VNREAL: Virtual Network Resource Embedding ALgorithms in the Framework ALEVIN

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***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 resources to physical resources, known as *virtual network embedding* (VNE), is a critical challenge. Several algorithms attempting to solve this problem have been proposed in literature, so far. However, comparison of existing and new VNE algorithms is hard, as each algorithm focuses on different criteria. To that end, the VNREAL project introduces ALEVIN, a framework to compare different algorithms according to a set of metrics, easily incorporate new VNE algorithms, and evaluate these algorithms on a given scenario for arbitrary parameters.**

I. Introduction

Network virtualization is recognized as a major driver for the Future Internet. By providing a convenient abstraction from physical resources, network virtualization is expected to deliver the flexibility needed for service-tailored future networks. 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. It can be divided in two different stages: node and link mapping. Figure 1 shows how a virtual node can be hosted by any available substrate node. On the other hand, a virtual link can be mapped to any path in the substrate network that connects the substrate hosts of its source and destination. The *virtual network resource embedding algorithms* (VNREAL) project is extending research on network virtualization by creating a framework for VNE algorithms, allowing researchers to evaluate and compare novel solutions to the VNE problem according to a wide set of criteria.

The approach taken by VNREAL is to provide an environment within which a large number of both substrate and virtual networks can be created and fed into previously implemented VNE algorithms. The algorithms then perform an embedding of the virtual networks into the respective substrate network. The embedding is rated afterwards by user-defined metrics to compare different algorithms. These goals have been achieved by the main result of the VNREAL project: the implementation of the *algorithms for embedding virtual networks* (ALEVIN) [1] software package. ALEVIN is a Java-based tool with documented interfaces for the creation of VNE algorithms and metrics. A set of popular VNE algorithms has already been implemented in ALEVIN and more can be added.

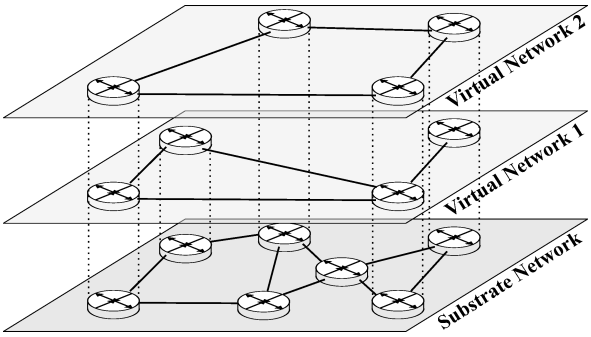

Fig. 1. Two virtual networks embedded in a substrate network.

Beyond the pure reimplementation of algorithms described in literature, ALEVIN also allows researchers to modify existing algorithms and investigate the result of these modifications, like an adjustment to support a different set of optimization criteria or a relaxation of constraints inherent to an algorithm. This flexibility provided by ALEVIN is expected to provide novel insights into the VNE problem.

The remainder of this work is organized as follows. In Section II, we present the highlights of ALEVIN software. Section III provides the scope of VNREAL within the Euro-NF vision. Section IV gives an overview of VNREAL achievements. Conclusions and future use cases are presented in Section V.

II. The ALEVIN Framework

The focus in the development of ALEVIN [1] 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.

The research leading to these results has received funding from the EC's Seventh Framework Programme ([FP7/2007-2013] [FP7/2007-2011]) in the context of the "Euro-NF" Network of Excellence (grant agreement no. 216366) through the Specific Joint Developments and Experiments Project "Virtual Network Resource Embedding Algorithms" (VNREAL) and in the context of the ResumeNet project, grant agreement no. 224619.

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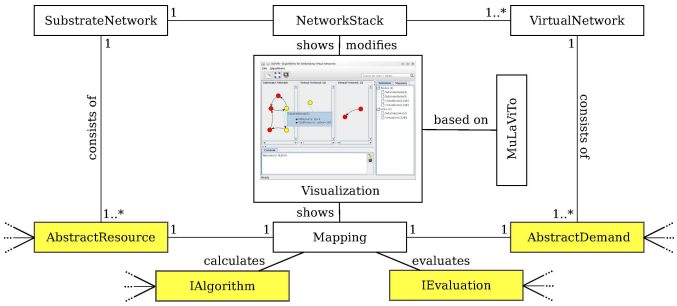

Fig. 2. The modular architecture of the ALEVIN software.

