# The Orchestration in 5G Exchange - a Multi-Provider NFV Framework for 5G Services

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***Abstract*—The goal of the 5G Exchange project is to enable cross-domain orchestration of services over multiple administrations. The system we build allows the end-to-end integration of heterogeneous resource and service elements of a multi-vendor technology environment from multiple operators by sharing their network and compute infrastructures via NFV orchestration. We will run an industry control 5G use-case, where one of the VNFs is offered by a 3rd party solution provider as a VNFaaS. We will show $i$) full automation for end-to-end network service orchestration over multi-provider NFV and VNFaaS offerings with latency and high availability constraints; $ii$) actor-role models and business interactions and $iii$) how - with a feedback loop to lifecycle management - the system can adapt to changes.**

## I. Multi-provider orchestration

Virtualization has significantly changed the IT realm and it is reshaping the networking ecosystem as Network Function Virtualization (NFV) gains ground. Together with Software Defined Networking (SDN), which addresses the softwarization of the network control plane, NFV establishes the basis of future networks. Future 5G services, such as coordinated remote driving, remote surgery or Tactile Internet with its 1ms round-trip latency bound, pose extreme requirements on the network, and call for the joint control of IT and network resources. Moreover, typical network services, realized by Service Function Chains (SFC), span not only over multiple domains, but over multiple operators as well, as we envision cost-effectiveness by resource sharing, and wide geographical reach of customers in the 5G ecosystem. As one of the most important use cases, the Factory of the Future will make an intensive usage of 5G technologies for supporting the digitization in the way conceived by the idea of Industry 4.0. High number of connected devices, collaborative robots, augmented reality, and the integration of manufacturing, supply chain and logistics, altogether open an opportunity window to operators for monetizing the provision of virtualized infrastructures and capabilities. In this demonstration, we present novel service and resource orchestration features that we have designed and developed in the NFV Orchestrator (NFVO) component, as in ETSI's terminology [1], within H2020 5G Exchange project: we show the necessary multi-provider orchestration capabilities applied to the control of robots emulating a critical industrial environment sensible to latency.

The multi-provider orchestration and management of network services have many facets, starting from resource discovery and business negotiations between operators that take part in the ecosystem [3], through the computation and monitoring of assured quality network connections among their domains [4], to the efficient embedding of services into the available resource set [2]. Here, however, we keep the focus on the novel features and technical enablers of our NFVO necessary for a flexible multi-provider setup. Our NFVO handles abstract sets of compute and network resources and provisions the necessary subset to the customer to deploy its service within, fulfilling the demanded service requirements. With well-defined interfaces and orchestration-management mechanisms, we make sure that operators can act not only as NFV infrastructure (NFVI) providers, but also as integrators of virtual network function (VNF) as a service (VNFaaS) offerings from 3rd parties. As such, operators can also act as virtualization platform providers that open interface for 3rd party components, e.g., VNF managers (VNFMs).

In our demonstration, we show how: *i)* the situational multi-provider orchestration hierarchy (e.g., while Operator (Op.) 1 is tenant of Op. 2, Op. 2 can also be tenant of Op. 1) works, organizing NFVOs into a multi-layer, possibly recursive hierarchy, depending on which operator receives the service request; *ii)* NFVOs can prepare the most well-suited resource subset from multiple operators' infrastructure domains for constraint-based orchestration in terms of delay, bandwidth, proximity for location-dependent service provisioning, anti-affinity for resiliency by disjoint resource allocation; *iii)* technological domain abstractions, service orchestration and heuristic service-to-resource embedding algorithm work together, splitting the responsibility between resource and lifecycle management of VNFs in the NFVO; *iv)* feedback loops to orchestration.

## II. Use case and demo setup

We show the aforementioned features in a time-sensitive scenario involving the NFVOs and data plane components, i.e., Virtual Infrastructure Manager (VIM) adapters, of multiple administrative domains. We track how compute resources, managed VNF capabilities and network topologies are propagated upwards and how automated network service orchestration works top-down with those given constraints (latency, bandwidth, CPU, memory, storage, VNF hosting capabilities) across technological domains. We assume 3 operators, 4 domains, 2 tenants and network services that provide remote control for LEGO® robots. In Fig. 1 we depict

