5G Multi-Operator Services and Exchange Solutions

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***Abstract*—In this paper we specify possible alternatives for technical and business coordination of 5G services enablers delivered and facilitated by service components from and across multiple providers. We discuss how this is achieved by means of the 5GEx wholesale service exchange and orchestration framework, and show the merits of supporting open standard interfaces, generic yet expressive abstraction models, and business coordination logic. The 5GEx framework enablers are adapting to multiple degrees of stakeholders' trust, degree of collaboration and market maturity. We focus on wholesale service models, challenges and pricing aspects, and present 5GEx deployment variants that are tailored to different degree of 5G stakeholders' collaboration and trust.**

***Keywords*—5G exchange; orchestration; multi-domain services**

I. Introduction

Internet services have experienced an enormous growth during the past years. The tremendous popularity, usage and integration of these services in the everyday life of billions of people, combined with the increasing usage of mobile devices as the means to access them, has also further diversified the way these services are orchestrated, composed, traded and consumed. In particular, the multitude of providers and end devices involved poses significant challenges for the network and service model. The 5G service model relies on the convergence of the Communications and Information Technology industries towards a common 5G infrastructure, with connectivity, storage and compute capabilities orchestrated altogether into composite, added-value packages.

5G provides service invocation capabilities over network and cloud infrastructures of multiple administrative domains. 5G envisions services for specific target segments (the so-called "verticals") with rich capabilities and quality features. A key aspect is Assured Service Quality (ASQ), reflected in Key Performance Indicators for service set-up, deployment and performance. 5G is a revolution of the network architecture and service model, enhancing end-user experience. 5G PPP, as depicted in Fig. 1, foresees prominent impact on the verticals of Media and Entertainment, eHealth, Energy, Auto-motive, Factories of the Future [1].

5G services rely on an all-IP fully softwarized 5G network architecture, spanning from core to edge, utilizing virtualized resources to orchestrate, trade, deploy and manage services in a fast, agile, secure, and efficient way. Software Defined Networking (SDN) and Network Function Virtualization (NFV) greatly contribute to this. In order to provide assured service quality to the user, customer-facing retail services rely on assured quality wholesale infrastructure services stitching network, storage and compute resources with elementary services of multiple Information Service Providers, traded and managed under a slicing and multi-tenancy paradigm [3].

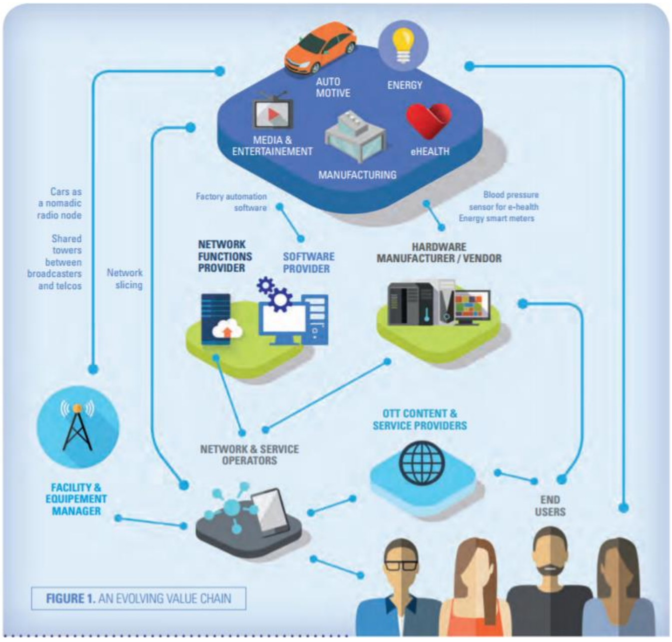

Fig. 1. 5G value chain and verticals [2].

In the wholesale market, an innovative offering is expected to come up, combining (i) innovative connectivity services, tailored to the vertical sectors needs and able to offer assured quality, offered by Network Service Providers (ii) Virtual Network Functions (VNFs) offered by Network Function Providers (iii) virtualized resources on top of the physical network, compute and storage infrastructure offered by hardware manufacturers/vendors. Content and services tailored to each vertical domain needs will be offered by Content and Service Providers, also typically referred to as Online Service Providers (OSPs). Value-added services are also expected from Orchestrators, Aggregators, Brokers and Marketplaces, akin to the Cloud service ecosystem today [1], [3].

