Multi-Domain Network Service Orchestration

A White Paper written by the 5G Exchange Project

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Executive Summary

5G networks are expected to offer the opportunity to launch, efficiently and cost-effectively, numerous new services, thus creating an ecosystem benefiting from both technical and business innovation. 5G will be built around people and things and will natively meet the requirements of three groups of use cases: Massive Broadband, Massive machine-type communication and ultra reliable low latency. In addition it will serve as technological enablers for several industries in a number of vertical sectors (i.e., areas like Media and Entertainment, eHealth, Energy, Automotive, and Manufacturing-Factories of the Future). Enterprises in all of these sectors will play the role of vertical customers of service and network providers playing such supportive role. To enable flexible 5G service delivery with real global reach, cooperation within a federation based ecosystem is required. The 5GEx project (http://www.5gex.eu) provides the first multi-domain (multi operators and multi technologies domain) orchestration framework and management toolset for such an ecosystem. Solutions in the ecosystem need to permit programmability, flexibility, and automation, but should also allow for agile contracting, invoking, and settling of services, significantly reducing the requested provisioning time (moving from the current nominal 90 days to a 90-minute target).

Central to the 5GEx architecture are the introduction of a **multi-domain orchestrator (MdO)**, deployed in each cooperating domain, and the definition of east-west interfaces among MdO's in different domains. There are three main interworking application programming interfaces (APIs) identified and specified in the 5GEx architectural framework. The MdO exposes service specification APIs (Customer-to-Business, C2B) allowing business customers to specify their requirements for a given service on the **interface** labeled **I1**. The MdO interacts with peer MdOs via **interface I2** APIs (Business-to-Business, B2B) to request and orchestrate resources and services across different administrative domains. Finally, the MdO interacts with legacy Domain Orchestrators via **interface I3** APIs to orchestrate resources and services within the same administrative domains.

The value proposition of the 5G Exchange multi-domain orchestrator produced by the 5GEx project is:

- Definition and design of more efficient, flexible, and globally controlled interconnection models, which can be used in a Software Defined Networking (SDN) and Network Functions Virtualization (NFV) context for operation of services spanning multiple autonomous systems.
- Definition and implementation of a function set supporting new business and partnership ecosystem enabled through normalized Application Programming Interfaces (API)
- Capabilities for trading slices of resources in a multi-domain environment
- Capabilities for controlling resources and managing the lifecycle of functions in external domains, providing the necessary information in terms of topology, monitoring, and SLA.

The 5GEx project has implemented a multi-domain orchestration system based on an architecture consisting of these interfaces. The multi-domain orchestration has been validated in a set of experiments where deployment times for virtual network functions are an order of magnitude better than the 90 minutes deployment time and closer to 90 seconds. See previous white paper on 'Multi-domain 5GEx Service Creation from 90 Days to 90 Minutes'[1]

[1] http://www.5gex.eu/wp/wp-content/uploads/2016/03/5GEx-White-Paper-v1.pdf

A focus in 5GEx is on the business and economic aspects of 5G, aiming (i) to identify the 5G ecosystem and market business needs and specify the functionalities required for the proper 5GEx operation in a multi-actor context, (ii) to define economic mechanisms that enables the multi-domain service negotiation, trading and provisioning, and collaboration models that gives rise to new business opportunities and (iii) to exercise the business and technical aspects of 5GEx against the project's business cases and quantify the different market segments this business cases covers.

In particular, the project is making the following tangible contributions in these aspects:

Definition of the fundamental business roles of the 5GEx ecosystem by providing a mapping to the 3GPP, 5G PPP and NGMN actor role models. Also, we studied the relationship of the 5GEx technical roles with the presented business roles and we performed a mapping to the 5GEx architectural elements. We envision that new roles will emerge in order to support the 5G market needs, such as roles for the support of NFV-related operation and the information or service aggregation thus facilitating the ecosystem scaling.

5GEx fully specified the coordination models for the multi-provider service composition (i.e. service discovery, negotiation and fulfilment) capturing all resource domains. The high-level scalability assessment study highlighted that the performance (in terms of communication overhead) of the different models greatly depends on the ecosystem structure. For a given scenario, the suitable coordination model is selected based level of trust among the involved stakeholders and the maturity of the market. We envision that the per-Provider centralized model in its hybrid variant is the most probable model of an emerging 5GEx business landscape.

Under the umbrella of 5GEx communities' concept, we investigated different collaboration schemes among the 5GEx providers both from technical and business perspective. We defined different types of 5GEx communities aiming to capture the different level of trust among the providers, by exploring different regimes of a 5GEx community governance model. We demonstrated the impact of the ecosystem structure to the governance model (i.e. policies, rules, procedures, etc.) and the type of a community, and presented indicative 5GEx community examples covering the project use cases. A key takeaway of this study is that the type of community to be established is highly affected by the market conditions and the business structure of the ecosystem, the balance of power among the community participants and the type, the degree of trust among the community members and the diversification of the service offerings being the core of established community. In addition to this high level study, we devised a mathematical model and we showed through numerical results that certain community policies can maximize the profitability and guarantee the sustainability of a 5GEx community.

5GEx specified the 5GEx Business Layer components and interfaces required for facilitating the multi-provider ecosystem-wide business processes and enabling the seamless integration of novel business logic and mechanisms.

