



FUTEBOL

Federated Union of Telecommunications Research
Facilities for an EU-Brazil Open Laboratory

Enabling 5G through end-to-end wireless and optical orchestration

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Acknowledgements



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 - Magnos Martinello, Cristina Dominicini, Moises Ribeiro, et al (UFES)
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5th Generation

An evolution or revolution?

- Radio access technology
 - Network architecture
- ↓
- Enhanced services
 - Vertical domains

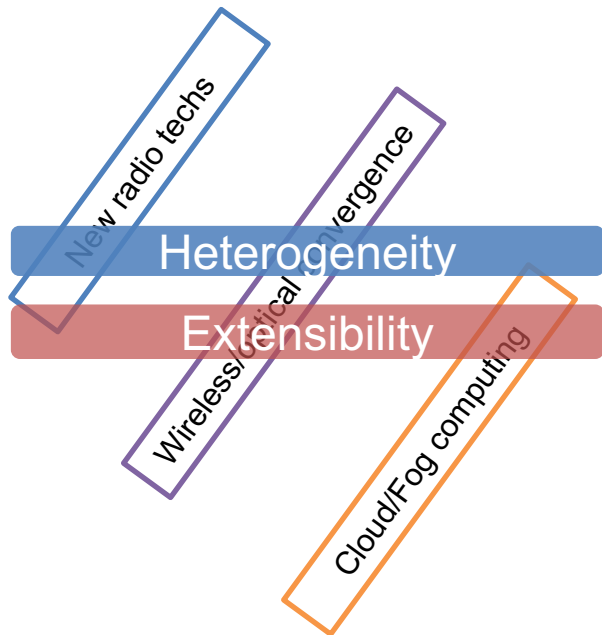
The infographic illustrates the 5G ecosystem. At the top left, it says '5G' and 'Data rates / applications'. The central part features a cloud-like shape containing several vertical domains: 'Smart grids' (with power lines), 'Connected house' (with a house icon and 'Domotics'), 'eHealth' (with a hospital icon and 'Traffic priority'), 'Entertainment' (with a stadium icon and 'Apps beyond imagination'), and 'Smart Car' (with a car icon and 'Car-to-car communication'). To the right, a table lists 5G specifications:

5G	Year	2020-2030
Standards	-	
Technology	digital	
Bandwidth	Ubiquitous connectivity	
Data rates	Fiber-like experience	
1 hr HD movie in 6 seconds		

Below the table are icons for various services: a globe, a person with a gear, a person with a speech bubble, HD, 3D, cloud, game controller, and a person with a gear.

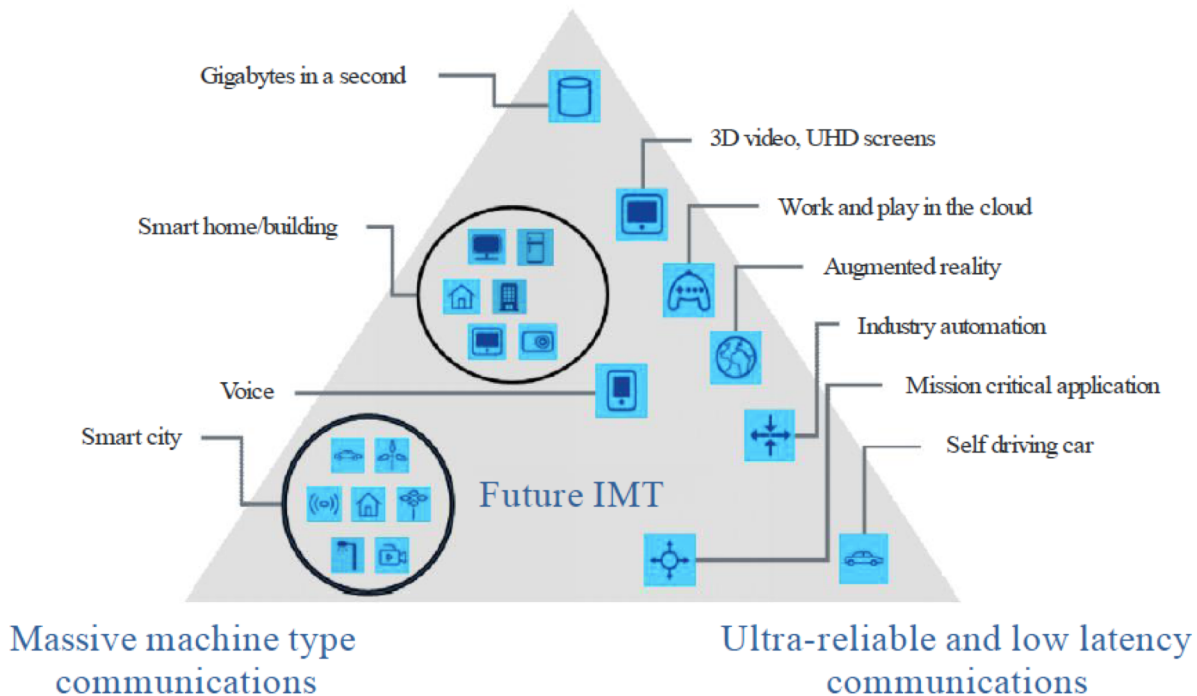
At the bottom, a red-bordered box contains the text: '5G is about Communication, Storage, Processing...'

People & Things



Usage scenarios of IMT for 2020 and beyond

Enhanced mobile broadband



Heterogeneity Interoperability



Wireless/Optical convergence solution



FUTEBOL

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To develop and deploy research infrastructure, and an associated control framework for experimentation, in Europe and Brazil, that enables experimental research at the convergence point between optical and wireless networks



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www.ict-futebol.eu



What is FUTEBOL CF ?



- The FUTEBOL Control Framework (CF) is a **cross-layer software**
- Allows the experimenter to form an **experiment's slice** so that it orchestrates resources across optical, packet and wireless networks assisted by the cloud
- CF supports the **control of experiments** offering **slice orchestration**
- Our vision of CF involves the **adoption and integration of SD(R)N and NFV** over the wireless, packet and optical domains



