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Energetic ABNO Driven Network Architecture with Flexgrid Orientation

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Abstract— The increasing demand of internet services is pushing cloud services providers to increase the capacity of their data centers (DC) and create DC federations, where two or more cloud providers interconnect their infrastructures. As a result of the huge capacity required for the inter-DC network, the flexgrid optical technology can be used. In such scenario, applications can run in DCs placed in geographically distant locations, and hence, multicast-based communication services among their components are required. In this project, we study two different approaches to provide multicast services in multilayer scenarios assuming that the optical network is based on the flexgrid technology: (1) establishing a point-to-multipoint optical connection (light-tree) for each multicast request, and 2) using a multipurpose virtual network topology (VNT) to serve both unicast and multicast connectivity requests. When that VNT is not able to serve an incoming request as a result of lack of capacity, it is reconfigured to add more resources. A control plane architecture based on the applications-based network operations (ABNO) one, currently being standardized by the IETF, is presented; workflows are proposed and PCEP extensions are studied for the considered approaches. The experimental validation is carried-out on a testbed setup connecting Telefonica, CNIT, and UPC premises.

Index Terms— Cloud Service Providers, Data Centers (DC), Flexgrid, Virtual Network Topology (VNT), Applications Based Network Operations (ABNO).

I. INTRODUCTION

The distributed nature of cloud computing entails that modular applications and services can dynamically distribute their components to be run on servers belonging to datacenters (DCs) spread across distant geographic locations. Huge data transfer is thus needed e.g., to synchronize databases (DB) or to distribute content, e.g., live TV, among DCs. The new capacity demands

advocate for an evolution towards optical transportbased solutions for DC interconnection. In this area, the flexgrid optical network technology is being extensively investigated because of its inherent spectrum efficiency and connection flexibility. Some applications might require group communication services (one-to-many or many-tomany) among their distributed components. Although point-to-point

(p2p) connectivity can be used thus, copying contents to each of the destinations; point-tomultipoint (p2mp) connections might fit better to this purpose. In the case that high capacity connectivity (e.g., 100 Gb/s) is required, p2mp connections can be established on the optical layer (known as light-trees). The feasibility of creating light-trees in flexgrid networks was demonstrated. Ruiz and Velasco compared the performance of using light-trees against p2p optical connections (light paths) and showed that, although resource utilization is improved using light-trees, its limitation lie in the spectrum continuity constraint and the connections' length. Another approach to improve resource utilization is creating a virtual network topology (VNT) that can be used to serve both p2p and p2mp connections. Ruiz and Velasco compare the performance of providing multicast services on the single layer and the multilayer approach.

This system extends our previous work and experimentally demonstrates the above approaches when the control of the flexgrid network resides in a centralized control element following the software defined networking (SDN) concept; in this paper we assume that the application-based network operations (ABNO) architecture is used. The DCs participating in the communication are considered to be part of a federation. As such, a cloud management system at federation level is in charge of managing intra-DC resources. Typically, one or more core Ethernet programmable switches within each DC are connected to the flexgrid optical core network providing the necessary interconnection among the DCs in the federation. The necessary coordination between the cloud management system in each DC and the ABNO based transport network control element is performed by a differentiated software element, named as Application Service Orchestrator (ASO), acting as an end-to-end orchestrator and responsible of translating the connectivity requests from the DCs to the ABNO element. A similar scenario was used to demonstrate unicast services on multi-layer scenarios.

The ABNO architecture is based on functional elements defined by the IETF, like the active stateful path computation element (PCE). As described most of interfaces among ABNO modules are PCEP. A specialized PCE can be used to perform complex computations, e.g., to perform inoperation planning.

A. Serve Multicast Connectivity Services

To implement multicast connectivity services in a multi-layer network, a VNT is needed to connect every switch. As a result of the large bitrate required for the multicast connectivity, the VNT can be created ad-hoc for each multicast request and removed when the multicast connection is torndown. Although alternative approaches can be followed

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in this system we assume that the ad hoc VNT is based on one single light-tree connecting the source switch to each of the destination switches. An example of the light-tree-based approach is depicted in Fig.1, where a 100 Gb/s light-tree is set-up in Fig. 1(a) Connecting the switch in DC-A to the switches in DCs B, C, and D. It is clear that, similarly as for p2p connections, specific p2mp routing and spectrum allocation (RSA) algorithms, similar to the one proposed, are needed to compute the route from the source to every leaf in the connection and allocate a contiguous and continuous spectrum slot. The resulting VNT consists in a single p2mp virtual link connecting the source switch to all the leaves (see Fig.1 (b)).

