ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

IJARMATE

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
Vol. 2, Issue 4, April 2016

# Test Assessment of Abno-Driven Multicast Integration in Flex grid Networks

Jayanthi.K[1], Subbulakshmi.G[2]

PG Scholar, Department of CSE, Vandayar Engineering College, Thanjavur, India [1]
Assistant Professor, Department of CSE, Vandayar Engineering College, Thanjavur, India [2]

***Abstract*— Internet is approaching cloud services providers to improve the capacity of data centres (DC) and create two or more cloud providers to interconnect their infrastructures. As a result, we need a large amount of capacity for the inter-DC network. To handle this, flex grid technology is being used. In order to provide multicast services in multilayer scenarios, we use two approaches. Assume that these approaches are based on flex grid technology. The first approach is introducing a point-to-multipoint optical connection (light-tree) and the second approach is using a virtual network topology (VNT) to provide both unicast and multicast requests. Because of the lack of capacity, VNT is not capable to provide this request. So it is necessary to insert more resources. To achieve this, a control plane architecture based on the applications-based network operations (ABNO) is offered by IETF. Finally justification is done on a test bed setup linking Telefonica, CNIT, and UPC premises.**

***Index Terms*— Datacenter interconnection, flex grid networks, optical multicast.**

## I. Introduction

### *A. Light-trees*

Establishing point-to-multipoint (P2MP) connections in the optical layer (*light-trees*) improves the performance of establishing a set of *light paths*. Note that a path is a special case of tree, where the set of destination nodes in the former contains just one node. In the case that high capacity connectivity (e.g., 100 Gb/sis required, p2mp connections can be established on the optical layer (known as *light-trees*).

### *B. VNT*

It is used to serve both unicast and multicast connectivity requests. This approach is used to improve resource utilization is creating a virtual network topology (VNT) that can be used to serve both p2p and p2mp connections. To implement multicast connectivity services in a multi-layer network, a VNT is needed to connect every switch. As a result of the large bit rate required for the multicast connectivity, the VN can be created ad-hoc for each multicast request and removed when the multicast connection is torn-down. The advantage of this approach includes the reduction of switching capacity in the switches, since multicast is performed by the optical layer.

### *C. ABNO*

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

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; *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.

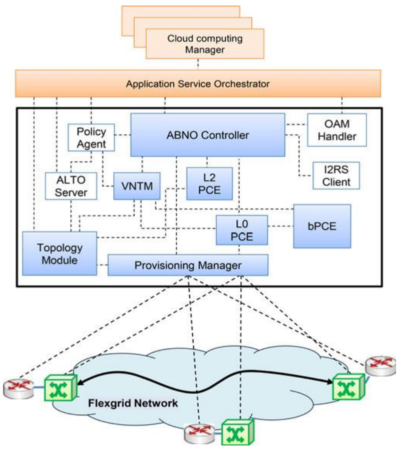


Fig 1 Control and Management Architecture

For this work, three main software components are consider to govern and control the network connectivity service: *i*) the cloud computing manager, which handles the computing resources in each DC; *ii*) the application service

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Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
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orchestrator (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 flex grid network.

## II. Related Works

### *A. Velasco, A. Asensio, J. Ll. Berral, E. Bonetto, F. Musumeci , V. López*

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-data center 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.

### *B. N. Sambo, G. Meloni, G. Berrettini, F. Paolucci, A. Malacarne, A. Bogoni, F. Cugini, L. Pot`ı, and P. Castoldit frequency conversion*

Emerging services, such as high-definition Internet Protocol TV (IP-TV) or data center migration, are going to increase the amount of multicast traffic in the Internet. The support of multicast directly in the optical domain, instead of at the IP layer, is a target for reducing the amount of optical-electronic-optical conversions (thus, the network operational and capital expenditure) and energy consumption. In parallel, flex-grid technology (e.g., bandwidth variable wavelength selective switches) is emerging as a candidate solution to be adopted in future optical transport networks given its capacity of improving spectrum efficiency.

This paper is focused on optical multicast in flex-grid optical networks and units control through the Path Computation Element (PCE). First, we present two node architectures supporting optical multicast.

