Thesis for the Degree of Master of Engineering

A Study on O-LSP Establishment Mechanism for Multicast Service in OVPN over IP/GMPLS over DWDM

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IP/GMPLS over DWDM에 기반을 둔 OVPN에서 멀티캐스트 서비스를 위한 O-LSP 설립 메커니즘 연구

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by

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A Dissertation

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Abstract

OVPN over IP/GMPLS over DWDM technology is seen as a favorable approach for supporting high bandwidth multimedia services with QoS assurances. In OVPN, point-to-point connection is not efficient way providing services such as HDTV, live auction, and video-conferencing in aspect of the resource utilization. In order to provide these services, the study on point-to-multipoint method should be considered. In this paper, therefore, the multicast optical-label switched path(O-LSP) establishment mechanism is suggested as the QoS guaranteeing technology for multicast service in OVPN. For the establishment of multicast O-LSP, we propose a new multicast routing generation algorithm VS-MIMR (Virtual Source based Minimum Interference Multicast Routing) that makes multicast tree by finding minimum interference path between virtual source nodes. And we also suggest a control mechanism to adjust the operation of the routing and signaling protocols of GMPLS in OVPN.

Ⅰ. Introduction

VPN (Virtual Private Network) over Internet has attracted a lot of attention of users for the flexibility of use and the economic benefit that additional network need not be built. However, there is difficulty in providing sufficient QoS and adequate transmission capacity for the high bandwidth services such as video-conferencing, VoIP, tele-learning, and shared virtual reality. To resolve these problems, the OVPN (Optical VPN) over IP/GMPLS over DWDM technology has been suggested as a favorable approach for realizing the next generation VPN services [1-3].

In the OVPN over IP/GMPLS over DWDM, the next-generation VPN technology, the technology to guarantee QoS for a wide variety of multi-media real-time services allows efficiently using optical resources, and selects and manages the optical path that meets the QoS requirements for all the allowed service connections in the DWDM network. For this reason, the QoS guaranteeing technology of the OVPN is considered to be a core technology so as to use the next generation optical Internet (NGOI) most efficiently [4].

The QoS providing technology in such an OVPN should be considered in the aspect of the unicast or the multicast manner according to the types of the OVPN services. In other words, one optimal light path between source and destination should be established for point-to-point (P2P) connection and also the establishment of point-to-multipoint (P2MP) connections must be considered for the support of the multicast services such as video telephony, video-conference, and Internet game etc. [5]. In this paper, specifically, the QoS guaranteeing technology of the OVPN is described in aspect of the multicast O-LSP establishment mechanism. The multicast O-LSP establishment mechanism consists of the O-LSP establishment preparation phase and the O-LSP establishment phase.

The O-LSP establishment preparation phase is operated by the various control protocols (the link management protocol (LMP) [6], the OSPF extensions in support of GMPLS (OSPF-TE+) [7] and the multiprotocol extensions of the BGP-4 (MP-BGP) [8]) of OVPN.

And the O-LSP establishment phase consists of three procedures; the SLA negotiation, the QoS guaranteed multicast tree calculation and the label distribution of the GMPLS. In this paper, the new multicast tree generation algorithm VS-MIMR that finds minimum interference path between virtual source nodes is used to calculate the QoS guaranteed multicast tree.

The rest of this paper is organized as follows. In section 2, we describe the functional architecture and operation of the QoS guaranteed OVPN. In section 3, we propose the multicast O-LSP establishment mechanism. In section 4, the effects of new MCRWA algorithm is shown by experiment results. In section 5, the conclusion and further study items are presented.

Ⅱ. Functional Architecture and Operation of QoS Guaranteed OVPN

Based on the OVPN over IP/GMPLS over DWDM framework [5], we propose the functional architecture for providing the optical QoS in OVPN as shown in figure 1.

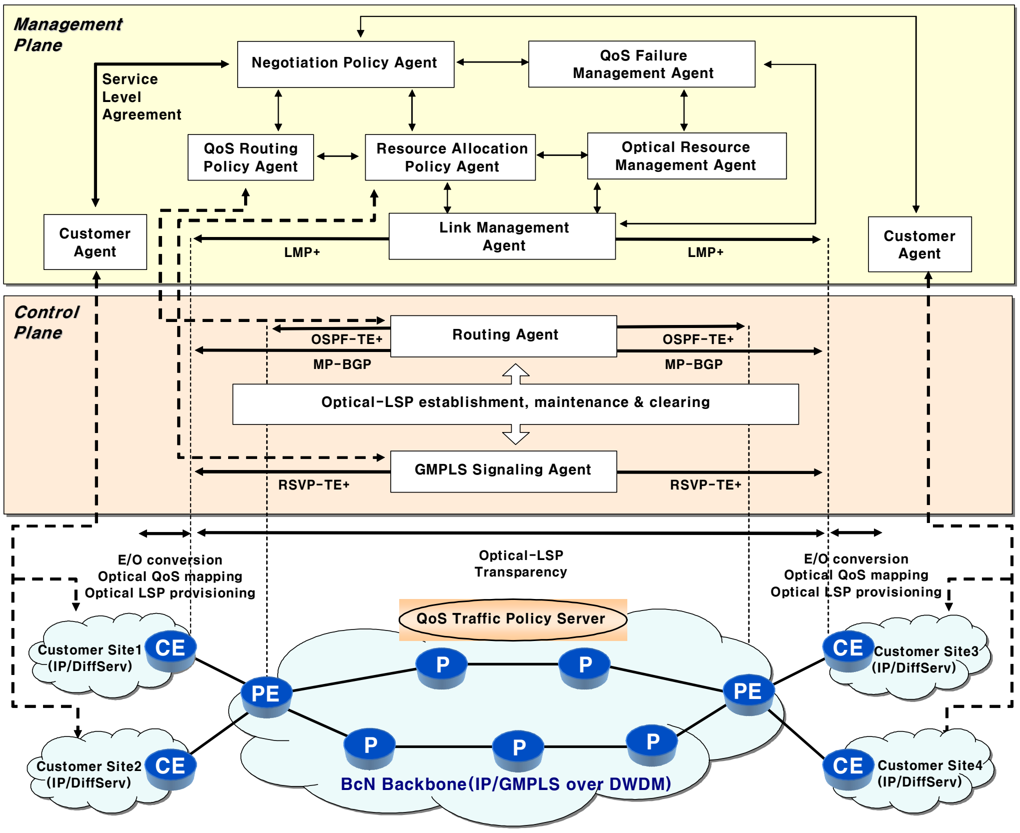


Figure 1. The functional architecture of QoS guaranteed OVPN

The proposed architecture consists of two planes; the control plane and the management plane, and is operated for the purpose of O-LSP establishment and the QoS maintenance for providing the QoS guaranteed multimedia service.

For establishing the multicast O-LSP establishment, at the customer site, a Customer Agent requests a CE-to-CE OLSP establishment with SLA parameters to the Negotiation Policy Agent. When the Negotiation Policy Agent in an ingress PE receives a trigger for setting up an OLSP, it invokes the QoS Routing Policy Agent for routing and wavelength assignment with the QoS parameters extracted from the request. In order to find the best QoS-guaranteed path, it is important for each optical node to broadcast the local resource use and neighbor connectivity information to other nodes so that each node has the global topology and resource information. In order to address this issue, the OVPN Routing Agent is used in the GMPLS-based OVPN control plane. In the OVPN Routing Agent, the OSPF-TE+ or IS-IS extensions in support of GMPLS (IS-IS-TE+) [9] are used as two standard interior gateway protocols (IGPs), and the MP-BGP is used for exchanging the OVPN membership and CE-to-PE,PE-to-PE routing information as the exterior gateway protocol (EGP). Based on the manual initial configuration, the above routing protocols can employ the neighbor discovery mechanisms to find the OVPN neighbor connectivity and resource information such as the number of ports, the peering nodes/ports, the number of wavelength per fiber, and the channel capacity.