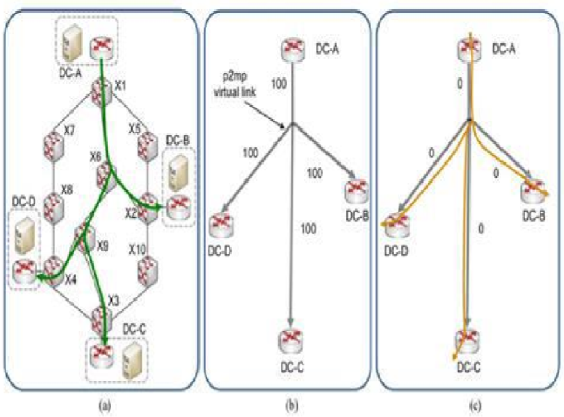

Fig.1 Light-tree-based VNT to serve an incoming multicast request

(a) Optical p2p provisioning (b) p2mp virtual topology (c) Multicast Provisioning

The multicast connection request can be served on the just created ad hoc p2mp VNT (see Fig.1(c)). The advantage of this approach includes the reduction of switching capacity in the switches, since multicast is performed by the optical layer. Although the p2mp virtual link created for the multicast connection request could be shared, the probability of another multicast request with the same source and set of destination switches as that virtual link arrive is clearly scarce. Thus, in case of some capacity would remain unused after serving the multicast request, as a result of a mismatch between the requested bitrate and the optical layer granularity, it would be unlikely reused. To foster capacity sharing, a single VNT can be created to serve any kind of connection request, including unicast and multicast connections. In this approach, connection requests are served on the VNT, which is updated to add extra capacity, e.g., new virtual links, in case an incoming connection cannot be served and releasing virtual links when any connection is using them. Fig.1.2 shows an example of the multi-purpose VNT approach. In Fig.2(a) the current multi-purpose VNT has not enough capacity to serve an incoming 100 Gb/s multicast request from the switch in DC-A to the switches in DCs B, C, and D. Therefore, the VNT is updated adding a new virtual link. Taking advantage of traffic grooming to improve resource utilization, the VNT can be supported on large capacity, e.g., 400 Gb/s, lightpaths; then a new virtual link connecting switch DC-C to switch DCB with 400 Gb/s of remaining capacity is now available in the VNT, as shown in Fig.2(b). Finally, the requested multicast connection can be served on the multipurpose VNT, as illustrated in Fig.2(c).

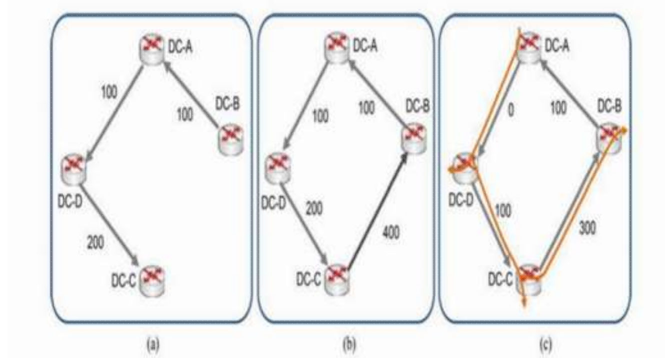

Fig.2 Multi-purpose VNT updating to serve an incoming multicast

Request (a) Current virtual topology (b) Updated virtual topology (c) p2mp Provisioning

B. Data Centre Management

The delivery of distributed cloud services implies the configuration of the networks involved in the service (both in the distributed DCs and in the domains connecting them). In the case of federated DCs, each DC is operated and managed separately. Service provisioning in such distributed scenario requires a tight coordination to ensure the consistency of the service delivery. This problem space is covered by the SDN framework, which is seen as the facilitator of this capability. For this work, three main software components are considered to govern and control the network connectivity service: i) the cloud computing manager, which handles the computing resources in each DC. Each intra-DC network can include a local SDN controller to configure resources within the DC. Such controllers are out-of- the-scope of this paper; ii) the ASO, which maintains the network information from the DCs requests and interacts with the network orchestrator; and iii) the inter-DC network orchestrator, based on the ABNO architecture, which configures the Ethernet switches and the flexgrid network.

