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Greener networking in a network virtualization environment

Juan Felipe Botero *, Xavier Hesselbach

Universitat Politècnica de Catalunya, Jordi Girona Street, 1 and 3, Barcelona, Spain

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ABSTRACT

Energy consumption of network operators can be minimized by the dynamic and smart relocation of networking resources. In this paper, we propose to take advantage of network virtualization to enable a smart energy aware network provisioning. The virtualization of networking resources leads to the problem of mapping virtual demands to physical resources, known as Virtual Network Embedding (VNE). Our proposal modifies and improves exact existing energy aware VNE proposals where the objective is to switch off as many network nodes and interfaces as possible by allocating the virtual demands to a consolidated subset of active physical networking equipment. As exact energy efficient VNE approaches are hard to solve for large network sizes and have an adverse effect in the number of successful embeddings, an heuristic approach to reconfigure the allocation of already embedded virtual networks, minimizing the energy consumption, is also proposed.

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1. Introduction

Network Operators (NOs) are becoming aware of the pressing necessity of energy saving. The Information and Communications Technology (ICT) industry has the potential to reduce from 20% to 30% of its greenhouse gas (GHG) emissions [1]. This growing interest of the NOs is mainly due to the rise of energy costs and the international community call to act against the global warming. In developed countries, telecom and NOs are alarmingly increasing their energy consumption [2]. A recent study [3] shows that the impact of energy aware strategies over the data and control planes of wired network infrastructures would approximately be of 50% energy savings in the short-term and 80% in the long-term, resulting in an unexpected potential for NOs to cut their energy bills in the near future.

Nowadays, networks are designed for traffic loads during the busy hour, making heavy use of over-provisioning to fulfill QoS constraints under high loads. However, this leads to resource under-utilization and, along with it, unnecessary energy consumption [4]. To deal with this problem, four different research areas have been recently identified [5]: Adaptive link rate (ALR), interface proxying, energy-aware applications and energy-aware infrastructure.

Most of the advances in energy efficient networking are concentrated in the former area. As the energy consumption of a link depends on its negotiated capacity, **ALR** goal is to adapt link energy consumption to its current load rather than to its negotiated rate. There are several proposals to *sleep* a link for idle times or to dynamically renegotiate its rate to fit the current load and save energy. **Interface proxying** techniques are applied to idle end devices dealing with control traffic that can be dropped or just delegated to be processed in different entities, leaving the device free to switch to sleep mode. **Energy-aware software and applications** is a research field where both user-level applications and kernel-level network stack have to be redesigned to save energy.

The remaining research area is concentrated on energy savings, not just in individual networking equipment, but in the whole network infrastructure. One key element of future network architectures will be their energy awareness; future Internet will rely on architectures that

* Corresponding author.
E-mail addresses: jfbotero@entel.upc.edu (J.F. Botero), xavierh@entel.upc.edu (X. Hesselbach).

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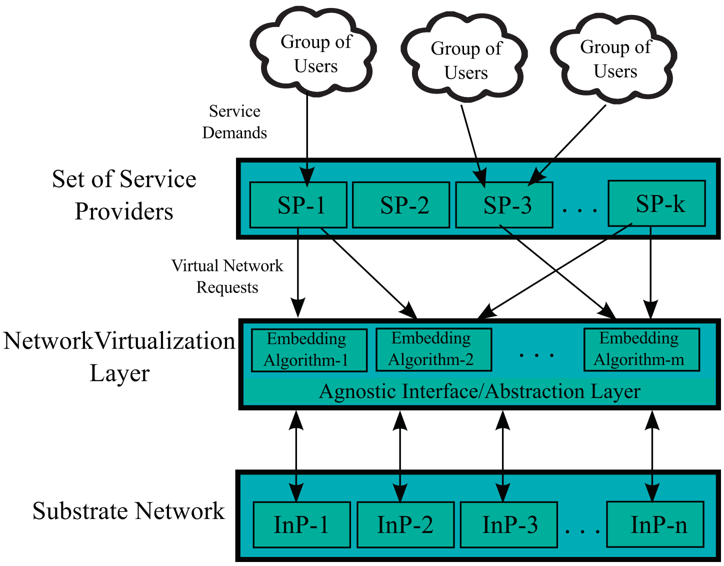

Fig. 1. Resource allocation in future Internet.

guarantee high performance and tight QoS while making an efficient use of the energy.

Future Internet is the set of approaches that are being proposed to surmount the inflexibility of current Internet [6]. This inflexibility can be seen as the current inability to integrate new core protocols (e.g. IPV6, IntServ, or DiffServ).

Network virtualization (NV) [7] is one of the most promising technologies to overcome the resistance of current Internet to fundamental changes. Network virtualization business model is based on the introduction of the Infrastructure as a Service (IaaS) paradigm [8]. It decouples the role of current Internet Service Providers (ISPs) in two new roles: The Infrastructure provider (InP) who deploys and maintains the network equipment and the service provider (SP), in charge of deploying network protocols and offer end-to-end services. Fig. 1 shows how service demands will be requested by different groups of users, and provided by the SPs that perform an efficient allocation of them over the substrate[1] network (SN) (composed by the networks owned by the set of InPs).

At the beginning, network virtualization was proposed as an evaluation platform where new protocols and services can be deployed and tested on live traffic. However, nowadays, rather than simply serving as an evaluation platform, NV can be thought of as an inherent component of the future Internet architecture [9]. In NV, the basic entity is the virtual network (VN). A VN is a combination of active and passive network elements (network nodes and network links) running on top of the physical/substrate network. Virtual nodes are interconnected through virtual links, forming a virtual topology. By virtualizing both node and link resources of a SN, multiple virtual network topologies with widely varying characteristics can be created and co-hosted on the same physical hardware.

One of the main characteristics of virtualization is the possibility of concentrating several virtual instances in one physical resource, commonly known as consolidation. This feature will be one of the main enablers of energy savings in future Internet architectures. These savings can be reached by the concentration of several virtual networks in a reduced subset of strongly consolidated physical equipment [2], leaving the rest of the infrastructure to be switched off or to enter in sleep mode during low traffic demand periods (e.g. night traffic).

Fig. 1 shows how, based on the set of service demands generated by the users, the SP creates customized Virtual Network Requests (VNRs). Each VNR contains a set of demands of networking and non-networking parameters needed to provide the required end-to-end QoS. After the VNR is created, an algorithm is executed to choose, over the heterogeneous resources provided by the SN, the optimal allocation with regard to some predefined objective. This problem is commonly known as **Virtual Network Embedding/Mapping**[2] (VNE) [10]. The mapping defines the relationship between virtual network elements and their respective counterparts in the substrate network and can be divided in two stages: First, *virtual node mapping*, where each virtual node of a VNR is mapped to one substrate node with enough capacity to accomplish the virtual node demand. In second place, *virtual link mapping*, where each virtual link is mapped to a set of directed paths in the substrate network with enough resource capacity to meet the virtual link demand.

The energy spent by today's routers and interfaces is insensitive to the traffic load (according to [11] an idle router consumes 90% of the power it requires when working at

[1] The words "substrate" and "physical" are used interchangeably throughout this paper.

[2] The words "embedding" and "mapping" are used interchangeably throughout this paper.

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