Control Mechanism for QoS Guaranteed Multicast Service in OVPN over IP/GMPLS over DWDM

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***Abstract*—OVPN over IP/GMPLS over DWDM technology with QoS assurances is considered as a promising approach for the next generation OVPN. In this paper, we suggest a multicast OLSP (Optical Label Switched Path) establishment mechanism for supporting high bandwidth multicast services in OVPN over IP/GMPLS over DWDM. For the establishment of the multicast OLSP, we propose a new multicast tree generation algorithm VS-MIMR that finds the minimum interference path between virtual source nodes. We also suggest an entire OVPN control mechanism to adapt the operation of the routing and signaling protocols of GMPLS.**

***Index Terms*—OVPN, QoS, Multicast RWA, GMPLS, DWDM**

I. Introduction

OVPNs (Optical Virtual Private Networks) are expected to be one of the major applications in the future optical networks. Therefore the OVPN over IP (Internet Protocol)/GMPLS (Generalized Multi-Protocol Label Switching) over DWDM (Dense Wavelength Division Multiplexing) technology has been suggested as a favorable approach for realizing the next generation VPN services [1 - 4].

OVPN should be considered in the aspect of the unicast or the multicast manner according to the types of the OVPN services. In the unicast method, one optimal light path between source and destination should be established for point-to-point (P2P) connection. On the other hand, the light paths should be established for point-to-multipoint (P2MP) connections in the multicast method. In general, major benefits of the multicast method are bandwidth savings and scalability inherent [5].

In this paper, the characteristics of the OVPN multicast services are analyzed. And the establishment of multicast OLSP is investigated in two steps; OLSP establishment preparation phase and OLSP establishment phase. In the OLSP establishment phase, a new multicast tree generation algorithm, VS-MIMR (Virtual Source-based Minimum Interference Multicast Routing), that finds the minimum interference path between virtual source nodes is proposed. We also suggest an entire OVPN control mechanism to establish multicast OLSP adapting the operation of the routing and signaling protocols of GMPLS.

The rest of this paper is organized as follows. In section II, we describe the functional architecture and operation of the QoS guaranteed OVPN. In Sections Ⅲ, we propose the multicast OLSP establishment scheme and a new multicast tree generation algorithm VS-MIMR. In Section Ⅳ, 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 [6], we propose the functional architecture for providing the optical QoS in OVPN as shown in Fig. 1. The proposed architecture consists of two planes; the control plane and the management plane for the purpose of OLSP establishment and the QoS maintenance to provide the QoS guaranteed multicast services.

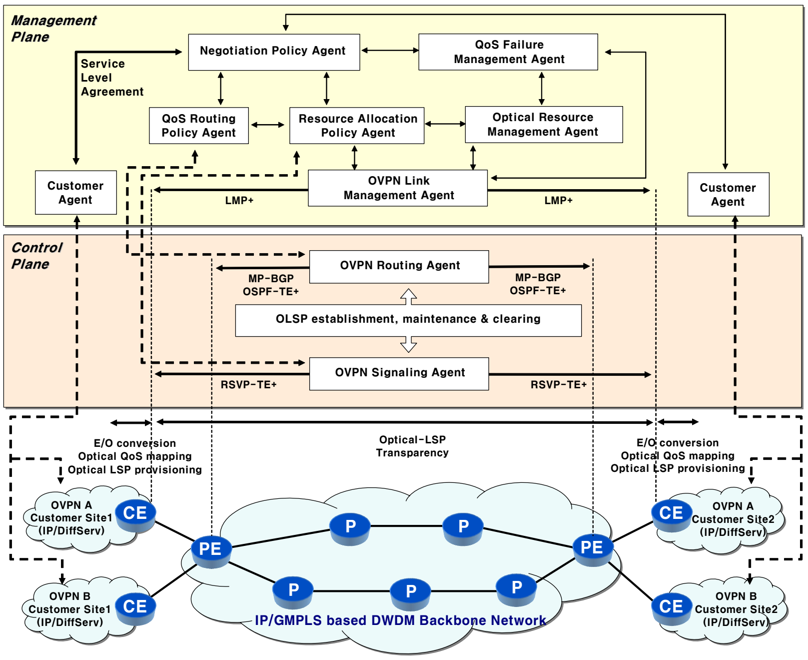


Figure 1. The functional architecture of QoS guaranteed OVPN

For establishing the multicast OLSP, at the customer site, a Customer Agent requests a CE (Client Edge)-to-CE OLSP establishment with SLA(Service Level Agreement) parameters to the Negotiation Policy Agent. Once the Negotiation Policy Agent in an ingress PE (Provider Edge) 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 this process, in order to find the best QoS-guaranteed path, it is important for each optical node to broadcast each local resource using status and neighbor connectivity information to other nodes so that each node has the global topology and resource information.