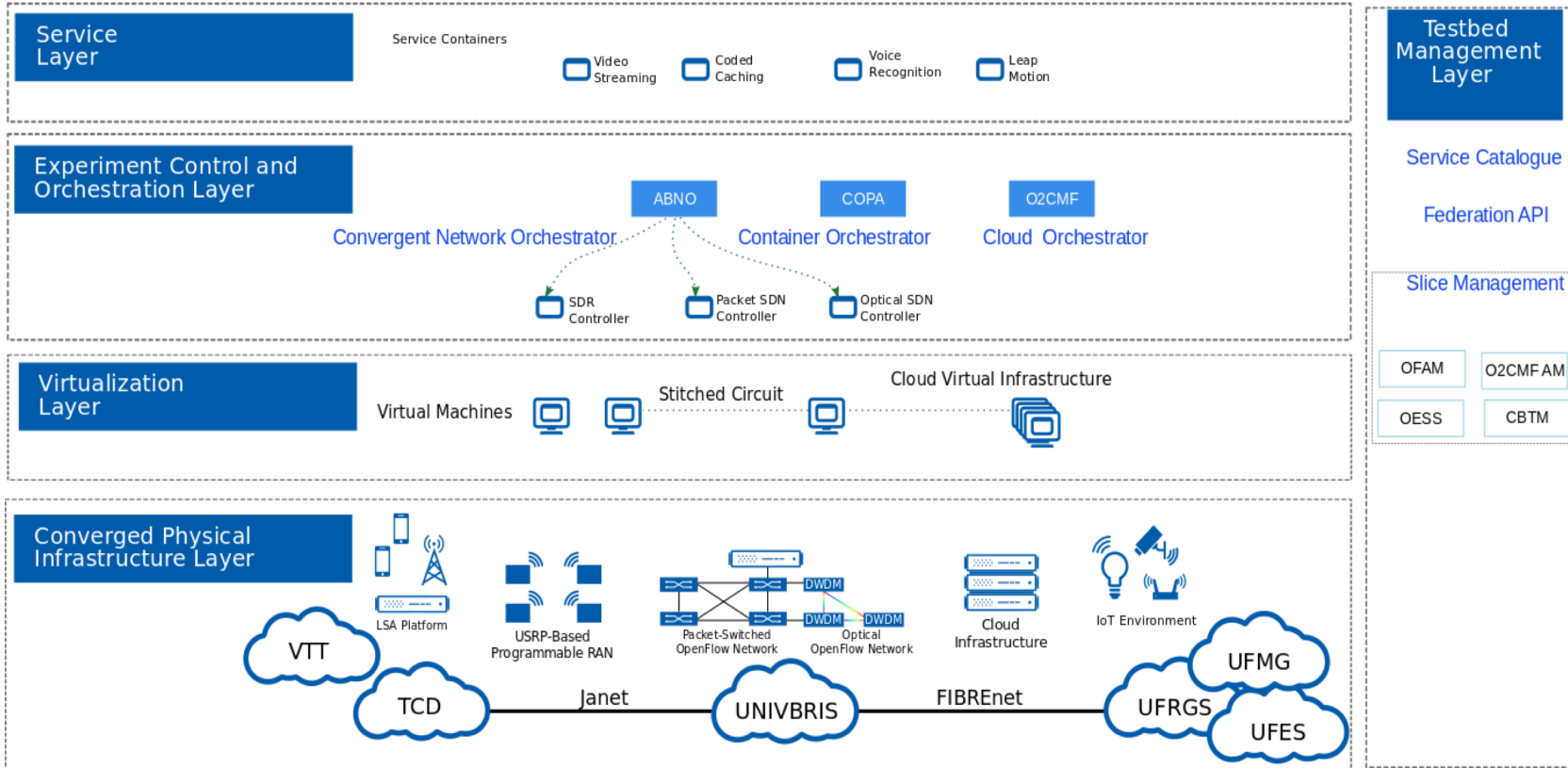
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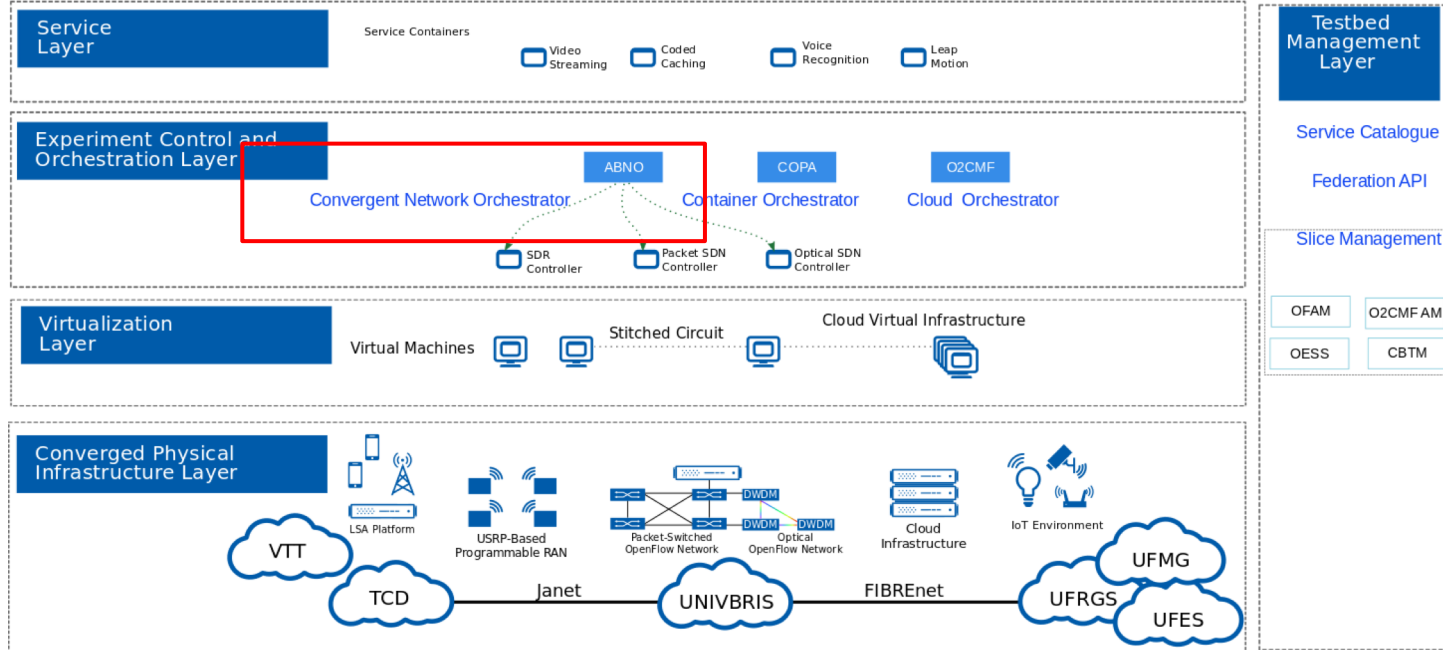
SD
NR

Architectural View of Futebol



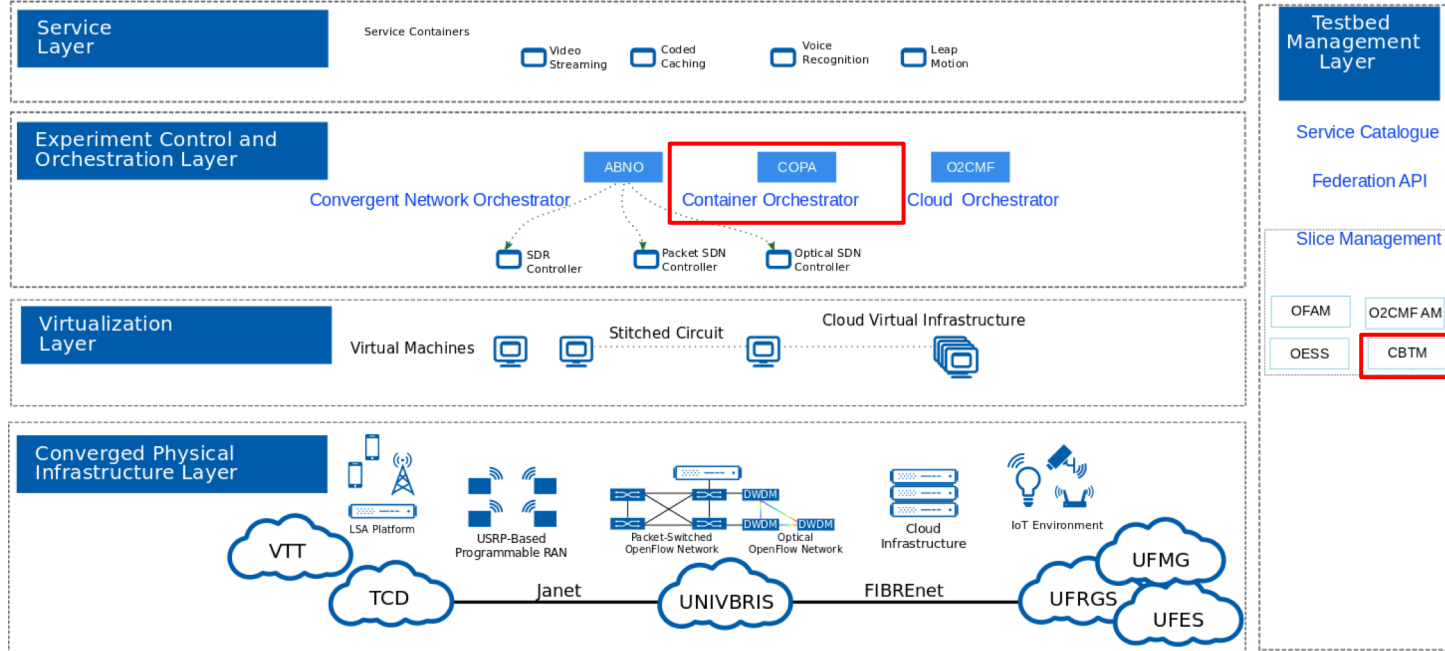


Challenge 1 : How to implement **network orchestration** across multiple network technologies ?



