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A combined energy-bandwidth approach to allocate resilient virtual software defined networks

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ABSTRACT

The Internet supports many applications for millions of users every day and will enable the creation of even more innovative services for all participants. However, there is still no Quality of Service (QoS) guarantee for the users. In order to specify requirements, clients establish Service Level Agreements (SLAs) with their Internet Service Providers (ISPs), where resilience and available bandwidth are key requirements for the success of Internet services. On the other hand, the ISPs aim to maximize their profit by establishing as many SLAs as possible and decrease the energy consumption to deliver their services. The mixing of Software Defined Networks (SDNs) and Virtual Networks (VNs), called Virtual Software Defined Network (VSDN), improves the flexibility and manageability of networks, arising it as an option to achieve these goals. Within this context, this paper presents two algorithms to allocate VSDNs: (i) the Bandwidth and Reliability According to Redundancy (*BRAR*) algorithm to achieve resilience; and (ii) the Bandwidth and Energy Efficiency Focus (*BEE-Focus*) algorithm to find paths taking into account bandwidth availability and energy efficiency. The results show the benefits of the proposed algorithms in deploying resilient VSDNs regarding energy efficiency, while improving bandwidth availability in the network infrastructure.

1. Introduction

The human society wants to be connected to the Internet all the time to share content or to be aware of events anywhere in the world with at least a minimal quality level support. However, the current Internet does not guarantee Quality of Service (QoS) in order to ensure this new social aspect of the Internet, which generates an elastic demand for networking resources. Currently, to pursue QoS between clients (e.g., companies) and Internet Service Providers (ISPs), a Service Level Agreement (SLA) is negotiated to define network parameters to be fulfilled by the ISPs (Carvalho et al., 2012; Garg et al., 2014). Therefore, the research community has made efforts to improve the management and planning of ISPs to provide a better access to the Internet (Nguyen et al., 2013).

The Software Defined Networks (SDNs) and the Virtual Networks (VNs) approaches emerge as prominent technologies to bring the desired flexibility and management features (Nguyen et al., 2013; Beck et al., 2015). Both approaches can be mixed, allowing the deployment of customized VNs under SDN infrastructures. We call this combination a *Virtual Software Defined Network* (VSDN). The implementation of VSDNs increases the ability of ISPs to manage and plan network features (Wang et al., 2015; Kim and Feamster, 2013). These features involve ensuring SLA specifications and having a better control of resources utilization, such as Bandwidth (Bw), energy consumption, among others.

The ISPs aim to maximize profit, and two metrics are related to this Chiaraviglio et al. (2012) and Pulakka (2002): (i) number of clients and (ii) the energy consumption. The number of clients is the number of active SLAs, so the more clients, the higher the ISP's profit can be Arslan et al. (2015). ISPs can increase the number of clients with the improvement of Bw utilization in their networks. On the other hand, energy consumption of the network infrastructure became an important point to be considered by the ISPs. Recently, triggered by the increase energy prices, agreements to reduce pollution, and expanding number of services being offered by ISPs, the energy efficiency issue became an important aspect in computer networking (Bolla et al., 2011). Energy issues can be evaluated from many perspectives, where energy efficiency can be

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defined as the amount of Bw allocated to clients per quantum of energy consumed by the network infrastructure.

Besides maximizing their profit, ISPs aim to fulfill the SLA parameters, since they impact the user's experience during possible failure events in the ISP. Within this context, resilience is a key requirement to ensure QoS to the users. Network resilience is the capacity of the network to keep a minimum specified level of service when failures occur (Sterbenz et al., 2010). Thus, resilience encompasses not only reactive actions to manage post-failure impact, but also pre-failure strategic planning. Tied to the resilience, the concepts of reliability and traffic congestion are important aspects to be considered during the service establishment (Nguyen et al., 2013; Sterbenz et al., 2010; Lee et al.).

Energy consumption and resilience are concepts which tend to have different focuses. The energy consumed is minimized when a few components of the network are used, but it weighs a great cost to resilience as there are no alternative paths in the topology after a failure. Therefore, it is necessary to consider both aspects during network management and planning. Within this context, the VSDN arises as a feasible approach to enhance the energy efficiency and resource usage in the ISPs infrastructure. Therefore, the ISPs need an allocation algorithm to provide their Internet access service through VSDNs.

An allocation algorithm decides which infrastructure components (links and nodes) will be part of the VSDN. This decision must encompass key issues like planning, energy efficiency, Bw availability, and others. Therefore, this paper proposes two algorithms to perform the VSDN allocation task: (i) the Bandwidth and Reliability According to Redundancy (*BRAR*) algorithm to achieve resilience; and (ii) the Bandwidth and Energy Efficiency Focus (*BEE-Focus*) algorithm to find paths in the network considering the impact of VSDNs allocation on the Bw availability and energy efficiency.