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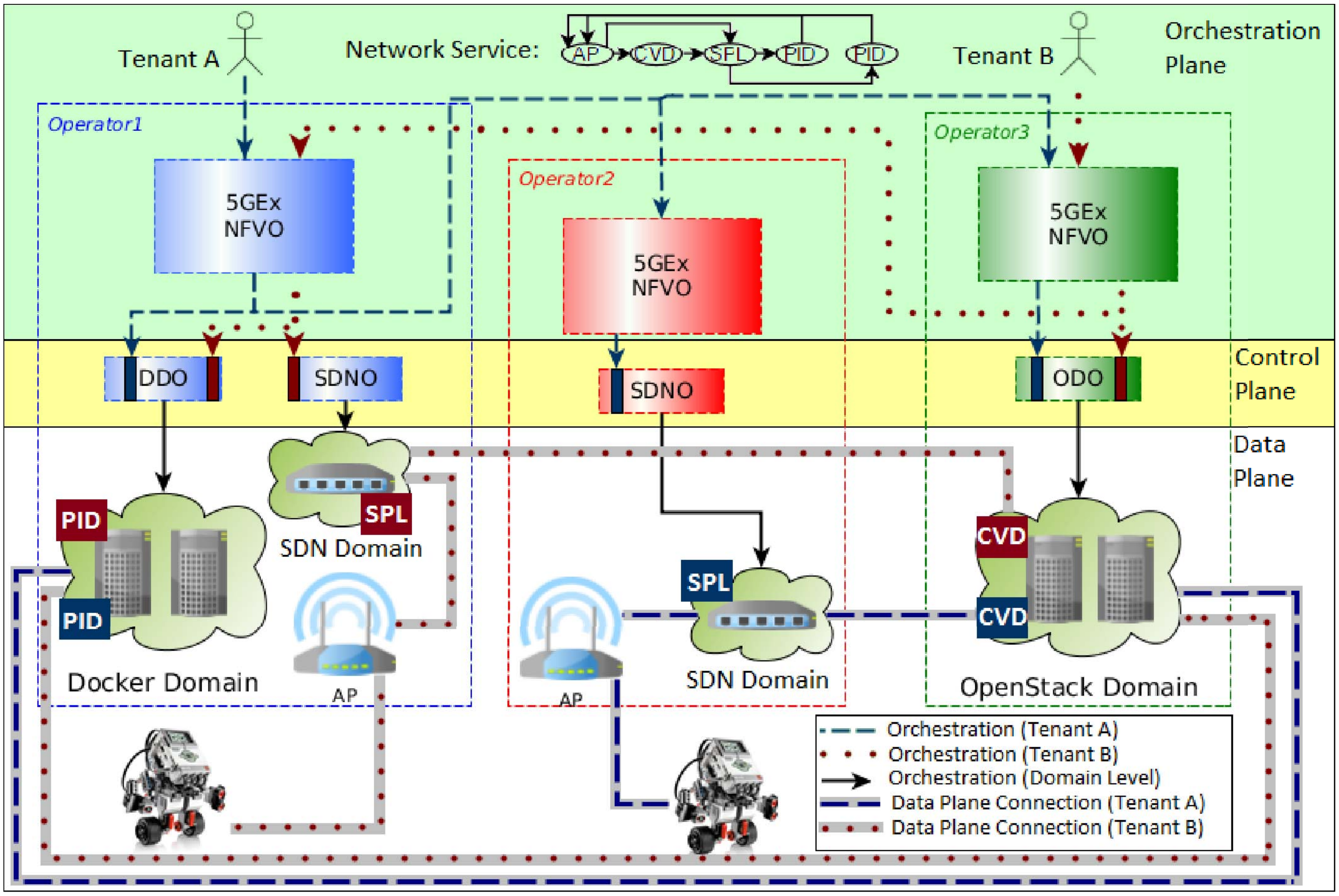


Fig. 1. The 5G Exchange orchestration architecture with the showcased components

the orchestration, control and dataplane components; operator administrative domains are drawn with unfilled dashed boxes; their domain orchestrators are depicted with color-filled dashed boxes and with the name of VIM adapters: DDO for Docker, SDNO for SDN and ODO for OpenStack Domain Orchestrator, respectively; technological domains are shown by pictograms. On the top, tenants A and B can be seen as stickmen, requesting their respective network services from Ops. 1 and 3. In the orchestration plane blue dashed and brown dotted arrows show the hierarchical relations between the NFVOs (Op. 1 is a tenant of Ops. 2 and 3, while Op. 3 is a tenant of Op. 1), and provisioned domain orchestrators, should those belong to local or remote administrative domains. Technological domains are controlled via domain orchestrators and their VIMs. The services are composed of the following VNFs: PID controllers that balance the robots up on two wheels; color vision drivers (CVD) that process the down-looking camera feed from the robot and steer the robot to keep it inside a given colored area of the ground; control splitters (SPL) that ensure that the lowest latency controller and driver VNFs control the robot. The first two VNFs run as Docker and OpenStack instances, the last type VNFs are implemented as OpenFlow flow rules. During the demo, we illustrate the business cases for various NFVIaaS and VNFaaS offers; we show the service creation steps and the service assurance. During service creation, we explain inter-NFVO actions that result in situational orchestration hierarchy, the resource set preparation based on the service definitions, and orchestration and lifecycle management procedures that provision the services. As a result, two robots will be controlled from three local and one remote domains with a possibility of sharing PID VNFs. During the service assurance phase, we show how an infrastructure failure will trigger an orchestration feedback loop up to the lifecycle management (VNFM) of the PID in the orchestration hierarchy to restore service high availability.

## Acknowledgement

This work has been performed in H2020-ICT-2014 project 5GEx (www.5gex.eu, Grant Agreement no. 671636), partially funded by the European Commission.

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