Flexible VNE Algorithms Analysis using ALEVIN

Juan Felipe Botero, Xavier Hesselbach
Universitat Politècnica de Catalunya,
Barcelona, Spain.

Michael Duelli, Daniel Schlosser
University of Würzburg,
Würzburg, Germany.

Andreas Fischer, Hermann de Meer
University of Passau,
Passau, Germany.

***Abstract*—Network virtualization is recognized as an enabling technology for the Future Internet that overcomes network ossification. However, it introduces a set of challenges. In any network virtualization environment, the problem of optimally mapping virtual demands to physical resources, known as *virtual network embedding* (VNE), is a crucial challenge. This paper analyses the behaviour of the main algorithms proposed to solve VNE by means of the ALEVIN framework. The VNE algorithms are evaluated with regard to appropriate metrics such as: cost, revenue, and virtual network acceptance ratio. We also analyse the impact of the recently introduced hidden hop demand concept in the performance of the VNE algorithms.**

I. Introduction

Network virtualization is expected to deliver the flexibility needed for service-tailored future networks [1]. One key problem to network virtualization is the *virtual network embedding* (VNE) problem. This problem deals with the question how a set of *virtual networks* (VN) can be embedded in a *substrate network* (SN) in an optimal way. ALEVIN [2] is a framework enabling researchers to evaluate and compare novel solutions to the VNE problem according to a wide set of criteria. We have implemented the most popular existing VNE algorithm proposals in ALEVIN. ALEVIN allows researchers to add new algorithms or modify existing algorithms and investigate the result of these modifications. This flexibility is expected to provide novel insights into the VNE problem.

Pre-defined metrics are used to evaluate different VNE algorithms. Several metrics have been proposed and studied so far. The cost-revenue factor and the ratio of accepted VNs have been found to be the main indicators on the quality of the VNE. In this work, a set of VNE algorithms are evaluated using the cost-revenue factor and the VNs acceptance ratio metrics. Moreover, the impact of hidden hop demands on the algorithms is investigated.

II. The ALEVIN Framework

The focus in the development of ALEVIN [2] was on modularity and efficient handling of arbitrary parameters for resources and demands as well as on supporting the integration of new and existing algorithms and evaluation metrics. ALEVIN is fully modular regarding the addition of new parameters to the VNE model.

A set of algorithms from existing publications was implemented in ALEVIN. They were chosen taking into account their novelty and the impact generated by their publication. The complete list of implemented algorithms is given in [3].

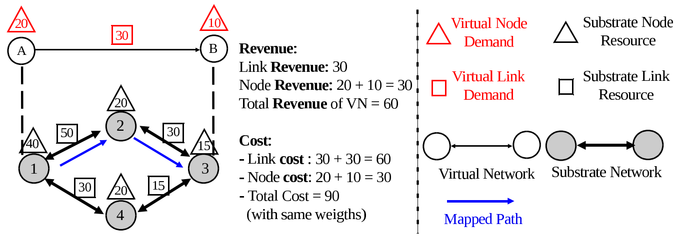

Fig. 1. Cost and revenue in VNE.

Moreover, a set of metrics has been implemented to compare the performance of the algorithms after VNE.

For platform independence, ALEVIN is written in Java. ALEVIN's GUI and multi-layer visualization component is based on MuLaViTo [4] which enables us to visualize and handle the SN and an arbitrary number of VNs as directed graphs.

III. VNE Metrics and Hidden Hops

Figure 1 presents the two main metrics that have been used to evaluate the performance of the VNE algorithms. The *revenue* metric can be seen as the economic benefit of accepting VN requests, while the *cost* metric measures the resources spent by the substrate network to map a virtual network. The combined cost-revenue ratio is a commonly used metric to evaluate the performance of a VNE algorithm, with the quality increasing the lower the ratio is. A detailed overview of VNE algorithm metrics is presented in [3].

The hidden hop demand concept is introduced in [5]. It takes into account the additional demand on intermediate nodes of a directed path in the SN that is used to map a specific virtual link of a VN. This reflects the fact that, for instance, packet forwarding of traffic on a virtual link requires additional forwarding capacity on intermediate nodes.

The implementation of the hidden hop demand concept in ALEVIN helps to understand the impact of hidden hops on the embedding and to devise modifications in current algorithms to optimally deal with it.

IV. Algorithms and Evaluations

To compare different VNE algorithms, we create scenarios with different SNs, as well as different VNs, which cause a certain average resource load.