Based on the OVPN membership and resource information, the OVPN

Routing Agent calculates the QoS guaranteed multicast tree for establishing the multicast O-LSP. In this paper, VS-MIMR choosing a tree that does not interfere too much with the potential future connection requests by avoiding the congestion links is proposed to calculate the QoS guaranteed multicast tree. After the QoS guaranteed multicast tree calculation, the OVPN Signaling Agent in the control plane is invoked to reserve the optical resource with the GMPLS signaling protocol, the resource reservation protocol with traffic engineering extensions (RSVP-TE+) [10] or the constraint-based routed label distribution protocol with extensions (CR-LDP+) [11].

In this paper, the RSVP-TE+ has been taken as the downstream-on-demand ordered control method to allocate labels. The PATH message allocates a wavelength or port by means of its GMPLS objects such as the Generalized Label Request, Suggested Label, Label Set, Upstream Label, and so on. If an ingress CE node receives the RESV message, the label distribution is operated on all nodes of the optical path between the end users. The new MCRWA algorithm proposed in this paper and GMPLS signaling procedure using RSVP-TE+ will be further illustrated in the next section.

For maintaining the QoS, the protection/restoration management contains the four functional components [12]; failure detection, localization, notification, and recovery. The detection of the fault/attack by continuous or periodic checking is the very first step in order to take provisions to repair it. When a link or node failure is detected by the hardware when the lower-layer impairments such as loss of light occur, or by the higher layer via the link-probing mechanism, the localization procedure gets started immediately by the LMP [6] that runs between the adjacent nodes. It sends the LMP CHANNELSTATUS messages between the adjacent nodes over the control channel maintained separately from the data-bearing channel. After the localization procedure, the notification procedure is started by the Notify messages of RSVP-TE+ that specify that errors be notified to the upstream and downstream nodes. At this time, the QoS Failure Management Agent of the management plane accomplishes the QoS recovery function. It decides on the necessity for using the recovery mechanism by verifying the limitations of the corresponding QoS requirements.

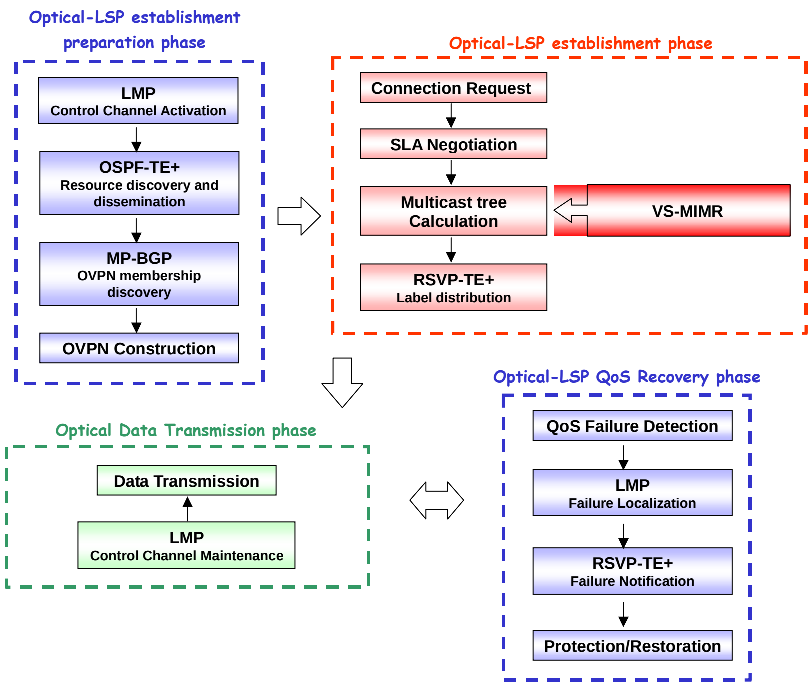


Figure 2. The operation sequence of QoS Guaranteed OVPN

Figure 2 represents the OVPN operation for providing QoS. In the O-LSP establishment preparation phase, the LMP and routing protocols exchange the information of the link and node for organizing the OVPN. The OLSP establishment phase consists of three procedures; the SLA negotiation, the QoS guaranteed multicast tree calculation and the label distribution of the GMPLS. At this time, we use VS-MIMR to calculate the QoS guaranteed tree for establishing the multicast O-LSP. This phase is covered in detail in the next section. After the O-LSP establishment, the user data is transmitted transparently through the OVPN optical backbone network. And there is the QoS failure recovery phase for the QoS failure caused by network faults or attacks in the OVPN backbone network. The organization of these four phases allows providing the QoS guaranteed OVPN service.

Ⅲ. Multicast O-LSP Establishment Mechanism

1. O-LSP Establishment Preparation Phase

1.1 Establishment of CE-to-CE control channel by LMP

The control channels can be used to exchange the control-plane information such as the link provisioning and fault management information, path management and label distribution information (implemented using a signaling protocol such as RSVP-TE+), and network topology and state distribution information (implemented using traffic engineering routing protocols such as OSPF-TE+ and IS-IS-TE+). Therefore, the control channel between the CE nodes should be established and maintained by the LMP as shown in figure 3.

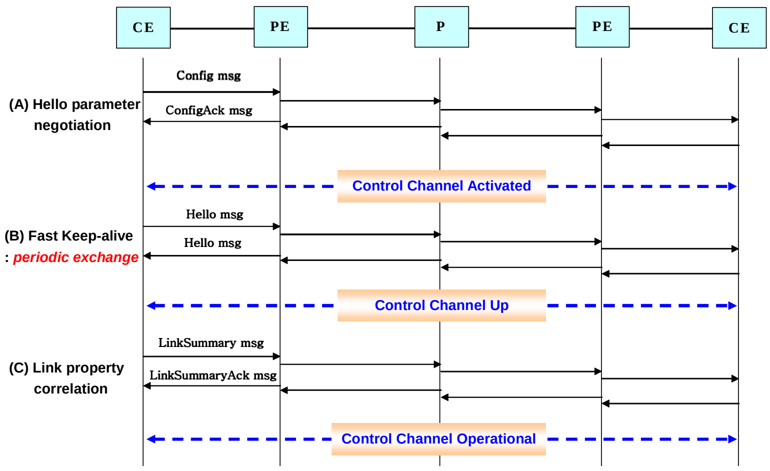


Figure 3. Control channel establishment procedure

The two core procedures of the LMP are the control channel management and link property correlation [6]. The Control channel management is used to establish and maintain the control channels between the adjacent nodes. This is done by using a CONFIG message exchange and a fast keep-alive mechanism between the nodes. The latter is required if the lower-level mechanisms are not available to detect the control channel failures. The Link property correlation is used to synchronize the TE link properties and verify the TE link configuration.