5GEx defined the flexible and minimalist 5GEx Information model that provides a simple abstraction of both the NFVI resources and the provisioned services at the same time. This information model supports recursive loops that enable the abstraction of hierarchical orchestration topologies. Note that our model is in compliance with ETSI NFV Service offerings and can support the multi-actor context that was initially ignored by the ETSI NFV MANO architecture. In addition, we provided different service life-cycle approaches and example of them under certain service offerings, highlighting the 5GEx system capabilities utilized under each approach.

5GEx exercised the technical and the business aspects project use cases again the 5GEx service model, aiming for the commercial foundation of the experiments conducted in the project. For each of the use cases, we investigated different business scenarios illustrating the service/money flow among the stakeholder and business procedures enabled by the 5GEx components and interfaces.

5GEx provided a 5G market quantification touching all the market segments that are of 5GEx use cases interest. We analyse the structure and the value chain of each case, and we present traffic volume and pricing related data for each market segment both the current status (AS-IS market) and after the adoption of 5GEx solution (TO-BE market). The results of the analysis show that there is a growth forecasted in several segments of the vertical industry markets that benefit from multi-provider orchestration systems, such as 5GEx. The 5GEx solution will have positive impact on various market either by increasing traffic and thus revenues or by achieving significant cost reduction.

5GEx refined the 5GEx charging principles and illustrated different charging examples involve different service layers providing. We envision that this charging principle can support the emerging 5G ecosystem in different maturity levels of 5G market. Also, we highlighted the impact that the 5GEx ecosystem structure have on pricing of 5GEx services and the business relationships that a provider can maintain.

5GEx demonstrated the effectiveness of the utilization-based pricing scheme by means of simulations and we introduced e-negotiation agents that will enable the structured and automated negotiations within 5GEx.

1. Provider Environment

5G networks are expected to offer the opportunity to launch, efficiently and cost-effectively, numerous new services. This will create an ecosystem for technical and business innovation. 5G will serve as technological enablers for several industries in a number of vertical sectors (i.e., areas like Media and Entertainment, eHealth, Energy, Automotive, and Manufacturing-Factories of the Future). Enterprises of all of these sectors will play the role of vertical customers of service and network providers playing such supportive role. Clearly, vertical customers do not want any restriction in terms of coverage, service capability, resource constraints, geographical footprint, etc., coming from any potential limitation of the communications provider with which they maintain a commercial relationship as their primary provider.

Nowadays, the wide deployment of computing facilities across operator's networks brings the opportunity, enabled by multi-tenancy, of offering a subset of such infrastructure to third parties, for the deployment of network functions, or even the trading of entire resource slices.

With this landscape, the ability of sharing resources and services is considered even more and more by service providers and telco operators as the path to optimize the usage of available infrastructures, including both computing and networking resources. The deployment and orchestration of network services over multiple domains is then key to achieving this resource optimized sharing.

A 5G ecosystem is envisioned consisting of multi-domain services provisioned in an automated on-demand manner, by using virtualization and slicing capabilities in order to accommodate services beyond the footprint of a single administrative domain. These solutions should permit programmability, flexibility, and automation, but should also allow for agile contracting, invoking, and settling of services reducing significantly the time for provision (stepping down from the current nominal 90 days to a 90-minute target).

As consequence of this paradigm shift, several standards organisations (e.g. ETSI NFV, 3GPP, MEF, etc.) have recently started to pay attention to multi-domain aspects. This is relevant since multi-domain implies the interaction and interconnection of different organizations, possibly with platforms from different vendors and different implementations, where interworking becomes a key enabler.

The present mode of operation in service and network providers does not allow achievement of the expectations of the vertical industry sectors. To achieve better inter-domain arrangements, the following aspects have to be addressed by providers:

- Definition of more efficient, flexible, and globally controlled interconnection models. The levers for that can be the capabilities brought by Software Defined Networking (SDN) and Network Functions Virtualization (NFV).
- Definition of a new business and partnership ecosystem enabled through normalized Application Programming Interfaces (API) and/or protocols.
- Capabilities for trading slices of resources
- Capabilities for controlling resources and managing the lifecycle of functions in external domains, providing the necessary information in terms of topology, monitoring and SLA (Service Level Agreement) parameters, etc.

5GEx covers all these objectives by the definition of an open ecosystem for trading of resources (with the slice as extreme case) in a multi-provider, multi-domain environment Figure 1 shows the new environment as envisioned by 5GEx from the perspective of a service or network provider.