OVPN Routing Agent in the GMPLS-based OVPN control plane uses the OSPF-TE+ (Open Shortest Path First with Traffic Engineering extensions) or IS-IS (Intermediate System to Intermediate System) extensions in support of GMPLS [7] for the IGPs (interior gateway protocols), and the MP-BGP (MultiProtocol Border Gateway Protocol) is used for exchanging the OVPN (CE-to-PE) membership and PE-to-PE routing information as the EGP (exterior gateway protocol).

Based on the initial configuration, the above routing protocols can employ the neighbor discovery mechanisms to find the OVPN neighbor connectivity by using 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 tree for establishing the multicast OLSP. In this process, the VS-MIMR algorithm choosing a tree that does not interfere too much with the potential future connection requests by avoiding the congestion paths 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 RSVP-TE+ (Resource ReSerVation Protocol with Traffic Engineering extensions) [8] or the CR-LDP+ (Constraint-based Routed Label Distribution Protocol with extensions) [9].

For maintaining the QoS, the protection or restoration management contains the four functional components [9]; 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

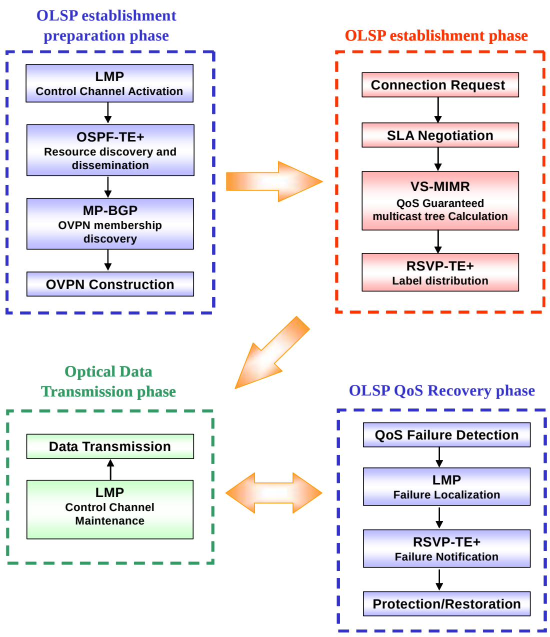


Figure 2. OVPN control mechanism for providing QoS

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 [11] 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.

Fig. 2 represents the OVPN control mechanism explained above.

Ⅲ. MULTICAST OLSP ESTABLISHMENT

A. Preparation Mechanism for OLSP Establishment

a. Establishment of CE-to-CE Control Channel by LMP

The control channels are 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 Fig. 3.

The two core procedures of the LMP are the control channel management and link property correlation [10]. 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 later 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 about the initial negotiated sequence number of the HELLO message.

(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, and bundling are exchanged to operate the activated control channel between the nodes. After such procedures are carried out, the control channel is operated

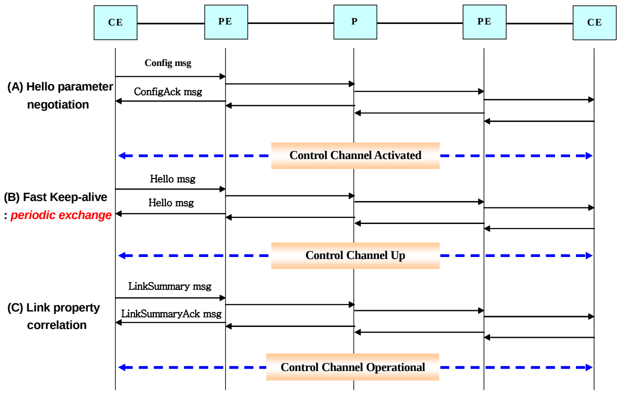


Figure 3. Control channel establishment procedure

between each node and the routing information of each node is distributed according to the routing protocol.

b. Routing Information Exchange by OSPF-TE+

In this paper, we assume the routing information is distributed by OSPF-TE+ [11]. Fig. 4 shows the procedure of exchanging the routing information of 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, 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".