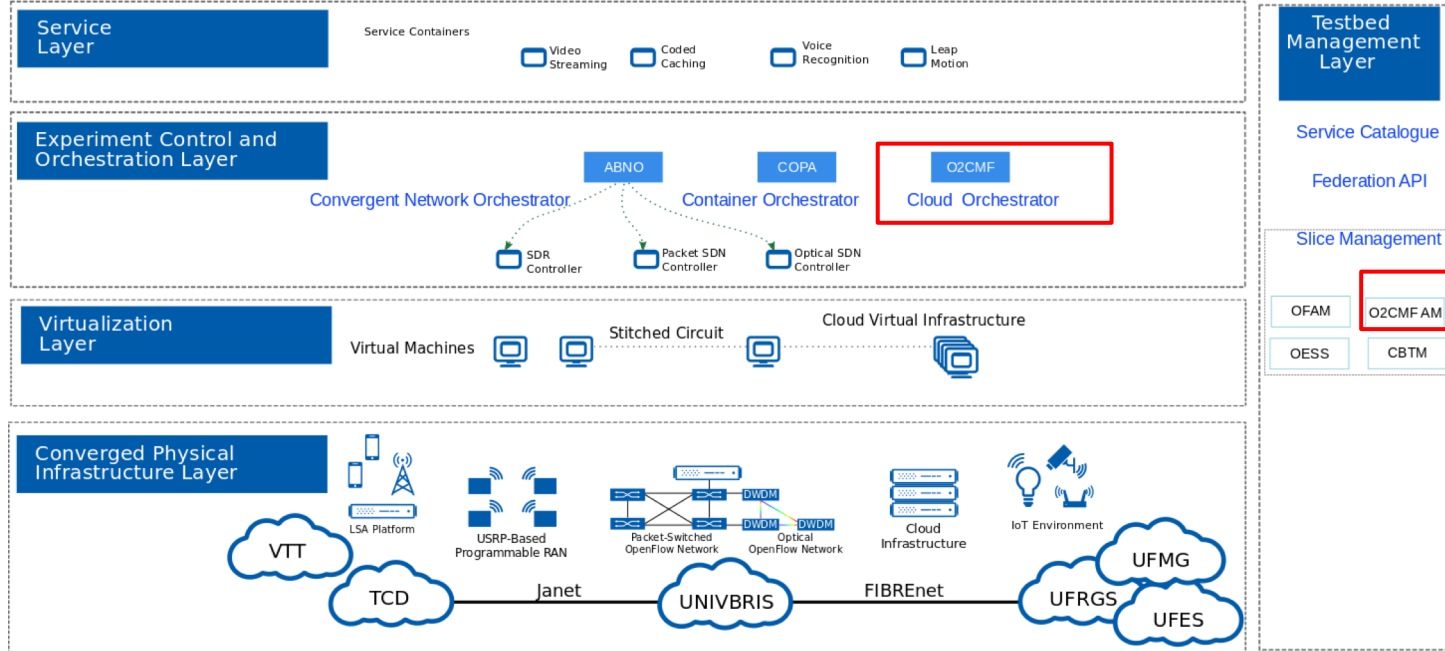


Challenge 2 : How to implement VNF live migration across distributed and heterogeneous testbeds ?





Challenge 3: What the cloud brings on provisioning of computing resources ?

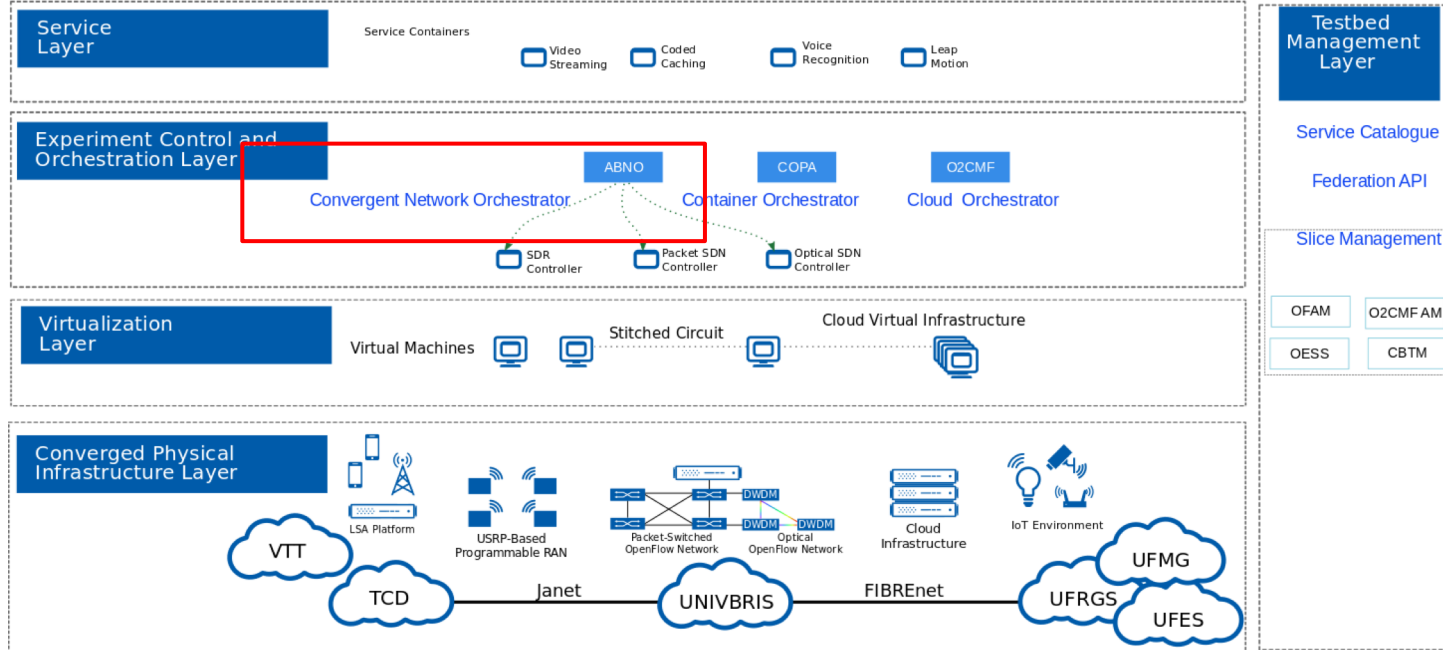


Addressing the challenges





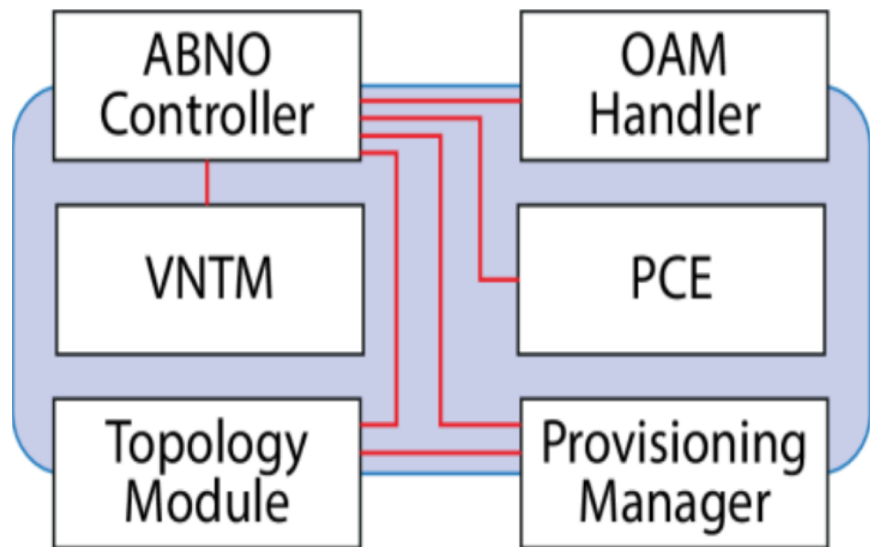
Challenge 1 : How to implement **network orchestration** across multiple network technologies ?





How does ABNO work ?

- **Orchestration:** ABNO Orchestrator –
- The Application-Based Network Operations (ABNO) architecture
 - (D. King and A. Farrel “**A PCE-Based Architecture for Application-Based Network Operations**”, RFC 7491)
 - More capabilities: Extension to orchestrate / interact with (SD) radio platform:
 - SRS



Architecture of ABNO orchestrator



Network Orchestration

- Orchestration over **packet and optical domains**

Ali Hammad, et al., “**Demonstration of NFV content delivery using SDN-enabled virtual infrastructures**” in Optical Fiber Communication Conference, USA, 2017

Video for the **convergent orchestration**:

<https://www.dropbox.com/s/nv5cgtnu6hi1wy7/Video-demo-convergent-orquestration.mp4?dl=0>

The screenshot displays a network orchestration interface from the University of Bristol. The main area shows a network topology with nodes and links. The nodes are labeled with OpenFlow IDs: openflow:360287970189639681, openflow:360287970189639683, openflow:1834829790, openflow:186712074, openflow:360287970189639684, openflow:169934858, and openflow:192.168.0.1. The links are colored blue and grey. The interface also includes a 'Service Information' table and a 'Node Information' table.