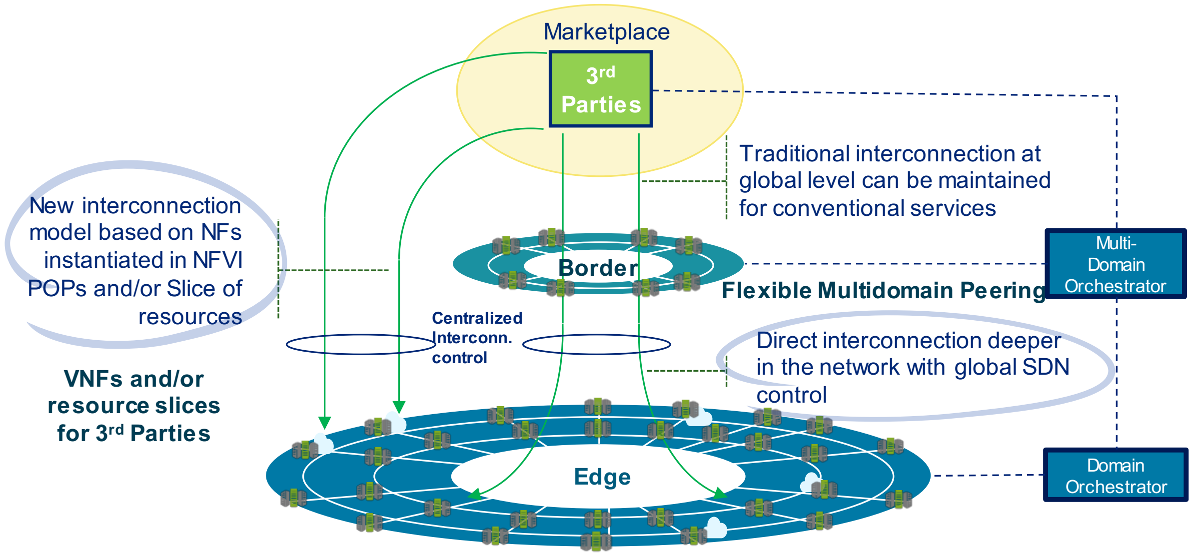

Figure 1 Provider's environment as envisioned by 5GEx

2. 5GEx Multi-Domain Orchestrator Interfaces

Interfaces are central to the 5GEx architecture are between multi-domain orchestrators (MdO's). In the 5GEx architecture framework there are three key interworking application programming interfaces supporting a set of actors as per the example in Figure 2.

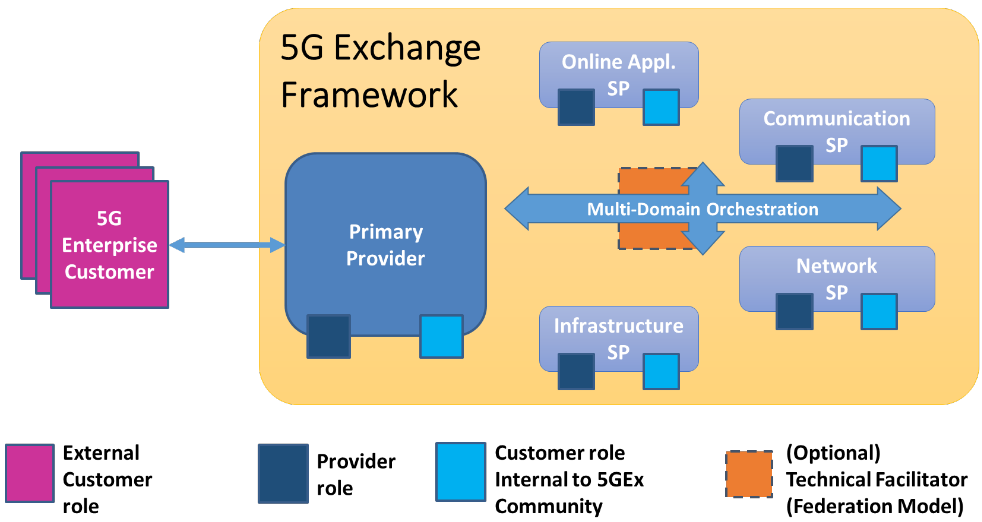

Figure 2 5GEx Framework and example actors

Figure 3 provides the detail of the 5GEx architecture. The MdO exposes service specification APIs (Customer-to-Business, C2B) that allow business customers to specify their requirements for a service on **interface I1**. The MdO interacts with other MdOs via **interface I2** APIs (Business-to-Business, B2B) to request and orchestrate resources and services across administrative domains. Finally, the MdO interacts with Domain Orchestrators via **interface I3** APIs to orchestrate resources and services within the same administrative domains. Note that MdO-only service providers (such as the one labelled as "3rd party" at the top of Figure 1 are also considered by the reference framework. These MdO service provider does not own resource domains, but uniquely operates at multi-domain orchestrator level to trade resources and services.