When federated DCs need connectivity services they are requested to the ASO, who asks ABNO to create unicast and multicast connections between the involved DCs (see Fig.1.3). Unicast IP services were demonstrated for multi-layer scenarios in our previous work. In this system, Ethernet services over flexgrid are provided instead of IP/MPLS, but the orchestration process for p2p services is similar.

C. ABNO Architecture

The ABNO architecture includes i) a controller, responsible for implementing workflows orchestrating operations among ABNO modules; ii) a Layer 0 active stateful PCE (L0 PCE) with label switched paths (LSP) initiation capabilities, responsible for path computation on the optical topology. The LSP-DB stores information about the LSPs that are provisioned and operational; iii) a virtual network topology manager (VNTM), responsible for maintaining a virtual topology between the DCs using resources in the optical topology; iv) a stateless Layer 2 PCE (L2 PCE), which computes paths on the virtual topology; v) a provisioning manager (PM) dealing with the configuration of the network elements (switches or optical nodes) and vi) a topology module (TM) maintaining the traffic engineering database (TED). In addition, a back-end PCE (bPCE) capable of performing computationally intensive tasks, such as solving the p2mp RSA algorithm or finding the optimal reconfiguration of the VNT, is available within ABNO.

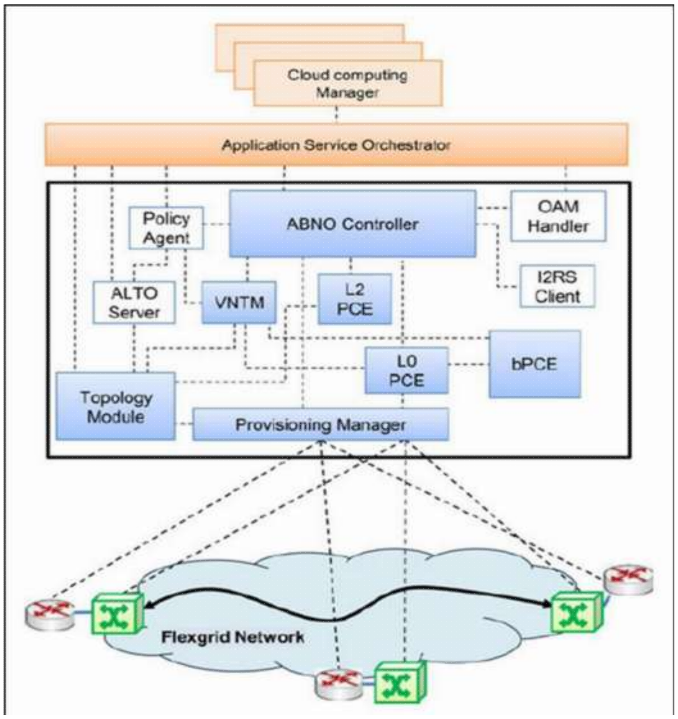

Fig.3 Control and management architecture

II. PROBLEM STATEMENT

The major part of the project development sector considers and fully survey all the required needs for developing the project. Before developing the tools and the associated designing it is necessary to determine and survey the time factor, resource requirement, man power, economy, and company strength. Once these things are satisfied and fully surveyed, then the next step is to determine about the software specifications in the respective system such as what type of operating system the project would require, and what are all the necessary software are needed to proceed with the next step such as developing the tools, and the associated operations.

A. Scalability of Telecom Cloud Architectures for Live-TV Distribution

Hierarchical distributed telecom cloud architecture for live-TV distribution exploiting flexgrid networking and SBVTs is proposed. Its scalability is compared to that of a centralized architecture. Cost savings as high as 32 % are shown. Two different telecom cloud architectures for live-TV distribution have been studied: the centralized and the distributed architecture. From the results, the distributed architecture scales the best. Moreover, the number of SBVTs to be installed is noticeable lower, which results in a lower total network CAPEX for the distributed architecture.

B. Elastic Operations in Federated Datacenters for Performance and Cost Optimization

The huge energy consumption of datacenters providing cloud services over the Internet has motivated different studies regarding cost savings in datacenters. Since energy expenditure is a predominant part of the total operational expenditures for datacenter operators, energy aware policies for minimizing datacenter's energy consumption try to minimize energy costs while guaranteeing a certain Quality of Experience (QoE). Federated datacenters can take advantage of its geographically distributed infrastructure by managing appropriately the green energy resources available in each datacenter at a given time, in combination with workload consolidation and virtual machine migration policies. In this scenario, inter datacenter networks play an important role and communications cost must be considered when minimizing operational expenditures. In this work we tackle the Elastic Operations in Federated Datacenter for Performance and Cost Optimization (ELFADO) problem for scheduling workload orchestrating federated datacenters. Two approaches, distributed and centralized, are studied and integer linear programming (ILP) formulations and heuristics are provided. Using those heuristics, we analyze cost savings with respect to a fixed workload placement. For the sake of a compelling analysis, exhaustive simulation experiments are carried out considering realistic scenarios. Results show that the centralized ELFADO approach can save up to 52% of energy cost and more than 44% when communication costs are also considered.