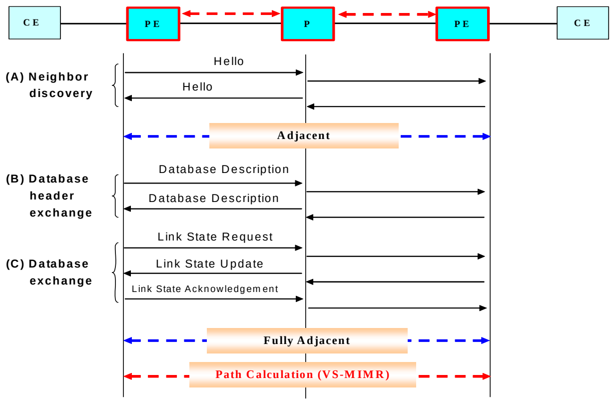


Figure 4. Routing information exchange procedure by OSPF-TE+

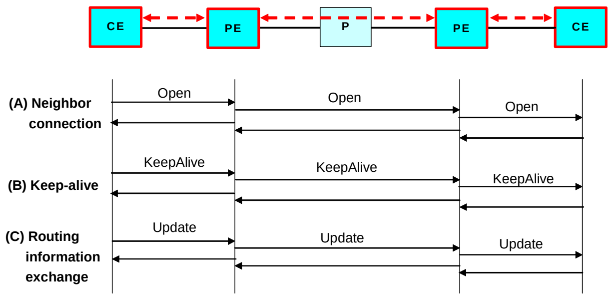


Figure 5. Routing information exchange procedure by MP-BGP

c. 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 [13]. It is also used for the exchange of the membership information among the customer sites in the same OVPN. Fig. 5 shows the procedure of the routing and membership information exchange of the 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. The appropriate OLSP is calculated by the mechanism explained in the next section.

B. *Multicast Tree Construction mechanism*

In order to calculate OLSP, some multicast routing algorithms based on the Source-based tree and Steiner-based tree [14] were proposed. But they need high tree-construction-time because the destinations of a session are distributed over the globes. And the tree may need to be reconstructed when link or node failures occur. Moreover, just some nodes have splitting capability due to the cost of the network (the concept of sparse-splitting [14]), consequently the tree construction algorithm could be more difficult and complicated.

To overcome these limitations, VS-based tree generation method is proposed [15 - 16]. For example, using a VS node that has both the splitting and wavelength conversion capabilities can transmit an incoming message to any number of the output links on any wavelengths. And the setup time for a VS-based multicast tree is much less compared to that of the source-rooted multicast tree construction.

a. Tree Construction using Virtual Source-based Approach

In the VS-based tree generation approach, 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.

- Network Partitioning Phase

The given network is partitioned into some parts based on the nodes adjacent to the VS nodes as shown in Fig. 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 VS1 and VS2 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 [15 - 16].

- 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

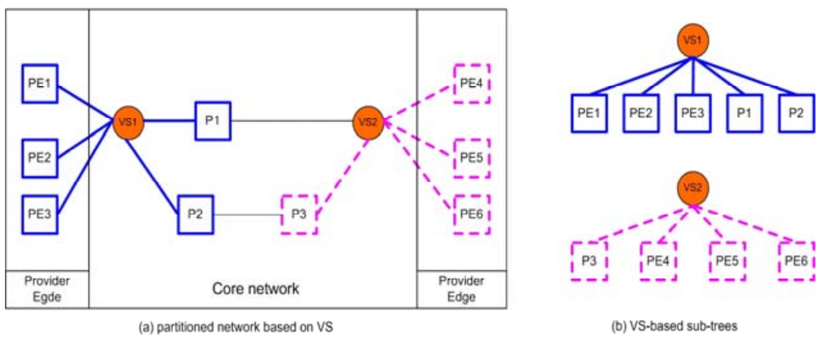
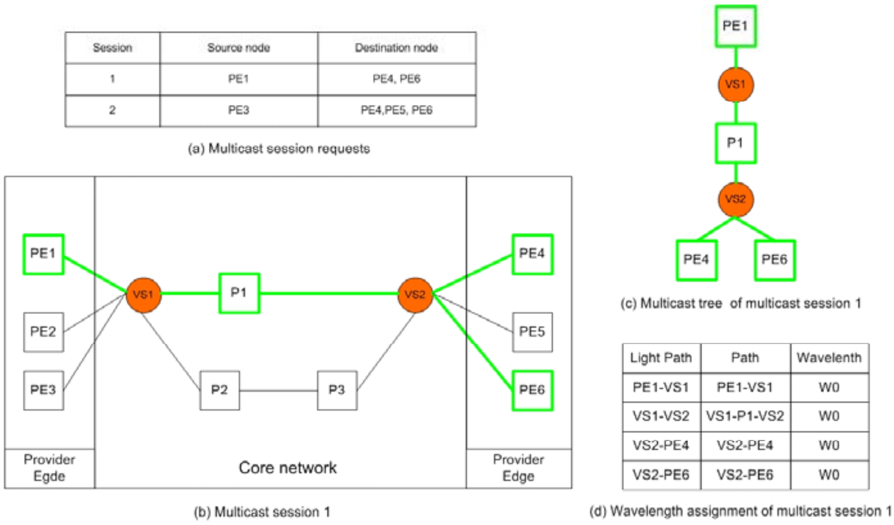


