On the Impact of Physical Network Topologies on Virtual Network Embedding

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Network virtualization is a mechanism that allows the coexistence of multiple heterogeneous virtual networks (VNs) sharing resources of the same physical network. The architectures, protocols, and topologies used in these VNs are unconstrained by the physical network on which they are instantiated. Through network virtualization, Infrastructure Providers (InPs) are able to easily allocate and deallocate virtual networks with proper resource isolation.

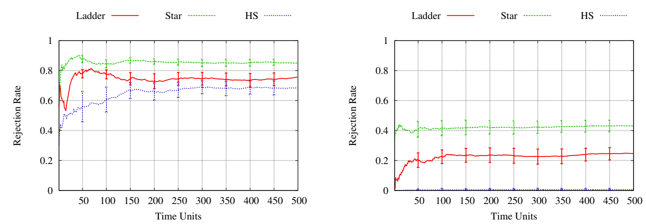
One of the major research challenges in network virtualization is the efficient mapping of physical resources to virtual networks (VNE – *Virtual Network Embedding*). The resource mapping process must consider the capacities of physical network devices, as well as the demands of virtual networks (for instance, virtual link bandwidth and processing capacity of virtual routers). Although previous work explores the problem of online virtual network embedding [1]–[3], considerably high rejection rates are commonly observed (as high as 53%).

Despite efforts to solve the virtual network embedding problem, we were not aware of previous attempts to investigate the influence of physical network topologies in the process of virtual network embedding. Moreover, previous work in this area has considered topologies that often do not reflect those observed in commercial networks [4]. Understanding the relationship between the employment of different network topologies and the mapping process is important to determine how certain topological features influence this process.

In this abstract, we characterize the impact of different classes of topologies typically employed in commercial infrastructures on the quality of the virtual network embedding process. This characterization was performed by means of the formalization of an optimal virtual network embedding model and its evaluation on physical networks with different types of topologies, namely *star*, *ladder* and *hub & spoke*. The interested reader may refer to [5] for details about the work.

To perform the experiments, we adopted a strategy in line with related work, such as the ones conducted by Yu *et al.* [1]. Like them, we relied on time units and distribution models for the arrival and duration of requests. We developed a virtual network request generator, which is run for a period of 500 time units for each experiment. Two scenarios were evaluated on each physical topology. The distinctive feature of each scenario is the presence or absence of location requirements.

We analyze the rejection rate of virtual networks requests in the previously mentioned scenarios. Virtual network requests are only rejected if it is not possible to map all of its routers and links on the physical network. Figure 1 depicts the average rejection rate in each scenario. Each point on the graphs represents the average rejection rate since the beginning of the experiment until the current time unit. It is clear that when location requirements are considered, rejection rates are substantially higher (ranging from 65.38% to 83.71%) in all three physical topologies, in comparison to scenarios with no such requirements (in which rejection rates range from 0% to 41.32%). This behavior is influenced by the reduction in the exploration space of feasible solutions caused by the presence of location constraints. The graphs depicted in Figure 1 also reveal that there is considerable difference in rejection rates when using different physical topologies. *Hub & spoke* networks lead to a lower rejection rate in comparison to other topologies in both evaluated scenarios (68.44% in the scenario with location requirements and 0.53% in the scenario without such requirements). In contrast, *star* topology networks lead to the worst performance (rejection rate of 85.04% in the scenario with location requirements and 43.10% in the scenario without location requirements). *Ladder* topology networks present rejection rates of 75.63% and 24.66% for the scenarios with and without location requirements, respectively.



(a) Scenarios with location requirements.

(b) Scenarios without location requirements.

Fig. 1. Average percentage of rejected requests in all experiments.

The obtained results evidence the significant impact caused by embedding virtual networks on physical networks with different topological features. The ability to embed virtual networks is strongly influenced by the connectivity degree of the physical network. The embedding process is hindered by resource depletion in some specific points of the physical infrastructure, although a global view of the network reveals that there are still resources available in the remainder of the physical network. This impact is even more expressive when the embedding model considers location requirements of virtual networks.

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