# 5G Wholesale Services and Pricing

Manos Dramitinos, George D. Stamoulis
Department of Informatics
Athens University of Economics and Business
Athens, Greece
mdramit@aueb.gr, gstamoul@aueb.gr

Håkon Lønsethagen
Telenor Research
Fornebu, Norway
hakon.lonsethagen@telenor.com

***Abstract*—This paper contains an original classification of the 5G wholesale services and a novel proposal for the respective pricing schemes for these services. Motivated by the envisioned 5G customer services, this paper introduces the services that need to be offered, orchestrated and traded among infrastructure and service providers, so that end-to-end 5G services can be efficiently orchestrated and provisioned. The paper proposes and assesses candidate pricing schemes for these services.**

***Keywords—5G; services; assured quality; pricing***

## I. Introduction

5G is the next big revolution in communication networks, integrating networking, cloud and Internet of Things (IoT), ubiquitous access over multiple access technologies and a fully softwarized infrastructure. 5G is a holistic service platform that morphs network, compute and storage resources through slicing, built upon virtualization and softwarization, into one programmable flexible multi-tenant infrastructure. A *slice* is a managed set of 5G resources and (potentially) network functions tailored to support a particular type of user or service.

5G by design enriches the customer-facing services (the so-called "*verticals*") with new capabilities and quality features, boosting end-user experience over multiple service domains; PPP foresees the most prominent and immediate impact on the verticals of Media and Entertainment, eHealth, Energy, Automotive, Manufacturing-Factories of the Future [1].

5G requires drastic re-engineering of the network and its wholesale infrastructure services, incorporating virtualization, softwarization, intra-provider collaboration and service quality assurance. The overview and classification of these wholesale services, as well as the proposal for suitable pricing models for them that are aligned with the 5G ecosystem peculiarities are the main contributions of this paper. We argue that these contributions are novel since most related work so far focuses on 5G technical and architecture issues. Also, they are important since they are the catalyst for business coordination in 5G and for specifying the 5G service and revenue/business models needed to monetize and roll-out 5G services.

## II. 5G Ecosystem and 5GEx

5G integrates connectivity and managed services with cloud and IoT, (virtual) network functions, applications and Slice and Anything as a Service offerings in an all-IP ubiquitous-access service model. This requires in addition to the technical network transformation a radical revisit of the business models: Moving from the traditional single-provider service model to a partly collaborative where infrastructure is opened to the competition with quality as a major value creation driver is a big challenge for network operators. There is a trade-off between the new opportunities and value to be acquired from the new services and the risk of becoming a low-margin replaceable stakeholder in a multi-stakeholder service value chain. Multiple Network (including 5G radio access), Cloud and Online Service Providers constitute the multi-actor value chain of 5G services. Thus, multi-operator business and service coordination is required for 5G services.

Network Service Providers (NSPs) and cloud (including datacenters) operators providing any type of physical or virtual resources can be classified as *Infrastructure Providers*. *Online Service Providers* build services on top of the resources of the Infrastructure Providers. This category includes Application Service Providers, Content Providers, Content Distribution Networks (CDNs), Over-The-Top Providers (OTTs) like Internet Retailers and Market Places/Exchanges. Note that there exist providers that may operate both as Infrastructure and Service Providers, e.g., an NSP offering CDN services. Finally, end-users may be classified as residential and business.

5GEx [2] is an open multi-operator internetworking approach for orchestrating and provisioning 5G wholesale - infrastructure services. 5GEx introduces an exchange framework enabling NSPs and Clouds to trade, orchestrate and manage services on the fly, so as to meet end user demand for 5G services. Specifying the 5G wholesale services and their respective pricing schemes is of prominent importance for [2] and 5G in general, thus motivating our research that is in part reported in this paper. The 5G wholesale services are the foundation of 5G high-level services and verticals by composing lower-level 5GEx fundamental services that are dynamically orchestrated and controlled over standard interfaces, also ensuring that 5GEx works over multiple administrative and technology network and cloud domains.

## III. 5G Wholesale Services

### A. *Service categories*

There are many classifications of 5G services; our novelty is that we focus on the wholesale services needed to support the end-to-end services mentioned in related work, such as [3]. We identify three families of 5G wholesale services:

*a) Connectivity*, supporting rich communication, VPN, content streaming and broadcast services.