Figure 6. Partitioned OVPN backbone network



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

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

Figure 7. Multicast tree generation of multicast session 1

connection information provided in the network partitioning phase.

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

(a) of Fig. 7 represents two sessions and the multicast tree for the second session can be generated in the same fashion. In the similar manner, the multicast trees can be obtained for the third and fourth sessions.

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 Fig. 7 and Fig. 8, both of the multicast sessions use the same fixed connection VS1-P1-VS2. Therefore, we propose a new VS-MIMR algorithm with considering the potential future multicast session requests. This algorithm is covered in detail in section Ⅲ.C.b.

C. QoS guaranteed Tree Establishment Mechanism

a. SLA Negotiation for Multicast Session

In the case of the multicast OLSP establishment, the SLA negotiation procedure is also required between the OVPN backbone network and the customer site to establish the QoS guaranteed multicast tree.

When the QoS-TP server (we assume this server is belong to the management plane in Fig. 1) 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 Fig. 8. All the VSs, which have one or more

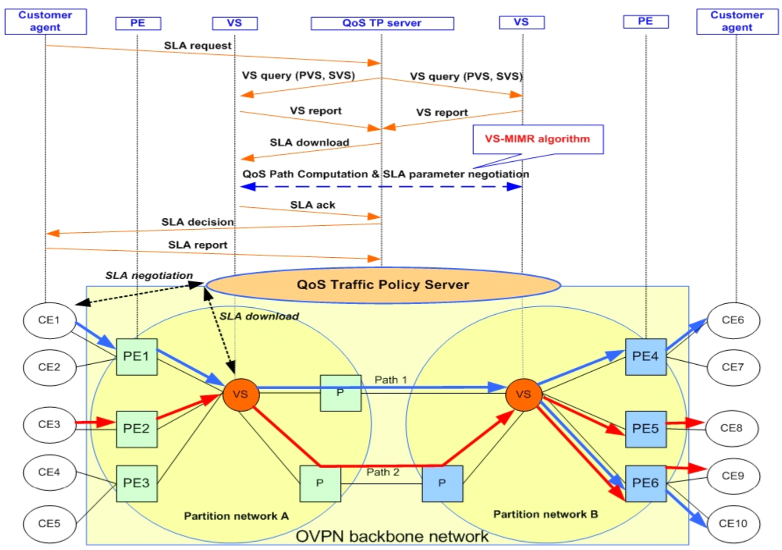


Figure 8. SLA negotiation procedure for multicast service

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, we improve the resource utilization in the OVPN backbone network.

b. VS-MIMR for multicast tree generation

The VS-MIMR algorithm is suggested to choose minimum interference paths. The proposed algorithm overcomes the limitation of VS-based method and provides an efficient use of wavelengths.

