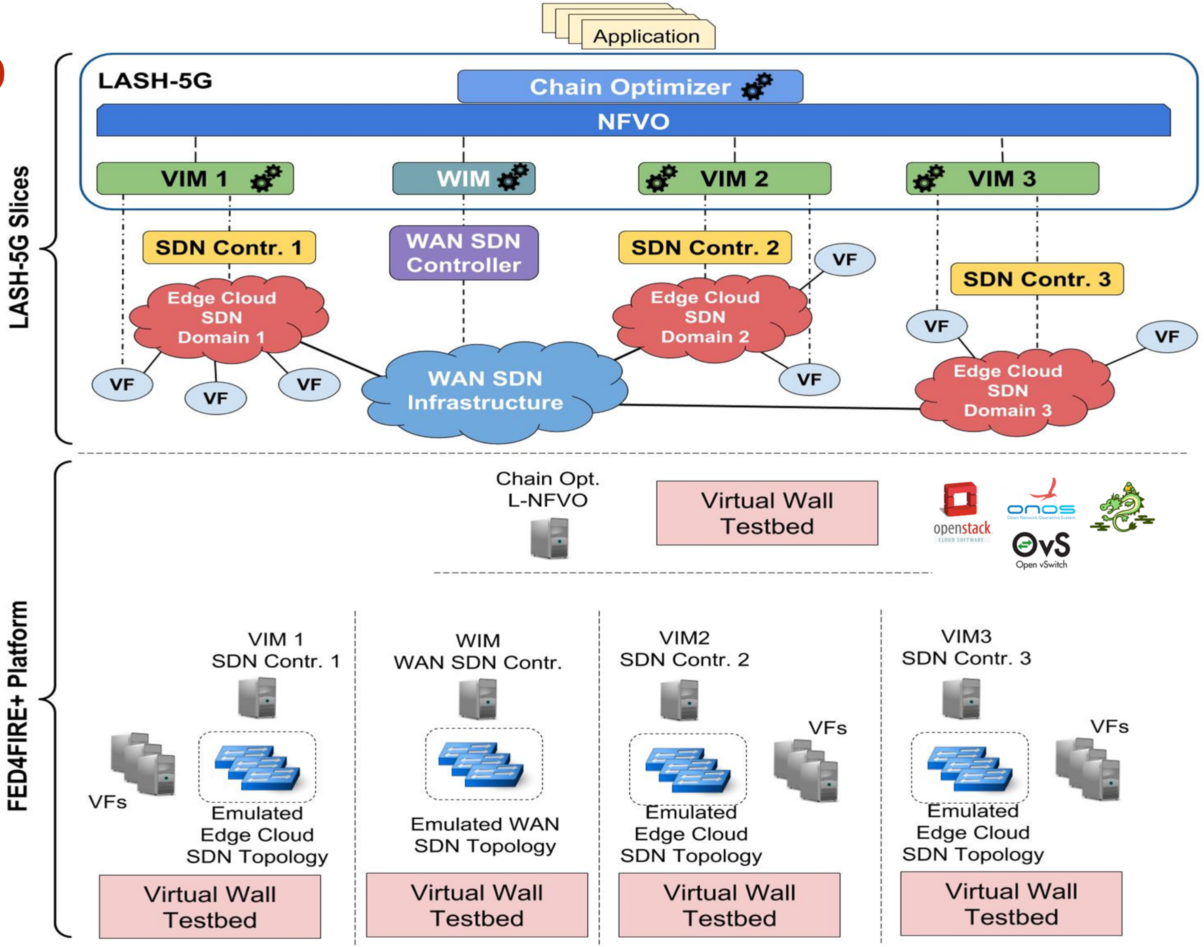
Distributed set-up of clouds/micro-clouds interconnected through an SDN network (i.e., multi-domain/multi-technology domains)

- 3 Edge cloud domains
- VFs deployed by means of a cloud-computing platform (e.g., OpenStack)
- SDN technologies are used to properly configure traffic flow steering rules within and across cloud domains

LASH-5G orchestration system lies on top of the SDN controllers and cloud managers and includes:

- enhanced Virtualized Infrastructure Manager (VIM)
- enhanced WAN Infrastructure Manager (WIM)
- Chain Optimizer software module