The objective of these algorithms is to allocate a VSDN which is planned to be resilient under failure events, fulfilling the SLA parameters, and also reducing Bw utilization and energy consumption from the network infrastructure under normal operation. In order to accomplish this, the resilience is achieved with strategic planning for failure events, where the *BRAR* algorithm deploys alternative paths with the best ratio between network reliability and bandwidth allocated to the VSDN. In the same way, the objective of *BEE-Focus* is to find a path between the desired nodes focusing on maximizing the energy efficiency of the ISP to solve the requests and allocate paths which own more Bw available to deal with the elastic behavior of the traffic demand. This elastic Bw allocation is possible due to the combination of the SDN and VN approaches in the proposed VSDN.

This paper is organized as follows. Section 2 defines key concepts on SDN, virtualization, VSDN and network reliability, as well as shows some related work. Section 3 describes the resilience strategy through *BRAR* algorithm. Section 4 introduces the *BEE-Focus* algorithm, while Section 5 describes the evaluation of the proposed energy-efficient allocation, and Section 6 concludes the paper and presents future work suggestions.

2. Background

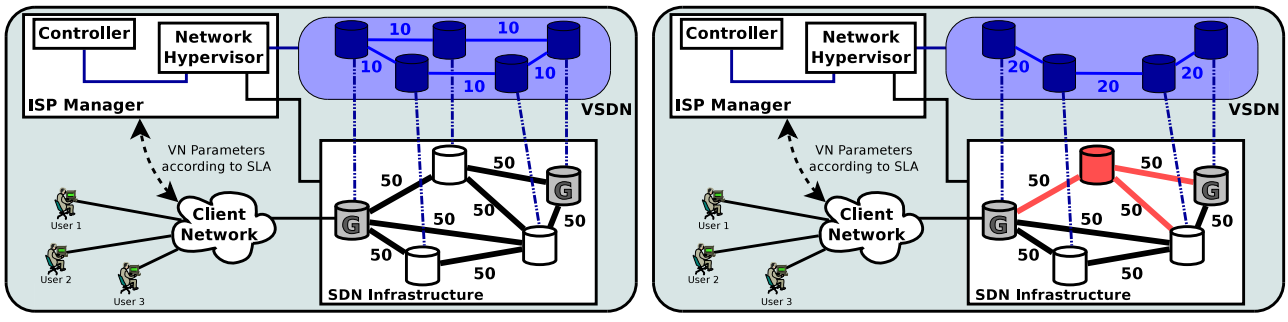
In this section we briefly describe concepts needed for the proposal understanding. We first introduce the concept of Virtual Software Defined Networks (VSDNs), and then we define network reliability in the context of this work. Finally, Section 2.3 reviews the related work.

2.1. Virtual software defined networks

The basic idea of SDN is to decouple control and data planes to make network environments more manageable. In an integrated SDN/NV approach, a hardware component can be allocated in two virtual networks (called VSDNs), thus being accessed by the controllers through the network hypervisor (e.g., such as Flowvisor Sherwood et al., 2010 or Openvirtex Al-Shabibi et al., 2014). The behavior of the VSDN is defined through the controller configuration, where each controller is responsible for one VSDN created in the network hypervisor (Sherwood et al., 2010; Al-Shabibi et al., 2014). Thus, this approach allows the customization of network parameters and services, providing flexibility to adapt the service according to the user's requirements. This paper uses this ability and perform VSDN allocation for the clients according to the SLA definition. The term “client” is related to the access network (i.e., the ISP's client), and the term “user” represents the final user who accesses the Internet to upload/download content.

The VSDN parameters encompass diverse metrics, among which resilience, energy efficiency, and bandwidth are the focus of this work. The resilience comprises several aspects, from which reliability and traffic tolerance are the ones addressed in this paper. The reliability is directly related to the number of alternative paths of the network, where the higher redundancy of paths, the greater the reliability: when a link/node fails, the primary path affected by the failure switches the traffic over to its respective secondary path (Lee et al.). However, it is not advantageous for the ISPs to allocate a full redundancy network for a client who does not desire such reliability (and will not pay for it), since it represents a waste of resources. On the other hand, traffic tolerance is related to the increase of Bw allocated to a path when an unpredictably high injection of traffic occurs. Usually, it is caused by a *flash crowd* or convergence of traffic due to failure in the network, such as a disaster (Sterbenz et al., 2010).

Fig. 1(a) shows an applicability scenario of this proposal. The client and the ISP negotiate an SLA, and the VSDN must be deployed by the ISP accordingly. To allocate the VSDN from the existing SDN infrastructure, the ISP needs to define the topology,



(a) Normal operation. (b) Operation with failure.

Fig. 1. Scenario representing the context of this work.

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