Hence, the value chain of 5G services inherently involves multiple stakeholders, who provide elementary resources and/or services, across the infrastructure and end-user service provisioning layers. This inevitably calls for *multi-provider business and service delivery coordination over the network, compute and storage domains*. In this paper we specify the possible alternatives for technical and business coordination of 5G services and how this is achieved by means of the 5GEx wholesale service exchange and orchestration framework.

II. 5G Exchange and Service Categories

5GEx [4] is an open multi-operator cooperating approach for orchestrating and provisioning 5G wholesale-infrastructure services. 5GEx exchange framework enables Network and Cloud Service Providers to trade, orchestrate and manage services on the fly, thus providing the enabling wholesale services described in section I. As said, the 5G retail market is targeting end users (verticals). The wholesale market includes 5G infrastructure providers where high-value services, enablers of the retail service offerings, are traded, composed, set-up and deployed. Wholesale services are the foundation of 5G high-level and verticals-addressed services, and in turn leverage the composition of lower-level 5GEx fundamental services, dynamically orchestrated over to-be standardized interfaces.

5GEx framework provides the required technical and business coordination for orchestrating and trading 5G infrastructure services, which are categorized in three families:

a) *Connectivity*, supporting rich communication and transport functions towards Network Service Providers and Enterprise Customers such as Online Service Providers of e.g. content streaming and live event infotainment services.

b) *Virtual Network Function as a Service (VNFaaS)* enabling specific end-to-end service features and functions such as caching for a content distribution service.

c) *Slice as a Service*, a managed superset of Connectivity, VNF and "raw" infrastructure services, supporting the most demanding control and management requirements.

Both for 5GEx and 5G in general, SDN and NFV greatly simplify service orchestration and management. 5GEx specifies standard interfaces, depicted in Fig. 2, so as to accommodate the multi-provider setting of 5G services: Interface (1) for multi-domain orchestrator to translate the 5GEx customer (e.g. Live Event studio) service request to a chain of VNFs and underlying network, storage and cloud resources; Interface (2) for SLA-based trading of services among 5GEx-enabled orchestrators; Interface (3) for the management of own or leased - via interface (2) - slices.

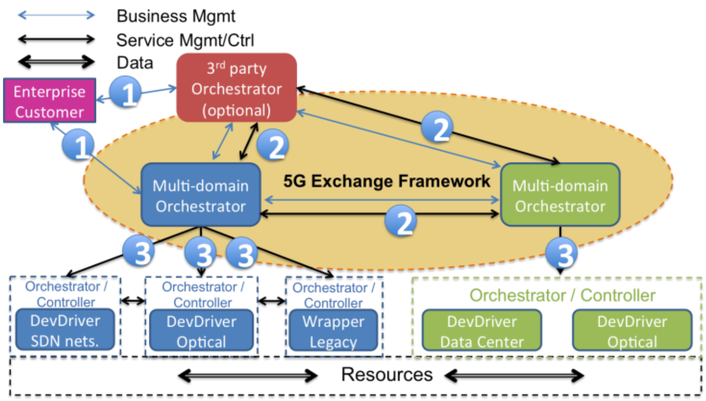

Fig. 2. 5GEx conceptual architecture and standard interfaces.

5GEx standard interfaces enable 5GEx to operate over diverse networks, datacenters and cloud platforms. Enterprise Customer is the wholesale service customer, i.e. an Online or Network/Cloud Service Provider, willing to utilize the wholesale service - purchased through Interface (1) - to support the provisioning of vertical services towards 5G end users.

III. Wholesale Service Model and Layering

A. Service Definition and Capabilities

The 5GEx service model is driven by verticals and adopts a layered approach to match the different layers of market and traffic granularities, ranging from aggregate to session layer. The *Core Assured Service Quality (ASQ)* Connectivity Services are set up among NSPs, over multi-operator backbone networks carrying the traffic of 5G and Internet services. These are the wholesale services that pertain to aggregate data flows, possibly crossing multiple administrative and technological domains. A key capability of the 5GEx approach is to enable and support assured service quality (ASQ) connectivity on top of which *Value Added Connectivity Services (VACS)* can be provisioned, supporting both the improved quality (IQ) and the assured quality (AQ) modes. IQ is positioned with relative higher performance than the basic quality (BQ) mode, while the AQ mode offers absolute performance guarantees. A background (BG) traffic mode is also anticipated. The ASQ connectivity enables NSPs to innovate by end-to-end VACS offerings, also unleashing an innovation potential by SMEs and OSPs that are not able to build their own global backbone network to offer predictable service deliveries [5].