5 slices from Virtual Wall testbed



Experimental Set-up

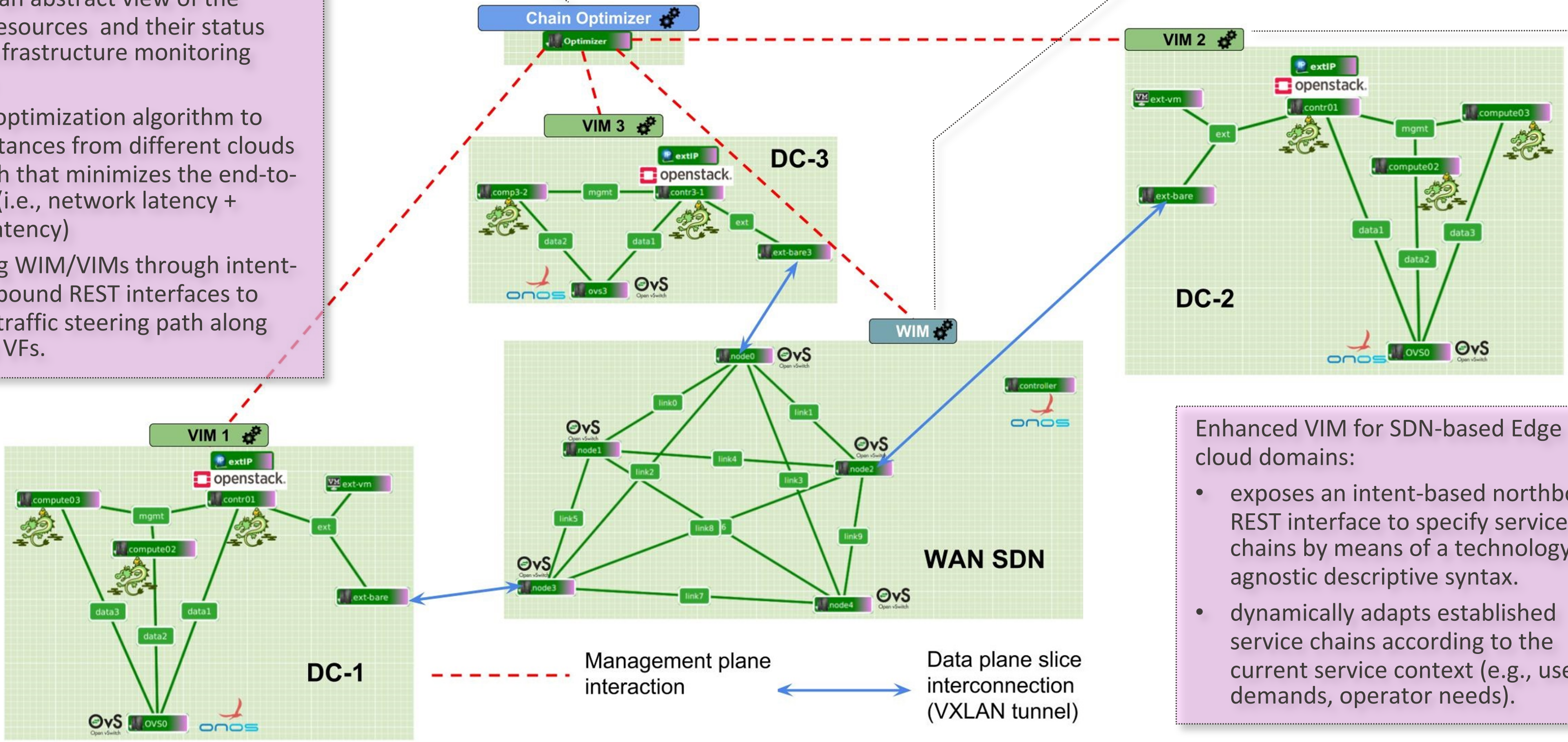
SYSTEM VIEW

Chain Optimizer handles service function chaining requests by:

- maintaining an abstract view of the underlying resources and their status leveraging infrastructure monitoring information
- invoking an optimization algorithm to select VF instances from different clouds over the path that minimizes the end-to-end latency (i.e., network latency + processing latency)
- orchestrating WIM/VIMs through intent-based northbound REST interfaces to enforce the traffic steering path along the selected VFs.

WIM Orchestrator for SDN interconnection networks:

- provides programmable service chain paths by means of an intent-based northbound REST interface
- periodically collects monitoring data to obtain current load of switches
- offers reliable service chains by redirecting service paths to recover from network congestions.



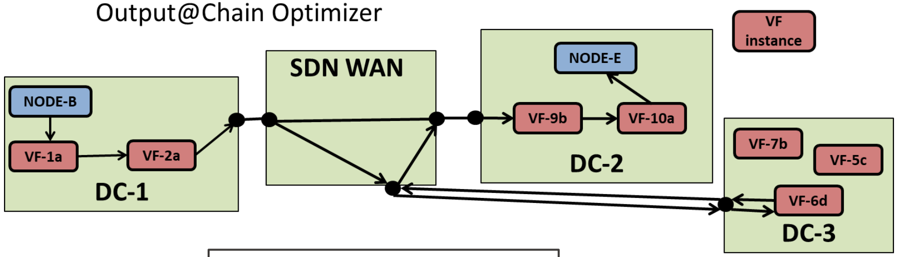
Enhanced VIM for SDN-based Edge cloud domains:

- exposes an intent-based northbound REST interface to specify service chains by means of a technology-agnostic descriptive syntax.
- dynamically adapts established service chains according to the current service context (e.g., user demands, operator needs).