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

*c) Slice as a Service (SlaaS)*, a manged set of VNFaaS and Connectivity services, also providing to the customer full control and management access to the virtual infrastructure and service elements, thus supporting the most demanding verticals such as industrial automation and remote control.

The envisioned hierarchy of resources and services is depicted as Fig. 1. Lower-level resources are the low-margin commodity building blocks of differentiated higher-level services. Virtual resources and Network Functions are composed into slices and infrastructure services, such as assured quality connectivity services (ASQ) enabling custom Value-Added Connectivity Services (VACS) for the support of verticals such as rich communication and media. This is similar to the cloud in terms of layered service provisioning and value proposition: The 5G wholesale service layers are similar to the cloud layers from e.g. low-layer Amazon's S3 and EC2 to the AWS CloudFront high-level streaming service. The higher the service layer is, the higher are the technical complexity, the customer value and monetization potential for that service.

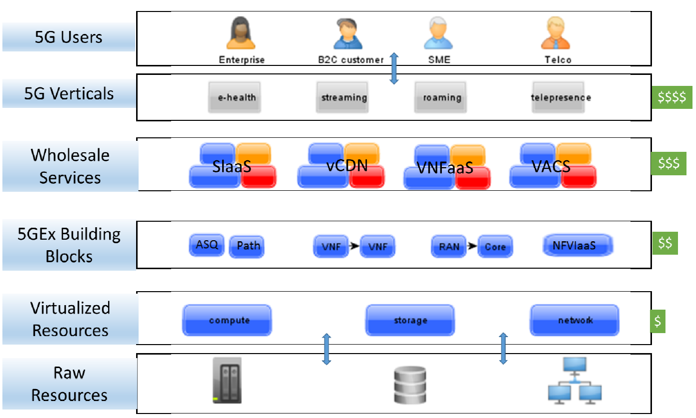


Fig. 1. The 5G service layers in terms of complexity, market and value.

## B. Catalogue of 5G Wholesale Services

The wholesale service offerings and envisioned business models have also been considered in 5GEx, which jointly address the needs of the wholesale, i.e. market among providers, and the retail, i.e. towards the end user, markets. 5G and Internet services pertain to two different layers and corresponding markets with different stakeholders and business relationships: The *Core Assured Service Quality Services* (ASQ paths, ASQ traffic exchange), which are set up and traded among NSPs, 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.

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 nodes of the edge NSPs that serve the end-points that take part in the VACS. By these policies, the VACS traffic is steered onto the Assured Service Quality (ASQ) paths for carrying the traffic across network domains. This separation has also been accepted by multiple 5G and Internet related initiatives in the communities, such as [4].

In the remainder of this subsection we provide an overview of the Catalogue of 5G Wholesale Services. In particular, in this paper we mostly focus on NSP-to-NSP services, as well as some initial proposals regarding NSP-to-Enterprise Customer, e.g. NSP-to-Online Service Provider. Assured Service Quality (ASQ) connectivity is the general term covering all granularity levels of connectivity, from Core ASQ paths, through VPN and Enterprise ASQ interconnection paths to Value Added Connectivity Session services (VACS) level. The main categories of 5G wholesale service types are the following:

*a) Core ASQ Connectivity Infrastructure services (NSP-to-NSP):* These are the multi-provider wholesale connectivity services that comprise the wholesale communication layer upon which all 5G services can be instantiated.

*b) Core ASQ Path Information services (NSP-to-NSP):* These are the ASQ capabilities "publication"/"directory" services of the ASQ path capabilities (e.g. capacity, delay, jitter) from one Point of Presence to another Point of Presence.

*c) Enterprise ASQ Connectivity Infrastructure services (NSP-to-Enterprise):* These are the wholesale connectivity services towards the Enterprise Customers. The granularity and scope of these services, their control and management API differ from *a)*, while adapting many of the same capabilities.

*d) Value Added Connectivity Session (VACS) services:* As explained above, towards the Enterprise Customer (e.g. Online Service Provider) or the NSP.

*e) ASQ Connectivity Supporting Information services:* Information services providing forecast or monitoring information on the quality anticipated or experienced over multi-domain paths, regions and specific VACS flows.

*f) Telco Cloud Infrastructure services:* These are Slice as a Service service offerings.

*g) Virtual Network Function services:* VNFaaS service offerings. As for the resource slice as a service (item *f)*) this service can be bundled with ASQ connectivity.