C. Performance Evaluation of Light-Tree Schemes in Flexgrid Optical Networks

New applications require conveying huge bitrate from a source node to multiple destinations. As a result, point-to-multipoint (P2MP) connections need to be established on the optical layer. In this paper, the P2MP routing and spectrum allocation (RSA) problem is formally stated and modeled as an Integer Linear Program (ILP). Exhaustive numerical results show that creating several transparent sub-trees noticeably improves the performance obtained by serving the demand using one single tree. Moreover, cost savings from exploiting traffic asymmetry can be obtained by installing directed optical transponders consisting of one single module.

D.Solving Routing and Spectrum Allocation Related Optimization Problems

Compared to wavelength switched optical networks (WSON), flexgrid optical networks provide higher spectrum efficiency and flexibility. To properly analyze, design, plan, and operate flexgrid networks, the routing and spectrum allocation (RSA) problem must be solved. The RSA problem involves two different constraints: the continuity constraint to ensure that the allocated spectral resources are the same along the links in the route and the contiguity constraint to guarantee that those resources are contiguous in the spectrum. As a consequence of its complexity, it is crucial that efficient methods are available to allow solving realistic problem instances in practical times. In this paper, we review different RSA-related optimization problems that arise within the lifecycle of flexgrid networks. Different methods to solve those optimization problems are reviewed along with the different requirements related to where those problems appear. Starting from its formulation, we analyze network life-cycle and indicate different solving methods for the kind of problems that arise at each network phase: from offline to in-operation network planning. We tackle two representative use cases: i) a use case for offline planning where a flexgrid network is designed and periodically upgraded, and ii) multilayer restoration as a use case for in-operation planning. Three solving methods are proposed for the off-line planning problem: mathematical programming, column generation and metaheuristics, whereas, as a result of its stringent required solving times, two heuristic methods are presented for the online problem.

III. PROPOSED SCHEME

In the proposed approach the data transmission speed is comparatively high, like if we use VNT approach it supports data transmission of 400 GB per second. In this system two approaches are used, first is a point to multi point optical connection, which is used for multicast request and the another approach is Virtual Network Topology (VNT), which supports both unicast and multicast requests. We experimentally assess the proposed workflows, including the PCEP messages. We start with a brief description of the deployed distributed set-up including the implemented modules. This approach experimentally demonstrate the above approaches when the control of the flexgrid network resides in a centralized control 25 element following the software defined networking (SDN) concept; in this project we assume that the application-based network operations (ABNO) architecture is used. The DCs participating in the communication are considered to be part of a federation. As such, a cloud management system at federation level is in charge of managing intra-DC resources.

A. Remote Server Manager

It is often used when it is difficult or impractical to be physically near a system in order to use it. A remote location may refer to a computer in the next room or one on the other side of the world. In this project remote server manager is used for handling or managing inter communication.

B. Application Service

Here application services are provided by the Application Service Provider, which is responsible for establishing connections between networks.

