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Towards Provisioning Hybrid Virtual Networks in Federated Cloud Data Centers

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Abstract: Network virtualization is an efficient way to enhance the resource utilization of physical network. It enables numerous heterogeneous virtual networks (VNs) coexist and share the resources of same physical network. Virtual network provisioning has been a key issue in network virtualization. Since the optimal virtual network provisioning is an NP-hard problem, existing studies devote to propose heuristic approaches for a tradeoff between computational complexity and the quality of VN provision. A traditional physical/substrate network usually sustains numerous infrastructure providers (InPs), and many applications in the substrate network can be characterized by hybrid virtual network which composed by both unicast and multicast virtual network. However, few research has conducted for the problem of hybrid virtual network provisioning (HVNP) among multiple domains. In our research, we model the HVNP problem through integer linear programming (ILP) for minimizing provisioning cost. Furthermore, we propose two effective algorithms to address the researched problem: *i*) the decomposition-based algorithm, HVNP_D; and *ii*) the spectral clustering based algorithm, HVNP_SC. Extensive simulation experiments have been carried out to assess the proposed algorithms. Simulation results demonstrate that our approaches have better performance than existing approach.

Key Words: Hybrid virtual network; provisioning; cloud computing; data center

1 INTRODUCTION

Cloud computing has emerged as an important paradigm which enables convenient on-demand access to shared configurable computing resources pool through Internet. In cloud computing, software (applications, databases, or other data), infrastructure and computing platforms are used as services for data storage, management and processing [1,2]. Network virtualization (NV) is an efficient paradigm and key enabler to enable heterogeneous networks coexist on and share the physical network [3-4] of cloud computing. For virtualizing a network, physical resources (i.e., network nodes and links) usually can be sliced as virtual resources to allow users to use them on demand. This paradigm makes the resource utilization more efficient and enriches the diversity of network applications to meet different requirements from users. In network virtualization, a user's request usually is abstracted as virtual network (VN), in terms of a collection of virtual links and virtual nodes. A virtual node demands a specific quantity of resources (e.g., disk, memory or CPU) form physical node and each virtual link requires a specific amount of physical link resource (i.e., bandwidth). Thus, efficiently provisioning virtual networks in physical network while satisfying the quality of service (QoS) requirements (e.g., node and link resource requirements, transmission delay or reliability) is a significant and urgent issue needs to be addressed [5-8].

Due to numerous VNs coexist and share the same underlying network, designing an efficient strategy for deploying VNs to physical network gives benefits to both network providers and users. Specifically, it is beneficial for increasing the revenue of network provider, reducing the operation cost of VN and improving the quality of experience (QoE) of users. However, the virtual network provisioning has always been a NP-hard problem [9]. Therefore, efficiently mapping VNs on substrate network has become very challenging.

According to their characteristics, VNs can be classified into three main categories: multicast service oriented VNs (MVNs), unicast service oriented VNs (UVNs) and hybrid VNs (HVNs) [10,11]. Where, an HVN request composed by UVN and MVN requests, thus it has the characteristics of both UVN and MVN requests.

Most existing studies focus on mapping either unicast or multicast services oriented virtual networks onto a physical network [3,12-21]. However, a large number of real applications can be abstracted as HVNs. For example, an HVN can be used to provide video conferencing service, information service, live events and competitions discuss services to users. These services have intrinsic features of both unicast and multicast services. Moreover, these HVNs need to be mapped onto infrastructures to meet the location constraints. There are two main constraints in the multicast network application: (*i*) the transmission delay of all the multicast link must satisfy the transmission delay constraint of a user; and (*ii*) the delay variations should not exceed a certain threshold [14], since delay and delay variations may affect the performance of services (e.g., online games and online conferences).

Furthermore, a physical/substrate network usually composed by multiple domains owned by different infrastructure providers (InPs) [4,22,23]. Usually, in multiple-domain environment, the information on topology and resources is not shared among InPs. Therefore, the virtual network provisioning problem in multiple domains becomes more challenging than that in single domain.

In our research, we focus on the issue that hybrid virtual network provisioning (HVNP) across multiple domains in cloud computing. We first formulate the researched problem by using integer linear programming (ILP) to minimize the provisioning cost. Since optimal virtual network provisioning is an NP-hard problem [15], we design two efficient approaches for addressing the researched HVNP problem: *i*) a decomposition-based algorithm, HVNP_D, in which a HVN request is decomposed into a UVN request and MVN request, and then perform the provisioning process; and *ii*) a spectral clustering-based algorithm, HVNP_SC, which divides the HVN request as