E2E Traffic Engineering Routing for Transport SDN

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Abstract: The article proposes a hierarchical routing approach, validated by simulation on real network operator, based on a novel adaptive virtualization scheme, suitable for transport SDN, allowing dynamic configuration of heterogeneous multi-domain packet-optical networks.

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1. Introduction

With the advent of cloud computing and data center services, end users are demanding high bandwidth end-to-end (E2E) connections that have to be provisioned dynamically and automatically. This leads a change in current transport, requiring more dynamicity and flexibility in classic transport management and operation. "Transport SDN" (T-SDN) is an emerging architecture with the goal to satisfy this requirement in current transport network. Born from service providers SDN, T-SDN makes the transport network more programmable decoupling the management layer from the data layer both in case of packet and circuit (TDM, optical) nodes. The applicability of T-SDN concept in real transport network is a challenging item, due to the heterogeneity of control plane and data plane systems: the classic transport network of operators consists of several "islands" with different control systems (both standard and proprietary) and with different switching technology (like packet and optical).

As a consequence, T-SDN requires a re-engineering of the network functionalities making them suitable to such contexts. One of the most important functionality is the routing of services across the transport network, where it is needed the combination of the dynamicity and network resource optimization that is time consuming, especially in WDM domains.

Different solutions are proposed in [1-2] to obtain resource optimization. "Hierarchical Path Computation Element" (H-PCE), proposed in [3], is a promising approach. The solution defines two levels of path computation in a hierarchical relationship: high-level path computation called "Parent PCE" (P-PCE), is responsible to compute the domain sequence and low-level path computation called "Child PCE" (C-PCE) provides the internal connectivity in each domain.

In this article, it is proposed a new routing solution based on H-PCE architecture that is suitable for T-SDN. The solution introduces an efficient virtualization scheme that abstracts the physical resources (packet and optical) in an equivalent simplified vision based on service parameters (peak bandwidth, guaranteed bandwidth, delay, jitter…) which speed up path computation of the transport services enabling a better network programmability. This is important especially for WDM domains where the complexity of path computation due to physical impairment validation procedure is hidden. In addition the virtualization scheme introduces a novel adaptation technique that allows and efficient usage of network resources as validated by experimental results.

2. Proposed Solution

The approach described in [3] causes limitation on the applicability in T-SDN: it generates scalability issues in network with a great number of domains, due to a huge amount of data to being exchanged with a consequent increase of communication overhead and computation time. In addition the optimality of E2E paths generated is not always obtained, as the domain selection does not take into account of the state of the domains.

The proposed solution overcome these limitation introduces a novel virtualization of the physical resources (both packet and optical) in service parameters (peak-bandwidth, guaranteed bandwidth, delay, jitter). This is very important for optical domains where the complexity due to physical impairment validation is hidden to P-PCE and computed asynchronously by C-PCE. In addition the virtualization scheme introduces a novel adaptation technique allows and efficient usage of network resources, making the solution suitable for T-SDN. In the following subchapters the virtualization scheme and the monitoring are detailed

2.1. Virtualization Scheme

Two inputs are provided to the virtualization scheme: the amount of traffic that is expected to be routed inside the domain and a set of service classes (CoS) driven by service parameters (like peak-bandwidth, guaranteed bandwidth, delay, jitter, loss) that differentiate the traffic routed in the transport networks.

According the traffic and the CoS definition, the request are clustering in CoS according the defined range of bandwidth and delay, jitter. The output is an expected traffic matrix organized for CoS. C-PCEs responsible of the domains provide a set of physical paths inside the domain that satisfies the expected matrix. Algorithm described in [4] is used. Such paths are computed with the objective to have to maximize the disjointness and consists of a couple of border nodes (*BNin, BNout)* and the CoS that is expected to serve *CoSp*. After that a set of logical connections are created according the triple (*BNi*, *BNj*, *CoSk)* where *BNj* and *BNi* are the border node of the domain and CoSk is the k-th element of CoS definition.

Logical connections are associated with computed paths as each path is uniquely associated to a specific logical connection, where each path is associated to the logical connection with the triple *(BNin = BNi, BNout =BNj, CoSp=CoSk)*.

Each logical connection is then associated to a Summarized Link (SL) connecting the Border Nodes *BNi*, *BNj* with the service parameters equals to the range defined by CoS. Each SL is communicated to P-PCE. After this procedure is done by each C-PCE of the domain, P-PCE builds the complete virtual topology map. Whenever a service request is received, P-PCE finds it out on the network virtualization combining the SL that satisfies the service request parameters. For each SL of the sequence, the C-PCE responsible of the SL, selects a physical path from the related logical connection.

2.2. Virtualization Monitoring

As the service requests can be different from the expected traffic used for logical connection dimensioning, it is possible that a logical connection is frequently used and at certain point some requests cannot be routed due to the lack of physical resources in the logical connection. For such reason a monitoring method of logical connection usage is introduced.

The monitoring method is based on measurement of logical connection population (i.e. the number of paths associated to the logical connection). Whenever the number of physical paths into a logical connection reaches a critical prefixed threshold, the C-PCE is triggered in order to provide further resources according to the virtualized logical connection parameters. The resources discovery is executed on the residual intra-domain topology and only for the logical connection with resource lack.