Project Results

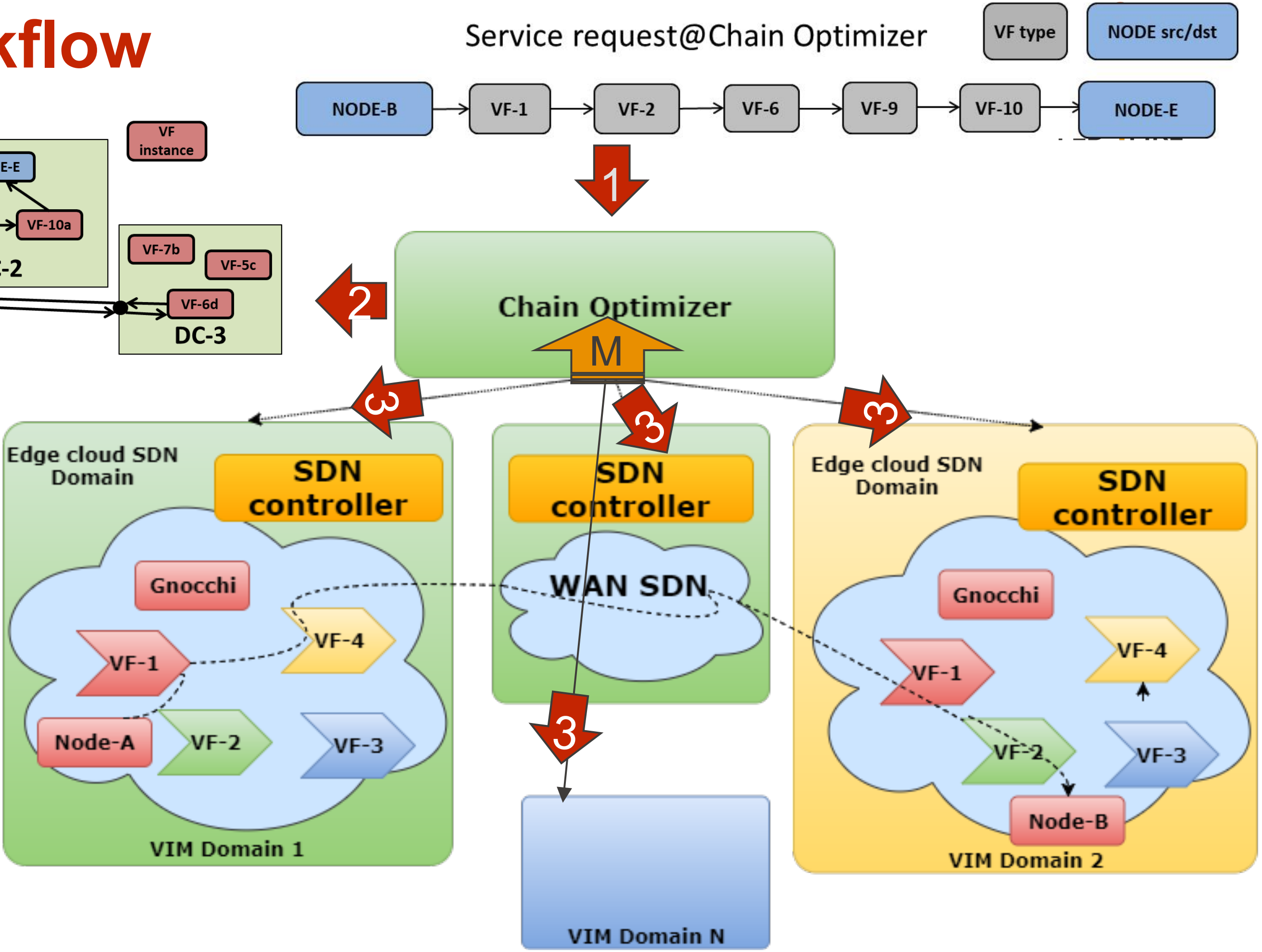
Experiment workflow

Output@Chain Optimizer




```
{
    "src":"Node-B.dc1",
    "dst":"Node-E.dc2",
    "serviceType":"Type5",
    "maxLatency":300,
    "vnf":[
        {
            "name":"VF-1",
            "port_sym":false,
            "terminal":false,
            "path_sym":false
        },
        {
            "name":"VF-2",
            "port_sym":false,
            "terminal":false,
            "path_sym":false
        }
    ],
    "dup":[

    ]
}
```

Measurements

	ADD	DELETE
ONOS	2.17 (+/- 1.55) ms	14.41 (+/- 2.45) ms
Ryu	5.09 (+/- 0.84) ms	5.04 (+/- 0.46) ms

· Response time of the Edge cloud SDN controllers NBI (average and stdev)

ADD	REDIRECTION
17 (+/- 3) s	6 (+/-120ms) s

Setup and redirection time of the WAN SDN controller (average and stdev)

Metrics	Mean (ms)	Std deviation (ms)
Request handling time	17,28	12,16
Overall response time	17213,78	7937,89
Computation time	3,27	0,43

CO performance for service chaining creation and update requests

Lesson Learnt

- Hand-on practice on SDN/NFV software platforms (Openstack, ONOS, Ryu) gained by deploying a composite 5G infrastructure with 3 cloud domains interconnected through SDN).
- Need for nodes with higher capacity (especially in terms of RAM) to host SDN controllers and applications and to cope with the dynamicity and the large amount of data to process in relatively large networks (e.g., increasing the number of OvS from 5 to 20 caused a controller overload).
- SDN controllers need more configuration time in real network environments (although virtual) with respect to emulated ones (e.g., Mininet)
- SDN switches discard packets during path reconfigurations in LASH-5G network environments on the contrary to what happen in emulated ones (e.g., Mininet)
- Throughput at the VFs can reach optimal levels even when traffic crosses up to ten VFs, unless multiple slices are traversed

Business Impact

Which was the impact on CNIT business?

Relevant scientific benefits expected at CNIT in terms of:

- enhanced expertise and hand-on practice on SDN/NFV software platforms (Openstack, ONOS, Ryu)
    - new ideas in other related areas that deserve investigations (e.g., integration in MEC)
    - new opportunities for collaborations and partnerships with 5G industries
    - improved quality of graduate/post-graduate curricula and Ph.D. programs
- significant reserch outputs to disseminate
    - obtained large-scale experimental results
    - increased involvement in SDN/NFV/5G scientific communities
    - new opportunities for partnership in EU projects
- increased cross-fertilization of ideas and backgroud across CNIT Research Units
    - acquired expertise can be disseminated internally through workshops or in-house training sessions
    - new opportunities for internal sinergies and collaborations
    - novel CNIT developments that could further attract 5G industries

How did Fed4FIRE help us?

- Prior LASH-5G, we carried out separate test campaigns each aiming at validating the single orchestration components in specific and separated scopes (i.e., a single cloud data center, WAN interconnecting clouds, VF selection algorithm). With Fed4FIRE:
- we could perform tests in almost realistic network scenario thanks to a variety of available resources:
  - 25 physical nodes available for us to do the experiment
  - “Bare-metal servers” available made this experiment feasible
- we could set-up a full-stack SDN/NFV deployment thanks to flexibility of resource and capabilities:
  - deployment spanning from service orchestration to the resource orchestration layer and involving both cloud and SDN network resource domains
  - integration tests of 5 system components and test the integrated system toward a truly end-to-end orchestration and dynamic service chaining
- we could perform tests with a scale larger than typical scales of academic laboratory testbeds and obtains performance evaluation with more solid results
- we could benefit from direct access to nodes in F4F+ that allows us the easy access to and configuration of nodes and then execution of the experiment set-up with very high flexibility and manifold capabilities

Value perceived

Fed4FIRE offers "bare metal" capabilities that is definitely a distinguished feature for us:

- LASH-5G experiment would be not feasible in other 5G-related FIRE platforms
- realistic experimental environment which increments the value of LASH-5G experiments and give us a more solid system performance evaluations
- gained hand-on practice on different software platforms (Openstack, ONOS, Ryu) and orchestration

Return of value in terms of futher developments that would strenghten our position in the SDN/NFV/5G scientific community and would attract 5G indistries with new collaborations and partnerships:

- further development of vendor-independent and intent-based northbound interface offered to service and resource orchestration functions.
- extension of service orchestration functionalities to include complete service chain lifecycle management and SLA and policy management support.
- study of possible integrations with ETSI MANO and ETSI MEC platform services, leveraging LASH-5G end-to-end service orchestration, multi-domain and adaptation capabilities.

Why did we come to Fed4FIRE?