The first node architecture achieves optical multicast through passive light split and requires that the multicast connection satisfies the spectrum continuity constraint. The second node architecture achieves optical multicast with frequency conversion. In particular, a specific implementation of the second architecture is proposed in this paper exploiting a periodically poled lithium niobate (PPLN) waveguide.

Then, PCE architecture to control optical multicast (with and without frequency conversion) is proposed. Optical multicasting, based on the proposed node architectures, at 100 and 200 GB/s is experimentally demonstrated in a flex-grid network test bed. In particular, multicasting is demonstrated with 112 Gb/s polarization multiplexing 16 quadrature amplitude modulation (PM-16QAM) and polarization multiplexing quadrature phase shift keying (PM-QPSK), and with 224 Gb/s PM-16QAM considering the light-split node architecture. Moreover, optical multicast with two frequency conversions, achieved in a single PPLN device, is demonstrated for the first time with a 224 GB/s PM-16QAM signal. The test bed also includes the PCE, which is e- tended to control optical multicast in flex-grid optical networks.

### *C. L. Velasco, A. Castro, M. Ruiz, and G. Junyent*

Compared to wavelength switched optical networks (WSON), flex grid optical networks provide higher spectrum efficiency and flexibility. To properly analyze, design, plan, and operate flex grid 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 life-cycle of flex grid 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 off-line to in-operation network planning.

We tackle two representative use cases: i) a use case for off-line planning where a flex grid 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 met heuristics, whereas, as a result of its stringent required solving times, two heuristic methods are presented for the on-line problem.

### *D. M. Ruiz and L. Velasco*

Advanced services require a high bit rate, e.g., multi gigabit, multicast connectivity being provided by core transport

 

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IJARMATE

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networks. Multicast services can be supported either by one single tree connecting the source to every destination of the multicast request or by a set of paths. The tree scheme could reduce resource utilization, and as a result of the bit rate that might be required, providing them directly on the optical layer could bring benefits. Apart from those benefits, with the advent of flex grid technology, connections with 100 and 400 Gbits/s and beyond can be set up, which opens up opportunities to create virtual topologies on which multicast services can be provided. The kinds of transponders that are needed under the single-layer and multilayer approaches are slightly different. While bandwidth-variable optical transponders (BVTs) can be used in the multilayer approach, assuming that the virtual topology is supported on high-bit rate optical connections so as to facilitate the performance of grooming, using sliceable BVTs (SBVTs) in the single-layer approach might help to share capacity in the transponders. In this paper, we compare the performance of high-bit rate multicast services using the path and the tree scheme on the single-layer and multilayer approaches. Mathematical programming models for the tree scheme on the two approaches considered are developed to compute the routing for incoming multicast requests in dynamic scenarios. With the goal of reducing computation time, heuristic algorithms providing a much better trade-off between optimally and complexity are proposed. Exhaustive simulation results carried out on three national core network topologies show that the tree scheme on the multilayer approach outperforms the rest of the options.

### *E. L.Velasco, A.Asensio, J.Llberral, V.Lopez, D.Carrera, A.Castro and J.P.Fern Andez-Palacio*

Current inter-data-center connections are configured as static big fat pipes, which entails large bit rate over-provisioning and thus high operational costs for DC operators. On the other hand, network operators cannot share such connections between customers, because DC traffic varies greatly over time. Those connections are used to perform virtual machine migration and database synchronization among federated DCs, allowing elastic DC operations. To improve resource utilization and save costs, dynamic inter-DC connectivity is currently being targeted from a research point of view and in standardization form. In this article, we show that dynamic connectivity is not enough to guarantee elastic DC operations and might lead to poor performance provided that not enough over provisioning of network resources is performed. To alleviate it to some extent, we propose using the flex grid optical technology that enables finer spectrum granularity adaptation and the ability to dynamically increase and decrease the amount of optical resources assigned to connections. DCs can be interconnected through a flex grid-based network controlled using a centralized software defined network, based on the architecture currently being proposed by the IETF; a cross-stratum orchestrator architecture coordinates DC and network elastically. Illustrative results show that dynamic elastic connectivity provides benefits by reducing the amount of over provisioned network resources and facilitating elastic DC operations.

