CS854 Project Proposal: Virtual Network Embedding Across Multiple Domains

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Motivation

Embedding of virtual network (VN) requests from different service providers (SPs) onto underlying network resources is a basic challenge in the network virtualization environment (NVE) [2]. However, the VN embedding problem, with constraints on both virtual nodes and virtual links, is known to be $\mathcal{NP}$-hard. Several heuristics [6, 3] have been proposed to address this problem in the single infrastructure provider (InP) scenario.

However, in realistic settings, end-to-end VNs must be provisioned across heterogeneous administrative domains belonging to multiple InPs to deploy and deliver distributed network services. Even the most simplified version of the problem has at least the following stages:

1. Partitioning of VN requests among multiple InPs
2. Establishing inter-connection between the parts embedded onto different InPs' infrastructure
3. Embedding each part in a single InP administrative domain

Therefore, a solution to the cross-domain VN embedding problem must consider the following phenomena/requirements:

1. **Framework for resource trading:** In order to create geographically distributed end-to-end VNs, SPs must contact multiple InPs with available resources in those regions. One way is to establish individual agreements to put together a solution that will satisfy the constraints of all the concerned parties. But such a solution can be cumbersome as well as inefficient. In order to enable free trading and fair pricing, a framework is required that will enable SPs and InPs to communicate and partition VN requests among possible InPs. Such a framework can be distributed without the presence of any arbitrator between the requester SP and the provider InPs, as well as a centralized one.
2. **Tussles between parties with contrasting utility functions:** All the SPs and InPs are selfishly concerned about maximizing individual utility functions. Consequently, two major classes of contentions can arise:
   (a) *Between InPs:* Each InP will be interested in getting as much of the deployment as possible put on its equipment, and then optimizing allocation under given constraints. In addition, InPs will be more interested in getting requests for their high-margin equipment while offloading unprofitable work onto their competitors.
   (b) *Between SPs and InPs:* SPs are also interested in getting their requirements satisfied while minimizing their expenditure. Contentions might arise between SPs and InPs when each party try to optimize their utility functions.

3. **Interactions between heterogeneous parties:** Heterogeneity is a key characteristic of the NVE. Each InP can implement heterogeneous management, control, and data planes. In order to allow instantiation of cross-domain VNs, interfaces between adjoining InPs must be defined and agreements must be established. The defining force here will be the policies and agreements between multiple InPs.

4. **Complexities and fallouts of intra-domain VN embedding:** In case of inter-domain VN embedding, effects of intra-domain VN embeddings are not necessarily contained within the InP, i.e., intra-domain embeddings are not necessarily *mutually exclusive*; embedding inside one InP can still affect the rest even though there are regulatory policies in domain boundaries between the participating InPs.

5. **Concerns on information sharing between multiple InPs:** Intra-domain VN embedding algorithms assume that they have a complete picture of the substrate network. However, in the inter-domain VN embedding problem this may not be a reasonable assumption. InPs, in this case, might not be interested in sharing their topologies and other information with their counterparts. Each InP will have to embed a particular segment of the VN request without any knowledge of how the rest of the VN request has already been mapped or will be mapped.

Objective

The objective of this project is to develop a distrbuted framework/protocol for inter-domain VN embedding with minimal information sharing under the following assumptions and considerations:

- We will not concern ourselves with any game-theoretic analysis of contentions between competing parties. This decision stems from the experience described in [5] on applying game theory to inter-ISP route negotiation problem (which, as we understand, is similar to our problem at some level).
- Concepts from previous work on identity management framework in the NVE [4] can be used as a model for designing the proposed framework.
- Once a framework is established, VN embedding across multiple domains will be regulated by policies and agreements [2] between different parties to establish a negotiation based embedding mechanism.

Milestones

Our current research plan includes the following milestones -

- Survey existing literature on (i) intra-domain VN embedding, (ii) multi-domain resource provisioning, (iii) policy-based routing, (iv) inter-ISP route negotiation, and (v) inter-AS relationships.
- Formally define the inter-domain VN embedding problem by identifying its inputs, outputs, requirements, and constraints.
- Propose a distributed policy-based multi-InP VN embedding framework using iterative and/or recursive negotiation with partial information.
- Validate the framework through simulation and compare centralized vs. distributed approach. We might also perform experiments in PlanetLab [1] (if such experiments can provide extended insights not found in simulation studies).

References

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[4] N. M. Mosharaf Kabir Chowdhury, Fida Zaheer, and Raouf Boutaba. iMark: An identity management framework for network virtualization environment. To appear in IM, 2009.

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