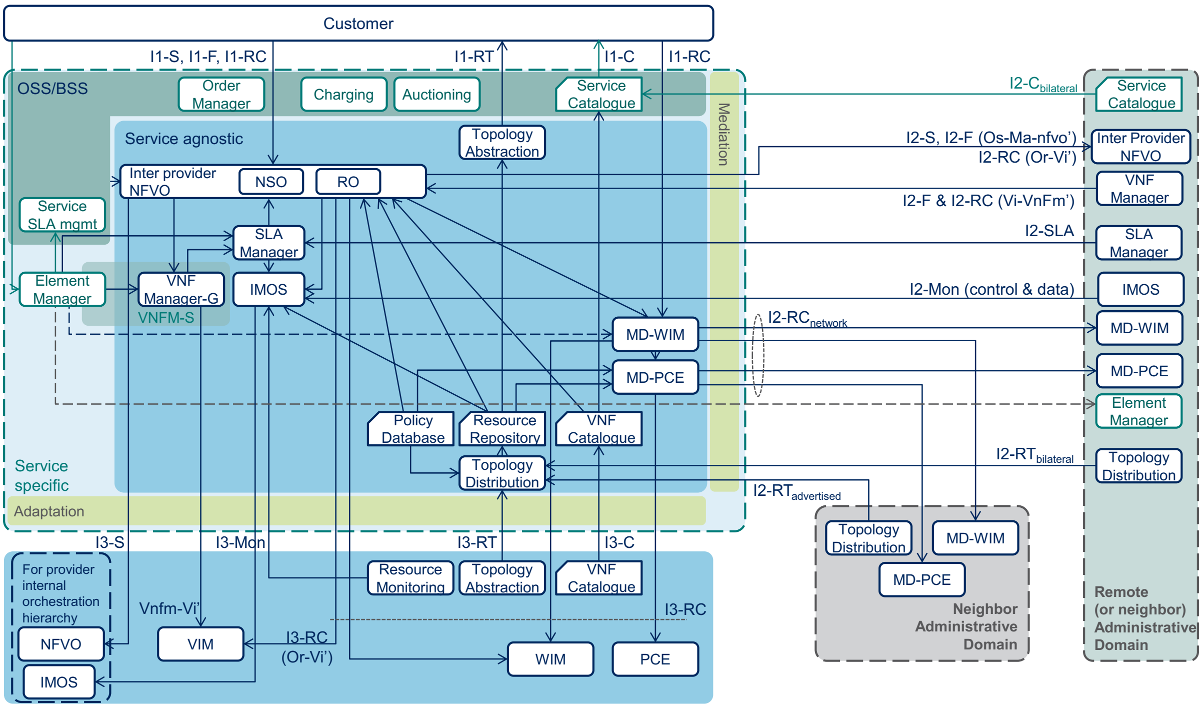

Figure 3 5GEx reference architectural framework

3. 5GEx Service Categories and Layers

Service Layers

We consider three service layers supporting end-customer facing service enablers, as shown in Figure 4:

- NFVIaaS: Network Function Virtualisation Infrastructure as a Service
- VNFaaS: Virtual Network Function as a Service
- VACS: Value added Connectivity as a Service coupled with assured service quality infrastructure connectivity

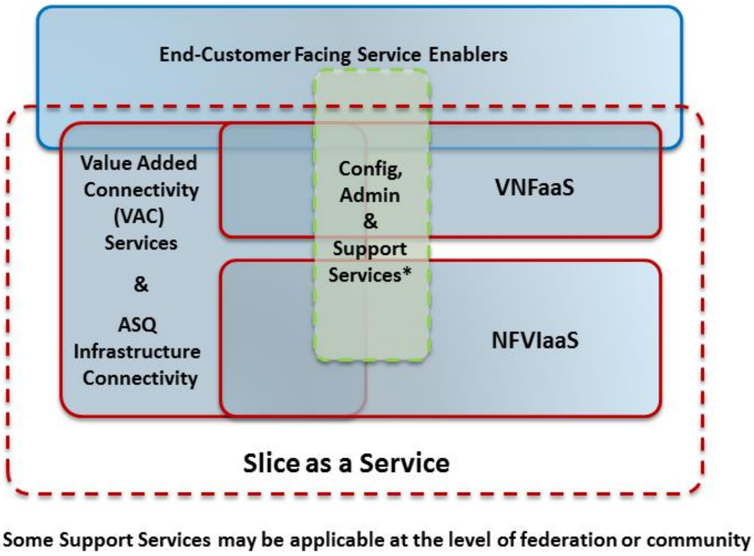

Figure 4 5GEx Service categories and layers

These service layers and categories are applicable to both interface I1 and interface I2. That is, these are the 5GEx wholesale Service Provider to Service Provider (SP-2-SP) business relationship where either both SPs are part of a 5GEx community (I2), as well as the SP-2-Enterprise business relationship where the Enterprise is a customer, for instance an online SP (OSP), interacting with the 5GEx primary service provider over I1.

Starting at the lower layer, there are infrastructure level services in the form of networking or connectivity services and virtual infrastructure services. For example, at this lower layer we have the Assured Service Quality (ASQ) infrastructure connectivity or the NFV infrastructure as a service (NFVIaaS). The ASQ infrastructure connectivity is either core infrastructure connectivity between Network Service Providers (NSPs), i.e. NSP-2-NSP, or enterprise infrastructure connectivity. The latter are relevant both in the NSP-2-NSP (I2) and the NSP-2-Enterprise (I1) relationship.

While the ASQ infrastructure connectivity services are defined for carrying medium to large traffic aggregates, the Value-Added Connectivity Services (VACS) are associated with consumer devices, machine type devices or SME end-points, or potentially VM end-points in Data Centres (DC). That is, the VACS layer is associated with flows or small traffic aggregates that can be managed by Service Edge Gateways (SEG), for instance provider edge (PE) nodes or DC gateways (GW). These nodes can perform resource and flow admission control as well as policy-based traffic steering of the VACS flows onto the appropriate ASQ infrastructure connectivity paths (ASQ paths).

The NFVIaaS may or may not be bundled with the inter-domain ASQ infrastructure connectivity. When offering a pure infrastructure service without the attached connectivity services (e.g. by a pure DC infrastructure SP, IaaS) it will be possible to bundle them with external connectivity services to build an NFVIaaS offering. This composition and the associated connectivity view could be handled by the customer itself, but in general, the NFVIaaS could cover several physical DCs, so the domain internal connectivity entities interconnecting the involved DC resources may in this case be hidden from the point of view of the customer. However, this may depend on the customer's own VNFs, their requirements, and how they are deployed onto the NFVIaaS.

NFVIaaS may also have relationship with higher level connectivity services. This can for instance be the Value-Added Connectivity Services (VACS) such as the Assured Connectivity on-Demand (ACoD). That is, the VAC services can be offered as separate services as well as in a bundle with NFVIaaS and/or VNFaaS. Additional service capabilities may be associated with the NFVIaaS such as high availability zones and VM migration.