Virtualization monitoring and path computation are computed at lower level by the C-PCE independently and asynchronously to P-PCE working. This allows the execution of time consuming operation (like physical impairment validation) off-line and in parallel way to the service traffic routing. In addition, this makes the solution able to fit the virtualization to unpredictable network variation; also it allows avoiding stability and scalability issues due to the absence of continuous communication between different level of PCEs.

3. Topology Description

Simulations are realized considering a real national network composed by 5 domains formed by heterogeneous for technologies (packet and optical), interconnected by an optical transport layer. The network topology is depicted Figure 1.

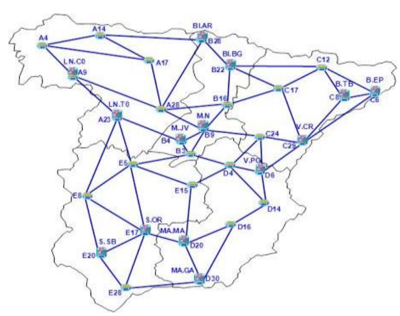

Figure 1 Network topology reference

4. Results

The results are done comparing the solution with virtualization monitoring (called “hierarchical dynamic routing” or HDR) and without monitoring (called “hierarchical static routing” or HSR) to the ideal routing approach. The ideal routing is the case where a single PCE that is aware of the network domains topologies, is responsible for providing a path for service requests. Three type of traffic matrix are used for simulation: “Expected T.M.” is inferred with same distribution of the traffic used for logical connection dimensioning. “Random T.M.” is computed completely uncorrelated with respect to the traffic matrix used to dimension the logical connections. “Partially Expected T.M.” is a mix of the previous matrixes composed by 50% of expected and 50% of random requests.

Figure 2 shows the number of served requests by HDR and HSR with respect to the ideal routing case. HDR performs better than HSR in every scenario, from 20% in case of “Expected T.M.” to 40% in case of “Random T.M.”, due to adjustment of physical resources (i.e. paths) associated to logical connections driven by the monitoring phase.

In any case, the performance of HDR as number of routed service traffic are good and very close to ideal routing approach, till 10% in case of uncorrelated traffic.

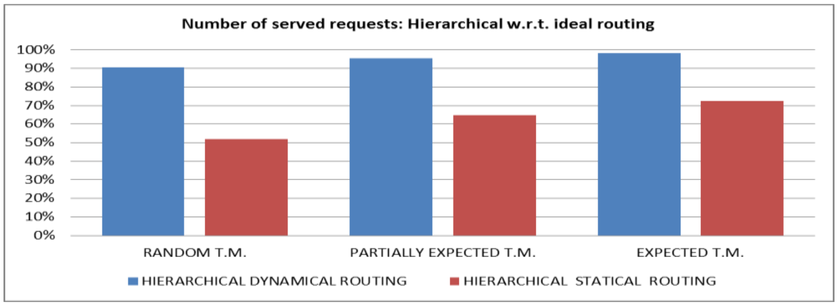

Figure 2 Number of served requests.

Ideal routing has an high overhead of domain communication due to state maintenance of the domains topologies, while HDR and HSR reduces the overhead thanks to the novel virtualization scheme

In Figure 3 it is depicted the percentage of overhead savings of HDR and HSR with respect to idela routing for the three abovementioned traffic matrix.

Virtualization in HSR and HDR introduces a remarkable saving of communications (from 94% to 100%). HDR performs worse than SDR for the communication surplus related to the resource provisioning triggered by the monitoring mechanism. In any case the overhead is not so relevant (till 5% in random) taking into account the high number of routed service traffic.

This virtualization scheme makes the system more scalable and efficient in terms of resources optimization.

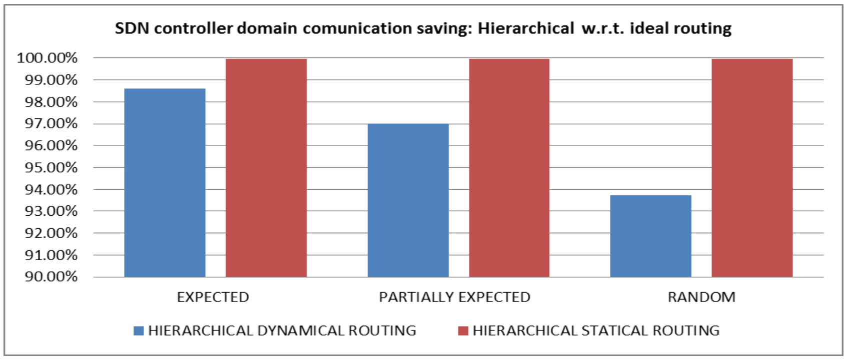

Figure 3 SDN controller domain communication saving.

As general result, HDR is a solution that provides a good compromise between efficient resource usage and scalability in terms of domain communication.

5. Conclusion

A novel multi-domain routing approach is proposed with a smart adaptive virtualization scheme that allows relaxing time computing operations (as physical impairment validation in WDM domains) and with a smart monitoring that dynamically adapts the solution to network and traffic changes.This makes the solution suitable for T-SDN.

6. References

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