ID	Type	From	Source	Dest	QPS	QPI
2504640	ESDProcessing	127.0.0.1	openflow:202287970189639683	openflow:202287970189639684	1000	1000

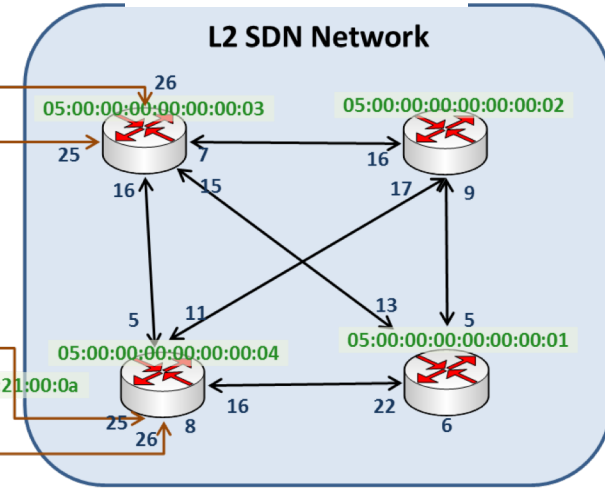
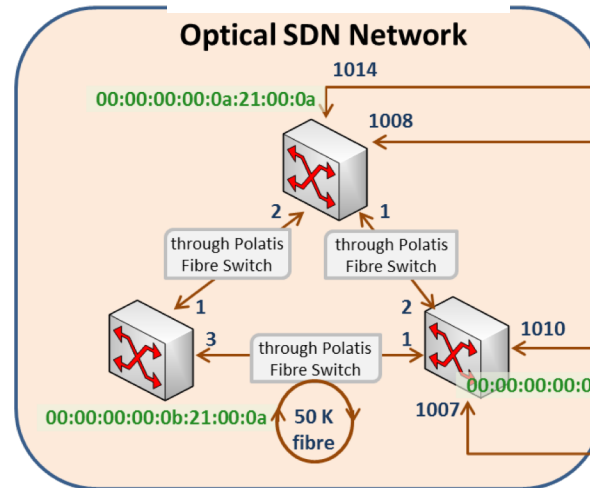
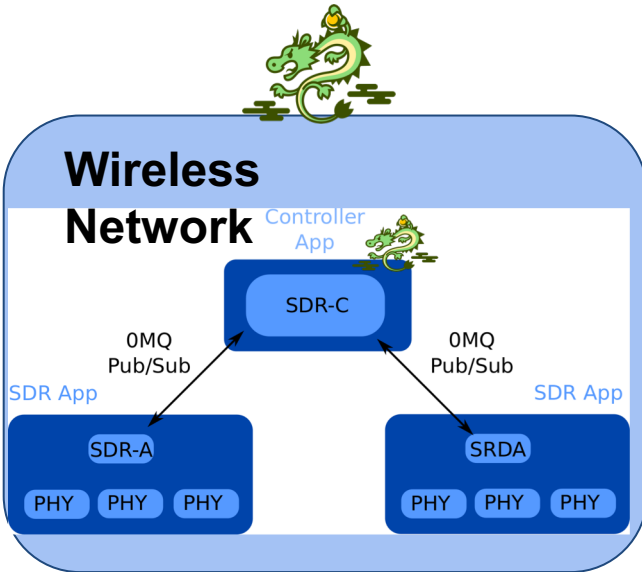
Name	Value
Type	OF

ABNO as a Convergent Orchestrator for Wireless, Optical and Packet-Switched Networks



Multi-domain SDN Orchestrator (MSO)

REST API commands



ABNO commands for multi-domain networks (Optical, Packet and Wireless Networks)



REST API for Optical Networks

Command: Configure a *cross-connection (LightPath)* through port 2 and 1008 at lambda 193.8 THz

- `curl -X POST -H "Authorization: Basic YWRtaW46YWRtaW4=" -H "Content-Type: application/json" -H "Accept: application/json" -H "Cache-Control: no-cache" -H "Postman-Token: c8516c14-3d24-d2a8-8d39-29f372376242" -d '{"input": {"node": "/opendaylight-inventory:nodes/opendaylight-inventory:node[opendaylight-inventory:id=\"openflow:169934858\"]", "command": "ADD", "hard-timeout": "0", "ofp-connect": {"wildcard": "ofpcw-in-port ofpcw-out-port ofpcw-in-tport ofpcw-out-tport", "num-components": "1", "in-wdm-port": {"wdm-port": [{"wport": "2", "wavelength": "193800"}]}, "out-wdm-port": {"wdm-port": [{"wport": "1008", "wavelength": "193800"}]}}}' "http://137.222.204.72:8181/restconf/operations/sal-flow:add-cflow"`

Command: Configure *power equalization* through port 2 and 1008 at lambda 193.8 THz

- `curl -X POST -H "Authorization: Basic YWRtaW46YWRtaW4=" -H "Content-Type: application/json" -H "Accept: application/json" -H "Cache-Control: no-cache" -H "Postman-Token: 325a9963-96fb-2ec4-5122-95dc3cc26527" -d '{"input": {"node": "/opendaylight-inventory:nodes/opendaylight-inventory:node[opendaylight-inventory:id=\"openflow:169934858\"]", "input-port": "2", "output-port": "1008", "wavelength": "193800"}}' "http://137.222.204.72:8181/restconf/operations/sal-flow:send-adv-power-equalization"`

ABNO commands for multi-domain networks (Optical, **P**acket and Wireless Networks)



REST API for **O**ptical Networks

Command: Configure a *cross-connection (LightPath)* through port 2 and 1008 at lambda 193.8 THz

- curl -X POST -H "Authorization: Basic YWRtaW46YWRtaW4=" -H "Content-Type: application/json" -H "Accept: application/json" -H "Cache-Control: no-cache" -H "Postman-Token: c8516c14-3d24-d2a8-8d39-29f372376242" -d '{ "input": { "node": "/opendaylight-inventory:nodes/opendaylight-inventory:node[opendaylight-inventory:id="\openflow:169934858\]", "command": "ADD", "hard-timeout": "0", "ofp-connect": { "wildcard": "ofpcw-in-port ofpcw-out-port ofpcw-in-tport ofpcw-out-tport", "num-components": "1", "in-wdm-port": { "wdm-port": [{ "wport": "2", "wavelength": "193800" }] }, "out-wdm-port": { "wdm-port": [{ "wport": "1008", "wavelength": "193800" }] } } } }' <http://137.222.204.72:8181/restconf/operations/sal-flow:add-cflow>

Command: Configure *power equalization* through port 2 and 1008 at lambda 193.8 THz

- curl -X POST -H "Authorization: Basic YWRtaW46YWRtaW4=" -H "Content-Type: application/json" -H "Accept: application/json" -H "Cache-Control: no-cache" -H "Postman-Token: 325a9963-96fb-2ec4-5122-95dc3cc26527" -d '{ "input": { "node": "/opendaylight-inventory:nodes/opendaylight-inventory:node[opendaylight-inventory:id="\openflow:169934858\]", "input-port": "2", "output-port": "1008", "wavelength": "193800" } }' <http://137.222.204.72:8181/restconf/operations/sal-flow:send-adv-power-equalization>

REST API for **P**acket-Switched Networks

Command: Configure a *packet flow* through input port 6 to output port 13 at VLAN 57

- curl -X POST -H "Authorization: Basic YWRtaW46YWRtaW4=" -H "Content-Type: application/json" -H "Accept: application/json" -H "Cache-Control: no-cache" -H "Postman-Token: 278684b2-43df-f765-ef93-18210ae549c6" -d '{ "input": { "node": "/opendaylight-inventory:nodes/opendaylight-inventory:node[opendaylight-inventory:id="\openflow:360287970189639681\]", "installHw": "true", "priority": "500", "match": { "in-port": "6", "vlan-match": { "vlan-id": { "vlan-id": "57" } } }, "instructions": { "instruction": [{ "order": "0", "apply-actions": { "action": [{ "output-action": { "output-node-connector": "13", "order": "0" }] } }] } }, "flow-name": "f1", "table_id": "0" } }' <http://137.222.204.75:8181/restconf/operations/sal-flow:add-flow>

ABNO commands for multi-domain networks (Optical, Packet and **Wireless** Networks)



Sample of REST API for **Wireless Networks** with Variable Rate Fronthaul using Long Reach PON bearer.

Command: Configure enodeB 1 to negotiate a transmission of 25 LTE Physical Resource Blocks (PRBs) with a fronthaul Committed information rate of 150 Mbps.

