Assignment of Virtual Networks to Substrate Network for Software Defined Networks

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ABSTRACT

Assigning multiple virtual network resources to physical network resources, called virtual network embedding (VNE), is known to be non-deterministic polynomial-time hard (NP-hard) problem. Currently software-defined networking (SDN) is gaining popularity in enterprise networks to improve the customizability and flexibility in network management service and reduced operational cost. A central controller in SDNs is an important factor that we need to take care of when we want to assign virtual networks to physical resources. In this work, we address virtual network embedding problems for SDNs. Indeed, our objective is to propose a method to assign virtual networks in the substrate network with minimum physical resources, and also minimizing delays between the virtual network controller and the switches in the virtual network. Our proposed algorithm considers the link and node constraints such as CPU and bandwidth constraints which is necessary to consider when we try to solve virtual network embedding problems.

KEYWORDS

Breadth-First Search (BFS), Network Hypervisor, Network Virtualization, Resource Allocation, Software-Defined Networking (SDN), Virtual Network Embedding

1. INTRODUCTION

The Internet has been a great success in the past years. Todays, the size of Internet makes the deployment of new network technology difficult (Peterson, Shenker, & Turner, 2004; Taylor, & Turner, 2004). Among several solutions, network virtualization provides an efficient way to address the conformity of the Internet (Peterson, Shenker, & Turner, 2004). And it is promoted as a powerful tool to diversify the future Internet by running multiple network services concurrently on a shared substrate network (Anderson, Peterson, Shenker, & Turner, 2004; Bavier, Feamster, Huang, Peterson, & Rexford, 2006). Therefore, as a long term solution for the future of Internet, network virtualization may play a vital role to support numerous architectures (Feamster, Gao, & Rexford, 2007). Network virtualization consists of leasing and sharing the Substrate Network (SN) infrastructure between several Virtual Networks (VN), with the aim of increasing the profitability of the physical resources.

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Beside virtual network embedding technology, software-defined network is another technology that has received a great deal of attention recently. Software-defined network (SDN) is a promising technology that separates the control plane and data plane in networks (Voellmy, Wang, Yang, Ford, & Hudak, 2013). By separating the control plane from the data plane, switches become data forwarding devices; while network management is controlled by logically centralized servers. SDN facilitates network experimentation, and allows for optimizing routing policies. It has shown a lot of advantages in simplifying network management. For example, network administrators have central programmable control of network traffic via controllers (Voellmy, Wang, Yang, Ford, & Hudak, 2013). OpenFlow (McKeown et al., 2008) was proposed as an interface between the control and data planes in SDN. It defines the low-level packet forwarding behaviors in the data plane. Developers can program the network from a higher level without concerning the lower level detail of packet forwarding and processing in physical devices.

To be more clear, from the control network architecture, a control network can be implemented either for an in-band or for an out-of-band (Zhong, Wang, Qiu, & Li, 2016). In a SDN environment, each switch communicates with its controller via a TCP connection over a secure channel such as standard Transport Layer Security (TLS). In-band control uses the same links for both the control and data traffic. It makes the network simpler; however, the network security would be low relatively. Out-of-band control uses separate infrastructure either physical or logical to connect forwarding devices to the controller, but it suffers from the extra cost of additional hardware. Figure 1 shows in-band control network (Figure 1.a), and out-of-band control network (Figure 1.b). We utilize the in-band control network when embedding the virtual networks. This makes to consider both data and control traffic together in the term of bandwidth requirement for a virtual SDN network.

The most important concepts of SDN are network function virtualization and control plane abstraction (Wang, Zheng, Lou, & Hou, 2015). The control layer in SDNs can take any topology, consists of a star, where a single controller manages the network; a ring which composed of a set of controllers that are managed using a distributed hash table; or even a hierarchical architecture, where controllers are connected creating a mesh network. Each one of these control layer topologies has circumstantial limitations. However, regardless of the topology, there are some general aspects, such as the distance among controller-switches and the workload on each controller, that affect the ability of the controllers to respond to network events (Wang, Zhao, Huang, & Wang, 2017).

One of the major functions of network virtualization is the assigning or mapping of substrate network resources to individual virtual network nodes and links. Allowing virtual networks to be assigned to the substrate network efficiently is desirable for increasing efficiency in the substrate resource utilization.

Figure 1. (a) Separate network for control and data traffic (Out-of-band control network). (b) Same network for both control and data traffic (In-band control network).
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