# IV. 5G Pricing Schemes

We now specify the pricing schemes for 5G resources and services, in line with the service classification of Section III.

## A. Connectivity

The proposals developed here take as a starting point the general concept of Sending Party Network Pays (SPNP), which was introduced in [5] and depicted as Fig. 2: two networks exchange assured quality traffic over Assured Service Quality paths (ASQs) according to agreed SLAs. That is, when for instance Network A (buyer) sends ASQ traffic to Network B (provider) Network A pays Network B for transporting the IP packets according to the SLA (A-to-B) to destination end-points of an agreed destination region (set of IP prefixes). SPNP charges for the traffic in the two directions are in principle separate issues.

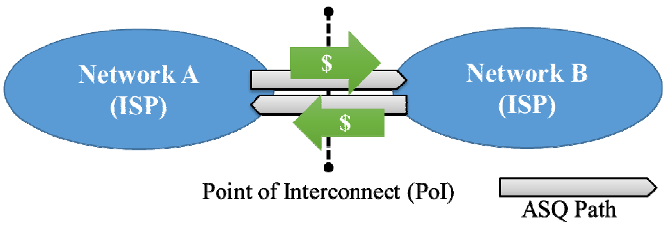


Fig. 2. The Sending Party Network Pays principle.

SPNP provides appropriate incentives to the provider NSP to deliver the traffic according to the agreed SLA. SPNP is a wholesale ASQ traffic exchange approach that is intentionally kept simple and low-cost and applies between NSPs; NSP offerings to the Application Service Provider is a different issue, depending on the service type and should not be confused with the end-customer application service. The original SPNP proposal left unexplored several topics: The specific charging formula of the SPNP principle, the size and extent of the SPNP destination region (All the way to the end-point or only the transit and core network parts?) and the feasibility of SPNP for the 5G network and resource slicing concept are the most prominent; these are considered further below in our proposal for 5G Connectivity pricing under the following two schemes (the basic idea of SPNP with 95th percentile has been introduced in part in a poster of ours [6]):

*1) Nominal capacity-based SPNP:* SPNP charging based on the nominal capacity requested *C*, regardless of its actual usage. This is a payment rule used in various exchange peering and its major advantage is simplicity, due to the lack of monitoring and metering and thus minimal accoutn and billing overhead. The unit price of the capacity *p* is expected to be region-dependent and also reflecting the quality assurance requested, thus creating the potential for product and price differentiation. Thus the total charge for a given availability and quality, as specified in the respective SLA, is defined as:

$$Total\ Charge = p * C \qquad (1)$$

*2) 95th percentile-based SPNP:* SPNP charging based on 95th percentile charging *perc* given the incentive properties of 95th percentile rule for traffic shaping of peaks and thus enhanced multiplexing potential of the network. Traffic must be sampled, typically per 5-min intervals to compute the 95th percentile that is lower than the nominal capacity. The 95th percentile is the industry de-facto transit pricing and provides incentives for efficient network usage since it penalizes traffic peaks and provides incentives for traffic shaping when necessary, thus increasing the potential for multiplexing gains in the network. Thus the total charge for a given availability and quality, as specified in the respective SLA, is defined as:

$$Total\ Charge = p * perc \qquad (2)$$

On top of the SPNP wholesale layer, additional charging layers and business models can be supported, including scenarios where even the "initiating end-customer" can pay for traffic in both directions if needed, as also elaborated later in this subsection with a simple videoconferencing example.

Regarding wholesale connectivity, we propose that the Core Connectivity services are always priced according to SPNP and the two aforementioned charging schemes; the motivation behind SPNP, its experimental assessment and a presentation of its advantages can be found in [6]. This will enable the provision of proper incentives for creating a backbone of assured quality connectivity services, which is crucial for 5G services. These services include both ASQ Point to Region and ASQ Point to Point services that should be charged with one of the two aforementioned charging schemes.

For multi-domain VPN and additional VACS services, the IPNP layer becomes relevant: For instance in a VPN or a two-way streaming/teleconference service there can be one party paying for the entire service. This means that the IPNP layer will pay for the service and also compensate for the underlying ASQ wholesale SPNP charge. We anticipate VACS services to be mainly instantiated on top of the backbone wholesale (long-lived) ASQ services, thus comprising an additional service-pricing layer. At the application layer there may be additional charging schemes, e.g., session-based or monthly subscription for a video streaming service, which do not pose any research challenges and thus are out of the scope of this paper.