## III. PROPOSED DESIGN

The ASO module is responsible for managing multiple DC networks as a single entity; it requests the ABNO controller for unicast and multicast services between Ethernet switches. Upon a multicast connection request arrives in the ABN controller, it requests a L2 p2mp path computation to the L2PCE. In case of a VNT with the same source and destination switches and with enough capacity is available, the L2 PCE would reply with the route for that request. However, this is unlikely to happen so the L2 PCE returns a *Reply* (PCRep) message (2) with a NO-PATH object. The controller delegate to the VNTM module updating the VNT, possibly adding MOR resources to serve the L2 p2mp request. To that end, an Initiate message (3) is sent containing the end points of the requestedp2mp connection. At this point the VNTM will implement either the light-tree based or the multi-purpose VNT approach. Regardless of the approach followed, the VNTM sends back a *Report* (PCRpt) message (9) reporting the results. In case of success, the ABNO controller requests a L2 p2mp path computation to the L2 PCE (10), which now finds a feasible route and returns it to the ABNO controller. Since L2 PCE is not active, the ABNO controller module delegates connection set-up to the PM (12) that configures the appropriate rules in each switch.

### *A. Light-Tree-Based VNT Approach*

In the case the light-tree based VNT approach is followed, upon reception of message (3) the VNTM sends a PCReq message (4a) to the L0 PCE to create optical connectivity among the specified end points; in this particular approach, a p2mp optical connection needs to be created.

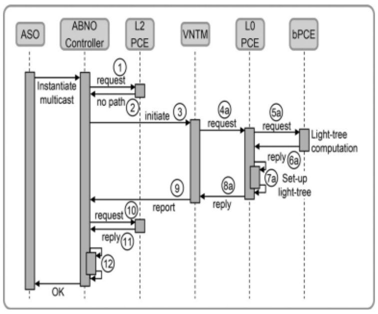


Fig 2 Workflow for the light-tree-based VNT approach

Because L0 p2mp path computation might take long time, L0 PCE delegates it to the specialized bPCE (5a). When the computation ends, the bPCE sends back the solution to the L0 PCE (6a). When the PCE receives the solution, it sends the appropriate commands to the underlying data plane (7a). When the L0 PCE receives the confirmation from the data plane, PCRep message is sent back to the VNTM.

 

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ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

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### B. *Multi-Purpose VNT Approach*

In this approach, upon reception of message (3) the VNTM needs to reconfigure the VNT, e.g., by adding some new virtual links. Similarly as in the previous case with the p2mp RSA problem, since computing a solution for VNT reconfiguration might take long time, the VNTM delegates it to the specialized bPCE, sending a PCReq message (4b). When the computation ends, the bPCE sends back the solution to the VNTM (5b) specifying the light paths to be set-up including the route and spectrum allocation for each of them.