In this work, we consider CPU cycles as a node resource, denoted by NR_{CPU}, and bandwidth as a link resource, denoted

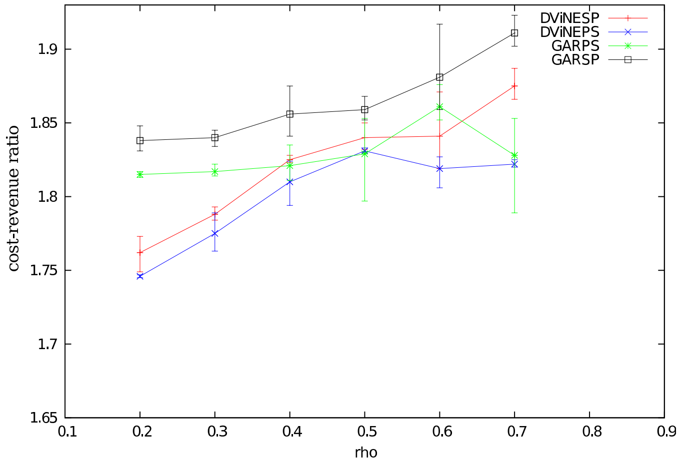

Fig. 2. Evaluation of cost-revenue ratio.

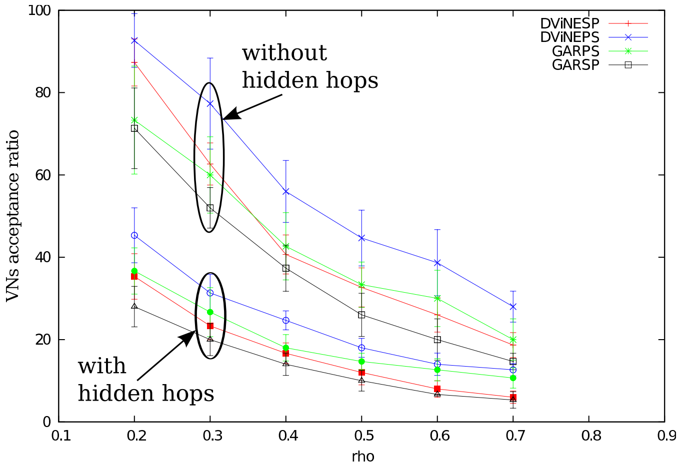

Fig. 3. Evaluation of VNRs acceptance ratio with and without hidden hops.

TABLE I
EVALUATED ALGORITHMS

Notation		Algorithm Description
DViNE	SP	Coordinated node and link mapping with k-shortest paths
	PS	Coordinated node and link mapping with Path Splitting
GAR	SP	Greedy available resources with k-shortest paths
	PS	Greedy available resources with Path Splitting

by LR_{BW} in the substrate network. We uniformly distribute the resource values with a maximum of $NR_{CPU}^{max} = 100$ and $LR_{BW}^{max} = 100$. As a trade-off between runtime of some algorithms and realistic scenarios, we chose the number of substrate nodes to be 50 and the number of virtual nodes per virtual network to be 20. To explore the impact of consolidation of VNs, we consider 15 VNs to be embedded. We performed 10 runs for each set of scenario parameters to reach a confidence level of 95%. Table I lists the evaluated VNE algorithms. For details, please refer to [3].

Figure 2 shows the simulation results using the cost-revenue ratio to compare the different VNE algorithms. It can be seen that it is better to use algorithms that treat the virtual node and link mappings in a coordinated way and not separately. It also shows that algorithms using path splitting (multi-path) solutions to map virtual links, have a better behaviour that those using shortest paths.

The evaluated algorithms were challenged by including a hidden hop demand factor of 0.5, i.e. each hidden hop on a substrate path will have a CPU demand equivalent to the 50% of the realized virtual link's demand. Figure 3 shows the VN acceptance ratio of the evaluated algorithms with the hidden hop factor and the behaviour of the algorithms without considering hidden hops. The decrease of the VNs acceptance ratio is very noticeable (up to 50% in the worst case).

V. Conclusion and Future Work

This paper presented an evaluation of VNE algorithms using ALEVIN. It has been shown that different algorithms can be compared by a common set of metrics. Moreover, it became clear that modification of the algorithms, e.g. with the hidden hop demand, can give significantly different results. Taking into account possible further optimization goals, like security, resilience, or energy-efficiency, it becomes clear that further analysis of these effects is needed.

Optimization of energy consumption in the SN will require significant modification of existing algorithms. Likewise, the incorporation of security and resilience goals will have a significant impact on results. We plan to use ALEVIN to investigate these constraints. Moreover, the application to large testbed scenarios (e.g. G-Lab) will be an interesting goal.

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