- Fed4Fire is an appropriate platform for the execution of LASH-5G since it provides a high programmable and versatile environment that perfectly matches the requirements of LASH-5G
- Fed4Fire is the only FIRE initiative that allows us to perform this experiment because offering the level of control we need to change resource configurations, e.g., traffic rules to switches, that implies interaction with infrastructure controllers/managers.
- The relevant set of resources made available to the experimenters constitutes an important advantage since the only alternative to perform large scale tests would be to resort to simulations which are much less realistic

Feedback

Used resources and tools

- Fed4FIRE Testbed used:
  - Virtual Wall (iMinds) – 25 nodes
  - Ofelia testbed
- Fed4FIRE tools used:
  - jFed
  - direct SSH connection to Virtual Wall nodes
- Other tools set-up in ‘physical nodes’ were provided by us, i.e., tool for generation of trafic, in-built tools for network latency measurements

Added value of Fed4FIRE

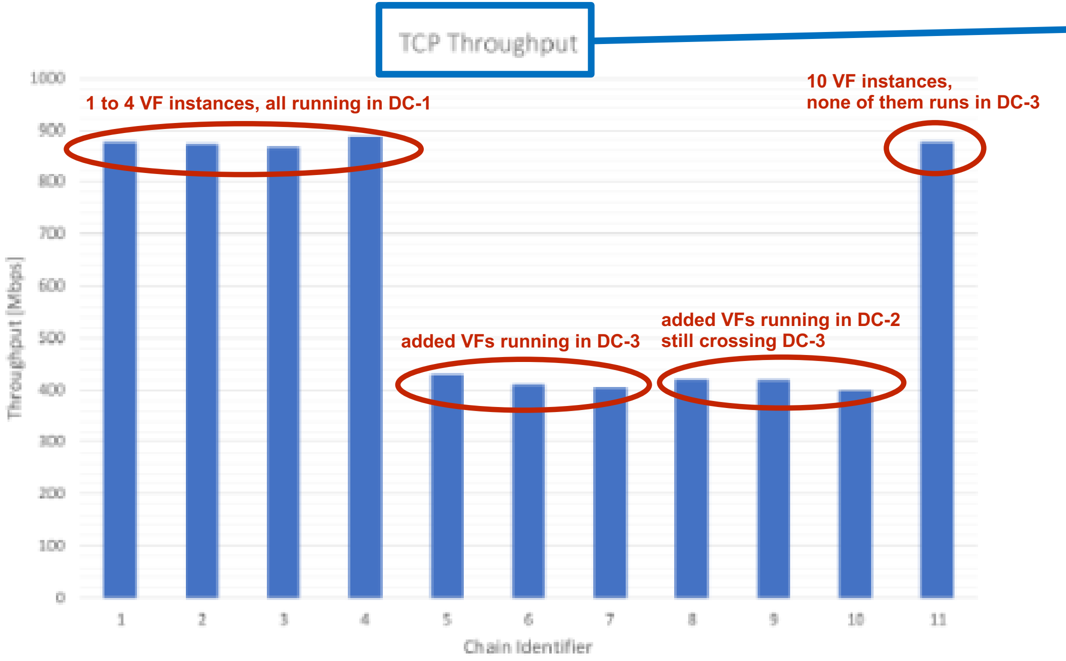
The most important added value of Fed4Fire we perceived are:

- the large availability of heterogeneous facilities
    - large scale experimentation
- availability of ‘physical nodes’ as offered resources
    - built our own NFV/SDN infrastructure on top of ‘real’ testbed
- flexibility of offered capabilities
    - possbility to access directly the nodes (through SSH)
- documentation and support in case of issues
    - tutorials for experimenters ere very precious especially at the beginning
    - issues were rapidly addressed thanks to the prompt support

Feedback based on set-up of experiment on Fed4FIRE

- Possibility to use multiple slices for the same project: for example add Edge cloud domains incrementally and independently of the other ones => save configuration and setup time with respect to the alternative option of deploying a single slice including all three domains.
- Possibility to share the slice(s) among different users belonging to the same project => very helpful for us coming from different CNIT research groups and working in different CNIT sites
- Once configured in a correct manner, it was easy to save the configuration and reuse it again to repeat the experiment. We also were able to create images from already configured virtual machines and reuse them, thus gaining much time in the configuration phase.
- Connectivity issues among the testbeds represented a real issue for our experiment. It was due to technical limits/failures that the testbeds managers were unfortunately not able to fix.
- The available resources were a bottleneck since our experiment required an important set of them (25 nodes) and it was difficult to reserve them for a long period.
- Limited number of available public IP addresses that we used to expose GUIs of experiment components and to try overcoming connectivity issues between testbeds

Feedback based on running of experiment on Fed4FIRE



Throughput of data traffic traversing service chains with an increasing number of VF instances

The Virtual Wall facility is able to provide full capacity to a typical NFV/SDN infrastructure based on OpenStack and Open vSwitch components due to the possibility offered by Virtual Wall to deploy slices using bare-metal servers avoiding nested virtualization

Fed4FIRE+ facilities (and Virtual Wall in particular) can be considered a good candidate to perform realistic experiments on non-trivial NFV/SDN infrastructures based on production-level software tools

Feedback on Fed4FIRE portfolio, documentation and support

The positive aspects were the availability and easy access to the resources and capabilities of Fed4FIRE specifically appropriate for 5G infrastructure-related experiments (i.e., bare-metal server offering). the testbeds were overall available all the timeframe and the access guaranteed and secured through the use of passwords and public/private keys.

The negative aspects regard mainly the issues relative to the connectivity among the different testbeds, which prevented us not only from considering more than one testbed and from using a hardware OpenFlow swtiches

A minor issue relates to:

- sharing of the resources between different experiments, which results in the competitiveness in reserving the physical nodes among experimenters
- some breakdown occurred that denied the access to the infrastructure (e.g., interfaces down, renewal of certificate)

The availability of a well described documentation and the responsiveness of the technical managers of the testbeds in case of specific issues has been appreciated.

Dealing with a single service provider was very helpful and less complicated than dealing with different testbeds managers that might be not coordinated or aware of the use of the other testbeds.