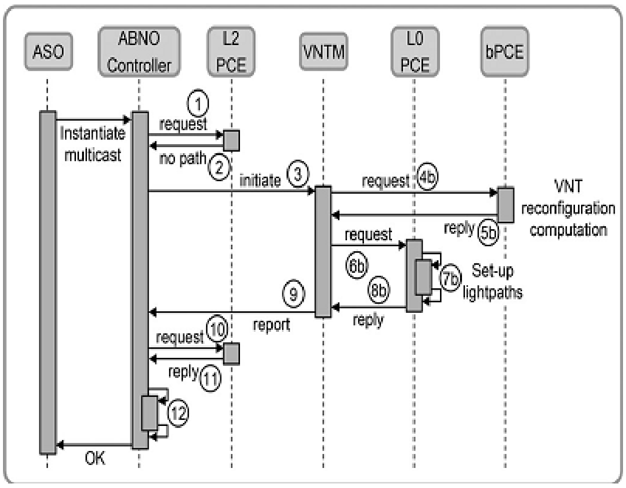
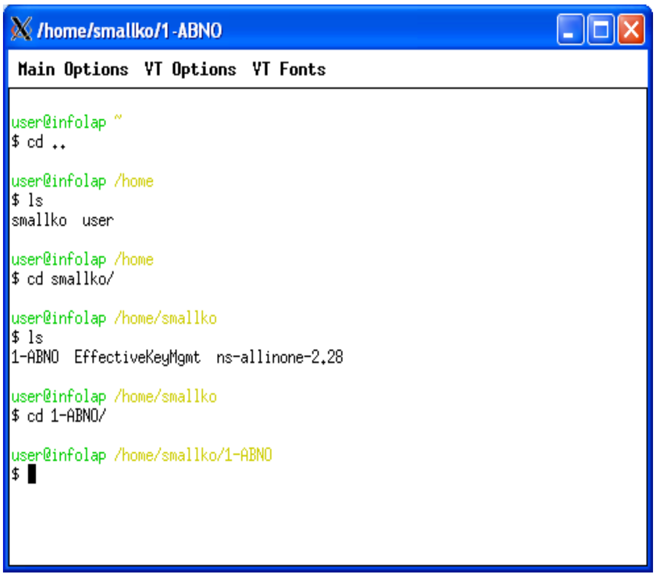
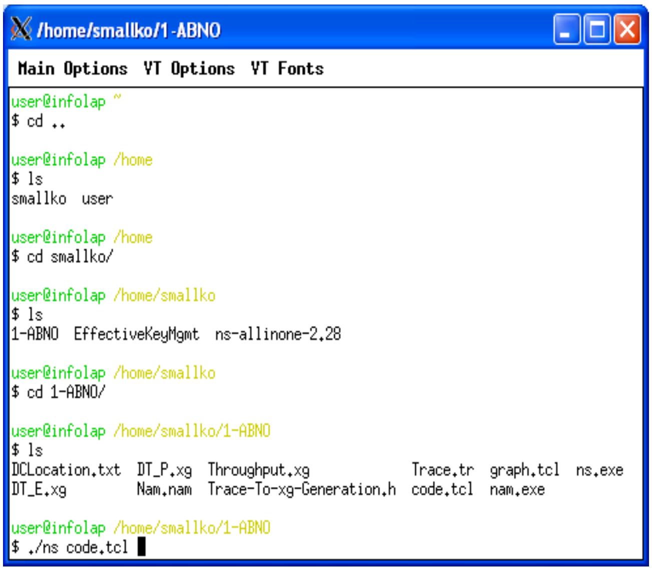
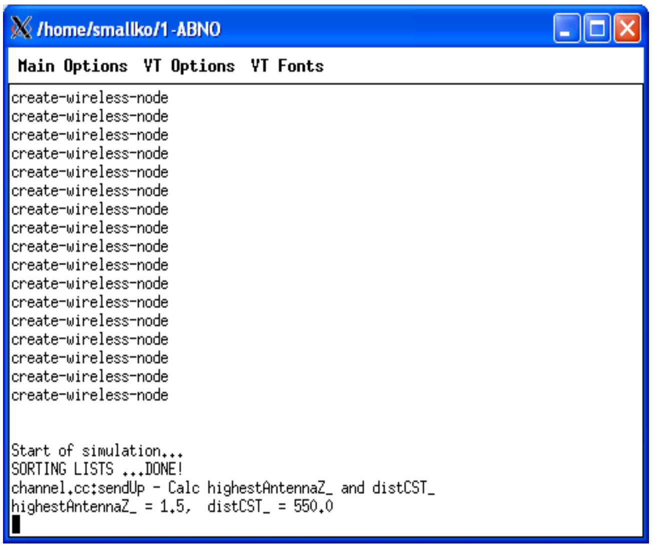


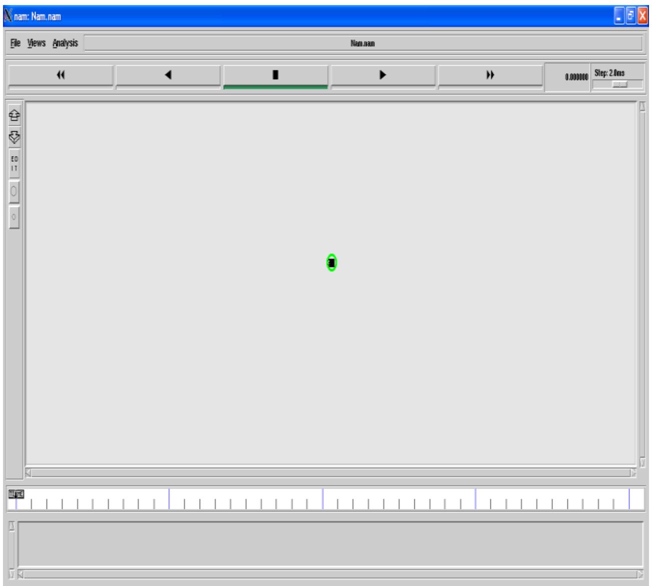

Fig 3 Workflow for the multi-purpose VNT approach.