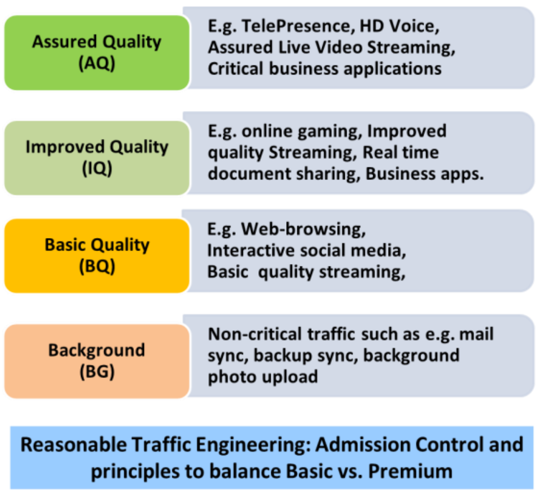

Fig. 3. Multiple traffic modes and quality levels.

5GEx introduces a 5G Wholesale Service Catalogue. In this paper we mostly focus on NSP-to-NSP and NSP-to-Enterprise Customer services. These include the *Core ASQ Connectivity Infrastructure services* (NSP-to-NSP and NSP-to-Enterprise) that serve as the wholesale communication layer upon which all 5G services, such as the *Value Added Connectivity Session (VACS) services*, can be instantiated. The advertisement of the former services is done by the *Core ASQ Path Information services*, while the *ASQ Connectivity Supporting Information services* provide forecast or monitoring information on the quality anticipated or experienced over multi-domain paths, regions and specific VACS flows. *Virtual Network Function* and *Cloud Infrastructure* services can be bundled with ASQ connectivity and Value Added Connectivity (VAC) services to make up Slice-as-a-Service type offerings.

B. Service Layering and Challenges

Under the ASQ connectivity approach we position the VACS as a separate charging layer on top of the ASQ path layer (ASQ tunnel or aggregate/bulk traffic exchange services). The latter is based on the *Sending Party Network Pays (SPNP)* charging principles between NSPs for such a bulk traffic layer [6]. In this way the VACS layer is positioned as the service offering for IQ or AQ traffic flows to device and consumer terminal end-points. VACS may also be used for finer granular aggregates to intermediate network gateways. This two-layered approach is illustrated below, where VACS is the service category oriented towards the retail market, while still imposing wholesale market requirements. We also propose the Initiating Party Network Pays mechanism on-top-of SPNP (not illustrated). This will allow a business model where money may flow from end-points of customers willing to pay into network regions that are less well-developed, with end-customers that lack the financial strength to pay for VACS.

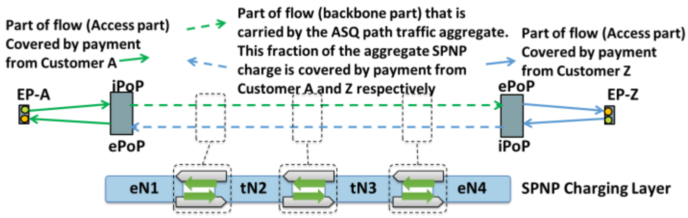

Fig. 4. VACS charging “on-top-of” the SPNP Charging Layer.

The combination of ASQ paths at the core infrastructure layer and VACS for enabling and facilitating a verity of retail value added services do pose non-trivial scalability and operational challenges as discussed and illustrated below.

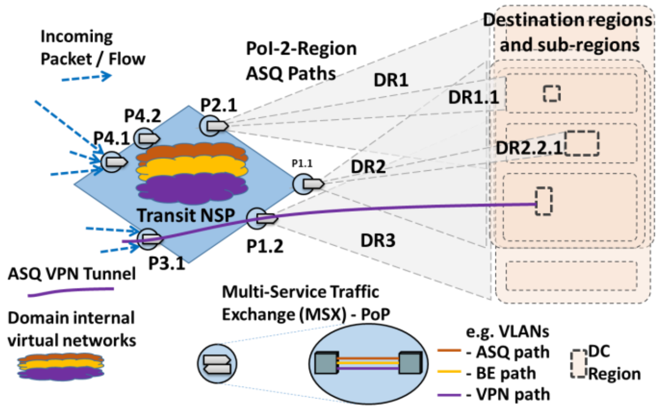

Fig. 5. ASQ paths: PoI-2-Region services and an ASQ tunnel.