*3) SPNP Challenges*

The proposed pricing schemes significantly advance the state of the art by providing concrete and novel pricing scheme instantiations of the SPNP principle. This subsection contains some inherent to SPNP challenges that have not addressed in the literature (including [6]) and ways to address them.

Our SPNP-based pricing proposal applies to Core and VACS services that may be differentiated in terms of quality parameters such as *delay*, *time duration*, *bandwidth*, *jitter*, *packet loss*, and *availability*. Especially *availability* is considered to be extremely important in order to be able to offer Core connectivity services that are robust, fault-tolerant and carry sensitive 5G traffic such as signaling. Different values of the *availability* parameter are expected to correspond to different unary prices *p* for the proposed pricing schemes.

SPNP is best in deciding the tradeoff between the cost and quality trade-off and is in line with similar charging solutions from other industries, e.g. post, packet delivery. Multiple paths, regions and granularities are possible for the SPNP-charged Core services. These regions can be charged differently, as is also the case for the different (partial) transit prices in Europe, Asia and USA. Related challenges and potential solutions are depicted in Fig. 3: Looking at traffic from left to right (source to destination) ASQ is established to ingress edge PoP a1; then multiple options are possible, i.e. for the ASQ path to go through transit PoP t1 or t2. At t1 the choice is whether to select service by NSP B or NSP C. Hence, NSP A interacts via session service API with NSP B to check availability of ASQ all the way to destination end-point and based on received information, on current traffic load and price, resource and admission control for the specific ASQ can be given and traffic steering decision at a1 can be made.

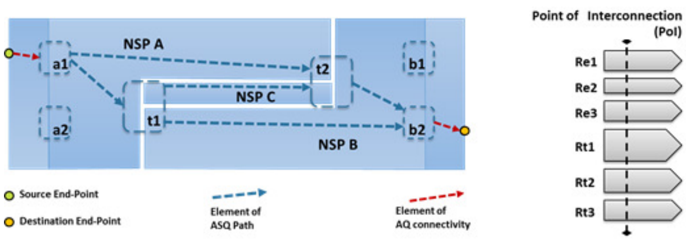


Fig. 3. Challenges and potential solutions for SPNP-based pricing.

Fig. 3 right hand side depicts the granularity and properties of destination regions, which, as already mentioned, can be hierarchically organized. Example regions are: Re: Region offered by NSP in the edge NSP role given this PoI; Re1: no charge (destination region close to last PoI); $Re_i$: Price $Pe_i$ for $i$=1,2,3,...; Rt: Region offered by same NSP but for these regions in the transit NSP role. Thus, ASQs and SPNP can provide standard yet customizable, in terms of reach, scope and service quality wholesale network services, which are of high value for 5G. We foresee the evolution of 5G exchange points so that traffic, network capacities, NFVI and VNF are traded among NSPs to support Any Slice as a Service. SPNP with 95th percentile charging fits nicely inter-domain Datacenter-to-Datacenter traffic exchange, as the base-layer for ASQ traffic exchange charging (aggregate traffic). For example, let us consider in Fig. 3 media services such as. telepresence, live events, using media processing VNFs (e.g. vCDN, i.e. virtual CDN network function) under three scenarios, all assuming content origin is in NSP A, for instance in a2:

*Scenario 1:* Customer of NSP A roaming into NSP B; NSP A is buying NFV IaaS at t2 of NSP B or NSP C and deploying vCDN-VNF at t2. CDN interconnection is set up between vCDN at t2 and vCDN at bx of NSP B.

*Scenario 2:* Customer of NSP B demands content from NSP A (e.g. travelers wan content from "home" country). Then NSP B is buying NFV IaaS at t1 of NSP A or NSP C, NSP B is deploying vCDN at t1 and CDN interconnection is established between vCDN in NSP A and vCDN of B at t1.

*Scenario 3:* NSP C facilitates a CDN offering to global content aggregator, enabling it to reach NSP B end-customers.

For all three scenarios we envision SPNP with 95th-percentile charging from source to set of DC end-points in other domain for the respective Core ASQ path traffic, resulting in innovative, cost efficient and managed SLA-based quality. Hence, SPNP is compatible with the 5G slicing concept [3] and SPNP with 95th percentile charging is an innovative step forward for the efficient provisioning of 5G services and substantial value creation. In fact, SPNP with 95th percentile charging is applicable to both legacy networks and SDN-enabled networks supporting VNFs. Concluding, our pricing proposals are in line with both research and industry best practices regarding pricing layers, namely *capacity*, *bulk usage* and *per session* charging [7]: pricing operates independently on each of the layers, while metering and clearing functions compute the final charge.