(A) is the procedure where the CONFIG message is exchanged and negotiated to activate the control channel between the adjacent nodes. The CONFIG message contains the time interval when the HELLO message is exchanged and the information that the initial sequence number of the HELLO message is negotiated.

(B) is the procedure where the HELLO message is periodically exchanged between the adjacent nodes by observing the negotiated time interval of the CONFIG message and sequence number to maintain the connectivity of the control channel between the nodes.

(C) is the procedure where, by using the LINKSUMMARY message, the characteristics of the data link such as the multiplexing ability, protection mechanism, bundling is exchanged to operate the activated control channel between the nodes. After such procedures are carried out, the control channel is operated between each node and the routing information of each node is distributed according to the routing protocol.

1.2 Routing information exchange by OSPF-TE+

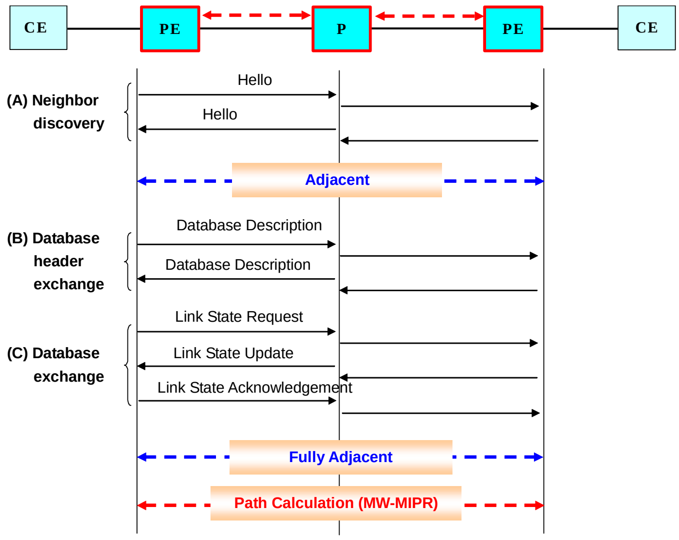


Figure 4. Routing information exchange procedure by OSPF-TE+

In this paper, the routing information is distributed by the OSPF-TE+ [7]. Figure 4 shows the procedure of exchanging the routing information of the OSPF-TE+ for routing between the PE nodes in the OVPN backbone network.

(A) is the procedure where the connection with the adjacent nodes is attained by exchanging the Hello packet between the adjacent nodes between the PE nodes, and the state where the neighbor discovery has been completed means that the nodes are in the relation of “Adjacent”, and the neighbor connection is maintained by the periodical exchange of the Hello packet.

(B) is the procedure of the database header exchange. Only the link state advertisements (LSA) headers are exchanged and the recent needed information among them is checked through the Database Description packet.

(C) is the procedure of the database exchange. The recent needed information is requested through the Link State Request packet after the LSA headers are exchanged in the procedure (B), and the Link State Update packet containing the LSAs (Router-LSA, TE-LSA and Network-LSA etc.) transmits the routing information. And the initial database exchange is attained by responding with the Link State Acknowledgment packet, and the state where the database exchange has been completed is called “Fully Adjacent”.

1.3 Routing information exchange by MP-BGP

The MP-BGP is an extended BGP-4 protocol for the exchange of not only the IPv4 routing information but also the routing information of the diverse network layer protocols [8]. It is also used for the exchange of the membership information among the customer sites in the same OVPN. figure 5 shows the procedure of the routing and membership information exchange of the MP-BGP.

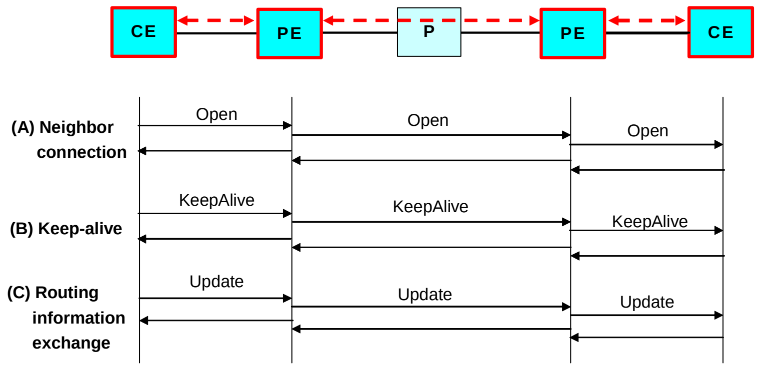


Figure 5. Routing information exchange procedure by MP-BGP

(A) is the procedure of the neighbor connection. The adjacent relation is set with other nodes by using the OPEN message, and the autonomous system (AS) number, the version of BGP, BGP Router ID, and the Keep-alive Hold Time etc. are exchanged for the negotiation of the related parameters.

(B) is the procedure where the adjacent nodes get confirmed to see if they are alive by periodically exchanging the KEEPALIVE message in order to maintain the neighbor connection.

(C) is the procedure of the routing information exchange. The network address, and the AS number list and next hop through which are passed to get to the destination are exchanged by using the UPDATE message.

After forming such an entire routing table of the OVPN, the QoS guaranteed path is established through the SLA negotiation procedure at the time of a connection request.

2. Multicast Tree Construction Mechanism

2.1 Multicast Routing Protocols

One of the critical issues in OVPN is Routing and Wavelength Assignment problem that is embossed as very important and plays a key role in improving the global efficiency for capacity utilization. In addition, many applications such as television broadcast, movie broadcasts from studios, video-conferencing, live auctions, interactive distance learning, and distributed games are becoming increasingly popular. These applications require point-to-multipoint connections among the nodes in the networks.

As a solution of such applications, multicast provides an efficient way of disseminating data from a source to a group of destinations, so the multicast problem in the optical networks has been studied for years and many efficient multicast routing protocols have been developed [13-17].

2.1.1 Source-rooted approach

In Source-rooted approach, a multicast tree is constructed with the source of a session as the root of the tree. The objective here is either to minimize total cost of the tree or to minimize individual cost of paths between the source and destinations. Depending on the objective there are two methods to construct a multicast tree (i.e. Source-based tree and Steiner-based tree) [13-14]

In Source-based tree generation methods [13-14], the destinations are added to the multicast tree in the shortest path to the source of a multicast session. These algorithms provide a computationally simple solution to the multicast tree generation, but have some limitations. Table 1 summarizes the properties, merits and demerits of each multicast tree generation method in the source-based tree approach.

Table 1. Comparisons of Source-based tree generation methods

	Re-route-to-Source	**Re-route-to-Any**	**Member-First**
Properties	Each destination finds its reverse shortest path heading for the source.	Each destination finds the nearest node in the current tree heading for the source.	The tree is constructed according to the link priorities, which was determined by whether or not the link is leading to destinations.
Advantages	Shortest delay, and simple implementation.	Moderate wavelength, channel resources, and delay required.	The least number of wavelengths and short delay.
Disadvantages	It requires the largest amount of channel resources and wavelength numbers.	The constructed tree may have some paths, which are not the shortest paths.	Computational complexity.

In Steiner-based tree [13-14], the destinations are added to the existing multicast tree one at a time in such a way that the total cost of the tree is minimized. To add a node to the tree, it is required to find the minimum cost path tree to all nodes in the tree. This approach is computationally expensive. Hence, heuristics are provided to choose a node to which the present node can be connected. Table 2 summarizes the properties, merits and demerits of each multicast tree generation method in the Steiner-based tree approach.

