

Virtual network embedding through node connectivity

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Abstract

Virtual network embedding (VNE) is an essential part of network virtualization, which is considered as one of the most promising way for the future network. Its main object is to efficiently assign the nodes and links of a virtual network (VN) to a shared substrate network (SN). The NP-hard and exiting studies have put forward several heuristic algorithms. However, most of the algorithms only consider the local resource of nodes, such as CPU and bandwidth (BW), to decide the embedding, and ignore the significant impact of network attributes. Based on the attributes of entire network, a model of the connectivity between each pair of nodes was formulated to measure the resource ranking of the nodes, and a new two-stage embedding algorithm was proposed. Thereafter, the node mapping and link mapping can be jointly considered. Extensive simulation shows that the proposed algorithm improves the performance of VNE by increasing the revenue/cost ratio and acceptance ratio of VN requests while reducing the runtime.

Keywords virtual network virtualization, VNE, attributes of entire network, connectivity

1 Introduction

To overcome the developmental impediment of the current internet, the network virtualization was proposed as one of the primary attributes of the future network paradigm [1–2], it supports multiple VNs running on the shared physical SN simultaneously [3–4]. Each VN is composed of virtual nodes and links with a virtual topology. Thus, in a network virtualization environment, the traditional internet service providers (ISPs) is replaced by two market participants: the infrastructure providers (InPs), who build and manage the SNs, and service providers (SPs), who deploy different VNs dynamically to offer multiple services for the end-users or business users without the limiting condition in the current Internet [5].

The VNE problem is a main challenge to resource management in network virtualization, its purpose is to allocate the VN resources, including nodes and links onto the physical substrate. Hence, the VNE can be separated into two phase: virtual node mapping stage, where assign

the virtual nodes to the substrate nodes, and virtual link mapping stage, where the virtual links are mapped onto substrate links connecting the former selected substrate nodes after the node mapping [5]. The allocation should be realized in an optimal way to improve the resource utilization while satisfying the constraints of both nodes and links in VNs.

The VNE problem is NP-hard with the constraints of nodes and links. Early researchers restricted to find heuristics solutions [6–9]. Most of them divided the VNE problem into two independent phases. First, the virtual nodes are mapped according to the local resource ignoring their network attributes. In the second phase, the virtual edges are mapped based on shortest path algorithms. However, the network attributes (i.e., distance and available BW between nodes) have significant influence on the performance of VNE algorithms, since the state of network determine the connectivity of the nodes in a network. And it will make sense to consider the attributes of both nodes and links in VNE problem.

This article corporately considered two phases, node and link mapping, by measuring the importance of the nodes in entire network, which means the whole network topology,

before node mapping. Since the VNE problem is based on the central control system, it is easy to gather the information of network attributes. The article models the connectivity between each pair of nodes in network according to the shortest path determined by both distance and available BW, rather than only consider the distance in traditional ways. We devise a new VNE algorithm to achieve efficient utilization of physical resource.

In VNE problem, if a node is easier to establish connection to the other nodes while satisfying the constraints of BW, this node should be considered more important in the network and be selected to map preferentially, which would be helpful to the following link mapping. Based on the attributes of entire network, we can work out the nodes which are more likely to establish connection to other nodes with the constraints of BW satisfied.

Different from previous solutions, not only the local resource of nodes, such as CPU and connected links resource, but also the entire topological attributes, including link information and the resource of other nodes in network, are taken into consideration to measure the importance of a node in node mapping, which would improve the success and efficiency of VNE algorithm. A new two-stage VNE algorithm was devised, which sort the nodes in both VN requests and SN firstly considering the attributes of the entire network. In node mapping stage, virtual nodes are assigned to the substrate nodes according to the node rank. In the second stage it maps the virtual links by using the k -th shortest path algorithm.

The major contributions the authors devote are summarized as follows:

- 1) According to the shortest path determined by both distance and available BW, a model of the connectivity between each pair of nodes is formulated to measure the resource ranking of the nodes.

- 2) A two-phase VNE algorithm is devised based on the attributes of entire network.

- 3) A VNE simulator model is developed to evaluate the proposed algorithm. Compared with three representative existing algorithms, the results show that our algorithm get better performance. Both the acceptance ratio of VN requests and average revenue are higher while decrease the cost of physical resource. And even the runtime of the algorithm is saved.

The remainder of this article is organized as follows. Sect. 2 reviews the related work briefly. Sect. 3 presented

the network model and defines the VNE problem. In Sect. 4, we introduce the method to measure the resource ranking of nodes based on the entire network attributes. The new VNE algorithm was presented in Sect. 5. In Sect. 6, we evaluate our algorithm using a developed simulator. And Sect. 7 gives conclusion.

2 Related work

The VNE problem is NP-hard, even if some of the constraints are ignored. Early researchers restricted the problem space in heuristics solutions which only consider the link constraints by setting that the virtual nodes are assigned to the substrate [6–9]. Some work addressed the problem in an offline condition [7,9], where the VN requests are known in advance, or without performing admission control while the physical resource is deficient. An online algorithm, considering the constraints of both nodes and links by introducing a mechanism with admission control, was proposed in Ref. [10], which assumed the substrate support path splitting. All the studies above addressed the VNE problem by considering the local resource of nodes, which made the node mapping and link mapping isolated.

Cheng et al. [11] introduced a Markov random walk (RW) model to measure the topological attributes of nodes in node mapping stage by considering not only the local resource of a node but also the quality of its neighbor nodes, which didn't study the attributes of links in network.

Wang et al. [12] proposed VNE algorithms by using closeness centrality analysis to characterize the nodes in a network, which select the shortest path only by the distance in a traditional way and may malfunction if the constraints of links are not satisfied.

Liu et al. [13] presented the proximity principle in VNE problem which consider the distance factor during the node mapping. To reduce the BW cost in link mapping stage, virtual nodes are preferentially allocated onto physical nodes that are directly connected, which consider the hops as the only factor of distance between each pair of nodes in VNE problem.

Chowdhury et al. [14], assuming that the physical substrate supports path splitting, proposed a mixed integer program model for VNE problem through augmenting SN. They relax the constraints and use rounding model to obtain the linear formulation. However, the rounding

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