VNFaaS goes to a higher abstraction level than NFVIaaS by providing a Network Service (NS) that may be composed by one or several linked VNFs. The service provider (SP) builds the VNFaaS instance based on the following constituent elements: *i)* The VNF instances according to the VNF descriptors, made up by one or more VMs[2] (VNF Components) interconnected by a forwarding graph, containing and running the subcomponents of a given virtualized network application; *ii)* VNF lifecycle management component (VNFMs); *iii)* service management components (e.g., EM driven by the OSS/BSS); and *iv)* the NFVI physical infrastructure, inclusive of the virtualization layer, hosting the running VNF instance (VNFM and EM as necessary). These VNF implementation details are hidden from the customer and are an internal matter for the SP.

Deployment

The service provider (SP) is typically responsible of deploying the SW image (or images, and their domain-internal interconnectivity) constituting the VNFaaS running instance. The situation may be that the SP itself does not own these SW images. In this case, the SW image owner may inform the VNFaaS provider of the dependencies between the VNF SW components. This could typically be done previously during VNF on-boarding process, with such information being embedded in the proper VNF description.

If the service provider is missing any of the above components, it may then outsource those functions to 3rd parties (if they are needed for the service). The business relations behind such service offering are key aspect of multi-provider interactions. The purchasing process between the service provider and the vendor offering the VNF SW package to the service provider, as explained in the previous paragraph, is outside the scope of the VNFaaS as such.

On the other hand, the NFVIaaS customer may deploy his/her own VNFs "on-top-of" the NFV infrastructure purchased as a service (i.e. the SW images are owned by the customer) and the NFVIaaS must come with capabilities enabling such remote deployment of VNFs as well as any VNF management agent functions that the customer prefers to deploy remotely along with its VNFs.

Configuration Administration and Support

In addition to these main layers, we also have a separate category of Config, Admin, and Support Services. These may be associated with the NFVI service (NFVIaaS) or the VNF service (VNFaaS) as already indicated above. It may also be a service category by its own, associated with VNFs controlled by the client (i.e. the customer) and running on or associated with the infrastructure enabled by a NFVI service. Such support functions "outside" the VNFaaS and NFVIaaS can for instance be operations

[2] For simplicity we refer here to VMs even though 5GEx is not limited to VMs as virtualization technology, being possible to use other technologies also like containers.

and support functions coordinating operations and maintenance across multiple VNFaaS and customer's own VNF instances.

Serving the customer

The needs and requirements of the customer, whether an I1 or I2 customer, can greatly vary. The customer can in principle request any combination of services from the above categories as long as their dependencies can be accommodated for. As Figure 4 above suggests, in 5GEx the concept of Slice as a Service (SlaaS) is the overarching service category that encompasses a bundle of all the services from the indicated layers or categories offered either over I1 or I2. That is, there can be a mix of provider-managed VNFs (VNFaaS) and facilitation of customer owned images whose services and supporting services can be requested and managed into a holistic end-to-end service together with NFVIaaS to deploy those VNFs. This can also include basic connectivity services, or what is typically known as best-effort Internet connectivity delivered as a basic Internet access service.

The end-customer facing service enablers are application functions and (value added) capabilities built from the elements below, offered to the 5G Enterprise Customer over I1. These capabilities may be part of the SlaaS offering, or can be positioned and handled outside the slice as a service concept. This service category is outside the scope of this document.

Connectivity

5GEx connectivity services also include best-effort Internet Access Services that are already widely used to support various cloud services, and can as well be used in various 5GEx service cases. However, we will focus on assured service quality (ASQ) connectivity in their various forms and variants as well as advances in VPN solutions for supporting multi-provider NFV scenarios.

We introduce ASQ connectivity and how this concept is reflected into two main layers:

- The *Core Assured Service Quality Interconnection Services* (ASQ paths, ASQ traffic exchange), which are set up and traded among Network Service Providers, over a multi-operator backbone network supporting 5G/Internet. These are the core infrastructure services that pertain to aggregate data flows, possibly crossing multiple administrative and technological domains.
- The *Value-Added Connectivity Services* (VACS) that are the customer-facing connectivity services (on-demand session level) where the network performance is either assured (absolute performance objectives) or improved (relative performance objectives). These services involve the end-user and QoS must be taken care of, even at per-flow level, as opposed to the Core services where due to scalability and cost efficiency reasons only large traffic aggregates are managed.

The 5GEx Framework has prepared for the setting where the on-demand and real-time end-to-end quality management of the end-user connectivity (VACS) can be satisfactorily handled, by coordinating the policy control and enforcement at the service edge nodes of the edge NSPs hosting the end-points of the VACS service. By these policies, the VACS traffic is steered onto the Assured Service Quality (ASQ) paths for carrying the traffic across network domains. In this deliverable we also elaborate on the concept of VACS for the enterprise and DC-2-DC connectivity that can be invoked and managed in a similar way by coordinating the policy control and enforcement at the provider edge nodes or DC GWs of the (edge) NSP(s).

In a similar way as for the core ASQ path, dealing with aggregate level traffic, we also define Enterprise ASQ Interconnection (service) offered by NSPs to Enterprise customers like DC service providers, Online (Digital) Service Providers (OSP) or Enterprise ASQ Interconnection (services) in relation to Enterprise VPN Customers.