Here we focus on the ASQ path layer and the aggregate traffic exchange at the point of interconnection (PoI) between NSPs, respectively for i- basic quality Internet (aka. Best-effort), ii- assured service quality Internet, and iii- Enterprise VPN traffic exchange (Multi-Service Traffic Exchange, MSX). For simplicity of illustration and for facilitating the discussion Traffic is flowing from left to right, although similar argument will apply for traffic exchanged in the opposite direction. Going into some more details (leaving the detailed exploration and numerical comparison for further work) a first note is that the Internet IP packet exchange is assumed to continue as-is. To extend the simple SPNP into a more advanced and distance based SPNP approach, leveraging upon the capabilities of the PoI-2-Region abstraction, it is suggested that the AS Path prepending mechanism of BGP is use for the ASQ traffic. This information is exchanged using a separate Extended Community marking as agreed by the NSPs establishing this ASQ connectivity community. This will allow the NSP to prepend the AS Path with any additional “AS hop counts” to signal the added cost for sending the traffic over the NSP domain, or for terminating traffic for the IP prefix when the traffic is receive at the given far away PoI. This approach allows a simpler way of traffic volume counting already available at the AS border routers, where ASQ traffic eXchange (AQX) CDRs can be generated directly base on the volume of IP packets belonging to each hop-count.

It is anticipated that the PoI-2-Region ASQ path, as illustrated and envisaged above, will become a powerful abstraction and mechanism to effectively enable multi-domain ASQ connectivity. Competing with the current Internet IP transit and peering models we are looking for cost effective, simple but sufficient mechanisms, evolving from a bootstrapping context to the more advanced solutions as the ASQ traffic is growing along with anticipated growing demands for specialized services and more challenging requirements. For bootstrapping we suggest to just use the Internet BGP destination based forwarding, while also recognizing DiffServ Code Points mapped into a few Per-Hop-Behaviors for the backbone part. A separate Virtual Routing and Forwarding plane for policy-based routing (PBR) of the ASQ traffic can be introduced at a later stage per individual NSP decision. The PBR can be achieved by a combination of business layer information exchange through the 5GEx Multi-Domain Orchestrator and more advance handling of the BGP information processing. This will allow policy-based next hop decision based on balancing and optimizing quality requirements as of the SLAs and the price according to the SPNP agreements.

We anticipate that the destination Regions can evolve from very large to finer granular regions along with the evolution just mentioned. We are currently exploring different properties of regions beyond purely for the purpose of SPNP charging. That is, the notion of sub-regions may be used to improve inter-domain traffic engineering and resource control as well as to introduce additional SPNP charging levels. Regions may also be applicable specifically to reach NFVI datacenters (DC Regions) where geographically abstracted set of NFVI-PoPs can be addressed. Moreover, we are exploring how SPNP charging can be used also for traffic carried in VPN tunnels, and even for the basic quality (aka. Best-Effort) and background traffic (aka. Least-Effort) complementing current practice for the basic (best-effort) Internet.

Next, we take a closer look at the NFV related abstractions and wholesale service offerings. The NFVIaaS category includes services composed by infrastructure resource slices, similar to the IaaS service category in the cloud computing realm, characterized by the ability to stitch into a service instance resources located not only in different Points of Presence, but even in different providers’ infrastructures. The key assumption is that the share of NFVIaaS located in a given domain is fully isolated from the rest of the local infrastructure, not only to its customer (like in the cloud IaaS case) but also to the cross-domain orchestrators, both in the service provisioning and in its lifetime management. The access to resources in a different administrative domain is always mediated by the cross-domain orchestrator local to that domain, via Interface (3). A cross-domain orchestrator can never access Interface (2) in a visited domain.

The VNFaaS category includes services composed by stitching black-box Virtual Network Functions, resembling the ETSI NFV MANO architectural model, again with a functional extension enabling the VNFs to run in different administrative domains. In this case, the service takes the VNF as an end-to-end functional block, and has neither visibility nor access at all to the internal details of the VNFs, including resource location and internal connection topology. The service customer can only tweak the configurable parameters of the functionality provided by the VNF (e.g., set policies of a virtual firewall).