Table 2. Comparisons of Steiner-based tree generation methods

	Member-Only	Capability-Based-Connection	
Properties	It is similar to the Member-First method. However, if some intermediate nodes are located in equal distance from the present node, the node is connected to one of them selected arbitrary.	Spawn-from-VS heuristic	Capability-based-priority heuristic
		To spawn a new tree, each VS node acts like a source.	The Nodes in the networks are assigned with priorities depending on the wavelength conversion and splitting capabilities.
Advantages	It requires the least number of wavelengths and wavelength channel resources among all four algorithms (including this) already explained.	This approach needs less wavelength and channel resources compared to the Member-Only method.	
Disadvantages	Long delay, and computational complexity.		

For a given multicast session, the methods of the source-rooted approach construct a set of trees with an objective of either minimizing the total cost of the tree or minimizing the individual cost of the path between the source and the destinations. But the source-rooted approach has to consider all intermediate nodes that were laid in the paths between the source and the destination nodes in order to establish efficient path constructions. Therefore it has a long light tree setup time. In addition to the long setup time, the light tree needs to be reconstructed if the tree structure is changed or a link fails. For such a case, the Virtual Source-rooted approach was suggested.

2.1.1 Virtual Source-rooted approach

The algorithm based on this approach overcomes the limitations of the source-rooted approach. In the VS-based tree generation approach [14-17], firstly some nodes are chosen as VS nodes in the entire network. At this time, the nodes that have the highest degree, or the most number of adjacent nodes, are chosen as VS nodes. And the VS nodes have both splitting and wavelength conversion capabilities. The light path is established between these VS nodes, and the entire network is partitioned into each VS node by exchanging information through the established path. When a multicast session is requested, the multicast tree is constructed for each session based on the partitioned area between the VS nodes and the mutual connectivity. Therefore, the VS-based tree construction approach is generally divided into the network partitioning phase and tree generation phase.

A. Network Partitioning Phase

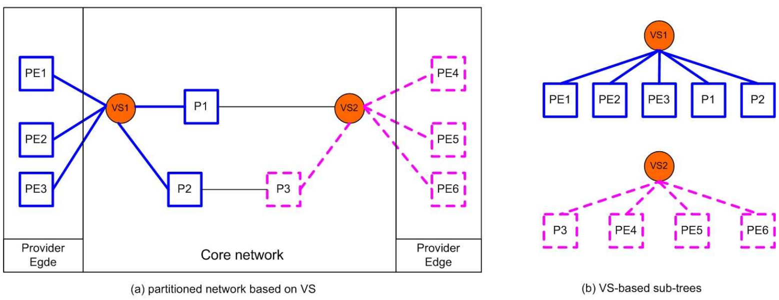


Figure 6. Partitioned OVPN backbone network

The given network is partitioned into some parts based on the nodes adjacent to the VS nodes as shown in figure 6. The degree of VS1 and VS2 is 5, the degree of P1, P2 and P3 is 2, and the degree of the other nodes is 1. Thus, the nodes that have a high degree are chosen as VS nodes. Once the VS nodes are identified, then the paths between all VS nodes are computed.

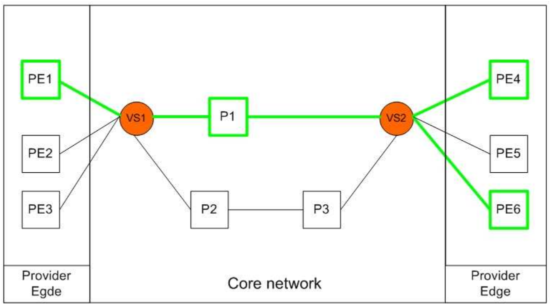
Every VS establishes connections to all the other VS nodes. As a result, the network can be viewed as a set of the interconnected VS nodes, and the remaining nodes in the network grouped into trees each with the root as a VS node [21,22].

B. Tree Generation Phase

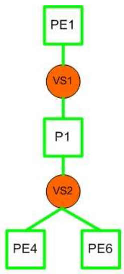
In the tree generation phase, when the set of source and destinations for each request of multicast session are given, the multicast tree is generated by using the connection information provided in the network partitioning phase.

Session	Source node	Destination node
1	PE1	PE4, PE6
2	PE3	PE4,PE5, PE6

(a) Multicast session requests



(b) Multicast session 1



(c) Multicast tree of multicast session 1

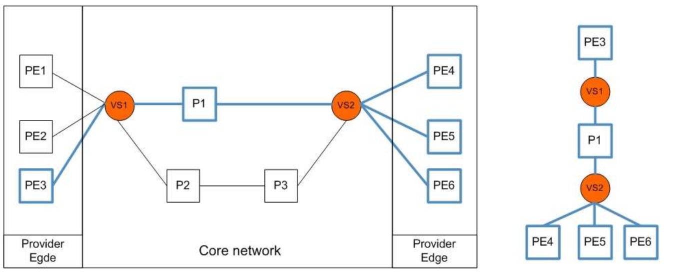
Light Path	Path	Wavelenth
PE1-VS1	PE1-VS1	W0
VS1-VS2	VS1-P1-VS2	W0
VS2-PE4	VS2-PE4	W0
VS2-PE6	VS2-PE6	W0

(d) Wavelength assignment of multicast session 1

Figure 7. Multicast tree generation of multicast session 1

When the set of the source and the destination node of each session is as shown in (a) of figure 7, the multicast tree according to each session can be established as follows. The source node requests the multicast tree generation to the primary virtual source (PVS) that contains the source node as a group member (VS 1 in figure 7). The PVS finds the secondary virtual sources (SVSs), which are the VS nodes of the groups that have one or more destination nodes of the given multicast session. (b) of figure 7 represents the multicast tree for the first session that is finally generated, and (c) shows the distribution of the wavelengths assigned to the generated multicast trees.

Figure 8 shows the generation of the multicast tree and the assignment of the wavelength for the second session in the same fashion. In the similar manner, the multicast trees can be obtained for the third and fourth sessions.



(a) Multicast session 2 (b) Multicast tree of multicast session 2

Light Path	Path	Wavelenth
PE3-VS1	PE3-VS1	W0
VS1-VS2	VS1-P1-VS2	W1
VS2-PE4	VS2-PE4	W1
VS2-PE5	VS2-PE5	W0
VS2-PE6	VS2-PE6	W1

(c) Wavelength assignment of multicast session 2

Figure 8. Multicast tree generation of multicast session 2

In this VS-based tree method, all multicast sessions choose the same fixed minimum-hop path between the VS nodes. This can lead to high blocking probability by inefficiently using the resource due to the traffic concentration on the minimum-hop path between the VS nodes. As shown in figure 7 and figure 8, both of the multicast sessions use the same fixed connection VS1-P1-VS2. Therefore, we propose a new MCRWA method considering the potential future multicast session requests based on the VS-rooted approach and MIPR [18-20] algorithm, called the virtual source-based minimum interference multicast routing (VS-MIMR) [21]. This algorithm is covered in detail in section 2.2.2.

2.2 QoS guaranteed tree establishment mechanism

In the multicasting scheme, the network partitioning phase of the VS-rooted approach is included in the tree establishment preparation phase. After the network partitioning for supporting the multicast service, the routing information is distributed by the OSPF-TE+ and MP-BGP, and the multicast OVPN is constructed.