The documentation was helpful in setting up and running the experiment, especially tutorials and the mailing list

FED4FIRE

LASH-5G

Co-funded by the European Union

Co-funded by the Swiss Confederation

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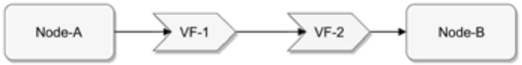
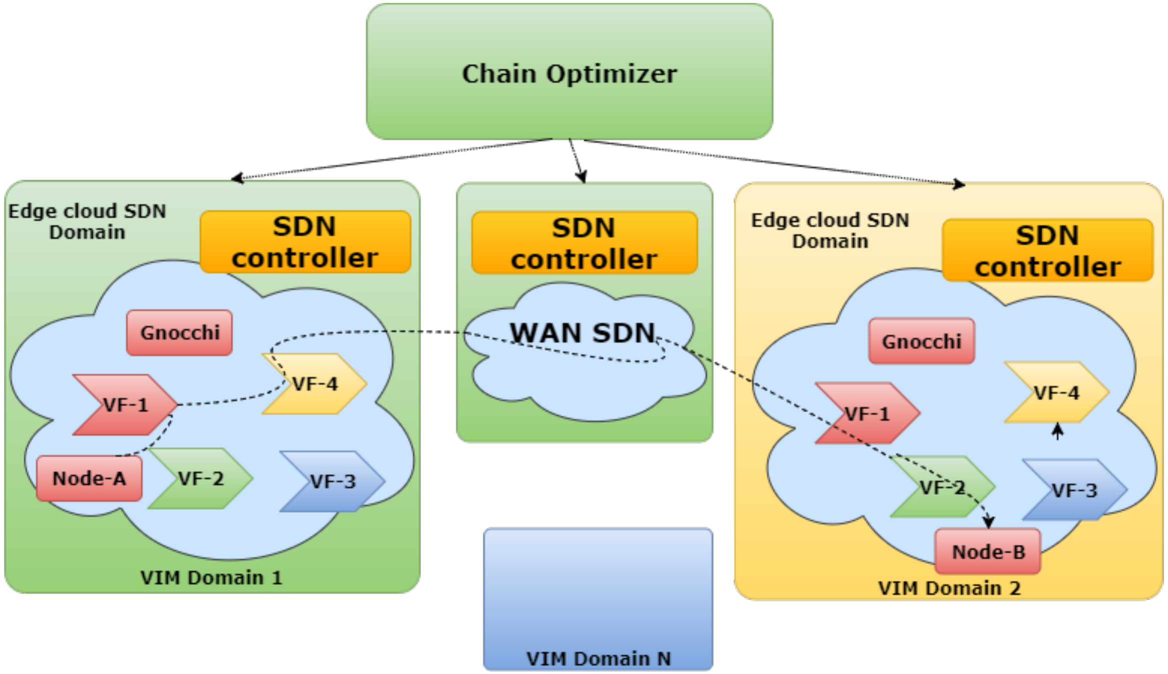
WWW.FED4FIRE.EU

Chain Optimizer (1/3)

- Handles abstract service chaining requests and defined concrete service chain instances on top of a multi-DC environment
- Orchestrates WIM/VIMs through NB intent-based interfaces for sending appropriate forwarding instructions enforcing traffic flows to be steered along the selected VF instance




```
{"serviceType":"TypeA",
"maxLatency":300,
"source":"Node-A.dc1",
"destination":"Node-B.dc2",
"vfChain":"VF-1,VF-2"}
```




```
"vfChain":"VF-1 in DC1,VF-2 in DC2"}
```

Chain Optimizer (2/3)

REST APIs for CRUD operations on service chains.

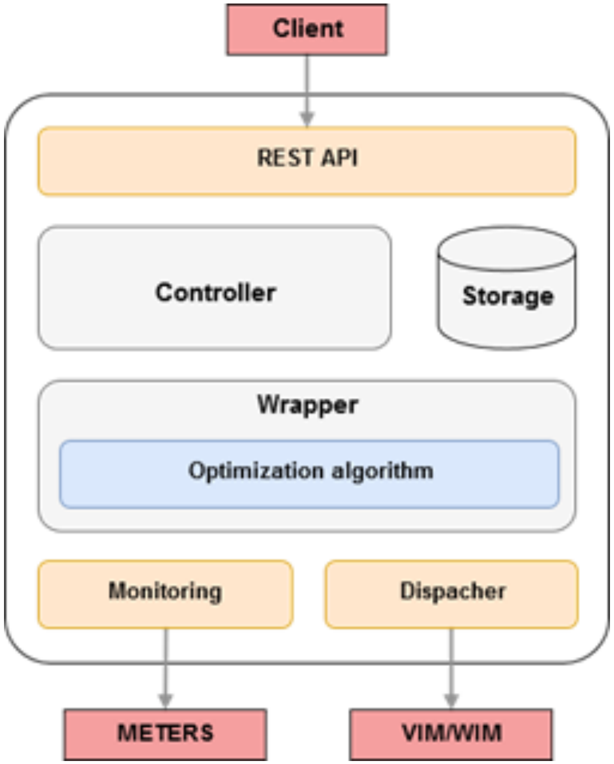
Controller: It manages incoming requests.

Wrapper: It invokes an optimization algorithm that selects the nodes (i.e. DCs) that provision the VFs over the path that minimizes the overall latency (i.e. network and processing latency).

Monitoring: this component periodically interacts with VIMs and WIM monitoring API to collect measurements needed to maintain an up-to-date view of the underlying infrastructure topology. Collected measurements include: inter-DC latencies, types and instances of VF deployed at each DCs and related processing latency.