Fig. 8 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 resource reservation for the path between a PVS-SVS pair, the other multicast session may share the same path having a minimum-hop 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 requests even though the path is longer than Path 1. We define that a segment means a path between a source (or a destination) and nearest VS node or between VS nodes. And each segment must follow the wavelength continuity constraint [17], because only VS nodes can have a wavelength splitting and conversion capability. 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.
- (v_p, v_s): A PVS-SVS node pair.
- (a, b): A PVS-SVS node pair to require the resource reservation for a multicast session when constructing a multicast tree, where $(a, b) \in (v_p, v_s)$.
- Λ: The set of potential PVS-SVS node pairs that can be requested by multicast session in the future.
- S_{ps}^n : The set of minimum hop segments connecting the path between the (v_p, v_s) pair. (n=1,2,3)
- $\partial F_{ps}^n / \partial v$: The interference weight to reflect the change rate of available wavelengths in S_{ps}^n
- : The number of available wavelengths in S_{ps}^n

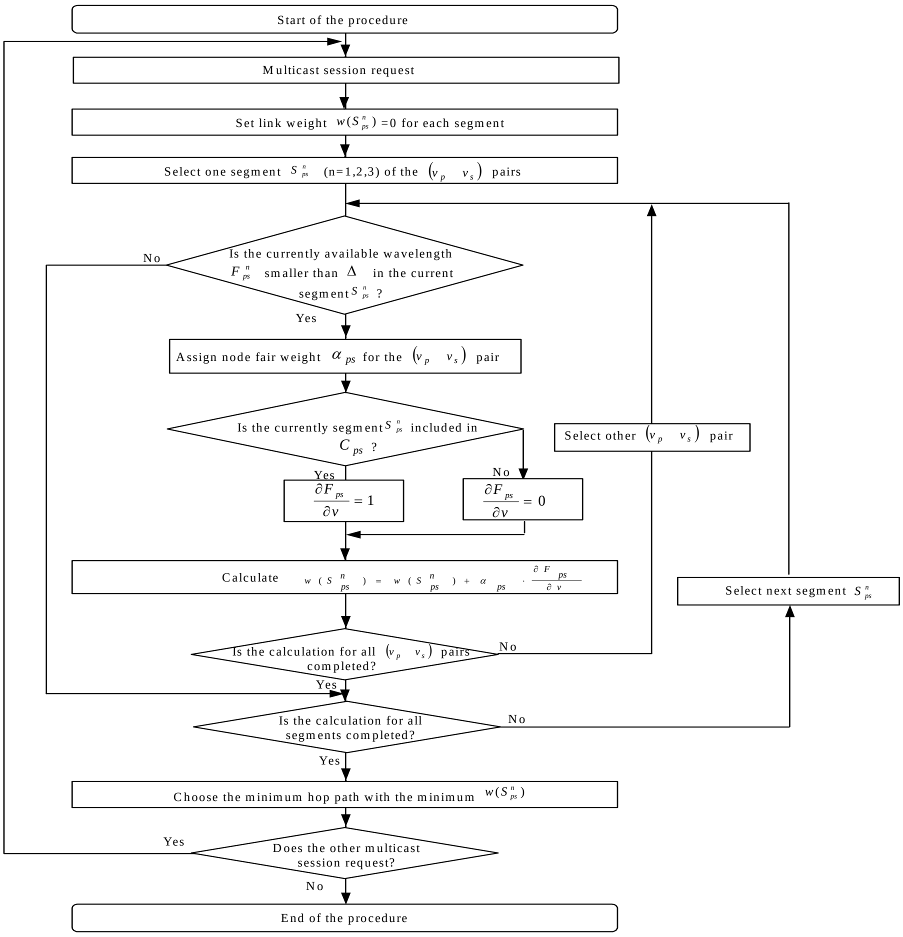


Figure 9. VS-MIMR algorithm

- 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.
- $w(S^n_{ps})$: The accumulated total weights for S^n_{ps}
- Δ : A threshold value of available wavelengths on S^n_{ps} (30% of the total wavelengths in S^n_{ps}).

Among the notations, α_{ps} and C_{ps} are key parameters in VS-MIMR. Here α_{ps} statistically presents the weight for a segment according to the degree of multicast session resource reservation requests between the PVS node and SVS node, and 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 segment weights are determined as follow:

$$\text{Max} \sum \alpha_{ps} \cdot F^n_{ps} \ . \tag{1}$$

$$CP_{ps} : (S^n_{ps} \in C_{ps}) \cap (F^n_{ps} < \Delta) \ . \tag{2}$$

$$w(S^n_{ps}) = \sum_{\forall (v_p, v_s) \in \Lambda \setminus (a,b)} \alpha_{ps} (\partial F^n_{ps} / \partial v) \ . \tag{3}$$

$$\begin{cases} \partial F^n_{ps} / \partial v = 1 & [\, if \ \ (v_p, v_s) : S^n_{ps} \in CP_{ps} \,] \\ \partial F^n_{ps} / \partial v = 0 & [\, otherwise \,] \end{cases} \tag{4}$$