4. Process for provision of multi-domain services

The provision of multi-domain services involves a series of interactions between service providers that can be summarized as in Figure 5.

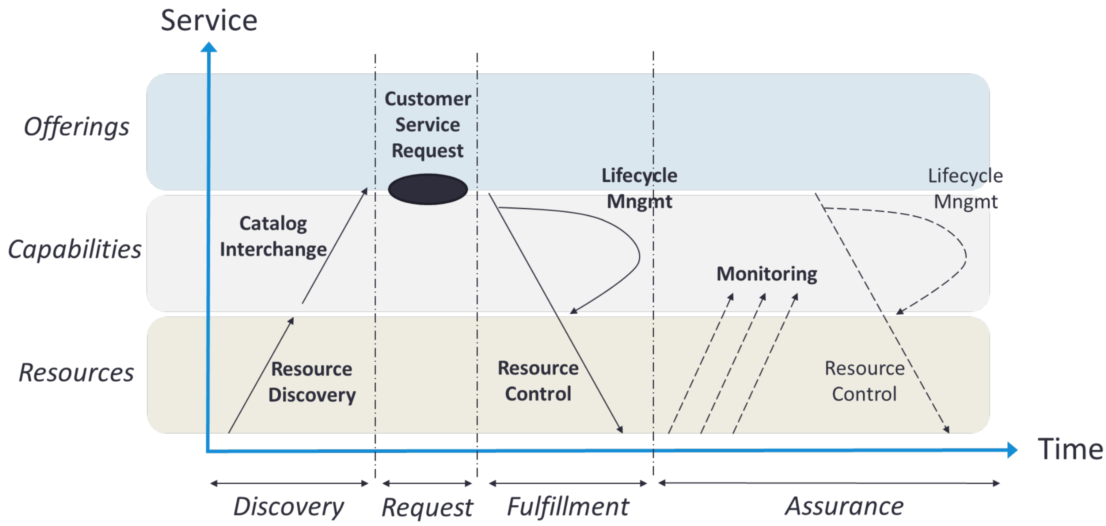

Figure 5 Steps in the provision of multi-domain services

From the service perspective, the distinct providers populate the capabilities that each of them supports by disseminating the resources and the catalogue of services to the rest of providers participating in the ecosystem. With this information each provider is able to build service offerings for external customers or verticals.

Four steps are constituent of the entire process: *(1)* the discovery phase, for the distribution and population of single own capabilities, as well as the formation of the entire view of the multi-domain ecosystem by each of the service providers participating on it in the form of service offerings; *(2)* the request phase, where the external customers solicits the provision of services; *(3)* the fulfilment phase, where the lifecycle management of the required network functions is handled, and the necessary resources are configured and control; and *(4)* the assurance phase, where the service environment is monitored and, as consequence of that, more control and management functions for lifecycle of the VNFs and configuration of resources could be performed for ensuring service levels.

The different actions identified before lead to the need of functionally splitting the capabilities of the generic I1, I2 and I3 interfaces of 5GEx for supporting all of them.

Figure 6 graphically summarizes the functional split of these interfaces.

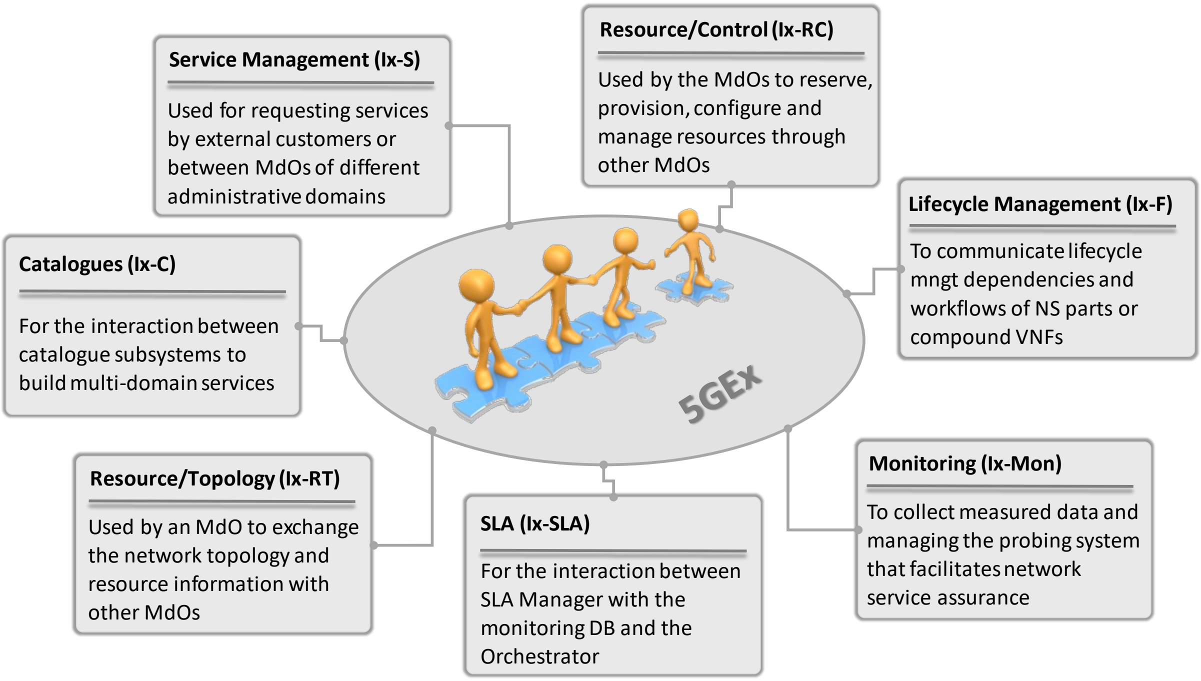

Figure 6 Functional Split of 5GEx Interfaces

This paper has covered the work on interface specification. Different candidate solutions were analysed focusing on the functional behaviour to be supported by each interface in the 5GEx architecture.