- `curl -X POST -H "Authorization: Basic YnJva2VyOnBhc3N3b3Jk" -H "Content-Type: application/json" -H "Accept: application/json" -H "Cache-Control: no-cache" -H "Postman-Token: 819bf1b2-fc3a-11e7-8450-fea9aa178066" -d '{"input": {"node": "broker1", "payload": {"enodeb": "1", "prb_number": "25", "fronthaul_cir": "220"}}}'`
<http://10.10.10.53:5000/controller/api>

Experimenting with the extended ABNO

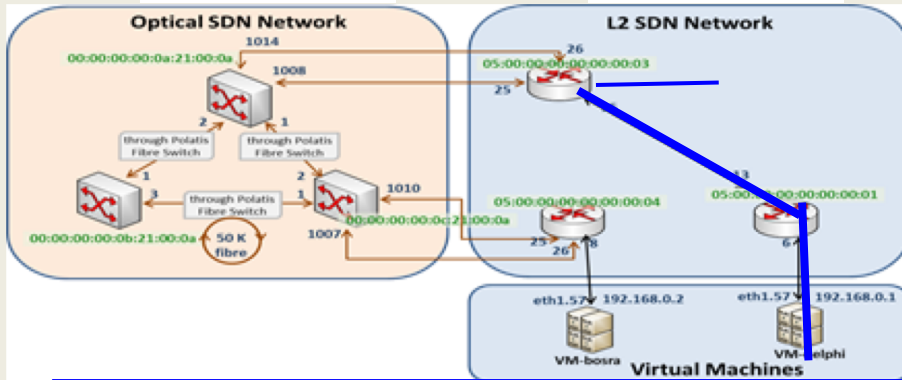
(Controller at Bristol + Controller at TCD + OpenFlow enabled devices)

Multi-domain SDN Orchestrator (MSO)

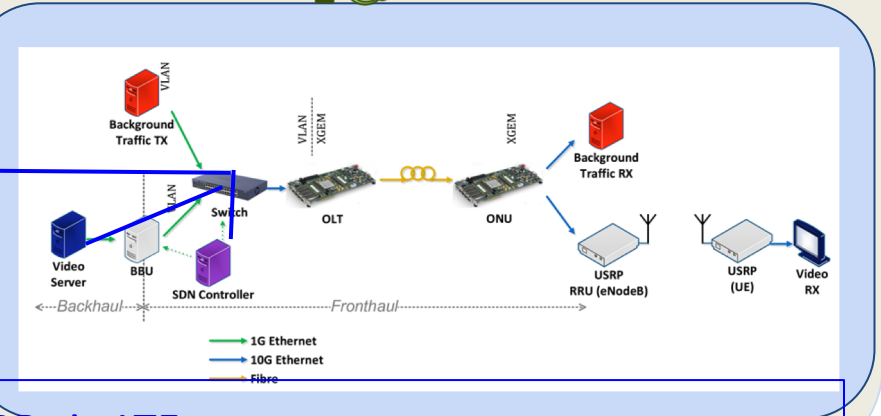
ABNO sends commands to Controllers (add flow within the slice, change wireless BW)

VXLAN (slice)

Bristol testbed



TCD testbed



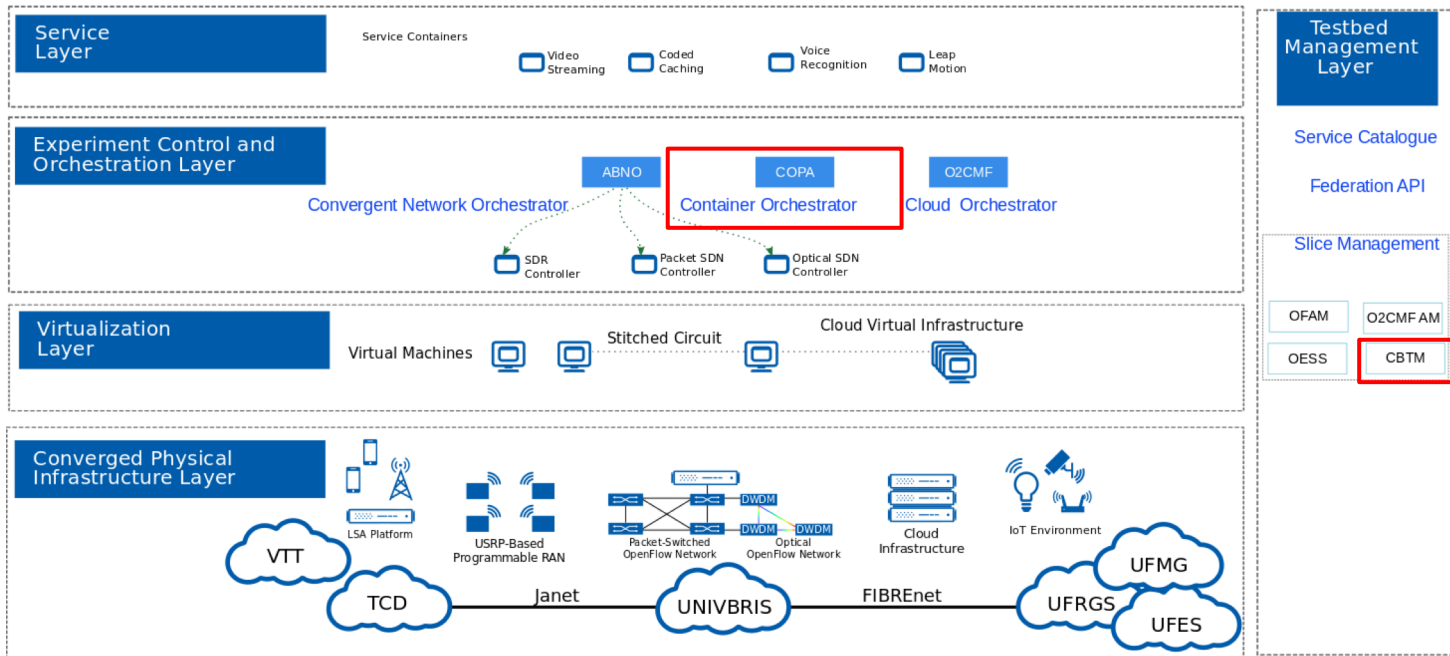
From 1.8 Mbps = 1.4 Mhz Bandwidth = 6 PRBs in LTE

To 4.6 Mbps = 3 Mhz of Bandwidth = 15 PRBs in LTE



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2018
June 18-21

Challenge 2 : How to implement VNF live migration across distributed and heterogeneous testbeds ?

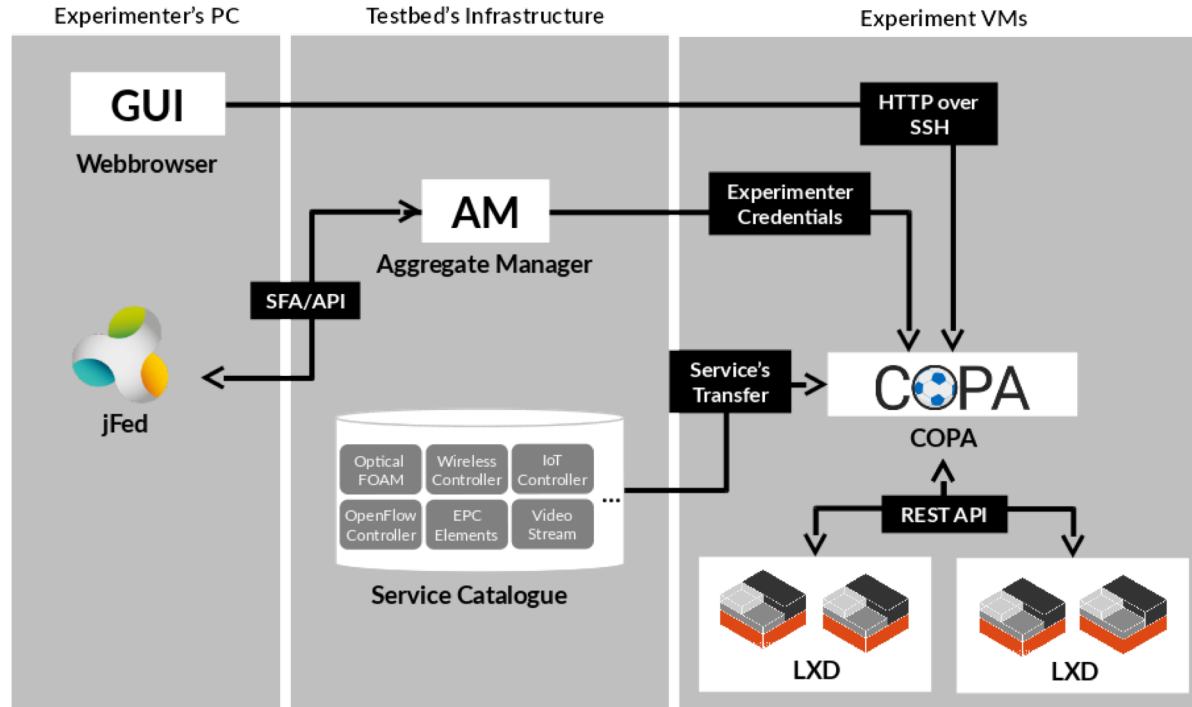


Challenge 2: How to implement VNF live migration across distributed and heterogeneous testbeds ?