### B. *Virtual Network Function as a Service (VNFaaS)*

Pricing VNFaaS can be seen as a special case of Software as a Service (SaaS), which is extremely rich, including multiple dimensions such as versioning, packaging, regional pricing, customer/market segmentation, loyalty and volume discounts, payment and usage type adjustments, promotions, upgrades fees, channel discounts. It is important for 5G to come up with simple yet efficient VNFaaS pricing schemes that are aligned with VNF configuration and pricing model parameters setting [8]. To this end, also inspired by the pricing models used for popular software services ranging from desktop applications to elementary cloud functions such as AWS Lambdas [9], we propose the following pricing schemes for VNFaaS:

*1) Pay per time duration per VNF instance:* The simplest scheme where the customer is allowed to execute one or up to $n$ instances for a pre-specified amount of time $t$ for a price $p$.

$$\textit{Total Charge} = p * n * t \qquad (3)$$

Total charge is independent of the actual usage, implying simplicity, lack of monitoring and pre-specified charge. The major disadvantage is the lack of any incentive for reducing the actual usage and the fact that the pre-specified (time and volume) usage limits may not serve all customers' needs: if there is a price $p_0$ for executing a single instance and a price $p_1$ for 10 instances for a period of 1 month, this scheme may not be attractive for users needing 5 instances for a week.

*2) Pay per request and execution time duration:* This is the scheme used for AWS Lambdas [9]. The charge of the VNFaaS instance is computed as the sum of the *Request charge* and *Compute charge*:

$$\textit{Total Charge} = \textit{Request charge} + \textit{Compute charge} \qquad (4)$$

The *Request charge* is defined as the total number of function requests $r$ times the unary price $p_{req}$.

$$\textit{Request Charge} = r * p_{req} \qquad (5)$$

The *Compute charge* is specified as the VNF execution time t times the respective unit price $p_{run}$:

$$\textit{Compute Charge} = t * p_{run} \qquad (6)$$

Both these pricing schemes are compatible with the Pay-as-You-Go model proposed by other researchers in T-NOVA project where different billing options were explored for VNFaaS, including licensing and subscription. The latter two were showed as not profitable nor fair for this case, concluding that Pay-as-You-Go is the most suitable for VNFaaS [10].

### C. Slice as a Service (SlaaS)

The 5G multi-domain service setup may entail significant amount of signaling, orchestration and business coordination processes and can potentially involve the reservation of a significant amount of resources. It is thus advised that for the pricing of connectivity services and slices when usage-based pricing schemes are applied, they are combined with an initial service set up cost $p_{setup}$, which depends on to the amount of resources and performance features requested. Especially for slices, for both simplicity and scalability reasons we propose that the price to be paid by the customer is the set-up cost $p_{setup}$ of the slice and the respective charge for the resources and services instantiated, as defined in the previous parts of this document. The set-up cost $p_{setup}$ can be the expected average price over multiple slice parameters and set up overheads.

### D. Resources

Pricing of storage and compute resources, including VNF Infrastructure, can be according to the current cloud market status quo where a predefined ontology of virtual compute and storage nodes of standard types are offered for a price for a given amount of time. Moreover, it is also possible to have spot markets such as the ones of Amazon for VMs for the on-demand leasing of resources. The fixed price approach can be an initial step for resource pricing in 5G, while the spot market approach is to be investigated further later, in a way customised to the scope of 5G and the respective services. Regarding the former, a piece-wise constant pricing scheme is typically followed: There are multiple utilisation limits with a different unary price, which may also depend on the physical location of the resources. Different prices for the same resource in different regions reflects the different costs of ensuring the availability of the respective resources over different regions, e.g., due to the different infrastructure availability.

### E. Discussion – Additional considerations

5G slicing and multi-provider service orchestration calls for pricing schemes should be able to work both in an independent and combined fashion under all the service models in a multi-provider context, without complex accounting and billing. For instance, a VNF forwarding graph translated to multiple links, VMs, connectivity services and VNFs will result in a total charge that will be the sum of the individual service elements composing the service. Each such element (VNF, connectivity service) will be priced according to the schemes specified in this section. Note that this is similar to e.g., a CDN service where the total CDN service charge is the total charge of the transit charge for the connectivity and the cloud charge for the compute and storage portion of the service. Therefore, modularity and layering of the pricing schemes is needed for a generic and functional pricing framework. This is a major driver for the schemes presented in this section.