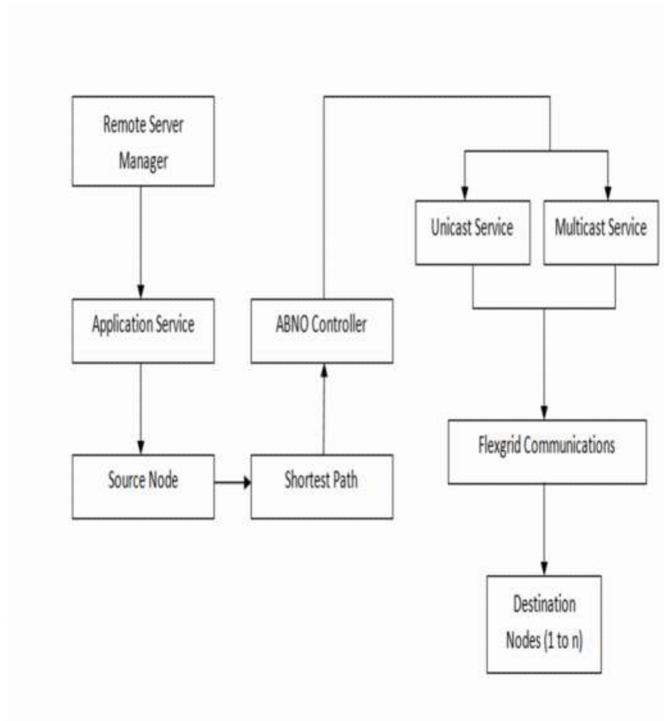

Fig.4 Block Diagram

C. Source Node

Intra communication. It is responsible for implementing workflows orchestrating operations among ABNO modules.

D. Unicast Service

Unicast services are responsible to provide unicast transmission, i.e. data transmission from one node to another node.

E. Multicast Service

Multicast service is responsible to provide multicast transmission, i.e. data transmission from one node to several nodes.

F. Flexgrid Communication

Flexgrid communication technology is used to provide huge capacity to data centers. Flexgrid optical networks are used to provide this type of communication between several nodes or

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data centers. Here flexgrid networks are using for flexible data transmission between same or different networks.

G.Destination Node

Destination node is the receiver node which receives

The source node first finds the shortest path for transmission purpose on the basis of minimum distance between nodes and then starts transmission of information. Shortest Path is used for the data transmission from source node to destination node.

ABNO Controller is a controller which provides the ability to the network to perform Inter as well as the information transmitted by the source node. It may be one for unicast transmission and many that is 'n' for multicast transmission.

IV. ARCHITECTURAL DESIGN

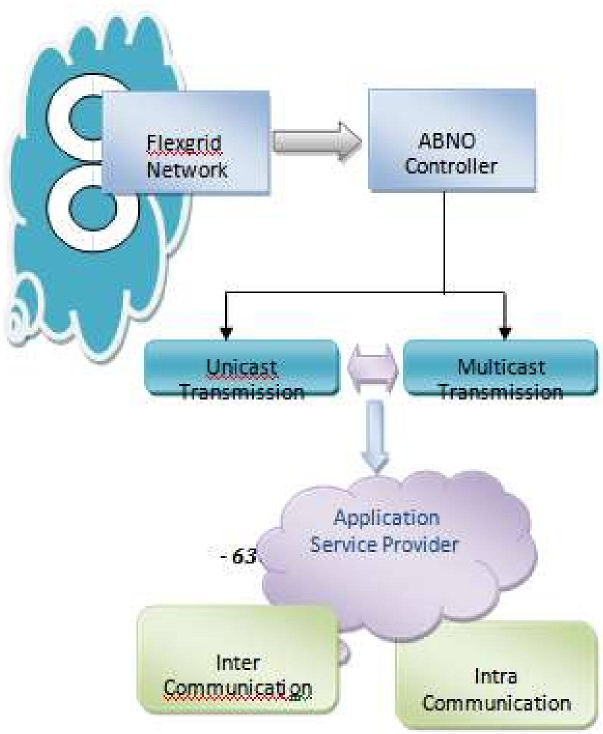

Fig.5 System Architecture Design

H.Flexgrid Network

Flexgrid network is a collection of nodes or assembled in a structured manner that is used for multiple connections. Flexgrid optical networks having the property of inherent spectrum efficiency and connection flexibility. The flexgrid optical technology provides huge capacity required for the inter-DC network.

I. ABNO Controller

Services such as content distribution, distributed databases or inter-data center connectivity place a set of new requirements on the operation of network. They need on demand and applicationspecific reservation of network connectivity, reliability and resources (such as bandwidth).An environment that operates to meet this type of requirements is said to be have Application-Based Network operations (ABNO).

J. Application Service Provider

An application service provider (ASP) is a vendor that provides individual users or an entire enterprise with software applications over a network, usually a local area network (LAN) or an LAN with Internet access. The provided software may be referred to as software as a service, apps on tap, or on demand software. One of the most basic forms of ASP is a vendor that provides access to particular application software using HTTP protocol.

K. Unicast Transmission

Unicast transmission is referred as the transmission of data or information from one node to another node.

L. Multicast Transmission

Multicast transmission is referred as the transmission of data or information from one node to multiple nodes.

M. Inter Communication

Communication that establishes between the nodes or data centers of two different networks is said to be Inter communication.