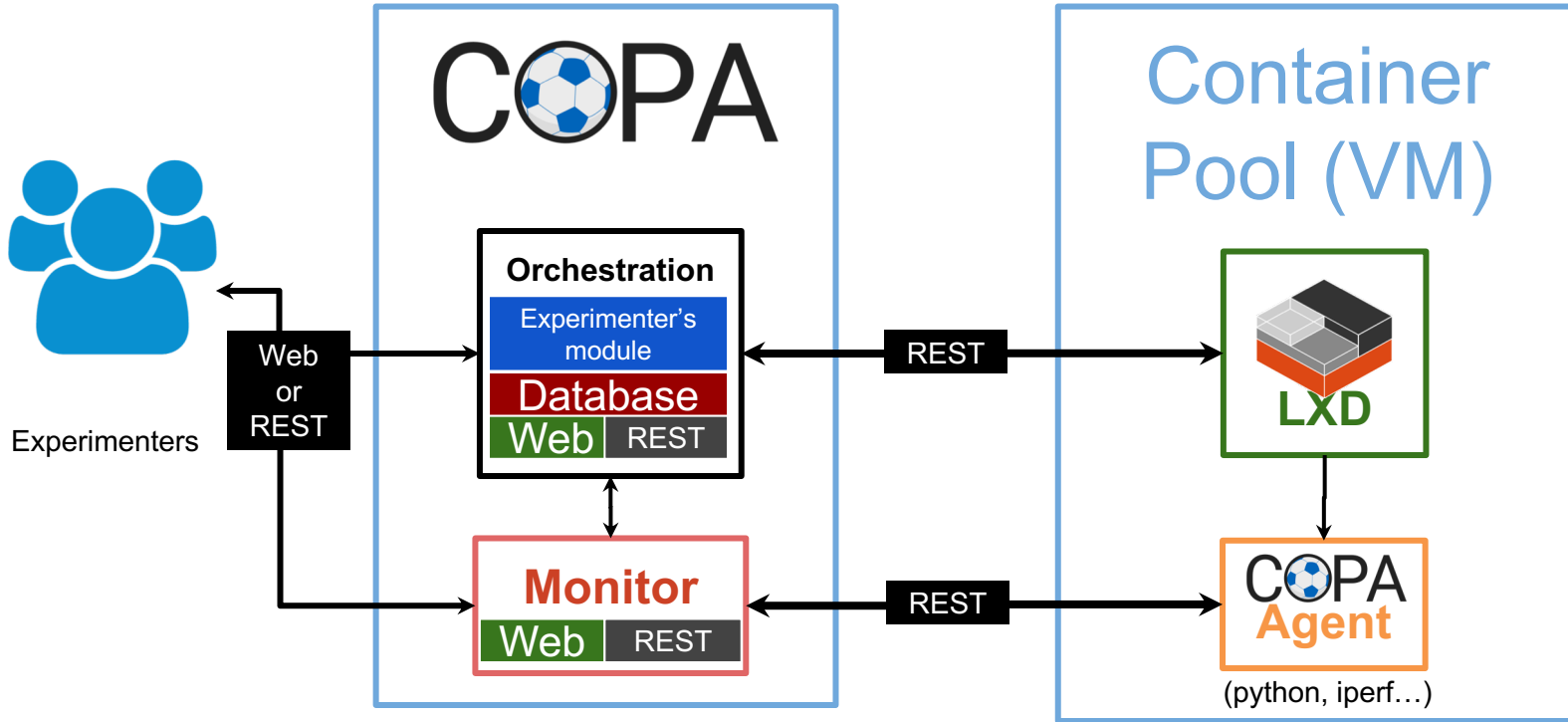


- To deploy and manage containers:
 - a new container orchestration and provisioning tool has been developed in FUTEBOL, **COPA (Container Orchestration and Provisioning Architecture)**. COPA allows the migration of virtual functions across testbeds
- For each experiment, one instance of COPA is deployed

COPA (Container Orchestration and Provisioning Architecture)



COPA (Container Orchestration and Provisioning Architecture)



New sample of COPA's Web-based GUI



The screenshot shows a web browser window with the URL `localhost:8000/core/containers_list/`. The page title is "COPA - Container Orchestration and Provisioning Architecture". The navigation bar includes "Containers list", "Add new container", and "CoLiSEU Monitor".

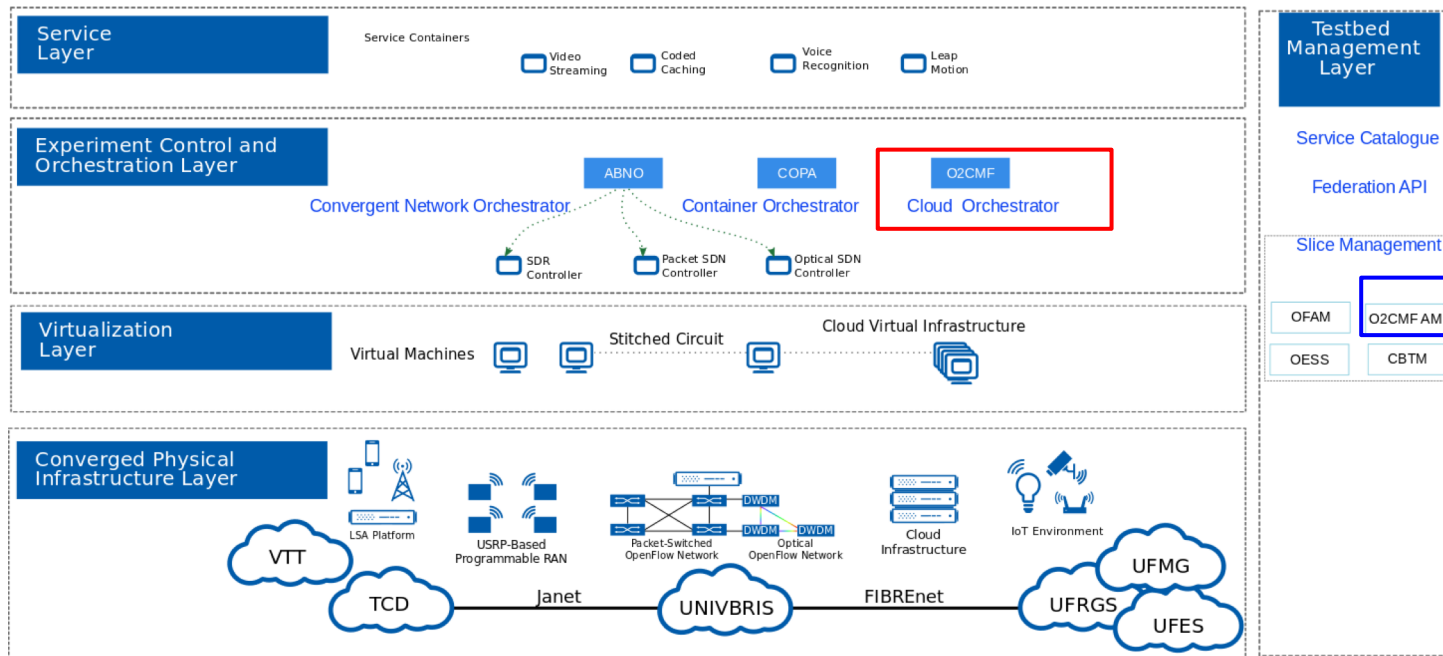
Containers list

All containers by each container pool

Server1

Container name	Network addresses	Created at	Status	Options
IQ	143.54.12.74/24	Aug. 17, 2017, 6:37 p.m.	Running	Stop Terminal Freeze Migrate
RX	143.54.12.64/24	Aug. 17, 2017, 6:10 p.m.	Running	Stop Terminal Freeze Migrate
SOFT-BIT	143.54.12.198/24	Aug. 17, 2017, 6:37 p.m.	Running	Stop Terminal Freeze Migrate
SUBFRAME	143.54.12.192/24	Aug. 17, 2017, 6:37 p.m.	Running	Stop Terminal Freeze Migrate

Challenge 3: What the cloud brings on provisioning of computing resources ?