$$w(S^n_{ps}) = \sum_{(v_p, v_s) : S^n_{ps} \in CPps} \alpha_{ps} \ . \tag{5}$$

Equation (1) represents the minimum interference of the wavelength path decision between the PVS node and SVS node (in order to choose the optimal path according to the present multicast session request). Equation (2) determines the path with congestion possibility for potential future connection requests between the VS nodes. If a segment S^n_{ps} belongs to the set of critical paths and simultaneously the number of available wavelengths in that segment is lower than the threshold value, then the segment S^n_{ps} becomes the congestion path.

We presents the weight of each segment for all (v_p, v_s)-pairs in the set Λ except the current request when setting up a connection as shown in equation (3). And equation (4) allocates the differentiated values to the nth segment 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. Calculating the weight of all nodes is difficult, so we apply equation (4) to equation (3). Finally, computing the segment weights is simplified as shown in equation (5). Therefore, the VS-MIMR decides a lightpath that has a minimum value of segment weight $w(S^n_{ps})$.

Fig. 9 illustrates the VS-MIMR algorithm to find the minimum interference path between PVS node and SVS node for constructing a multicast tree.

c. 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 services. 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) [18 - 19].

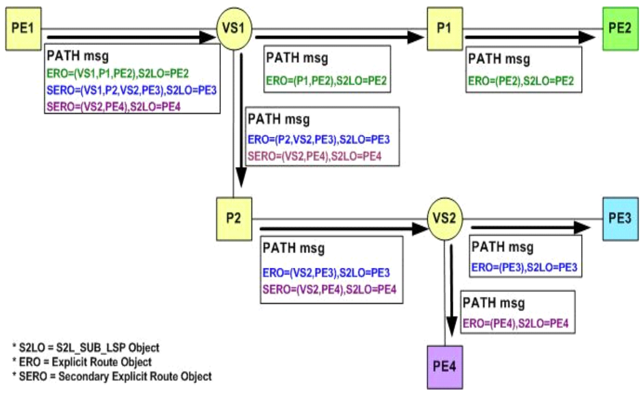


Figure 10. Multicasting distribution tree construction

Fig. 10 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 [19].

Ⅳ. Conclusion

In this paper, the functional architecture and the interoperation of the control plane and management plane of the QoS guaranteed OVPN are proposed. For the establishment of the multicast OLSP, we propose the VS-MIMR algorithm that finds the minimum interference path between virtual source nodes. We also suggest an entire OVPN control mechanism to adapt the operation of the routing and signaling protocols of GMPLS.

For the future research, we have a plan to evaluate the proposed VS-MIMR algorithm in the environment of various network topologies.

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REFERENCES

[1] Tomonori Takeda, Framework for Layer 1 Virtual Private Networks, draft-takeda-l1vpn-framework-02.txt, 2004.
[2] S. S. Dixit, IP over WDM: building the next-generation optical internet, John Wiley& Sons publication, 2003.
[3] 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.
[4] 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.
[5] 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.
[6] 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.
[7] 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.
[8] L. Berger, GMPLS Signaling Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extensions, IETF RFC 3473, January 2003.
[9] P. Ashwood-Smith and L. Berger, GMPLS Signaling Constraint-based Routed Label Distribution Protocol (CR-LDP) Extensions, IETF RFC 3472, January 2003.
[10] 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.
[11] J. Lang, Link Management Protocol (LMP), draft-ietf-ccamp-lmp-10.txt, IETF Internet Draft, October 2003.
[12] 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.
[13] T. Bates et al, Multiprotocol Extension for BGP-4, RFC2858, June 2000.
[14] 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.
[15] N. Sreenath et al., Virtual source based multicast routing in WDM optical networks, Proceedings IEEE International Conference on, pp. 385-389, Septempber 2000.
[16] 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.
[17] H. Zang et al., A Review of Routing and Wavelength Assignment Approaches for Wavelength Routed Optical WDM Networks, Optical Networks Magazine, vol.1, no.1, pp.47-60, Jan. 2000.
[18] Seisho Yasukawa, Requirements for Point to Multipoint Traffic Engineered MPLS LSPs, draft-ietf-mpls-p2mp-requirement-04.txt, IETF Internet Draft, September 2004.
[19] 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.

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