N. Intra Communication

Communication that establishes between the nodes or data center of the same network is said to be Intra communication. This type of communication establishes within a network.

V. SYSTEM MODULES

Following are the most frequently used project management methodologies in the project management practice:

1. Data Center Manipulation
2. Software Defined Networking
3. Multicast Activity
4. Virtual Link Creation

1) Data Center Manipulation

The delivery of distributed cloud services implies the configuration of the networks involved in the service (both in the distributed DCs and in the domains connecting them). In the case of federated DCs, each DC is operated and managed separately. Service provisioning in such distributed scenario requires a tight coordination to ensure the consistency of the service delivery. This problem space is covered by the SDN framework, which is seen as the facilitator of this capability. For this work, three main software components are considered to govern and control the network connectivity service: i) the cloud computing manager, which handles the computing resources in each DC. Each intra-DC network can include a local SDN controller to configure resources within the DC. Such controllers are out-of-the-scope of this system; ii) the ASO, which maintains the network information from the DCs requests and interacts with the network orchestrator; and iii) the inter-DC network orchestrator, based on the ABNO architecture, which configures the Ethernet switches and the flexgrid network.

2) Software Defined Networking

When the control of the flexgrid network resides in a centralized control element following the software defined networking (SDN) concept; in this system we assume that the application-based network operations (ABNO) architecture [9] is used. The DCs participating in the communication are considered to be part of a federation. As such, a cloud management system at federation level is in charge of managing intra-DC resources [10]. Typically, one or more core Ethernet programmable switches within each DC are connected to the flexgrid optical core network providing the necessary interconnection among the DCs in the federation. The necessary coordination between the cloud management system in each DC and the ABNO-based transport network control element is performed by a differentiated software element, named as Application Service Orchestrator (ASO), acting as an end-to-end orchestrator and responsible of translating the connectivity requests from the DCs to the ABNO element. A similar scenario was used to demonstrate unicast services on multi-layer scenarios.

3) Multicast Activity

To implement multicast connectivity services in a multi-layer network, a VNT is needed to connect every switch. As a result of the large bitrate required for the multicast connectivity, the VNT can be created ad-hoc for each multicast request and removed when the multicast connection is torndown. Although alternative approaches can be followed, in this system we assume that the ad hoc VNT is based on one single light-tree connecting the source switch to each of the destination switches. An example of the light-tree-based approach is depicted in this system, where a 100 Gb/s light-tree is set-up in the system, connecting the switch in DC-A to the switches in DCs B, C, and D. It is clear that, similarly as for p2p connections, specific p2mp routing and spectrum allocation (RSA) algorithms, similar to the one proposed, are needed to compute the route from the source to every leaf in the connection and allocate a contiguous and continuous spectrum slot. The resulting VNT consists in a single p2mp virtual link connecting the source switch to all the leaves. The multicast connection request can be served on the just created ad hoc p2mp VNT. The advantage of this approach includes the reduction of switching capacity in the switches, since multicast is performed by the optical layer.

4) Virtual Link Creation

The p2mp virtual link created for the multicast connection request could be shared, the probability of another multicast request with the same source and set of destination switches as that virtual link arrive is clearly scarce. Thus, in case of some capacity would remain unused after serving the multicast request, as a result of a mismatch between the requested bitrates and the optical layer granularity, it would be unlikely reused. To foster capacity sharing, a single VNT can be created to serve any kind of connection request, including unicast and multicast connections. In this approach, connection requests are served on the VNT, which is updated to add extra capacity, e.g., new virtual links, in case an incoming connection cannot be served and releasing virtual links when any connection is using them.

VI. CONCLUSION

Two approaches were proposed to serve large capacity (e.g., 100 Gb/s) multicast connectivity services in a multi-layer scenario where a set of federated DCs is connected through a flexgrid optical network. In the first approach, an VNT was created for each multicast request by establishing light-trees in the flexgrid network. In the second approach, multicast services are served on a multipurpose VNT supported by 400 Gb/s lightpaths, thus favoring resource utilization. The feasibility of implementing both approaches using standardized control plane protocols has been studied. In particular, the ASO module was responsible for managing multiple DC networks as a single entity interacting with the ABNO architecture in charge of controlling the interconnection network. PCEP was used among the modules within the ABNO architecture. Workflows were proposed for the considered approaches. Multicast connections (including light-trees) are supported in PCEP using p2mp extensions. However, VNT reconfiguration, entailing multilayer computation is not currently supported; an IETF draft was used as a guide.

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