2.2.1 SLA negotiation for multicast session

As in the case of the multicast OLSP establishment, the SLA negotiation procedure is required between the OVPN backbone network and the customer site in order to establish the QoS guaranteed multicast tree. When the QoS-TP server receives the SLA request that contains the multicast session information and the QoS parameters, it sends the VS_QUERY message to all the VSs in the OVPN network so that the PVS and SVSs can be found as shown in figure 9. All the VSs, which have one or more destinations of the multicast session, respond to the QoS TP server with the VS_REPORT message. When the QoS-TP server gets the information of all PVS and SVSs, it downloads the SLA parameters onto the Negotiation Policy Agent of the PVS in order to establish the connections to all the SVS nodes. At this time, using the VS-MIMR algorithm, which considers the potential blocking probability, improve the resource utilization in the OVPN backbone network.

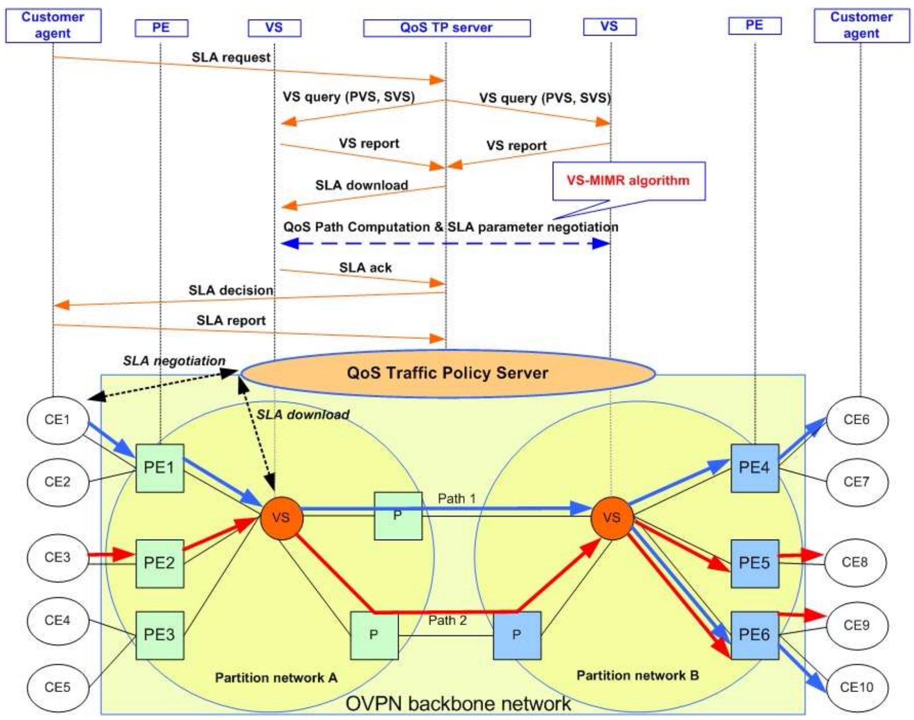


Figure 9. SLA negotiation procedure for multicast service

2.2.2 VS-MIMR for multicast tree generation

In this paper, the VS-MIMR algorithm is proposed to reduce the blocking probability of the original VS-based approach because of using the fixed path between VS nodes. The VS-MIMR finds the minimum interference path between the VS nodes by considering the potential blocking possibilities of the future connection requests.

Fig.9 illustrates the VS-MIMR algorithm. There are two potential source-destinations pairs such as (PE1, PE4&PE6) and (PE2, PE5&PE6). When Path 1 is chosen for the first multicast session in order to make a reservation for the path between PVS-SVS node pair, another multicast session may share the same path. It can lead high blocking probability by inefficiently using the resource due to the traffic concentration on that path. Thus, it is better to pick Path 2 that has a minimum interference effect for other future multicast session request even through the path is longer than Path 2. we define that a segment means a path between a source(or a destination) and nearest VS node or between VS nodes. Before formulating the VS-MIMR algorithm, we define some additional notations used in this algorithm as follows.

- G(N, L, W): The given network, where N is the set of nodes, L is the set of links, and W is the set of wavelengths per link. In this graph, the number of wavelengths per link is same for each link belonging to L.

- Λ: The set of potential PVS-SVS node pairs that can be requested by multicast session in the future.
- (v_i, v_j): the set of VS node pair.
- (v_p, v_s): A PVS-SVS node pair to require the resource reservation for a multicast session when constructing a multicast tree, where $(v_p, v_s) \in (v_i, v_j)$.
- S_{ps}^k: The set of minimum hop segments connecting the path between the (v_p, v_s) pair $(k = 1, \quad 2, \quad \ldots, \quad n)$, where $\forall (v_p, v_s) \in \Lambda$.
- $\partial F_{ps}^k / \partial v$: The interference weight to reflect the change rate of available wavelengths in S_{ps}^k.
- F_{ps}^k: The set of available wavelengths in S_{ps}^k $(k = 1, \quad 2, \quad \ldots, \quad n)$.
- α_{ps}: The weight for the (v_p, v_s) pair, where $\forall (v_p, v_s) \in \Lambda$.
- C_{ps}: The set of critical path between the (v_p, v_s) pair.

• $m(S_{ps}^{k})$: The accumulated total weight for S_{ps}^{k}.

• Δ : A threshold value of available wavelengths on S_{ps}^{k} (30% of the total wavelengths in S_{ps}^{k}).

Among the notations, α_{ps} and C_{ps} are key parameters in VS-MIPMR. Here α_{ps} statistically presents the weight for a segment according to the degree of multicast session resource reservation requests between the VS-nodes, and C_{ps} indicates bottleneck links between the VS-nodes, which are shared on the minimum hop paths of other node pairs at the same time. Based on these notations, the link weights are determined as follow:

$$Max \sum \alpha_{ps} \cdot F_{ps}^{k} \tag{1}$$

$$CP_{ps} : (S_{ps}^{k} \in C_{ps}) \bigcap (F_{ps}^{k} < \Delta) \tag{2}$$

$$\begin{cases} \partial F_{ps}^{n} / \partial v = 1 \; [if \; (v_p, v_s) : S_{ps}^{k} \in CP_{ps}] \\ \partial F_{ps}^{n} / \partial v = 0 \; [otherwise] \end{cases} \tag{3}$$

$$m(S_{ps}^{k}) = \sum_{\forall (v_i, v_j) \in \Lambda \setminus (v_p, v_s)} \alpha_{ps} ({}^{\partial F_{ps}^{k}} \!/\! {}_{\partial v}) \tag{4}$$

Equation (1) presents the minimum interference of the wavelength path decision between the VS-nodes in order to choose the optimal path according to the present multicast session request. And we can determine the links with congestion possibility for the potential future demand between PVS-SVS node pair in the network with the full WC capability as Equation (2). And equation (3) allocates the differentiated values to links between the VS nodes. If the segment belongs to the set of congestion paths, then the interference weight is equal to 1. If there is no interference with the previous light path, then it is equal to 0. And computing the total weight $m(S_{ps}^{n})$ of a segment is set as Equation (4). Finally, the VS-MIMR decides a lightpath as links that has a minimum value of weight $m(S_{ps}^{n})$.