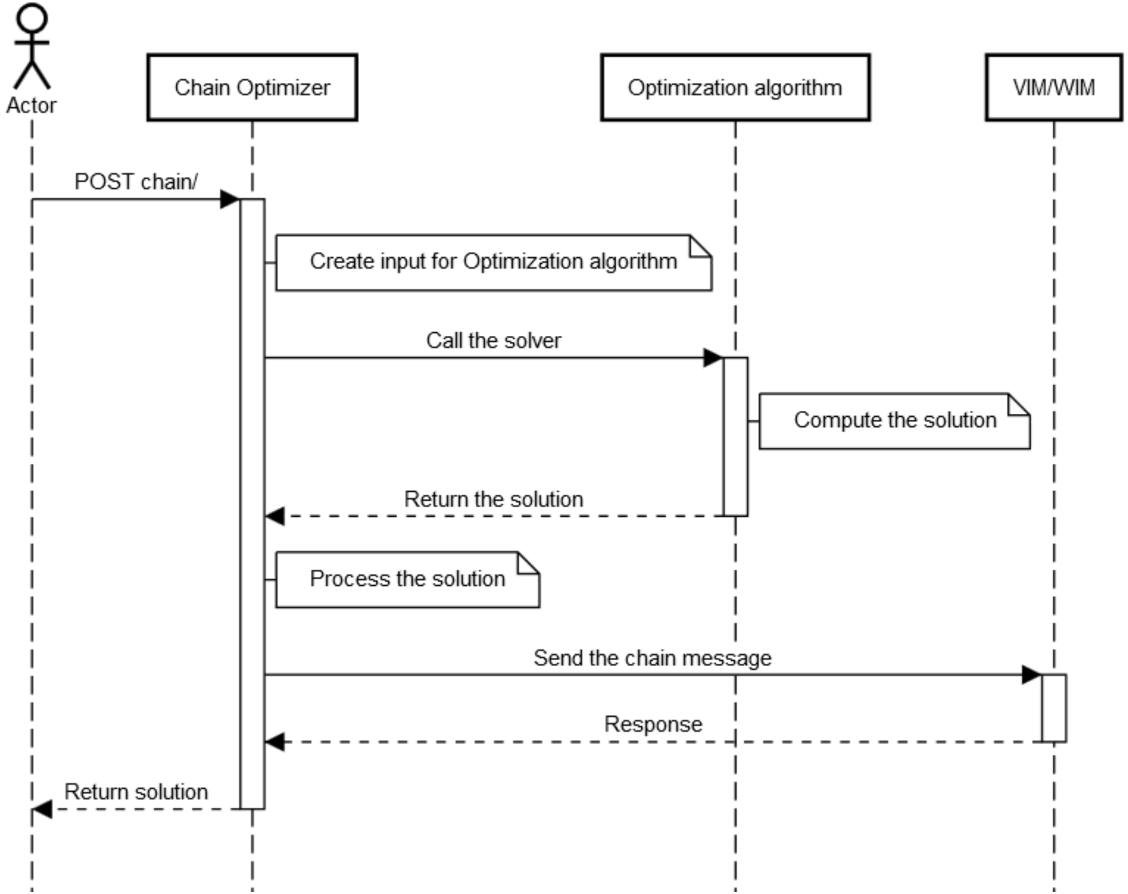
Dispatcher. It handles the interactions with VIMs and WIMs in order to enforce operations on a target service chain.

Storage. Relevant data concerning service chains are persisted for online operation (e.g. monitoring and update operation) as well as for collecting data for statistics (e.g. acceptance ratio, performance metrics, etc.