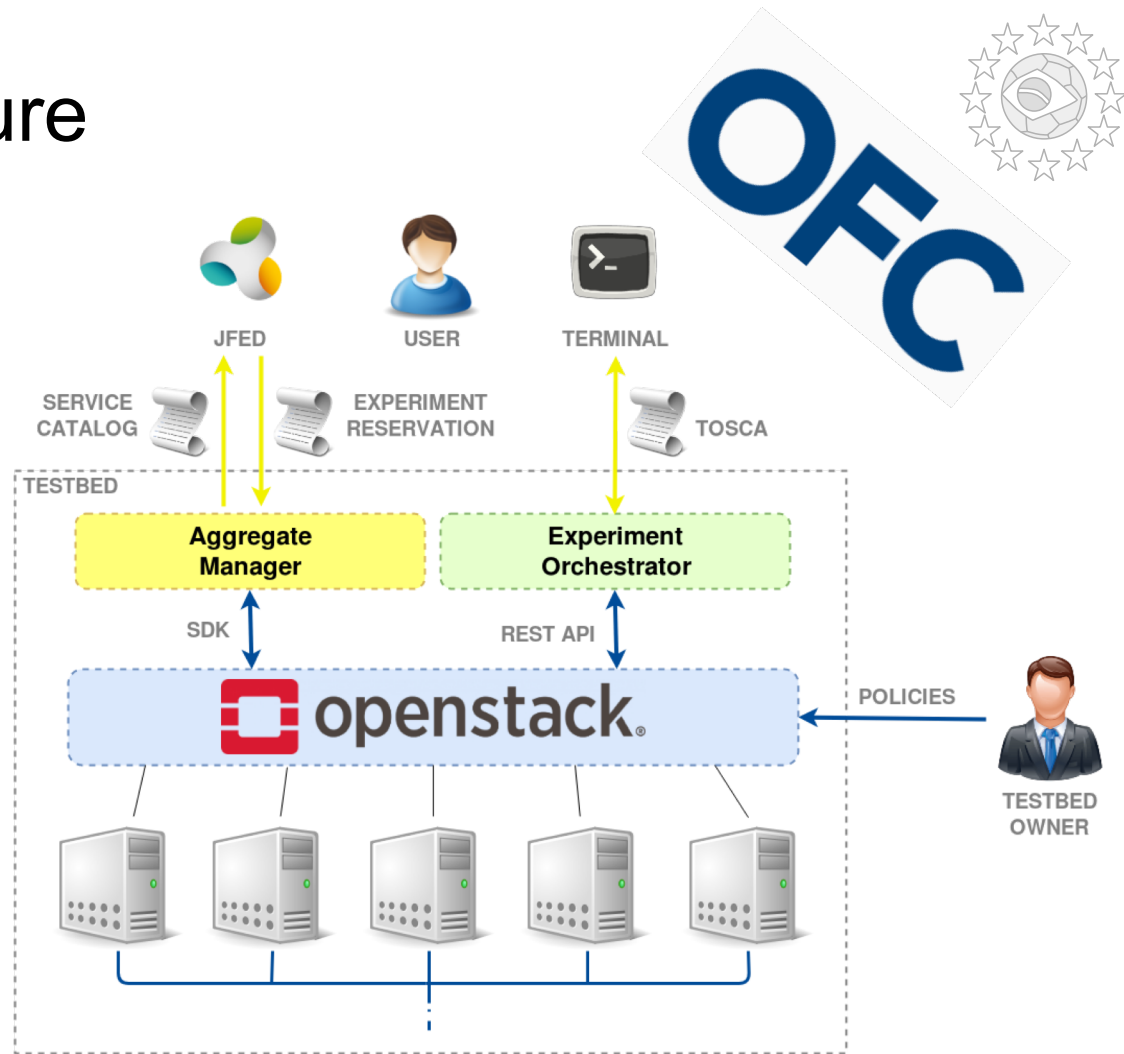
Challenge 3: What the cloud brings on provisioning of computing resources ?



- Cloud may provide experiment ***isolation*** offering a **virtual infrastructure (VI)** provisioning that assigns VLAN tag per experiment and setting the LAN connectivity automatically to the VMs;
- OpenStack enables testbeds to provide advanced NFV functionalities **required by FUTEBOL experiments** such as **horizontal scaling** ;

O2CMF Architecture

- Experimenters may create and manage VMs, LAN connectivity and VNFs;
- **AM:** resource discovery and reservation;
- **Orchestrator:** resource management;
- **OFC 2018 Demo**
(O2CMF:Experiment-as-a-Service for Agile Fed4Fire Deployment of Programmable NFV)



Cloud Orchestrator (experiment control phase)



Northbound API (with experimenter): CLI

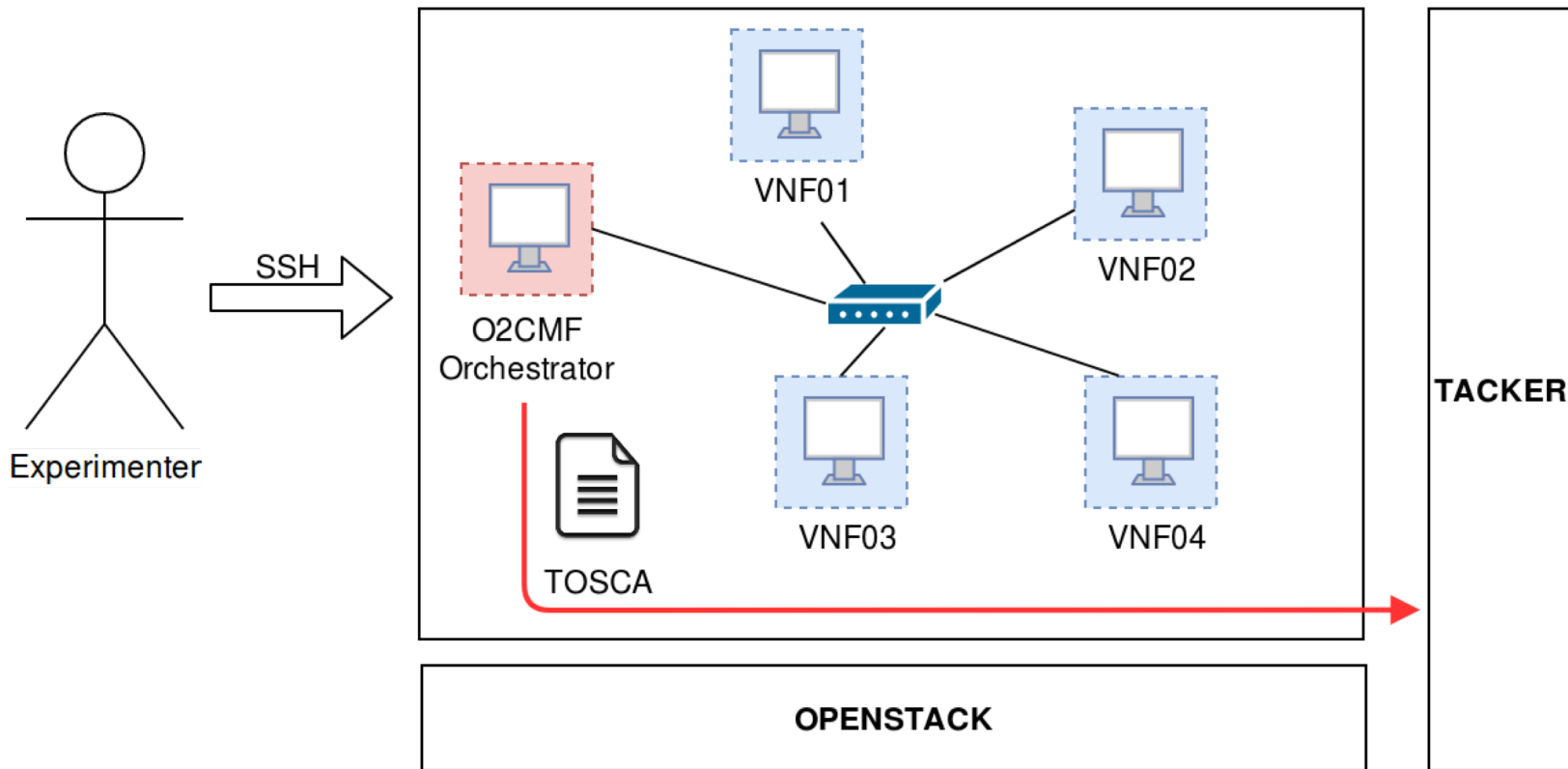
Commands for:

- Create a VNF descriptor (template);
- List VNF descriptors;
- Delete a VNF descriptor;
- Instantiate a VNF;
- List VNF instances;
- Trigger a VNF scale;
- Delete a VNF instance;

Southbound API (with OpenStack): REST



O2CMF Experiment Orchestration

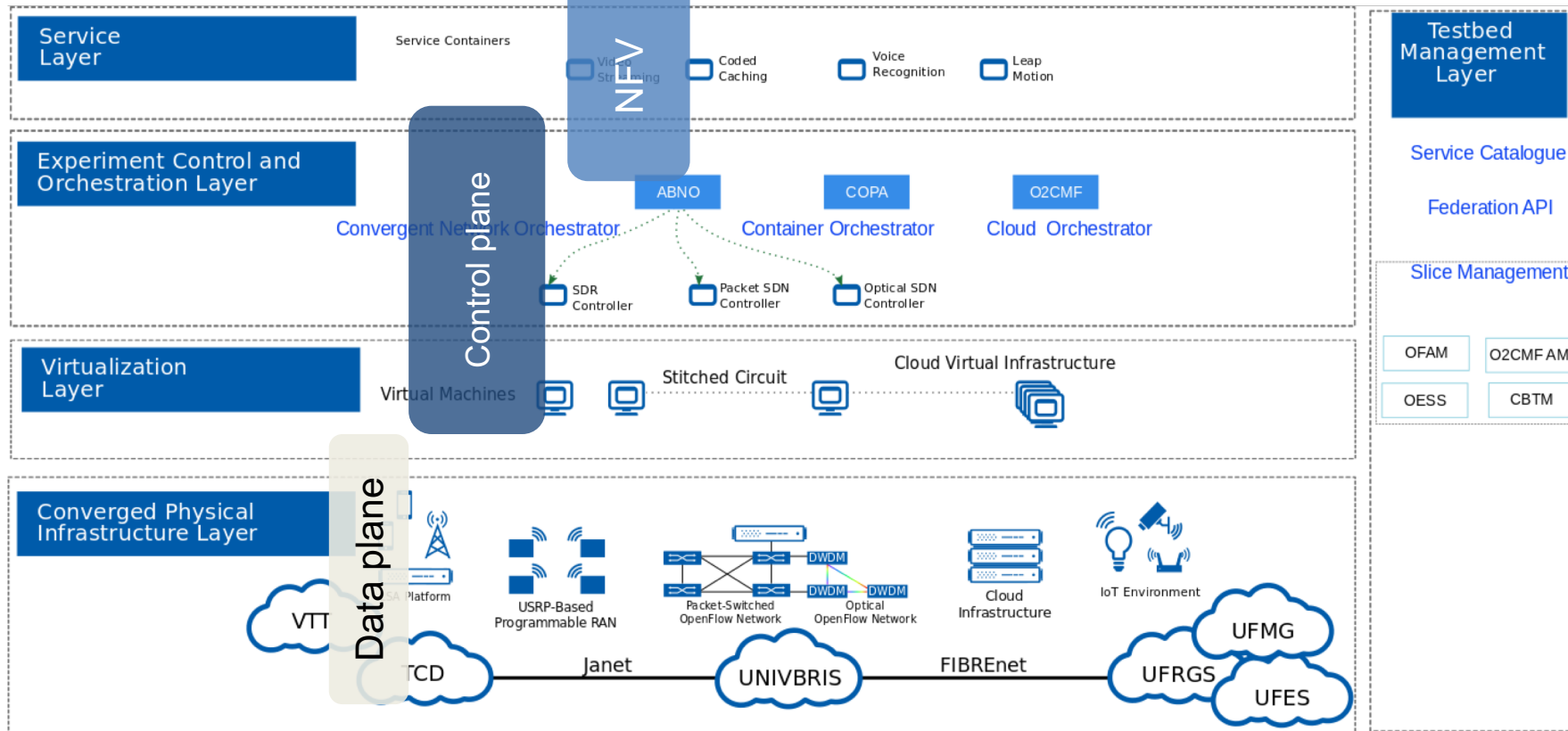


FUTEBOL CF



FUTEBOL

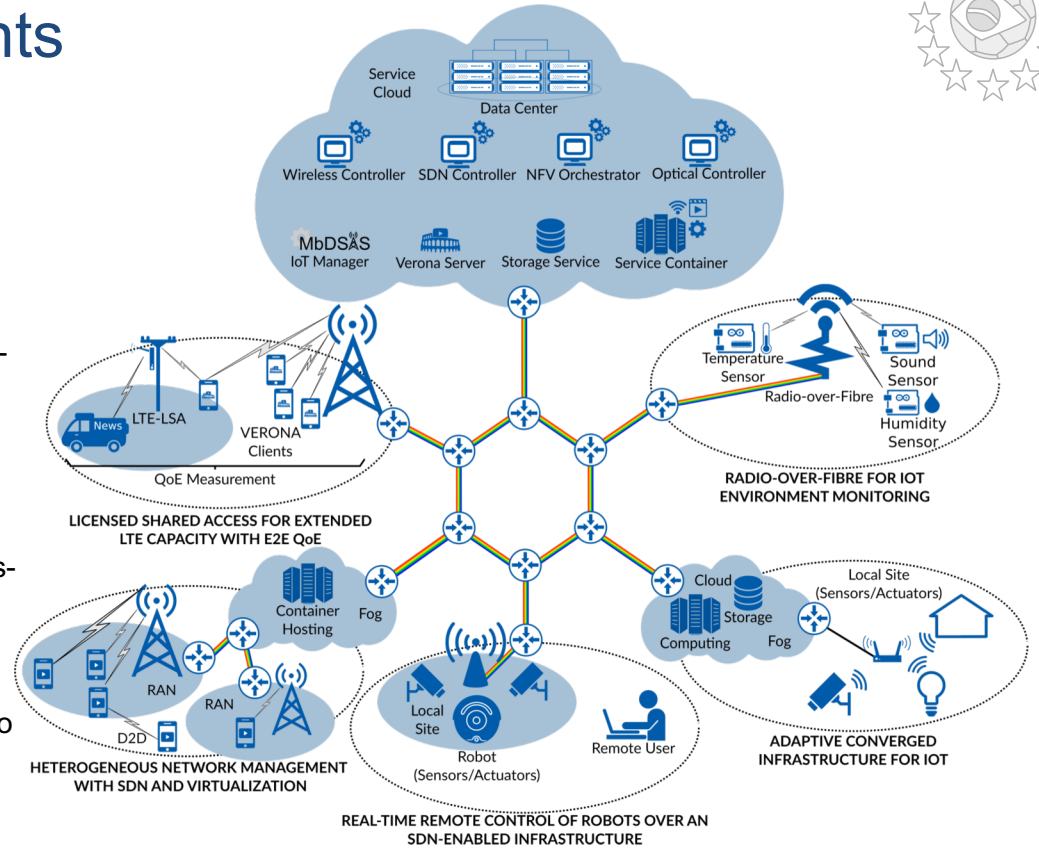
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Use cases and experiments



- **UC1: The impact of broadband wireless on optical backhauling**
 - Licensed Shared Access for extended LTE capacity with shared optical backhauling and end-to-end QoE
- **UC2: The design of SDN infrastructure for wireless-optical integration**
 - Heterogeneous wireless-optical network management with SDN and virtualization
 - Real-time remote control of robots over a wireless-optical SDN infrastructure
- **UC3: The interplay between wireless and optical networks for IoT**
 - Adaptive cloud/fog computing for IoT, according to network capacity and service latency requirements
 - Radio-over-fiber for IoT environment monitoring



CROWNCOM 2018 - 13th EAI International Conference on Cognitive Radio Oriented Wireless Networks

September 18-19, 2018
Ghent, Belgium

Submission deadline extended until 15/06, 2018

[SUBMIT PAPER](#)



Thank You!

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