As result, a number of protocols and APIs have been identified for implementation in the 5GEx prototypes. In some cases, those candidate solutions do not cover completely the functional needs of 5GEx. For that case, the project will work on contributing to the corresponding forum solutions for the identified gaps, in such a way that those solutions could be fully compliant with the multi-administrative service provision scoped by 5GEx.

Through the experience learnt in the implementation and experimental activities of 5GEx, the specification of these interfaces could be refined in the future. In addition, progress on standardization could be a source of refinement in the future.

Details of the interfaces are given in the Deliverable D2.2 ‘5GEx Final System Requirements and Architecture’ which can be downloaded from the 5GEx website[3].

5. Business aspects

In the example of Figure 7 three providers are involved in the creation of a service: the customer-facing provider, a middleman that provides Slice as a Service for the customer-facing provider, enriched with its own NaaS, finally a VNFaaS provider that offers the application logic, its management and infrastructure to run it. This example shows that in a specific case when no direct business

[3] http://www.5gex.eu/wp/?page_id=55

relationship exists between two providers on the edges of the service chain, one has to account for mediation costs, which might be considered as cost of a delegated orchestration service.

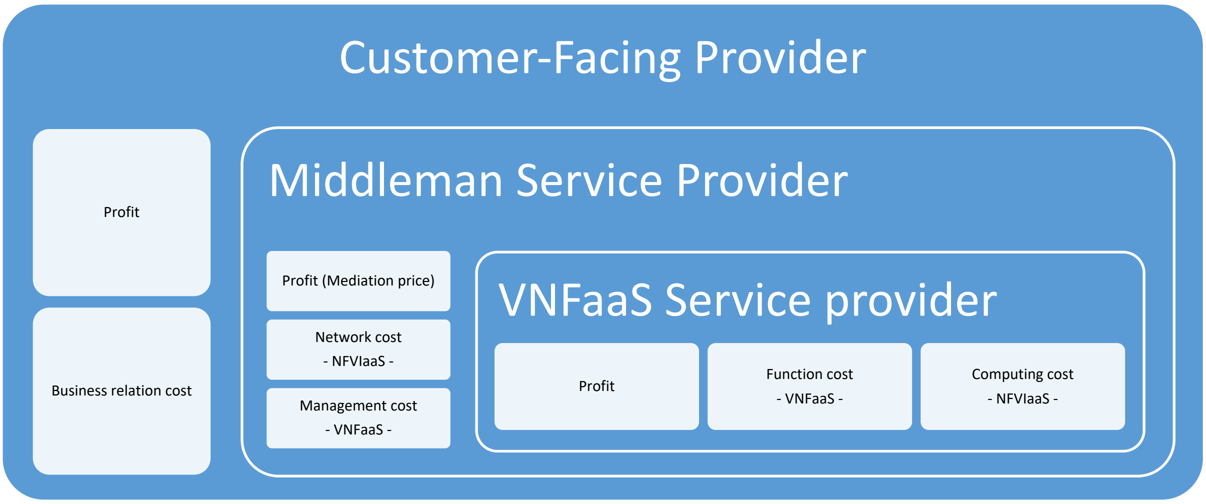

Figure 7 An example for the building elements of a 5G service's end-price

In summary, providers that are part of a 5G Exchange community need to ponder whether the benefits overshoot their overall costs. Profit might be made from exceptional business/geographic situation that enables the provider to act as a mediation hub between unlinked providers, resulting in a transit positional power due to e.g., locality of customers. On the other hand, community and coordination cost must be taken into account, such as the entry cost of communities, i.e., technical alignment, and the administrative costs of maintaining direct business relations with other 5G Exchange providers. These pricing aspects are of course on top of the general service costs (fix or usage-based pricing) and infrastructure costs (dynamic pricing, spot market). The different cost aspects that affect the total price that a provider charges are depicted in Figure 8. We argue that the formation of future 5G business networks is highly dependent and thus will be initially based on the current Internet topology. Therefore, we assume tiered structure following today's transit and peering relations as our initial network model to perform the evaluation on how the new 5G ecosystem may alter this topology.

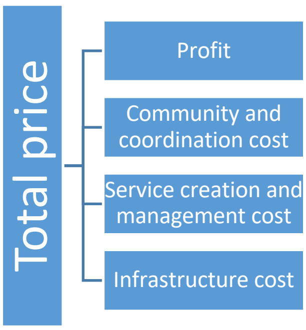

Figure 8 Separated layers of end-price determining cost elements

Federation

We consider a federation model as shown in Figure 9. There will be a wide range of providers serving the 5G market place, with many vertical sectors supported by 5G providers in multiple different types of value chain Some of these example vertical market sectors anticipated in 5G are shown in the diagram and these include eHealth, Automotive, Media and Entertainment. Industry, Smart City, Public Safety and others. Within the set of total 5G wireless providers we anticipate a set of bi-lateral partnerships who will collaborate on service delivery. Initially this might be multiple autonomous systems owned by the same provider, and it might grow to dual commercial domains sharing service resources. Beginning with Bi-laterals we see this expanding to multiple autonomous systems in federations of multiple commercial domains. Each autonomous system owner will align with neighbours, often depending on adjacent geography and adjacent commercial interests. We anticipate an exchange mechanism supporting the interconnection of resources in multiple autonomous systems to make slices which are delivered as services to 5G market place.