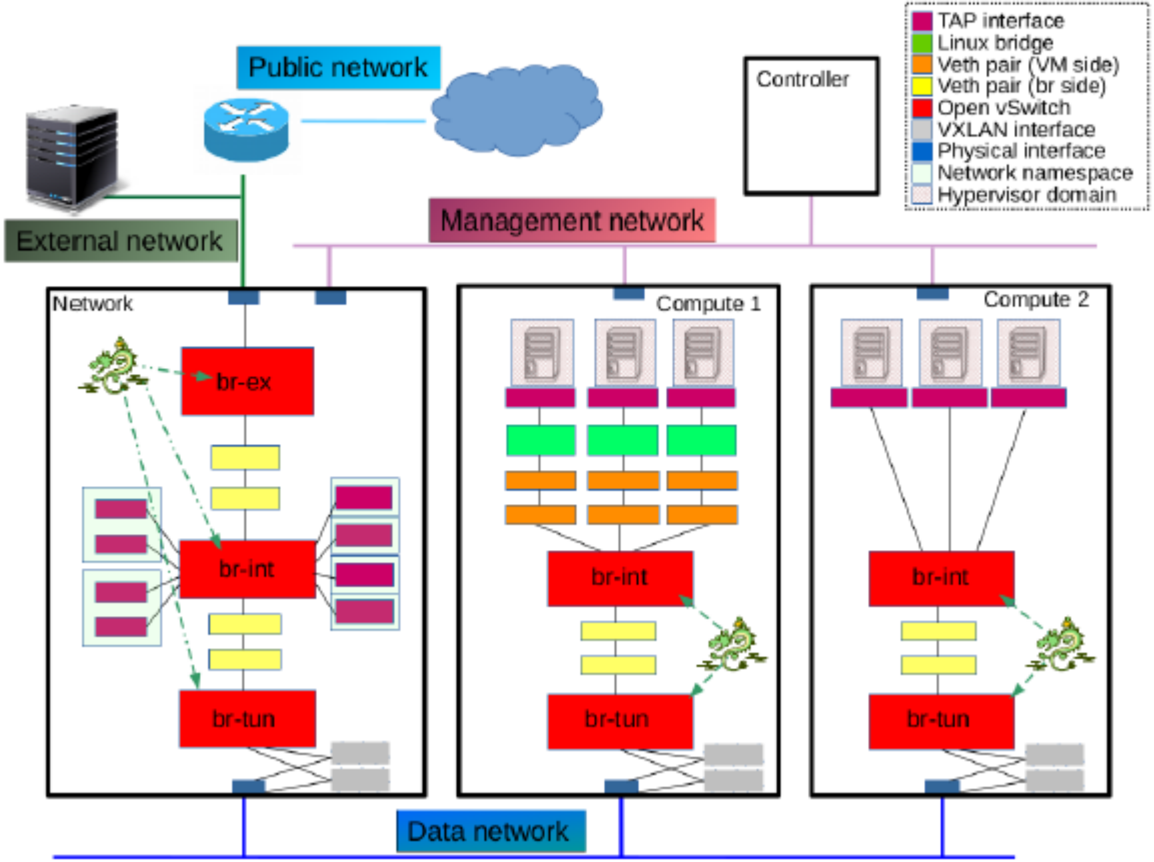


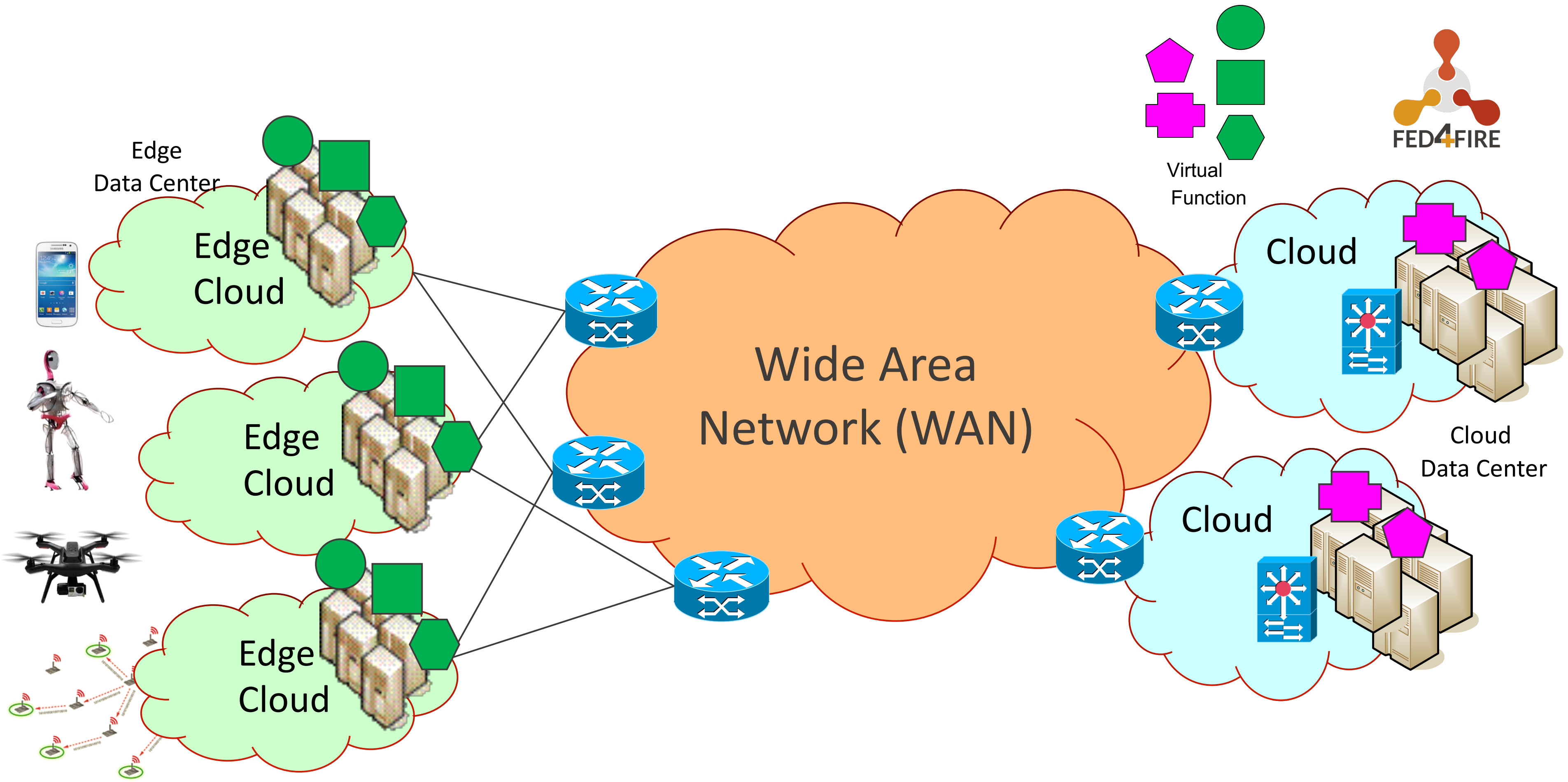
Chain Optimizer (3/3)

Sequence diagram of Chain Optimizer



SDN capabilities in OpenStack




Edge
Data Center
Edge
Cloud
Edge
Cloud
Edge
Cloud
Wide Area
Network (WAN)
Virtual
Function
Cloud
Cloud
Cloud
Data Center

Placement of VF across three Edge cloud domains (1/4)

Data centers	dc1			dc2			dc3	
Nodes	contr01	comp02	comp03	contr01	comp02	comp03	contr3-1	comp3-2
VF types	VF-5	VF-3	VF-1	VF-5	VF-6	VF-8	VF-7	VF-5
	VF-6	VF-4	VF-2	VF-6	VF-7	VF-9		VF-6
	VF-7	VF-5	VF-3		VF-8	VF-10		
Service Endpoints	0	1	2	0	1	2	0	0
		NODE-C.dc1	NODE-A.dc1		NODE-D.dc2	NODE-E.dc2		
			NODE-B.dc1			NODE-F.dc2		
VF instances	4	4	5	2	3	5	2	3
	VF-5b	VF-3b	VF-1a	VF-5d	VF-7d	VF-8b	VF-7b	VF-5c
	VF-6a	VF-4a	VF-1b	VF-6e	VF-7e	VF-9a	VF-7c	VF-6c
	VF-6b	VF-4b	VF-2a		VF-8a	VF-9b		VF-6d
	VF-7a	VF-5a	VF-2b			VF-10a		
			VF-3a			VF-10b		
Total no. of VMs	4	5	7	2	4	7	2	3

VFs deployment in DC-1 (2/4)