Figure 10 illustrates the VS-MIMR algorithm to find the minimum interference path between PVS and SVSs for constructing a multicast tree. When the PVS receives the multicast session request from the QoS-TP server, it starts to find the path to each SVS. If a segment belongs to the set of the critical paths, i.e., $S_{ps}^{k} \in C_{ps}$ and the number of the residual wavelengths on that segment is lower than the threshold value, i.e., $F_{ps}^{k} < \Delta$, then the total weight of the critical path is added by α_{ps}. After the weight calculation of all segments between the PVS and SVS, the VS-

MIMR chooses the optimal route with the smallest weight $m(S^k_{ps})$.

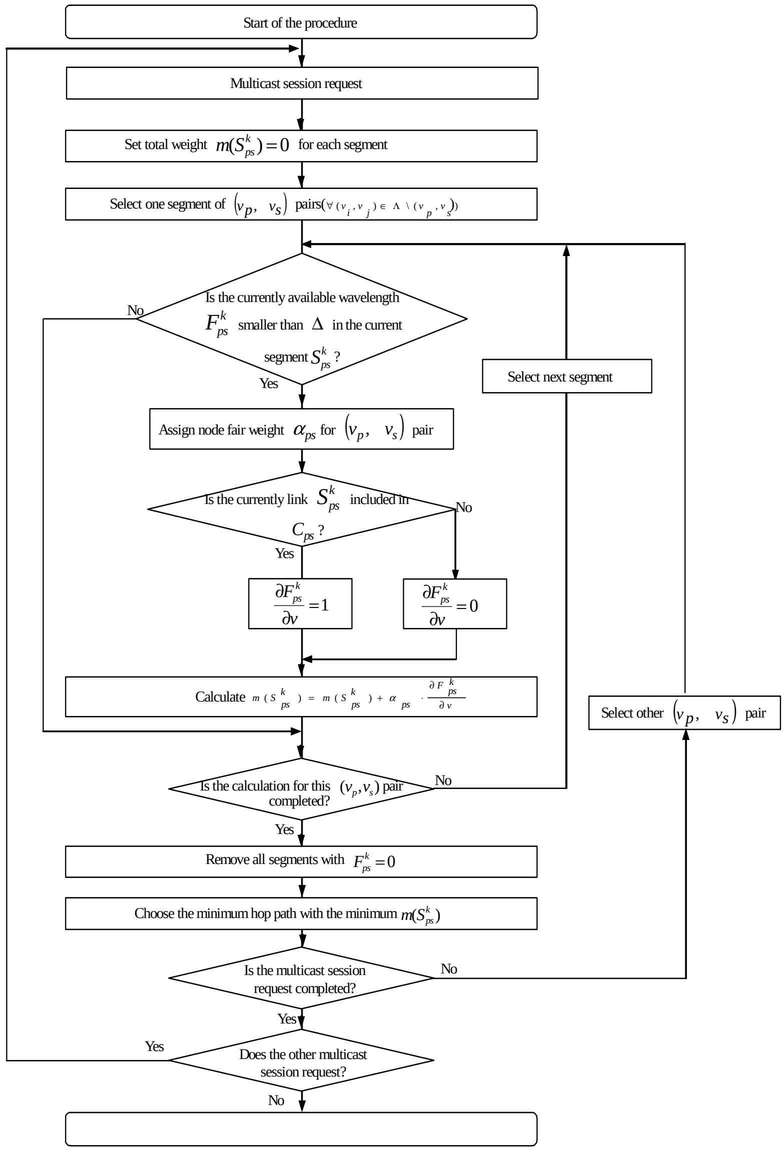


Figure 10. VS-MIMR procedure

2.2.3 Multicasting Distribution tree construction using RSVP-TE+

After the tree calculation, a point-to-multipoint OLSP tree (P2MP tunnel) must be constructed by the RSVP-TE+ extensions for multicasting in the GMPLS networks. Although the P2MP OLSP is constituted of the multiple source-to-one leaf (S2L) sub-OLSPs, we can signal all S2L sub-OLSPs in one PATH message with the EXPLICIT_ROUTE object (ERO), P2MP SECONDARY_EXPLICIT_ROUTE object (SERO), and S2L_SUB_LSP object (S2LO) [25,26].

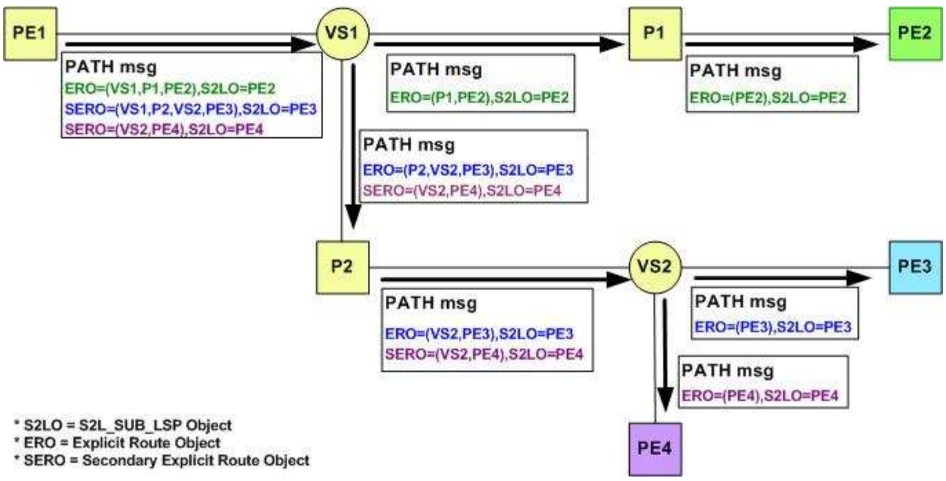


Figure 11. Extended RSVP-TE+ for multicast tree establishment

Figure 11 shows a P2MP OLSP with PE1 as a source node and three destination nodes (PE2, PE3 and PE4). We assume that the S2L sub-OLSP to PE2 is the first S2L sub-OLSP and the rest are the subsequent S2L sub-OLSPs. In PE1, the PATH message contains one ERO for the S2L sub-OLSP to PE2 and two SEROs for the S2L sub-OLSPs to PE3 and PE4. When the branch nodes (VS1 and VS2) receive the PATH message, it generates the multiple PATH messages with the different EROs and SEROs. In our example, VS1 sends a PATH message to P1 with the ERO encoded as {P1, PE2} and also a PATH message to P2 with the ERO={P2, VS2, PE3} and SERO={VS2, PE4}. After sending out the PATH messages to all nodes of the multicasting tree, this will be confirmed by the RESV message with the ROUTE_RECORD object (RRO) and P2MP SECONDARY_ ROUTE_RECORD objects (SRROs) at each link of the multicasting tree [26].

Ⅳ. Analysis and Simulation of VS-MIMR

In this section, simulation studies are carried out to evaluate the performance of VS-MIMR. The simulation is run on Pentium 4 PC with 2.8GHz CPU and 512MB RAM. The network model used in the simulations are 14-node topology, as shown in figure 12, that are currently often used as DWDM network models and adopted in most of the papers related to DWDM networks. And we assume that the multicast session requests arrive randomly according to the Poisson process.

We will compare the results of our algorithm with VS-based method in respect of the utilization of the wavelength numbers and the wavelength channel numbers, and analyze the gain of the wavelength numbers and the loss of the wavelength channel numbers. Here the gain and the loss mean the differences of the wavelength numbers and of the wavelength channel numbers between our algorithm and Virtual Source-based method, respectively.