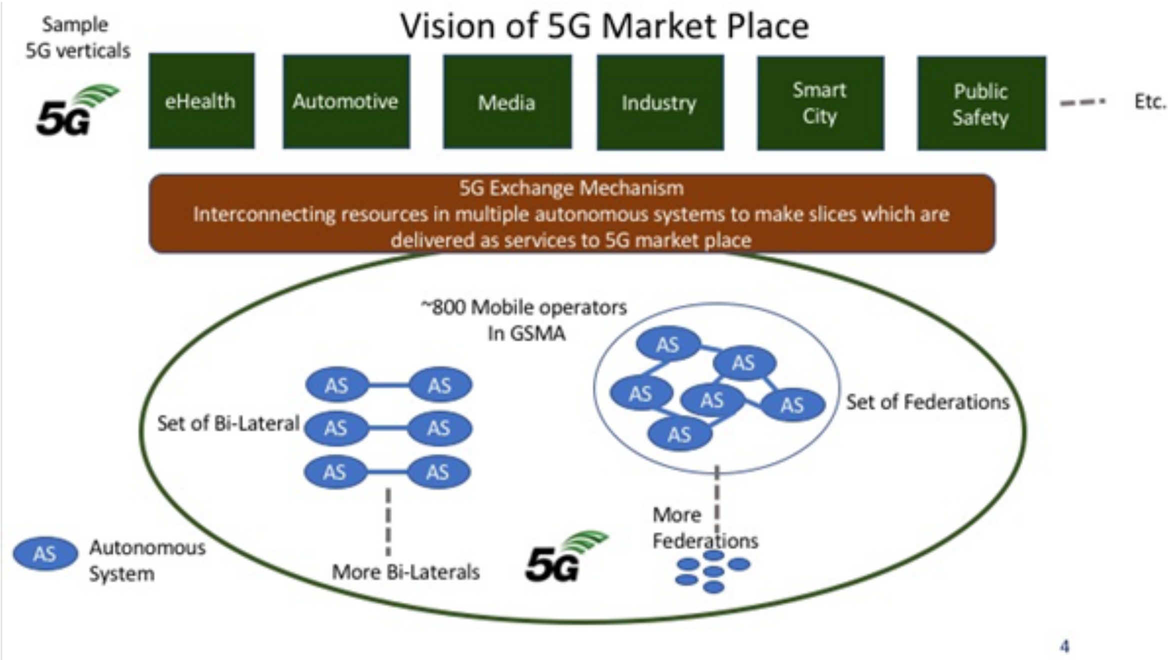

Figure 9 Federation Model

Value Proposition

The value proposition of the 5G Exchange multi domain orchestrator produced by the 5GEx project is:

- Definition and design of more efficient, flexible, and globally controlled interconnection models. Which can be used in a Software Defined Networking (SDN) and Network Functions Virtualization (NFV) context for operation of services spanning multiple autonomous systems.
- Definition and implementation of a function set supporting new business and partnership ecosystem enabled through normalized Application Programming Interfaces (API).
- Capabilities for trading slices of resources.
- Capabilities for controlling resources and managing the lifecycle of functions in external domains, providing the necessary information in terms of topology, monitoring, and SLA.

This white paper exposes how the 5GEx project provides an architecture, implementation and experimentation validation of the recommended multi-domain orchestration in a near operational context. The 5GEx service model and specification provides a consolidated and refined view of the 5GEx use case families as part of the overarching concept of multi-domain provision of Slice as a Service offering between different administrative domains.

The analysis of the project covers the requirements, the needs on the different interfaces, the development and the operation of the 5G Exchange.

A detailed analysis was performed for each of the functional behaviours considered in the 5GEx architecture, namely service management VNF lifecycle management, catalogues, resource topology resource control, monitoring and service level agreement. We have reused existing APIs and protocols whenever possible and identified gaps to be filled in our standardization efforts.

In summary 5GEx has confirmation of the validity of the 5GEx design, architecture, interface specification, functional components assessment, multi-domain orchestration implementation and experimental validation towards an operational and secure 5GEx architecture.

5GEx has aimed (i) to identify the 5G ecosystem and market business needs and specify the functionalities required for the proper 5GEx operation in a multi-actor context, (ii) to define economic mechanisms that enables the multi-domain service negotiation, trading and provisioning, and collaboration models that gives rise to new business opportunities and (iii) to exercise the business and technical aspects of 5GEx against the project’s business cases and quantify the different market segments this business cases covers.

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http://www.5gex.eu/wp/?page_id=55

Deliverable D2.3: 5GEx business & economic layer.

http://www.5gex.eu/wp/?page_id=55

WhitePaper: Multi-domain 5GEx Service Creation from 90 Days to 90 Minutes

http://www.5gex.eu/wp/wp-content/uploads/2016/03/5GEx-White-Paper-v1.pdf