The pricing framework that corresponds to the 5GEx service layering is depicted as Fig. 6. In particular, NFVIaaS is typically associated with ASQ Infrastructure Connectivity, including both NSP-NSP Core ASQ connectivity and Enterprise infrastructure connectivity. VNFaaS may in similar fashion be associated with both infrastructure services.

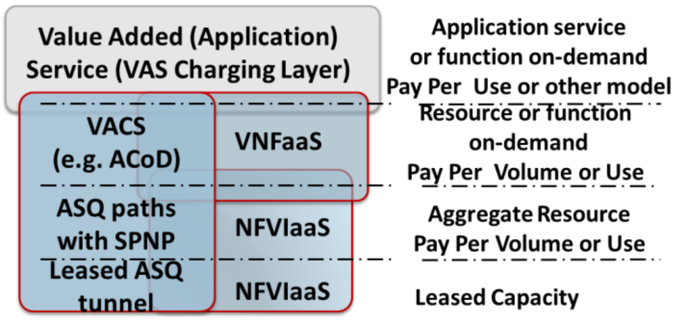

Fig. 6. Service and pricing layers.

On top of Core ASQ services, where SPNP is applicable, pricing schemes and money flows for specific 5G verticals and business cases may vary depending on the service provided due to the service ecosystem peculiarities best practices, market needs and business processes in place. VAC services may also have explicit and specific relationship with VNFs. Slice as a Service (SlaaS) is the overarching service layer that can encompass any set of 5GEx services offered over Interface (1) or Interface (2). The end-customer facing service enablers are value added capabilities offered to the 5G Enterprise Customer.

Provisioning network services towards vertical customers across multiple administrative network domains implies significant impacts at business level. This is due to the several communication, network and infrastructure service providers that may be involved as part of the same value chain, to provide an end-to-end service as the result of the aggregation of individual services defined at a single domain scope. For instance, several coordination models among the providers can be foreseen with different kinds of Service Level Agreements, pricing and revenue sharing models. Different mechanisms for sharing service offering catalogues must be studied depending on the different cases. Furthermore, NFV/SDN technologies as key enablers for 5G are still presenting gaps in their integration with existing OSS/BSS systems, which still hampers the achievement of full operational capability.

IV. 5GEx Solutions

The 5GEx framework supports a variety of specific deployment models referred to as 5GEx Solutions. These models apply to any 5G service orchestration framework, so it is important to briefly overview and discuss their properties.

First, the 5GEx framework can be realized via *distributed multi-party collaboration*, where the operators implement the exchange functionality in a distributed manner inside their own infrastructure. This option implies a bilateral (cascading) mode of collaboration among the 5GEx infrastructure providers and enterprise customers. It is the approach that is built incrementally on top of existing business relationships and interconnections in the market today. In parallel with these long-term business relationships, ephemeral such business relationships and service offerings can be materialized on the fly, taking advantage of the 5GEx agile service orchestration and trading. For instance, an Online Service Provider may create an ad hoc business relationship with an NSP, utilizing Interface (1), so as to get a point-to-region ASQ connectivity or virtual Content Distributed Network (vCDN) service; this is to be composed in a bilateral cascading way from the customer-facing NSP over Interface (2) to acquire the service elements owned other providers. The main advantages of this approach are simplicity, low cost and ease of deployment. The main limitations are barriers to entry since existing well-established NSPs are in advantageous position compares to smaller and new-comers, and lower expected probability of service orchestration, The latter is due to the lack of wide multi-party information exchange regarding topology and service capabilities and potential refusal of certain infrastructure providers to collaborate even on the fly with others due to business conflicts or myopic cut-throat competition strategies.

Second, *direct peering* at an already established local or remote IXP or IPX exchange point, but evolved towards compatibility with the 5GEx Framework, thereby operating as a 5GX. This approach is also motivated by one of the best practices in Internet interconnection. The common meeting point ensures a higher probability of service completion compared to direct peering, but also larger costs for providers to be present and align their business processes. The meeting point Orchestrator service may be beneficial for small providers but not appealing to larger providers, especially under a centralized orchestration mode. The business logic of the orchestrator and how a customer request is resolved to what kind of service solution over what providers will greatly affect the 5G providers' willingness to accept such a solution.