In order to prove the efficiency of VS-MIMR algorithm proposed in section 3, we showed the wavelength numbers and the wavelength channel numbers of VS-MIMR and the Virtual Source-based method; here the Group Size (GS) that determines the number of members to construct a multicast session is 0.3 and 0.4 [24]. Figure 13 reveals that the proposed VS-MIMR algorithm outperforms the Virtual Source-based method due to the selection of the minimum interference paths. Therefore VS-MIMR can accomplish approximately 24% improvements of the wavelength numbers in case of GS 0.3 of 14-node topology, in comparison with those of the VS-based multicast method, when the seventh multicast session arrived.

Although VS-MIMR needs slightly more numbers of wavelength channels than those of Virtual Source-based method due to the detour paths to avoid congestion links shown in figure 15, we can identify that the loss of the wavelength channel does not exceed 7% in 14-node topology, as shown in figure 16.

In conclusion, using VS-MIMR we can construct the multicast trees more efficiently than the Virtual Source-based method, even though we experience a bit of loss in the wavelength channel numbers.

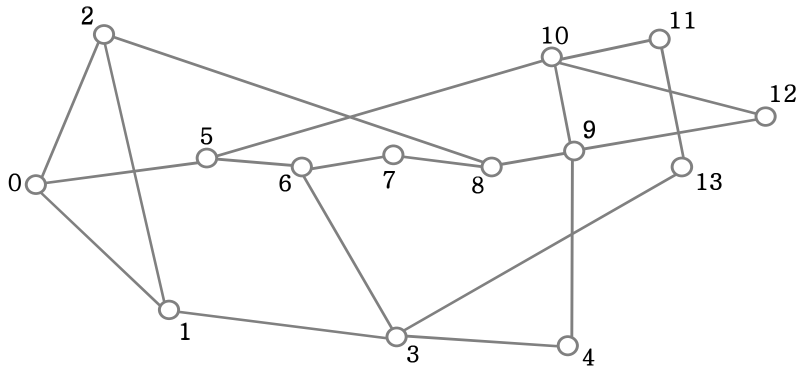


Figure 12. Example of 14-node network topology

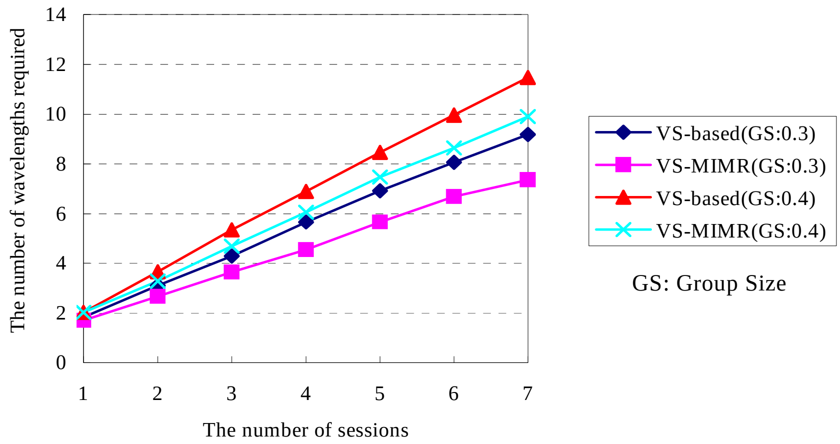


Figure 13. The number of wavelengths over sessions

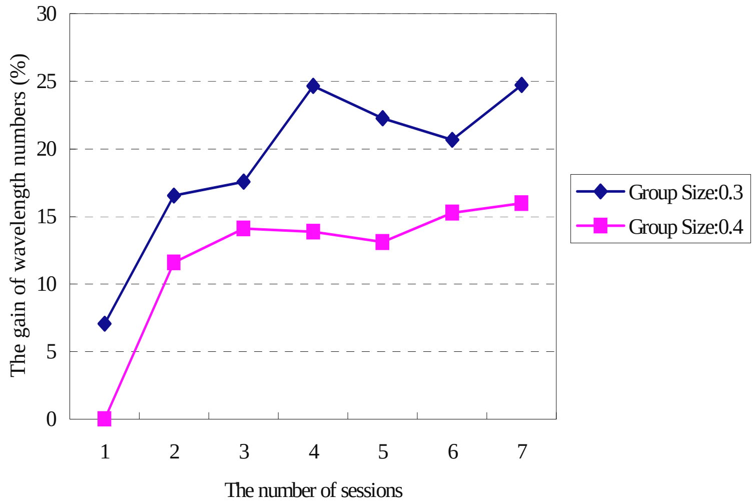


Figure 14. The gain of wavelength numbers over sessions

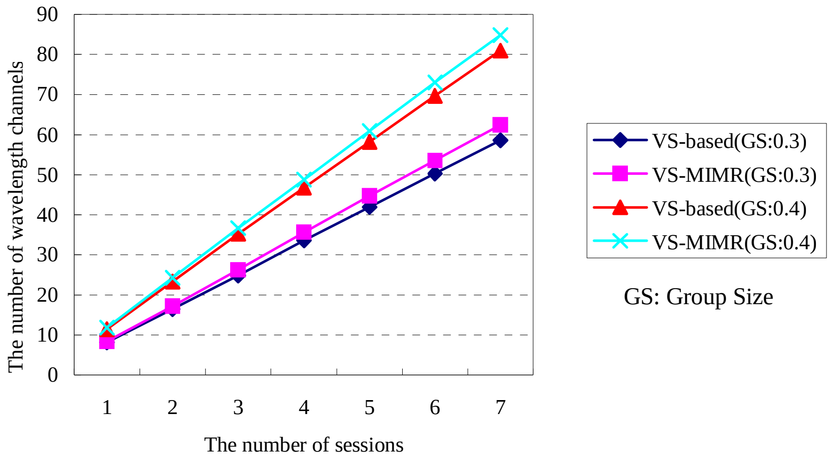


Figure 15. The number of wavelength channels over sessions

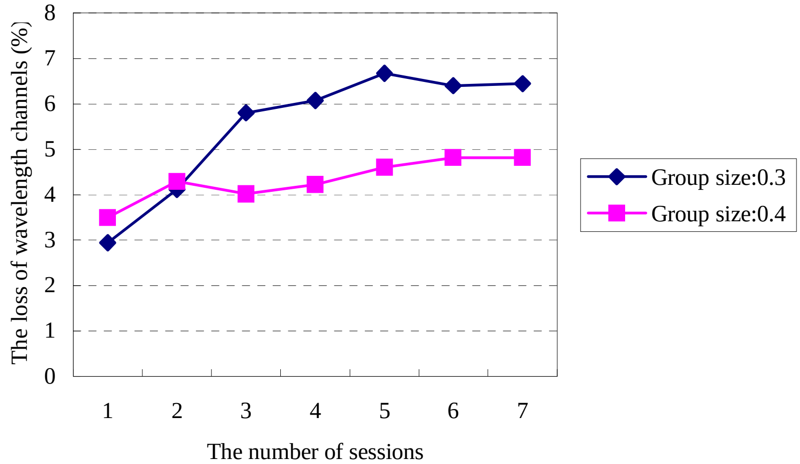


Figure 16. The loss of wavelength channel numbers over sessions

Ⅴ. Conclusion

In this paper, the functional architecture and the interoperation of the control plane and management plane of the QoS guaranteed OVPN are presented. Based on this technology, the multicast OLSP establishment mechanisms are suggested for providing QoS in OVPN over IP/GMPLS over DWDM. In this case, the new routing algorithms calculating the minimum interference multicast tree is described, and we showed the efficiency from simulation results. And the control protocols of the GMPLS such as OSPF-TE+, RSVP-TE+, LMP and MP-BGP are presented for applying to QoS guaranteeing OVPN framework.