## IV. Experimental Analysis



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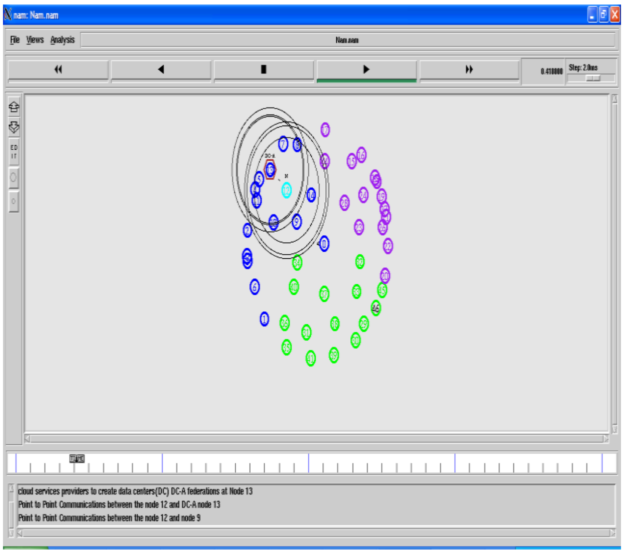


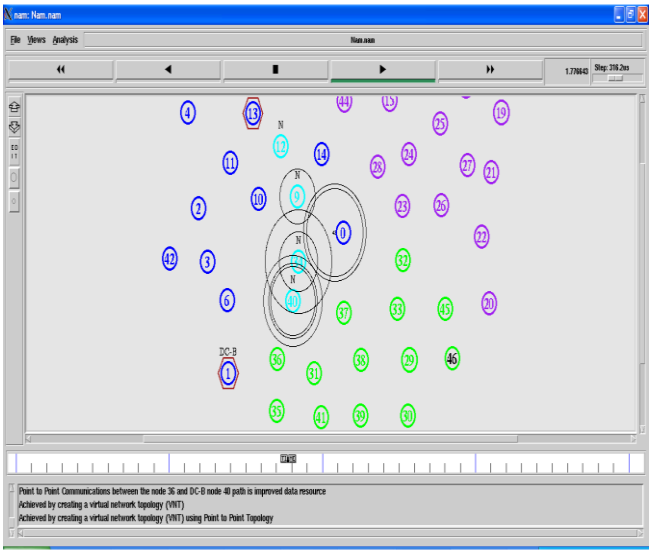


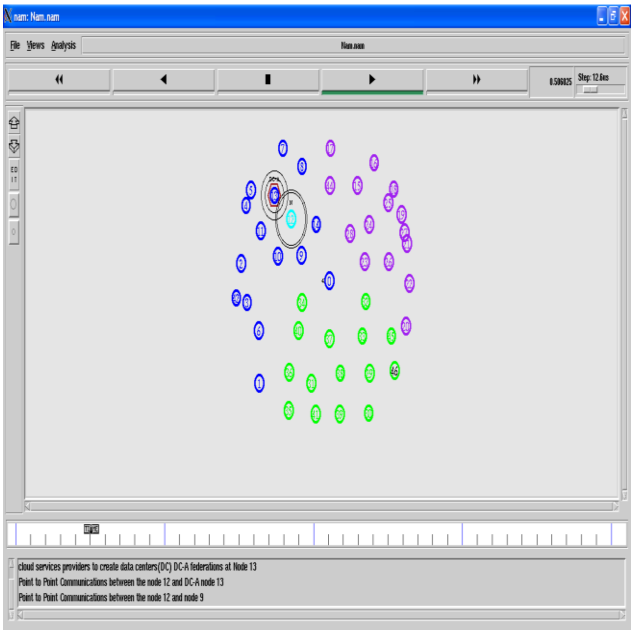


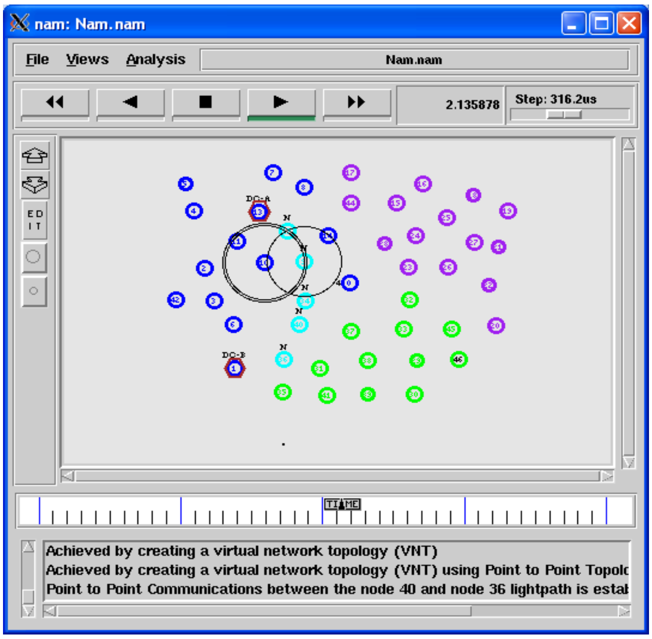


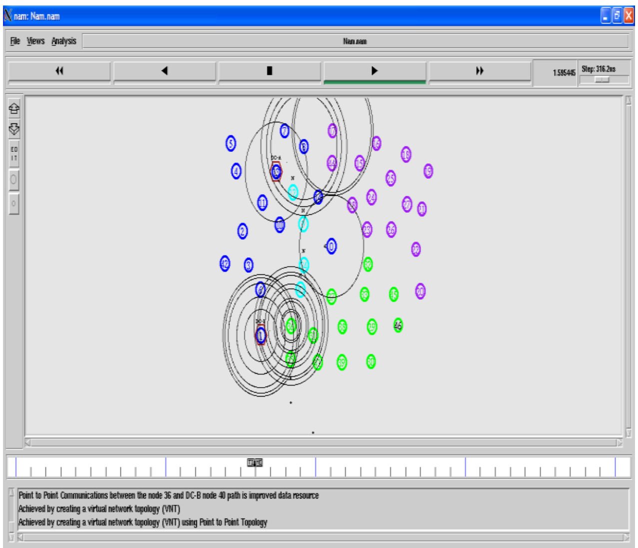


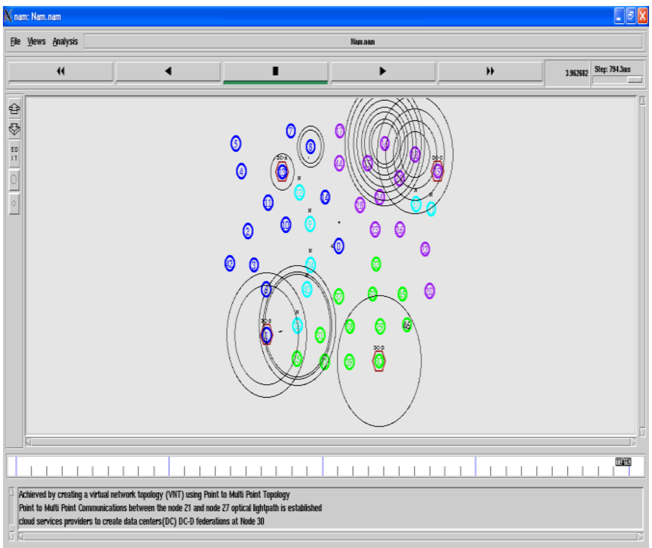


 

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ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

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Vol. 2, Issue 4, April 2016

## V. CONCLUSION

Two approaches were used to provide multicast connectivity services in a multi-layer scenario. In the first approach, a multicast request was created by establishing a point- to-multipoint connection the flex grid network. In the second approach, multicast services are served on a multi-purpose VNT, thus favoring resource utilization. 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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