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# Orchestrating Softwarized Networks with a Marketplace Approach

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**Abstract**

In the last years, network softwarization is gaining increasing popularity since it allows to achieve dinamicity and flexibility in network management, stimulating a lot of interest by both academia and industry. Cloud computing paradigm together with the new networking paradigms of Software Defined Networking (SDN) and Network Function Virtualization (NFV) are supporting this evolution, by providing network services as single Virtual Network Functions (VNFs) or chains of them. The main problem is scalability of both infrastructure and management. In fact, in order to support the SDN/NFV paradigm, the Telco Operator should deploy huge data centers, which have to be geographically distributed to guarantee low latencies to time-constrained flows, and implement complex orchestration policies. To this purpose, this paper proposes to extend the SDN/NFV framework with a marketplace where Telco Operator customers behave as third-party sellers with their hardware and software resources providing VNF as a service (VNFaaS), so helping the Telco Operator in providing network services in an efficient and scalable way.


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*Keywords:* Softwarized Networks, Orchestration, Resource Management, Marketplace Model, Game Theory.

## 1. Introduction

In the last decade, the Internet has registered a tremendous increasing in capillarity and networked devices such that the current network infrastructure can hardly meet the demands of network development. In this evolution, network softwarization, Software Defined Networking (SDN) and Network Functions Virtualization (NFV) [1] have become the focus of networking research and development worldwide.

Telco Operators (TO) have shown a great interest in supporting the evolution of this network softwarization process, thanks to its advantages in realizing more flexible networks where services can be instantly monitored, controlled, billed, and managed on the fly. Key elements for the design of these systems are allocation, management and orchestration of network resources, that result more challenging as compared to scenarios of legacy networks.

In this context, the main problem stays in the difficulties in deciding how many instances using for each virtual network function (VNF), how many servers, in the following referred to as *VNF Servers*, maintaining active in the network, which servers using to host the instances of each VNF, and the amount of hardware resources dedicating in

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each server in terms of computing, storage and networking. An additional problem, referred to as the *Service Chain Composition problem*[2], is how chaining VNF instances to realize more complex network services (NSs). This choice has to be done for each flow entering the network, and taking into account the users' requirements in terms of both required quality of service (QoS) and payment availability.

It is well-known that the service chain composition problem is NP-hard[3], and many optimal and sub-optimal solutions have been proposed in the previous literature[4,5,6,7]. However, those approaches are not well-suited to dynamic scenarios where the status of the network varies in time. Furthermore, those solutions often requires perfect knowledge, a condition which might not always be satisfied, and do not consider the competitive interactions among the service providers which are selfish and profit-maximizing.

To this purpose, starting from our previous work[8], this paper proposes to introduce the concept of *marketplace* into the NFV market, where VNF provision and network orchestration are centralized by the TO (see Fig. 1). According to the marketplace definition[9], customers of the TO can participate as third-party sellers with their hardware and software resources by offering VNFs as a service (VNFaaS), so helping the TO in providing NSs in an efficient and scalable way. In addition, in order to achieve scalability also in terms of management, unlike the classical approaches that entirely concentrate the complex tasks of orchestration and resource allocation into a single entity, i.e. the *Orchestrator*, here we propose, in line with the definition of marketplace, a distributed solution to the problem, where each user finds by itself, for each of its flows, the best service chain of VNF instances that accommodate its individual requirements. In particular, we consider NFV-specific network requirements, such as the congestion level on VNF servers, the latency incurred by traffic flows, and the price charged by VNF Servers to execute VNFs.

In order to allow users to autonomously compose the VNF chain that better satisfies their requirements, we will introduce the *Network Service Broker* (NSB), an entity aimed at representing one flow or an aggregate of flows with the same QoS and price requirements, and generated by users belonging to the same portion of network, in the following referred to as *NSB Scope*. Therefore, the marketplace actors are: 1) the VNF Servers, that are the sellers of the VNFs; 2) the Users, whose flows are represented by the NSBs, and that play the role of buyers; 3) the TO that, through the Network Orchestrator, coordinates the whole system.

Servers autonomously decide the price to be applied to each VNFs. NSBs, on the other hand, in order to compose a structured NS for the flows they are in charge to manage, choose one VNF instance for each VNF of the service chain realizing the required NS, and this is done according to the price specified by each Server and the corresponding expected performance in terms of both experienced latency and provided resources. In this way the task of associating each flow to a service chain is not decided by the Orchestrator, but is obtained in an autonomous and distributed way, as a consequence of the interaction between Users and VNF Servers. This interaction is performed by way of the Orchestrator not only to exchange the needed information, but preserving privacy for all the market place participants. Interactions between Servers and Users are modeled by leveraging on the game theory. In[8], we focused on a transitory analysis of the marketplace. In this paper, instead, besides a more detailed description of the system architecture, we extend the results in[8] by presenting an efficiency analysis of the proposed solution, and a steady-state analysis of the main parameters of the marketplace model such as prices, the number of users that decide to use each VNF Server, and the achieved profit.

The rest of the paper is organized as follows. In Section 2, we describe the reference system. In Section 3, the Marketplace model is discussed. In Section 4, the numerical results are shown. Conclusions are drawn in Section 5.

## 2. Reference System

In this section we describe the reference scenario, constituted by an SDN/NFV network of a TO. A NS is realized by one or more VNFs organized in chain, according to VNF Forwarding Graph (VNF FG)[10,11]. The main system players are the Users, the VNF Servers and the Orchestrator.

According to the flow type and its importance, Users request a specific NS for each of their flows. For example, different network services can be requested for video streaming and email traffic flows. Moreover, even two video streaming flows may require different levels of QoS, according to their importance and the willingness of the customers to pay no more than a given price.