

Bitrate Guarantees Strategies for Customer Virtual Networks Dynamic Reconfiguration

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Abstract—Application-specific Quality of Service (QoS) and additional Service Level Agreement (SLA) parameters to guarantee the committed service quality and avoid service interruption may be crucial in emerging applications and services. Moreover, among the wide range of services over IP transport networks, those requiring bandwidth-on-demand and related to network functions virtualization (NFV) are of particular interest. IETF is working on the Abstraction and Control of Transport Networks (ACTN) framework to facilitate network resources virtualization to support NFV. Customers can request on-demand connectivity between their end-points (EPs) to reconfigure customer virtual network (CVN) topology dynamically. In addition to CVN reconfiguration, QoS constraints and service guarantees can be requested to satisfy application-specific requirements. In this work we study two different approaches to satisfy the committed bitrate guarantees in CVN links. Exhaustive simulation results show that the diversity strategy highly improves performance and provides remarkable CAPEX savings.

Index Terms—Customer Virtual network reconfiguration; Abstraction and Control of Transport Networks.

I. INTRODUCTION

Emerging applications and services over IP transport networks require not only intelligent control and management architectures to provide bandwidth-on-demand, but also application-specific Quality of Service (QoS) and additional Service Level Agreement (SLA) parameters to guarantee service quality and avoid service interruption. Among the wide range of services over IP networks, those related to Network Functions Virtualization (NFV) are of particular interest. Expected NFV benefits are leading the research community and industry to explore network architectures and technologies to satisfy new challenges arising (see [1], [2]).

To provide application-specific network services, network virtualization can be used. Network operators can manage their virtual network using their own Software Defined Network (SDN) controllers. Moreover, they might require virtual network resources reconfiguration on-demand. As a result, network operators might need to reconfigure their IP/MPLS virtual topology to add or release capacity.

To support NFV, IETF is working on the Abstraction and Control of Transport Networks (ACTN) [3] framework to facilitate network resources virtualization. Three key entities can be differentiated in the ACTN framework: customers, service providers and network providers. Customers can

request on-demand connectivity between their end-points (EPs) using a Customer Network Controller (CNC) to reconfigure virtual topology. ACTN is supported by the currently standardized Application-Based Network Operations (ABNO) [4] architecture, which can accept on-demand connection requests via an ABNO controller. In addition, ABNO can be complemented with an Application Service Orchestrator (ASO) on top implementing a northbound interface aiming at facilitating applications' requests using applications' semantics [5], [6].

Service-specific SLAs become crucial to guarantee, not only the required QoS, but also a minimum bitrate to minimize service interruption. Bitrate guarantees could be based on recovery techniques such as *partial protection*, where two Shared Risk Link Group (SRLG) disjoint paths are established, being the capacity of the protection path that of the bitrate to be guaranteed. Another option is *diversity*, where two SRLG-disjoint paths are set-up with a combined capacity to satisfy the one requested and being the minimum individual capacity equal to the one to be guaranteed.

Based on the ACTN model, in our previous work in [7] we proposed using an ASO for providing on-demand reconfiguration of Customer Virtual Networks (CVNs). A generic landscape with a network operator and a set of customers was devised. The network operator owns and controls the network infrastructure, being thus aware of resource availability and able to collect performance monitoring data, such as effective throughput and delay, and correlate them into QoS indicators. Customers require virtual network services to connect EPs in geographically disperse locations; e.g. a Virtual Network Functions (VNFs) orchestrator requiring on-demand connectivity between DCs to implement service chaining among VNFs.

This paper focuses on the study of the aforementioned strategies to provide bitrate guarantees in CVN links.

II. CVN RECONFIGURATION WITH BITRATE GUARANTEES

To show the relation of CVNs with multilayer transport networks, Fig. 1a shows a layered network scenario, where three clearly differentiated layers are identified: *i*) the network operator's optical core network, at the bottom, consisting in a number of Optical Cross-Connects (OXC) and optical links; *ii*) the network operator's IP/MPLS network layer, consisting of a number of IP/MPLS routers connected through virtual links supported by optical connections (lightpaths); *iii*) the customer layer, on top, with CVNs connecting customer's EPs. Each link in the CVN is supported by MPLS paths.

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To manage and control such layered network, the architecture in Fig. 1b is assumed, with CNCs on top controlling each CVN and requesting their reconfiguration to the ASO. The ASO module maintains service-related databases; the CVN-DB describes the current state of each CVN in terms of EPs and CVN links, whereas the service DB includes, among other, SLA-related information. In contrast, ABNO maintains network-related databases, i.e. TED and LSP-DB. It is worth highlighting that CVN reconfiguration may be needed at any time without prior information for the network operator and can include, among others, operations either to set up or tear down CVN links as well as changes in the capacity and other SLA parameters. Fig. 1c presents an example of a CVN which topology and capacity requirements vary with the time.

