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Dynamic function composition for network service chain: Model and optimization

Peng Wang*, Julong Lan, Xiaohui Zhang, Yuxiang Hu, Shuqiao Chen

National Digital Switching System Engineering and Technological Research and Development Centre (NDSC), Zhengzhou, Henan 450000, China

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ABSTRACT

Current Internet has been unable to adapt to evolving diverse service requirements due to its inflexibility and complexity. Network service chain (*NSC*) which can promises increased flexibility and cost efficiency for future networks, has received considerable attention lately. However, the realization of *NSC* in current Internet faces severe challenges. The appearance of Software Defined Networking and Network Function Virtualization makes the realization and deployment of *NSC* possible. A key feature in NSC-Enabled networks is the capability of dynamic composing service functions into complex services. In this paper, we investigate model and optimization of dynamic function composition problem. We have developed a combinatorial optimization model to describe the resources and components of dynamic function composition, and proposed a distributed algorithm using Markov approximation method. Performance evaluation demonstrates that our algorithm is effective, scalable and cost-efficient, compared to traditional algorithms.

1. Introduction

The current Internet has gained tremendous success in providing simple data communication service [1]. However, it also shows its inherent shortcomings of being unable to flexibly adapt to increasingly diverse systems, protocols, and communication paradigms [2,3]. Especially, it is hard to introduce new network functions because of the inflexible and ossified structure of the Internet. To patch this deficiency, lots of middleboxes (e.g., firewalls, DPI, load balancer, etc.) have been introduced into the data path inside networks. In this context, typical service chains require a packet to traverse a sequence of middleboxes [4]. Middleboxes have extended the functionalities of the Internet to certain extent. However, the functionalities of these middleboxes must be carefully crafted to operate transparently with other devices. Moreover, once a network service is defined, little can change. In addition, deployment of specialized hardware devices for each new customization function is very expensive and does not scale. In short, the whole network is purpose-built and optimized for a few static services [5].

The current networking and Internet service models have been unable to accommodate novel network uses and functional requirements [6]. Moreover, these network uses and functional requirements are diverse and time-varying. Hence, the future Internet should be able to flexibly adapt to support evolving service and emerging networking paradigms. The appearance of SDN [7] and NFV [8] makes the realization of the above demands possible. NFV advocates distinguishing logical functions from physical resources and virtualizes multiple function blades through resource isolation. SDN emphasizes on decoupling of network control plane and data plane, moving the control functions of the network behavior to the third party software running on centralized controllers. The introduction of SDN and NFV enables flexible allocation, orchestration and management of network functions and services, and provides the substrate for network service chain (NSC). Achieving these benefits of

* Corresponding author. Tel.: +860371632821.
E-mail address: wangpeng.ndsc@gmail.com (P. Wang).

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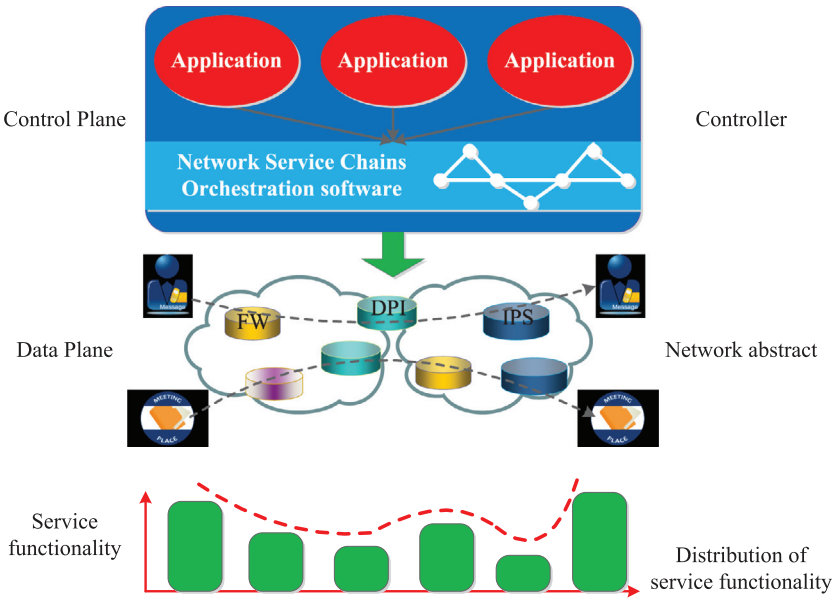

Fig. 1. Network service chain architecture.

SDN and NFV needs to carefully craft NSC to steer traffic through the desired sequence of service function instances.

Fig. 1 shows an abstract *NSC* architecture. Firstly, the *NSC* orchestration software gets a particular application requirement and it parses the requirements into a sequence of service function abstractions (*SFA*s) such as load balancing, content inspection, transcoding, etc. Then, the *NSC* orchestration software needs to select an appropriate service function instance (*SFI*) for each service function abstraction because there are various service function instances which may have different service capabilities, performances and costs. However, there still are not better means to optimally and dynamically decide the appropriate service function instances at runtime, that we called dynamic function composition problem. It is also our research target.

The rest of the paper is organized as follows. First, in Section 2 we briefly review the related works. Afterwards, we state the problem and propose our dynamic function composition model in Section 3. In Section 4 we propose a distributed function composition algorithm using Markov approximation method. Section 5 shows the experiments and Section 6 concludes the paper.

2. Related works

NSC has become one of the most promising applications of SDN and NFV. With the extensive deployment and application of SDN and NFV in data centers and clouding computing, *NSC* will present more and more important value. As an emerging research topic in SDN/NFV, research questions about *NSC* include *NSC* orchestration languages, optimization strategies for function composition, enforcement of policies, and security. Currently, the research on orchestration languages and enforcement of policies has made some progresses. Some network programmer languages such as Pyretic [9] and Maple [10] have been proposed to implement network functionality through controlling the flow of the data plane in a programmatic manner. In [11], the authors proposed to map arbitrary functions, which cannot be directly realized on physical switches, into policies, and a method to handle such policies. In [12], SIMPLE has been proposed to address challenges related to mapping towards physical resources and controller visibility into the functionality exposed by a middlebox. However, how to compose network service chain optimally and dynamically is still an open question. Especially, how to implement dynamic function composition based on network state and application requirements appears very promising, but has no answer at present.

The idea of function composition comes from web service composition which integrates an existing set of services into more complex service. Currently, many projects have been focusing on functional composition, and some proposals have been presented. Early approaches such as configurable protocol stacks [13] and protocol heaps [14] mainly concentrate on how to design and compose the protocol stack at the edges of the Internet. With further research on future Internet, a broader scope where services within networks have been also considered. In [15], the SILO architecture has been presented to realize fine-grained protocol functions by composing different functionalities. A simplistic composition approach which is proposed in [16] for SILO architecture is a recursive method based on pre-defined precedence constrains of services. Different from the SILO, NetServ [17] concentrates on the implementation of a content distribution network (CDN) enabled by additional services implemented on top of the Click Router [18]. In addition, there are many other researches related to the idea of functional composition [19–24]. However, these works do not delve into how to dynamically compose service function to a significant extent.

In the aspect of web service composition, researchers have proposed many methods to compose web services. The