Instances

Instance ID = ▾ | Filter | Launch Instance | Delete Instances | More Actions ▾

Displaying 16 items

☐	Instance Name	Image Name	IP Address	Flavor	Key Pair	Status		Availability Zone	Task	Power State	Time since created	Actions
☐	NODE-C.dc1	vnf-image-centos-7	10.100.100.23 Floating IPs: 192.168.6.107	ds1G	lash-5g-key	Active		nova	None	Running	8 hours, 47 minutes	Create Snapshot ▾
☐	NODE-B.dc1	vnf-image-centos-7	10.100.100.3 Floating IPs: 192.168.6.100	ds1G	lash-5g-key	Active		nova	None	Running	8 hours, 48 minutes	Create Snapshot ▾
☐	NODE-A.dc1	vnf-image-centos-7	10.100.100.24 Floating IPs: 192.168.6.105	ds1G	lash-5g-key	Active		nova	None	Running	8 hours, 51 minutes	Create Snapshot ▾
☐	VF-7a	vnf-image-centos-7	10.100.100.17	ds1G	lash-5g-key	Active		nova	None	Running	20 hours, 50 minutes	Create Snapshot ▾
☐	VF-6b	vnf-image-centos-7	10.100.100.22	ds1G	lash-5g-key	Active		nova	None	Running	20 hours, 51 minutes	Create Snapshot ▾
☐	VF-6a	vnf-image-centos-7	10.100.100.19	ds1G	lash-5g-key	Active		nova	None	Running	20 hours, 52 minutes	Create Snapshot ▾
☐	VF-5b	vnf-image-centos-7	10.100.100.15	ds1G	lash-5g-key	Active		nova	None	Running	20 hours, 55 minutes	Create Snapshot ▾
☐	VF-5a	vnf-image-centos-7	10.100.100.13	ds1G	lash-5g-key	Active		nova	None	Running	20 hours, 56 minutes	Create Snapshot ▾
☐	VF-4b	vnf-image-centos-7	10.100.100.6	ds1G	lash-5g-key	Active		nova	None	Running	20 hours, 56 minutes	Create Snapshot ▾
☐	VF-4a	vnf-image-centos-7	10.100.100.10	ds1G	lash-5g-key	Active		nova	None	Running	20 hours, 57 minutes	Create Snapshot ▾
☐	VF-3b	vnf-image-centos-7	10.100.100.5	ds1G	lash-5g-key	Active		nova	None	Running	21 hours	Create Snapshot ▾
☐	VF-3a	vnf-image-centos-7	10.100.100.7	ds1G	lash-5g-key	Active		nova	None	Running	21 hours, 1 minute	Create Snapshot ▾
☐	VF-2b	vnf-image-centos-7	10.100.100.11	ds1G	lash-5g-key	Active		nova	None	Running	21 hours, 1 minute	Create Snapshot ▾
☐	VF-2a	vnf-image-centos-7	10.100.100.9	ds1G	lash-5g-key	Active		nova	None	Running	21 hours, 2 minutes	Create Snapshot ▾
☐	VF-1b	vnf-image-centos-7	10.100.100.12	ds1G	lash-5g-key	Active		nova	None	Running	21 hours, 12 minutes	Create Snapshot ▾
☐	VF-1a	vnf-image-centos-7	10.100.100.2	ds1G	lash-5g-key	Active		nova	None	Running	21 hours, 24 minutes	Create Snapshot ▾

Displaying 16 items

VFs deployment in DC-2 (3/4)

Instances

Instance ID = ▾ | Filter | Launch Instance | Delete Instances | More Actions ▾

Displaying 13 items

Instance Name	Image Name	IP Address	Flavor	Key Pair	Status	Availability Zone	Task	Power State	Time since created	Actions
NODE-F.dc2	vnf-image-centos-7	10.200.200.19 Floating IPs: 192.168.16.102	ds1G	lash-5g-key	Active	nova	None	Running	8 hours, 39 minutes	Create Snapshot
NODE-E.dc2	vnf-image-centos-7	10.200.200.21 Floating IPs: 192.168.16.110	ds1G	lash-5g-key	Active	nova	None	Running	8 hours, 39 minutes	Create Snapshot
NODE-D.dc2	vnf-image-centos-7	10.200.200.20 Floating IPs: 192.168.16.113	ds1G	lash-5g-key	Active	nova	None	Running	8 hours, 40 minutes	Create Snapshot
VF-10b	vnf-image-centos-7	10.200.200.2	ds1G	lash-5g-key	Active	nova	None	Running	17 hours, 18 minutes	Create Snapshot
VF-10a	vnf-image-centos-7	10.200.200.9	ds1G	lash-5g-key	Active	nova	None	Running	17 hours, 19 minutes	Create Snapshot
VF-9b	vnf-image-centos-7	10.200.200.16	ds1G	lash-5g-key	Active	nova	None	Running	17 hours, 20 minutes	Create Snapshot
VF-9a	vnf-image-centos-7	10.200.200.7	ds1G	lash-5g-key	Active	nova	None	Running	17 hours, 20 minutes	Create Snapshot
VF-8b	vnf-image-centos-7	10.200.200.14	ds1G	lash-5g-key	Active	nova	None	Running	17 hours, 22 minutes	Create Snapshot
VF-8a	vnf-image-centos-7	10.200.200.8	ds1G	lash-5g-key	Active	nova	None	Running	17 hours, 23 minutes	Create Snapshot
VF-7e	vnf-image-centos-7	10.200.200.11	ds1G	lash-5g-key	Active	nova	None	Running	17 hours, 24 minutes	Create Snapshot
VF-7d	vnf-image-centos-7	10.200.200.12	ds1G	lash-5g-key	Active	nova	None	Running	17 hours, 26 minutes	Create Snapshot
VF-6e	vnf-image-centos-7	10.200.200.3	ds1G	lash-5g-key	Active	nova	None	Running	17 hours, 27 minutes	Create Snapshot
VF-5d	vnf-image-centos-7	10.200.200.4	ds1G	lash-5g-key	Active	nova	None	Running	17 hours, 30 minutes	Create Snapshot

VFs deployment in DC-3 (4/4)

Instances

Instance ID = ▾ | Filter | Launch Instance | Delete Instances | More Actions ▾

Displaying 5 items

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☐	VF-7b	vnf-image-centos-7	10.30.30.12	ds1G	lash-5g-key	Active		nova	None	Running	16 hours, 51 minutes	Create Snapshot ▾
☐	VF-6d	vnf-image-centos-7	10.30.30.13	ds1G	lash-5g-key	Active		nova	None	Running	16 hours, 51 minutes	Create Snapshot ▾
☐	VF-6c	vnf-image-centos-7	10.30.30.8	ds1G	lash-5g-key	Active		nova	None	Running	16 hours, 52 minutes	Create Snapshot ▾
☐	VF-5c	vnf-image-centos-7	10.30.30.9	ds1G	lash-5g-key	Active		nova	None	Running	16 hours, 55 minutes	Create Snapshot ▾

Displaying 5 items

LASH-5G demo

- We show a full-stack SDN/NFV deployment for 5G services
  - SDN-based cloud and WAN data plane
  - SDN network control plane
  - orchestration plane
- We demonstrate a dynamic service function chaining optimized in terms of end-to-end latency, flexibility and reliability
  - service chaining orchestrator
  - cloud resource orchestrator
  - SDN WAN resource orchestrator

LASH-5G demo will at boot #13