Regarding SLA parameters, in this paper we focus on two important ones: QoS, measured as delay, and bitrate guarantees in case of failure. Specifically for the latter, two SRLG-disjoint paths, one primary and one secondary paths, can be used. An example is depicted in Fig. 1a, where every optical link is associated with one or more SRLG identifiers. The SRLG of a MPLS virtual link includes all SRLGs supporting such link. Finally, the represented CVN link is supported by two SRLG-disjoint MPLS paths: one supported by SRLGs {1, 2, 3} and the other by SRLGs {4, 5}. In the event of a failure in an optical link, the CVN link capacity is squeezed to the bitrate of the remaining MPLS path.

Two main schemes to provide bitrate guarantees are considered and compared in this paper: *i) partial protection*, where a percentage of the bitrate requested for each CVN link is protected using a MPLS path SRLG-disjoint with the

primary one. For instance, let us assume that a 10 Gb/s CVN link needs to be served guaranteeing 5 Gb/s in case of failure. Then, the primary MPLS path will convey 10 Gb/s, whereas the secondary protection MPLS path will convey 5 Gb/s; *ii) diversity*, where the bitrate requested for each CVN link is divided and one MPLS path conveys the guaranteed bitrate, and the other path the rest of the CVN link capacity. In the previous example for 10 Gb/s CVN link provisioning, both MPLS paths will convey 5 Gb/s. Note that since the number of paths is restricted to two, the maximum guaranteed bitrate cannot exceed 50% of the total capacity.

An example to illustrate the impact of each scheme is depicted in Fig. 2. A four-node IP/MPLS network is represented, where each MPLS virtual link is supported by one or more lightpaths on the underlying optical network and its capacity is represented as *available capacity/total capacity*, in Gb/s. For clarity purposes, the optical network is not depicted in the figure. EPs {A1, A2, A3} and {B1, B2} owned by two customers, A and B respectively, are connected to IP/MPLS routers. In the example, the MPLS path routing is shown for the protection (left) and diversity (right) schemes, and each CVN topology and links' capacity is shown. Primary MPLS paths in the protection scheme are established through the shortest route and with the minimum delay.

In this small example one can observe that, although MPLS routing is the same under both schemes (in general this is not true), the remaining capacity in the existing MPLS virtual links is not equivalent, since primary paths must convey all the requested CVN capacity under the protection scheme in contrast to only the guaranteed bitrate under the diversity one.

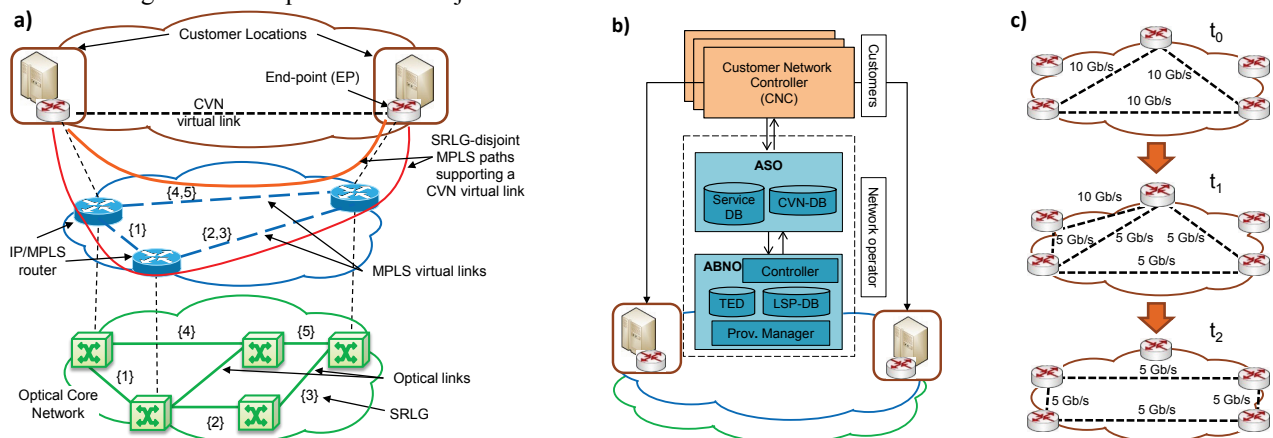


Fig. 1. Layered network scenario (a), network control and management architecture (b), and example of CVN connectivity reconfiguration along time (c).

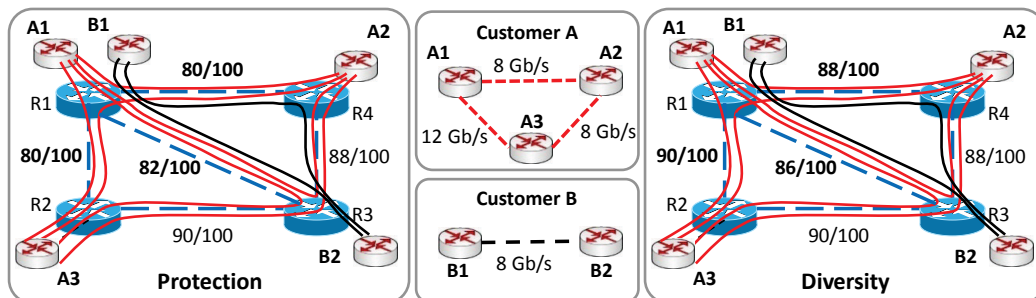


Fig. 2. Example of CVN based on protection and diversity schemes to support CVN links.