In the future research, we have a plane to implement the proposed OVPN framework with GLASS tool in order to verify the efficiency of the proposed algorithms and mechanisms. And OVPN survivability technology is needed for sustaining traffic continuity even for network failures since a short service disruption in DWDM based OVPN carrying extremely high data rates cause loss of vast traffic volumes.

References

[1] S. S. Dixit, IP over WDM: building the next-generation optical internet, John Wiley& Sons publication, 2003

[2] Z. Zhang, et al., An Overview of Virtual Private Network (VPN): IP VPN and Optical VPN, Photonic Network Communications, vol. 7, no. 3, pp. 213-225, May 2004.

[3] H. Ould-Brahim et al. Generalized Provider-provisioned Port-based VPNs using BGP and GMPLS Toolkit, draft-ouldbrahim-ppvpn-gvpn-bgpgmpls-03.txt, IETF Internet Draft, March 2003.

[4] Mi-Ra Yoon et al, Optical-LSP Establishment and a QoS Maintenance Scheme Based on Differentiated Optical QoS Classes in OVPNs, Photonic network communications, vol.7, no. 2, pp. 161-178, March 2004.

[5] Stephen French and Dimitrios Pendarakis, Optical Virtual Private Networks: Applications, Functionality and Implementation, Photonic Network Communications, vol. 7, no. 3, pp. 227-238, May 2004.

[6] J. Lang, Link Management Protocol (LMP), draft-ietf-ccamp-lmp-10.txt, IETF Internet Draft, October 2003.

[7] K. Kompella and Y. Rekhter, OSPF Extensions in support of Generalized Multi-Protocol Label Switching, draft-ietf-ccamp-ospf-gmpls-extensions-12.txt, IETF Internet Draft, April 2004.

[8] T. Bates et al, Multiprotocol Extension for BGP-4, RFC2858, June 2000.

[9] K. Kompella and Y. Rekhter, IS-IS Extensions in Support of Generallized Multi-Protocol Label Switching, draft-ieft-isis-gmpls-extensions-19.txt, IETF Internet Draft, October 2003.

[10] L. Berger, GMPLS Signaling Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extensions, IETF RFC 3473,

January 2003.

[11]P. Ashwood-Smith and L. Berger, GMPLS Signaling Constraint-based Routed Label Distribution Protocol (CR-LDP) Extensions, IETF RFC 3472, January 2003.

[12]D. Papadimitriou, E. Mannie: Analysis of Generalized MPLS based Recovery Mechanisms (including Protection and Restoration), draft-ietf-ccamp-gmpls-recovery-analysis-02.txt, IETF Internet Draft, May 2003.

[13]Xijun Zhang, et al., "On Fundamental Issues in IP over WDM Multicast," in Int. Conf. Computer Communications and Networks (IC3N), pp.84-90, Oct. 1999

[14]C. Siva Ram Murthy, and Mohan Gurusamy, " WDM OPTICAL NETWORKS: Concepts, Design, and Algorithms," Published by Prentice Hall PTR. ISBN: 0130606375 Published: Nov 26, 2001. Copyright 2000

[15]Xijun Zhang et al., Constrained multicast routing in WDM networks with sparse light splitting, Lightwave Technology, Journal of, vol. 18, no. 12, pp. 1917-1927,December 2000.

[16]N. Sreenath et al., Virtual source based multicast routing in WDM optical networks, Proceedings IEEE International Conference on, pp. 385-389,Septempber 2000.

[17]N. Sreenath et al., Virtual source based multicast routing in WDM networks with sparse light splitting, High Performance Switching and Routing, 2001 IEEE Workshop on, pp. 141-145, May 2001.

[18]J. G. Hwang et al., A RWA Algorithm for Differentiated Services with QoS Guarantees in the Next Generation Internet based on DWDM Networks, Photonic Network Communications, vol. 8, no. 3, pp. 319-334, November 2004.

[19]K. Kar et al., Minimum Interference Routing of Bandwidth Guaranteed Tunnels with MPLS Traffic Engineering Applications, IEEE Journal on Selected Areas in Communications, vol. 18, no. 12,

December 2000, pp. 2566 –2579.

[20] K. Kar et al., MPLS Traffic Engineering using Enhanced Minimum Interference Routing: An Approach based on Lexicographic Max-Flow, Proceedings of IEEE IWQOS 2000 (Karlsruhe, Germany, June, 2000), pp. 105 –114.

[21] Suk-Jin Lee et al. Virtual Source-based Minimum Interference Path Multicast Routing with Differentiated QoS guarantees in the Next Generation Optical Internet, Networking - ICN 2005: 4th International Conference on Networking, vol. 3420, March 2005

[22] R. Braden, Ed. et al, Resource ReSerVation Protocol (RSVP)-Version 1 Functional Specification, RFC 2205, September 1997.

[23] Seisho Yasukawa, Requirements for Point to Multipoint Traffic Engineered MPLS LSPs, draft-ietf-mpls-p2mp-requirement-04.txt, IETF Internet Draft, September 2004

[24] R. Aggarwal et al., Extensions to RSVP-TE for Point to Multipoint TE LSPs, draft-ietf-mpls-rsvp-te-p2mp-01.txt, IETF Internet Draft, June 2005

IP/GMPLS over DWDM에 기반을 둔 OVPN에서 멀티캐스트 서비스를 위한 O-LSP 설립 메커니즘 연구

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요 약

IP/GMPLS over DWDM 에 기반을 둔 광가설사설망(OVPN: Optical Virtual Private Network)기술은 방대한 대역폭을 요구하는 멀티미디어 서비스의 QoS(Quality of Service)를 보장하는 대안 중 하나로 여겨지고 있다. 이러한 OVPN 에서 다수의 가입자에게 서비스를 제공해야 하는 television broadcast, live auction, video-conferencing 등과 같은 서비스를 제공하기 위해서 일대일 연결 방식을 사용하는 것은 망 자원 사용측면에서 효율적이지 못하다. 따라서 일대다 연결 방식인 멀티캐스트를 통해 이러한 서비스들을 제공하는 연구가 필요하다.

이에 본 논문에서는 OVPN 에서 멀티캐스트 서비스 지원 시 망 자원의 효율적인 사용과 QoS 보장을 위한 방안으로 멀티캐스트 O-LSP(Optical Label Switched Path) 설립 메커니즘을 제안한다. 제안한 멀티캐스트 O-LSP 설립 메커니즘은 SLA(Service Level Agreement) 협상, 멀티캐스트 트리 계산, 시그널링 프로토콜에 의한 Label 분배과정으로 이루어져 있다. 멀티캐스트 트리 계산을 위한 새로운 방안으로 멀티캐스트 트리 생성 방식 중 하나인 가상 근원지 접근 방식을 기반으로 한 VS-MIMR(Virtual Source based Minimum Interference Multicast Routing) 알고리즘을 제안한다. 또한 VS-MIMR 의 성능평가를 통해 VS-MIMR 이 적용된 멀티캐스트 설립 메커니즘의 우수성을 증명하였다.

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