Defragmenting the Cloud

Oliver Michel (student), Eric Keller
{oliver.michel, eric.keller}@colorado.edu

Network virtualization is a widely used technique to enable a more dynamic infrastructure in the context of datacenter networks. Being a corner stone of cloud computing, virtual networks (VN) provide an abstraction that makes tenant networks more elastic by allowing them to add, remove, expand, or contract virtual networks dynamically. Performing these operations frequently tends to introduce fragmentation in the underlying substrate. This is analogous to fragmentation in a file system where files are not laid out in contiguous physical blocks of the storage device. In this work, we propose leveraging virtual network migration techniques to defragment the network. We see three key challenges that we are working toward:

1. Expanding and Contracting Virtual Networks. We built a simulation framework which manages a substrate network and is capable of adding, extending, removing, and contracting (virtual) tenant networks. We are running different versions of the VINE virtual network embedding (VNE) algorithm [2]. In order to design a defragmentation algorithm however, it is necessary to move virtual resources within a substrate. Toward the realization of this essential operation, we modified the VINE linear programming formulation and embedding algorithm to allow for expansion (and contraction) of already embedded virtual networks.

2. Fragmentation Metrics. Using this framework, we are currently studying different metrics to quantify fragmentation. A decreasing VN acceptance rate when the combination of available resources would technically suffice to accommodate the requests can be a signal for fragmentation in the network. Also, observing unnecessarily long virtual paths through the network (*i.e.,* an unbalanced ratio between virtual and physical hop counts of a path) is a clear indication for a fragmented network. An example of this condition is depicted in figure 1.

3. Heuristics for Defragmentation. While we can use live migration technology for entire networks (proposed in [1]), as a first step toward an actual network defragmentation algorithm, we need heuristics telling us when to trigger a defragmentation operation. Secondly, a defragmentation algorithm must propose a new (defragemented) VN assignment that optimizes fragmentation metrics as illustratively shown in figure 2. However, even with a computed, new, and defragemented network configuration, it remains a challenge to transition to this new state. In particular, it may become necessary to move a VN to a resource that is already occupied, such that effectively a swap operation using temporary resources becomes inevitable.

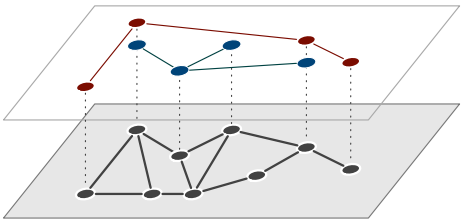

Figure 1: Fragmented Network

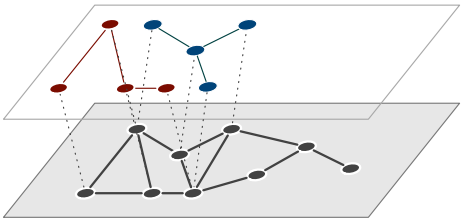

Figure 2: De-Fragmented Network

After all, in this poster, we would like to present our initial findings, particularly different fragmentation metrics, our network expansion algorithm, as well as first thoughts on heuristics for actual network defragmentation. We believe this work is highly relevant to the field of cloud computing as it may directly benefit a cloud provider's profit by being able to accept more VN requests and sharing physical resources in a more economical way.

References

[1] Keller, E., Ghorbani, S., Caesar, M., and Rexford, J. Live Migration of an Entire Network (and its Hosts). In *Proceedings HotNets 2013.*

[2] Chowdhury, M., Rahman, M.R., and Boutaba, R. ViNEYard: Virtual Network Embedding Algorithms With Coordinated Node and Link Mapping. In *IEEE/ACM Transactions on Networking Vol. 20 No. 1.*