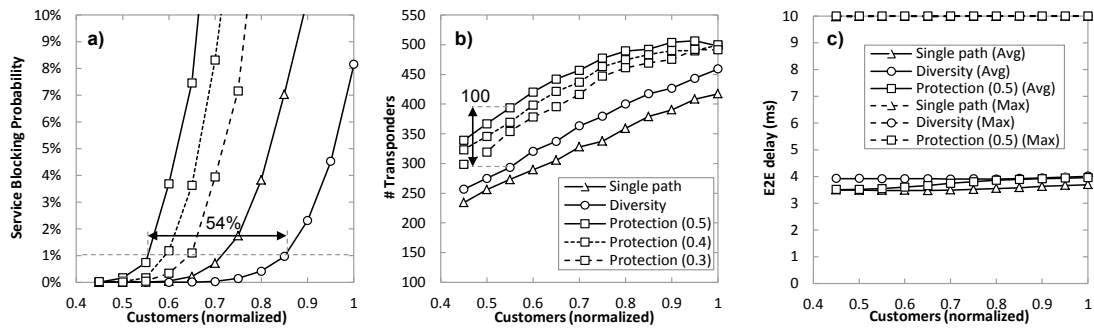


Fig. 3. Performance (a), total number of transponders (b), and e2e delay (c).

III. ILLUSTRATIVE NUMERICAL RESULTS

Performance and CAPEX for the two considered bitrate guarantees schemes are compared for the 30-node Spanish Telefonica (TEL) national network topology. No bitrate guarantees are additionally considered (one *single path* is set up to support CVN links) aiming at providing reference values. A heuristic algorithm to solve the CVN service reconfiguration with QoS constraints and bitrate guarantees (SQUBA) problem and the management architecture including CNCs, ASO, and ABNO were developed in C++ and integrated in an ad-hoc event driven simulator.

5-node CVNs topologies varying with daytime were considered; EPs were strategically placed in regions so as to cover the entire national geography. CVN reconfiguration requests were generated following an exponential distribution with mean 1h. Each CVN link's capacity varies according to a uniform distribution in the range [1,10] Gb/s. Customer QoS constraints were set to 10 ms. A CVN reconfiguration request is accepted if all the requested CVN link's capacity, QoS and bitrate to be guaranteed is served; otherwise the request is blocked.

Regarding the transport network configuration, 100 Gb/s transponders using 37.5 GHz were installed in the MPLS routers. Each MPLS was equipped with 30 transponders. Finally, each point in the results is the average of 10 runs with more than 10.000 CVN reconfiguration requests requiring an increment of capacity at least in one CVN link.

Fig. 3 shows the obtained results in terms of service blocking probability, total number of used transponders, and average weighted e2e delay, against the number of customers (normalized). As a result of the different bitrate requirements of the partial protection and diversity schemes (see example in Fig. 2), different service blocking probability is obtained. Fig. 3a shows gains in the offered load as high as 50% when the bitrate to be guaranteed is 50% of the required capacity. Although the obtained blocking probability improves when the bitrate to be guaranteed under the partial protection scheme decreases (40% and 30% of the required capacity), it is still far from that obtained under the diversity scheme. Interestingly, service with no bitrate guarantees does not always perform better than diversity in terms of service blocking probability, since benefits from using two MPLS paths (despite of being SRLG-disjoint) arise against using a single path.

Similarly, one can expect that the transponders to be equipped in the network are higher under the partial protection scheme compared to the diversity one; Fig. 3b plots the

number of transponders to be equipped in each case. For the point of 1% blocking probability under the 50% partial protection, savings in the number of transponders as high as 100 are observed when diversity is considered. Note also that the diversity scheme needs few more transponders than the no guarantees service.

Regarding the delay in CVN links, note that under normal conditions CVN link bitrate is conveyed by two MPLS paths under the diversity scheme (compared to only one path under partial protection). This fact might result in higher e2e delay. However, results in Fig. 3c show that, although average e2e delay is slightly lower under partial protection for low loads, both schemes perform similar.

IV. CONCLUDING REMARKS

This paper tackled the problem of guaranteeing bitrate for CVNs. To guarantee bitrate, network operators can take advantage of SRLG-disjoint paths to support CVN links. Two different approaches were considered to provide bitrate guarantees using SRLGs: partial protection and diversity.

Partial protection and diversity strategies to support CVN links were compared through simulation on a real-size national network. Results showed remarkable gains as high as 50% in the supported offered load (targeting at 1% of service blocking probability) when diversity was considered with respect to partial protection. Moreover, noticeable CAPEX savings in terms of required number of transponders were also shown. Interestingly, although partial protection results in slightly lower average e2e delay, no significant differences were obtained compared to diversity.

Considering the performance shown, diversity is worth to be considered as an alternative to partial protection.

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