Third, a new type of dedicated (for-profit) *Exchange Point* operated by a standalone entity called 5GX Provider (5GXP); 5GXP is somewhat similar to the Amsterdam Internet eXchange. This solution implies long-term relationships among the providers and the exchange and a centralized orchestration mode. The success of this solution in terms of service orchestration probability and revenue depends on whether 5GXP will manage to reach a critical mass in the 5G market over a (large) geographical region. Similar to direct peering, this solution may not be appealing for large providers who may want to use their own Orchestrator service so as to maintain control of their customer base, however it is a low-cost solution for small operators who may not have the resources to support an orchestrator service on their own and prefer to lease it.

An optional, but potentially important role in the 5GEx solutions ecosystem is that of the customer-facing 3rd Party Providers (3PPs). These entities do not necessarily own infrastructure, but they do implement the multi-domain orchestrator functionality, so they can facilitate service trading. At an abstract level, this role is analogous to a Mobile Virtual Network Operator in today's mobile market or to the broker role in the Cloud ecosystem. 3PPs can be present at a 5GX or private PoP, where the 5G Enterprise Customer and the respective provider meet for service negotiation and setup.

Regarding the potential roadmap, we foresee the *distributed multi-party collaboration* as an important first step to bootstrap 5GEx. The other two solutions will become increasingly appealing as the market of 5G services matures and increasing information sharing and collaboration is required.

V. VERTICAL-SPECIFIC BUSINESS CASES

5G impacts multiple industry and infotainment sectors, while 5GEx is even more about enabling new value propositions and business cases, covering all the layers of resources and services addressed by 5GEx. On one side we recognize the aggregate level connectivity and transport connections and the value added connectivity services and on the other side the NFV infrastructure and datacenter oriented services. From these basic services higher level business cases can be built that are composed using these basic services as resources for higher level services, as depicted below for some exemplary business cases that are also consistent with [1], [3]. Note that the "Enables" relation may represent different kinds of dependencies, from a strict dependency to optional or more of a support and indirect dependency. The business cases depicted cover all the 5G wholesale service categories [7].

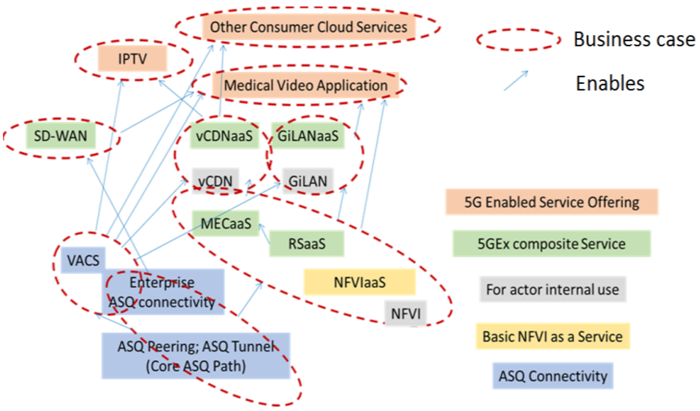

Fig. 7. Business cases and dependencies.

In particular, for Connectivity, we depict the SD-WAN business case that can be seen both as a potential 5GEx proposition and as a competing product. This as an overlay solution employing both physical and virtual appliances that perform network controlling and WAN bandwidth aggregation on top of existing MPLS, Internet WAN, LTE or satellite links offered by NSPs [8].

For VNFaaS we depict the "VNFaaS as managed service" as a fundamental managed service of this category. Also, we consider the "Multi-operator IPTV services in 5G networks" business case, which encompasses features of virtual CDN and corresponds to the Media and Entertainment vertical.

For the Slice as a Service (SlaaS) category, we consider the Gi-LAN/Roaming case, for providing roaming to mobile users via the network slicing and offering of a remote EPC in another telco datacenter/edge premises and ASQ connectivity to it. Two additional business cases are the 5G-generic "Mobile Edge Computing through SlaaS" targeting the wholesale providers' market and the "Smart Car – Balancing Robot" depicting a concrete business case of SlaaS for the Factories of the Future and the Automotive verticals respectively.

VI. CONCLUSIONS AND NEXT STEPS

In this paper we have discussed aspects of 5G services technical and business coordination. We have introduced 5GEx, the 5G exchange and service orchestration framework, supporting open standard interfaces, abstraction models and business coordination logic. We have highlighted service model, challenges, as well as 5GEx solutions that adapt to different degree of 5G stakeholders' collaboration and trust. Completing the 5GEx service catalogue and complementing the 5GEx business layer with additional market mechanisms and trading agents is on-going work.

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