Price dynamicity is an additional important factor that needs to be considered in the following ways: Either create pricing schemes and market mechanisms where prices are set dynamically according to multiple factors (e.g., utilization) or create markets that can generate the values of the parameters of the pricing schemes presented in this section. Examples of the latter include negotiation frameworks or a spot market where a market price for a certain resource or service is generated by the intersection of demand and supply; this is the approach used in cloud, electricity grids, etc. These issues are not addressed in this paper but they have been considered in the specification of the pricing schemes. Also the price may not appear as a price tag; its bounds may be provided and the exact value can be computed dynamically based on the underlying infrastructure utilization and operational conditions or as a result of a negotiation process among the providers involved.

## V. Evaluation

### A. Connectivity

Pricing based on 95th percentile is used in Internet transit interconnection, motivating research on traffic management mechanisms that do traffic shaping in short [11] or long time scales [12]: Due to the variability of the traffic patterns over time the non-urgent delay-tolerant traffic is sent when the real-time traffic levels are low, so as to lower the 95th percentile.

We have conducted simulation-based assessment of 95th percentile-based shaping (named ICC) and pricing in the context of Datacenter-to-Datacenter interconnection, which is also relevant for 5G. We have also collected results from an implementation of ICC on Juniper MX240 routers. Sample results are depicted in Fig. 4, while [11] contains a full report. Results show that 95th percentile pricing provides incentives for traffic shaping, making room for real-time services, increasing the efficiency of the network infrastructure and resulting in tangible monetary gains and cost savings for NSPs and Datacenters respectively. We argue that these results are transferable in the context of 5G wholesale communication, so no additional assessment has been carried out in this paper.

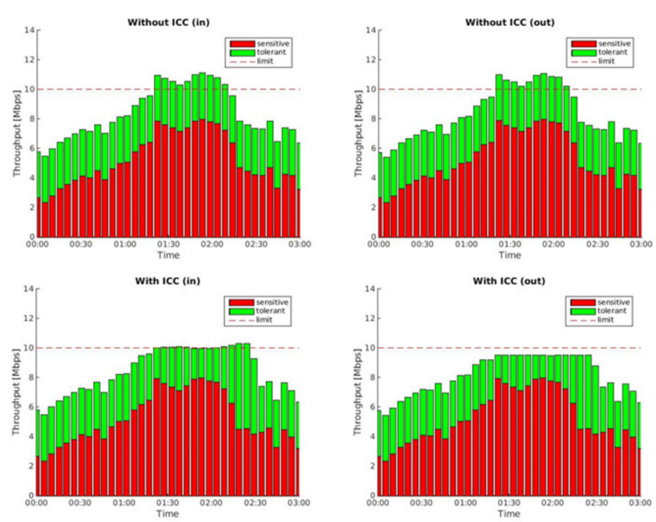


Fig. 4. 95th percentile pricing incentives for traffic shaping, sample results.

## B. *VNFaaS*

We have assessed the flexibility of the piecewise pricing functions for VNFaaS and their impact on number of instances purchased, seller profit and buyer surplus by means of numerical evaluation.

The main finding is that the seller can benefit from offering multiple utilization levels for discounted prices as consumption increases in order to maximize his revenue.

Buyers assess these offerings and select the one resulting in maximum individual surplus. We provide an example of such a numerical evaluation below, assuming 1000 buyers have random uniformly distributed demand for 1 to 10 VNF instances for a unary willingness to pay that is uniformly distributed in [1, 10].

Assuming the seller sets a unique selling price for each VNF instance we obtain the results of Fig. 5.

