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Survivable provisioning for multicast service oriented virtual network requests in cloud-based data centers

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ABSTRACT

Network virtualization technology plays an important role in cloud-based data centers that serve as an effective method for provisioning a flexible and highly adaptable shared substrate network to satisfy the demands of various applications. Although there has been some work on efficient mapping of unicast service oriented virtual networks there has been very limited work on addressing the problem of efficient mapping of multicast oriented virtual networks. Furthermore, how to guarantee survivability of multicast service oriented virtual network request has not been studied.

In this work, we investigate the survivable multicast service oriented virtual network mapping (SMVNM) problem and propose an efficient algorithm for solving this problem. We first formulate the SMVNM problem with the objective of minimizing mapping cost by using mixed integer linear programming. We then design an efficient algorithm to solve this problem since it is NP-hard. We validate and evaluate our framework and algorithms by conducting extensive simulations on different realistic networks under various scenarios, and by comparing with existing approaches. The simulation results show that our approach outperforms existing solutions.

1. Introduction

Cloud computing is a new paradigm that has attracted wide attention from academics and the industry due to its flexibility and efficiency in network provisioning. Cloud computing services and applications are commoditized and delivered in a manner similar to traditional utilities such as water, electricity, gas, and telephony [1]. In cloud computing, multiple geographically separated servers or server clusters interconnected by a physical network constitute the cloud infrastructure (data centers). Optical network works as the best choice for the physical network because of its advantages of high speed, transparent transmission and abundant bandwidth resources [2,3]. Users can access applications or services and infrastructure resources provisioned by cloud-based data centers using thin clients without knowing the actual location and characteristics of the resources, or how they are delivered. Infrastructure as a service (IaaS), software as a service (SaaS) and platform as a service (PaaS) are the three main categories of cloud computing service models. IaaS is a service provisioning model in which an infrastructure provider (InP) typically owns and leases substrate network resources to support various operations using a usage-based pricing model. The service provider (SP) rents resources from one or many InPs to serve the end users. More specifically, the SPs instantiate virtual machines (VMs) on demand for the purpose of running users tasks

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or applications. VMs which are hosted on hundreds of thousands of interconnected servers in multi-data centers allow the isolation of applications from the underlying hardware and other VMs, and the customization of the platform to suit the needs of the end-user. Today an increasing number of applications such as web service, large-scale simulation, high-performance computing and virtual labs have been deployed in cloud-based data centers [4]. Some examples of commercial cloud computing products include Amazon's Elastic Compute Cloud (EC2) [5], Microsoft Windows Azure platform [6], Google App Engine [7] and Yahoo! Data centers [8].

Virtualization or network virtualization in particular works as a key technology and enabler for cloud computing [9]. A network virtualization environment (NVE) [10,11] consists of a shared infrastructure (i.e., substrate network) and virtual network (VN) requests. The service or application request submitted to a cloud-based data center can be abstracted as a VN request, which consists of a set of VN nodes and VN edges. Each VN node requires a certain amount of node resources such as CPU, memory storage resources for executing the applications, and each VN edge requires a certain amount of communication bandwidth for the purpose of data and information exchange between the VN nodes. Multiple or multi-data centers are spread across multiple geographical locations and are interconnected with a network to constitute the infrastructure (i.e., substrate network), where each substrate node possess a certain amount of node resources and each substrate link possess a certain amount of bandwidth resources.

Multiple VN requests may be hosted on the same substrate network for sharing the substrate resources. An efficient cloud resource allocation strategy that intelligently uses the resources of the substrate network is important to both customers and InPs. How to efficiently map or embed a VN request onto the substrate network resources is a challenging problem in network virtualization.

Most existing work on the problem of VN provisioning only consider the case of unicast service oriented VN requests, and accordingly aim at designing efficient provisioning strategies for such VN requests. However, in many widely used applications such as video conferencing, online games and distributed database replication, the users' requirements on substrate resources can be abstracted as multicast oriented virtual network requests, wherein a data source sends data to a group of predefined destinations. Thus, a multicast virtual network (MVN) has a tree-like topology with a source node at the root and destination nodes at the leaves of the tree. In real world applications multicast service oriented virtual network requests have two important constraints: the delay constraints on VN edges and the location constraints of VN nodes. Therefore, in this work, we consider the delay constraint of each VN edge while mapping and routing it on the substrate links, as well the constraint on locations of each VN node while mapping it onto a substrate node while provisioning an MVN request. Furthermore, due to the shared nature of network virtualization, even small failures in the substrate network will interrupt a large number of MVN requests hosted on it. As an important issue, survivability of optical (WDM) network has been studied for many years [12–14]. Therefore, how to guarantee the operation of a mapped MVN request even when there are failures in the substrate network failing is a challenging problem in MVN provisioning. In this work we also study the problem of how to optimally provision MVN requests while considering their survivability, i.e., the survivable MVN provisioning (SMVNP) problem. We formulate the survivable MVN mapping problem as a mathematical optimization problem by using mixed integer linear programming (MILP). Our optimal problem focuses on minimizing the MVN mapping cost while satisfying all of the resource requirements and constraints. Since the optimal VN embedding or mapping problem is NP-hard [10], we propose heuristic algorithms for solving the MVN provisioning problem efficiently. We evaluate the performance of our heuristic by conducting extensive simulation experiments under various scenarios.

The remainder of this paper is organized as follows. Section 2 discusses the related works. We give the detailed MVN problem description in Section 3. In Section 4 we formulate the MVN problem using MILP. Section 5 presents an efficient heuristic algorithm for solving this problem. The simulation environment and simulation results are given in Section 6. Section 7 concludes the paper.

2. Related works

In this section, we describe recent research related to network resource provisioning in cloud computing and the problem of virtual network mapping.

2.1. Resource provisioning in cloud computing

Due to the popularity of cloud computing, there has been a large amount of research on resource provisioning in cloud computing or data centers. Two resource provisioning algorithms that aim at minimizing the workflow execution cost while meeting the deadline for deadline-constrained workflows in cloud computing have been proposed in [15]. The works in [16–18] consider energy consumption in data centers, and propose techniques for saving energy consumption in cloud-based data centers while fulfilling resource provisioning without violating quality of service (QoS) or service level agreements (SLAs). The authors in [19,20] have studied the problem of resource provisioning for a specific type (i.e., elastic applications and real time applications) of application across multiple infrastructure providers in cloud or cloud-based data centers. Aouna et al. [21] have proposed efficient network resource abstraction algorithms for network resource providers to share their network topologies without exposing the details of the underlying physical resources, for addressing the issues of confidentiality and scalability in cloud computing.

2.2. Virtual network provisioning

Network virtualization is one of the primary building blocks and promoters of cloud computing. There has been a significant amount of research on network virtualization and techniques for virtual network mapping due to the increasing popularity of cloud computing. Most recent