ALEVIN provides the ability to illustrate the deployment of resources in the SN and demands in an arbitrary number of VNs as well as the mapping of demands on resources calculated by a VNE algorithm. Moreover, ALEVIN can be used to create new VNE scenarios or import and export existing scenarios using an XML-based exchange format. ALEVIN is fully modular regarding the addition of new parameters to the VNE model. Thus, a convenient implementation of arbitrary parameters is possible. To increase ALEVIN's modularity and to make it a flexible and extensible platform to compare existing and upcoming algorithms, the implementation of algorithms is kept independent of the resource/demand implementation. To that end, a simple interface is provided defining the rough structure of an algorithm and connecting its output to the *graphical user interface* (GUI). Moreover, ALEVIN allows to implement the node and link mapping stages separately. In this way, node and link mappings from different VNE algorithm proposals can be mixed and recombined with existing or new node or link mappings to compare their results to the original algorithms. As a side effect, this eases the development of new VNE algorithms. Figure 2 depicts the architecture of ALEVIN and highlights the modular interaction of parameters for substrate as well as virtual networks, algorithms, and evaluation metrics.

A bunch of algorithms from existing publications was implemented in ALEVIN. They were chosen taking into account their novelty and the impact generated by their publication. A complete list of implemented algorithms is given in [2]. Moreover, a set of metrics has been implemented to compare the performance of the algorithms after VNE. These metrics are also used in the publication of the implemented algorithms. Among them are new metrics, like energy consumption, solely forwarding hops, and cost/revenue times mapped revenue. A complete list of metrics is given in [2].

For platform independence, ALEVIN is written in Java. ALEVIN's GUI and multi-layer visualization component is based on MuLaViTo [3] which enables us to visualize and handle the substrate and arbitrary virtual networks as directed graphs.

III. VNREAL in Euro-NF

ALEVIN is a powerful research tool that can be used in the design of Future Internet architectures based on network virtualization. The smart resource allocation in virtual networks can help in the optimization of future scenarios with regard to diverse objectives:

- Energy efficient networks: ALEVIN can be used to modify VNE algorithms to evaluate and optimize the energy consumption of the SN.
- Fault tolerance and load balancing: Smart algorithms for self-organization, based on virtual network migration, due to fault tolerance and load balancing, can be implemented and tested in ALEVIN.

IV. Achievements

The implementation of the ALEVIN framework with the main existing VNE algorithms, being able to compare them based on different metrics, and the possibility to easily add new algorithms, is the main outcome of VNREAL. Besides, the implementation of hidden hop demands [4] (indicating the demand posed on intermediate nodes of a substrate path mapping a specific virtual link), the creation of well-defined realistic evaluation VNE scenarios (missing in literature until now), the provision of formalisms to describe the VNE problem, and the creation of an XML-based exchange format for VNE scenarios are important achievements of VNREAL.

ALEVIN is released on an Open Source platform (SourceForge) under the GPL/LGPL license [1]. It will serve as a valuable tool for subsequent projects. Until now, two publications [2], [5] have been produced within VNREAL.

V. Conclusion and Future Work

VNREAL has been a successful project which has accomplished its objectives of creating a modular software (ALEVIN) which already implements the main VNE algorithms and allows comparisons based on a large set of metrics. The potential of ALEVIN can be further exploited in subsequent research projects addressing VNE with different objectives. This also includes the investigation of new optimization objectives, like security or energy-efficiency.

To obtain embedding results minimizing the energy consumption in the substrate network, the current Spanish TIN2010-20136-C03 project and the European FP7 All4Green project will use the ALEVIN framework. Moreover, the European FP7 ResumeNet project will use ALEVIN to compute resilient mappings of virtual resources. The German G-Lab phase 2 COMCON project considers to use ALEVIN's exchange format.

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