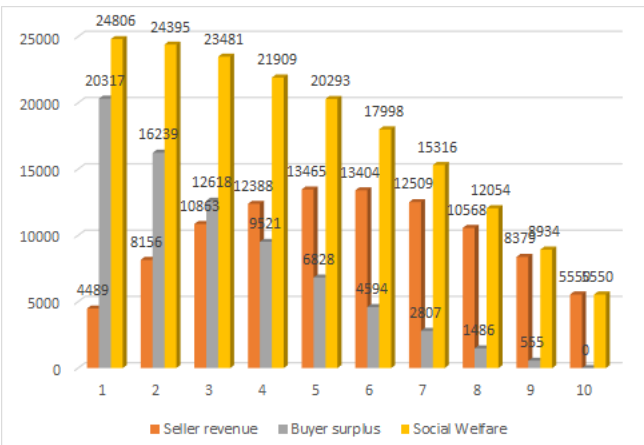


Fig. 5. Sample results for VNFaaS under a unique seller price.

The seller attains the highest revenue (13465) when the price is set to 5 by selling 569 VNFaaS instances. Social welfare is maximized, as expected, for a price equal to 1, since exclusion of buyers is not possible.

We then compare these results to the case that the seller can publish a piece-wise function for two minimum consumption levels. Then the optimal for the seller revenue is 18011 under prices (3, 7) for which social welfare is 30629 and the VNFaaS instances sold 739.

Hence, revenue and social welfare increase compared to the single price setting. Social welfare is maximized to 35976 for prices (1, 6) for which the seller revenue would be 15659.

## C. *Slice as a Service*

No assessment due to the simplicity of the pricing scheme.

## D. *Resources*

The piece-wise constant pricing scheme is assessed in the VNFaaS part of this subsection, results apply here as well.

# VI. Conclusions

We have provided in this paper an original classification of the 5G wholesale services anticipated in the 5G ecosystem and a proposal for the respective pricing schemes, their properties, challenges and potential. Our work has been motivated by existing business practices and justified by analysis, experimental evaluation and simulations.

Refining the 5G wholesale services targeting specific verticals is on-going work, also in the context of [2]. To this end, the Value Added Connectivity Services layer is currently being further elaborated so that the pricing peculiarities of specific verticals can be integrated in the 5G pricing framework proposed in this paper. Regarding pricing, dynamicity and market mechanisms aspects for the setting of the parameters of the pricing schemes comprises a promising topic for further research. Structured negotiations, supporting also agent-based negotiations over price and quality aspects of the 5G wholesale services is also on-going work. These negotiations are also part of the existing business culture in Internet connectivity services (e.g. for transit services) so integrating them in 5G is important also from a business point of view.

Overall, this paper as an important first step for specifying the 5G wholesale services and how to price then in the 5G multi-actor value chain.


# Acknowledgment

This work has been performed in the framework of the H2020-ICT-2014 project 5GEx (Grant Agreement no. 671636), which is partly funded by the European Commission. This information reflects the consortium view, but neither the consortium nor the European Commission are liable for any use that may be done of the information contained therein.


# References


[1] *5G PPP Whitepapers*, Available: https://5g-ppp.eu/white-papers/

[2] *H2020 5G PPP 5GEx project,* Available: http://www.5gex.eu/

[3] *NGMN*, Available: https://www.ngmn.org/home.html

[4] *NetWorld2020 Whitepaper on Service Level Awareness*, Available: http://networld2020.eu/sria-and-whitepapers/

[5] *FP7 ETICS Project*, Available: https://www.ict-etics.eu/home.html

[6] G. Darzanos, M. Dramitinos, H. Lønsethagen, I. Papafili, and G. D. Stamoulis, "Internet and 5G Tussles and How to Mitigate Them by Re-Engineering SPNP", EuCnC 2016.

[7] B. Briscoe, and S. Rudkin, "Commercial Models for IP Quality of Service Interconnect". In BTTJ Special Edition on IP Quality of Service, vol. 23(2), Apr 2005.

[8] *PWC*, Available: https://www.pwc.com/mt/en/publications/assets/pwc-the-future-of-software-pricing-excellence-saas-pricing.pdf

[9] *Lambda Pricing*, Available: https://aws.amazon.com/lambda/pricing/

[10] *T- NOVA D6.4*, "SLA and billing" Available: http://www.t-nova.eu/wp-content/uploads/2016/03/TNOVA_D6.4_SLAs_and_billing_v1.0.pdf

[11] M. Dramitinos and G. D. Stamoulis, "ICC: An incentive-compatible inter-cloud communication traffic management mechanism", CNSM 2015, pp. 36-42.

[12] N. Laoutaris, M. Sirivianos, X. Yang, and P. Rodriguez. "Inter-datacenter bulk transfers with netstitcher", ACM SIGCOMM. 2011


.