LETTER

Multi-Domain VLAN Path Signaling Method having Tag Swapping Function for GMPLS controlled Wide Area Layer-2 Network

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SUMMARY A multi-domain GMPLS layer-2 switch capable network with VLAN tag swapping is demonstrated for the first time. In this demonstration, we verify three new features; establishing path with designating VLAN IDs, swapping VLAN ID on prototype switch, and management of VLAN IDs per domain. Using those three features, carrier-class multi-domain Ethernet backbone networks which supports independently resource management per domain can be established.

key words: *GMPLS, RSVP-TE, Layer-2 Switch, VLAN*

1. Introduction

A wide area Ethernet is one of the promising technologies for next generation Internet infrastructure. With cost effective approach and seamless protocol among LAN / MAN / WAN, Ethernet became very attractive. However, wide area network is different in many ways from local area network. For example, reliability and QoS, management, control of the route, fault detection, and OAM are required. There are several research results and standardization related to the above issues [1].

A wide area Ethernet provides high-speed virtual line services among customers' LANs. The virtual line is established with VLAN technologies, which is called as a VLAN path. An Ethernet switch forwards the frame in accordance with the destination MAC address and the VLAN ID/tag header which is included in an extended Ethernet frame. When establishing or tearing down a VLAN path, all VLAN switch configuration along the path is required.

Generalized Multi-Protocol Label Switching (GMPLS) [2] enables to set up and tear down the label switched path (LSP) automatically. By using GMPLS, automatically VLAN path configuration to layer-2 switches on demand is possible. An automatic VLAN path configuration technique is a very important challenge especially for the wide area network. In order to accomplish this challenge, the Internet Engineering Task Force (IETF) started to make a framework of the automatic VLAN path setting protocol, named GMPLS Ethernet Label Switching (GELS) [3].

This paper focused on management of VLAN IDs in wide area layer-2 network, also presented experimental trial results of the multi-domain GMPLS controlled layer-2 network with VLAN tag swapping function. We successfully demonstrate the three features, a) establishing a path with designating VLAN ID, b) swapping VLAN ID on prototype layer-2 switch, and c) per domain VLAN ID management.

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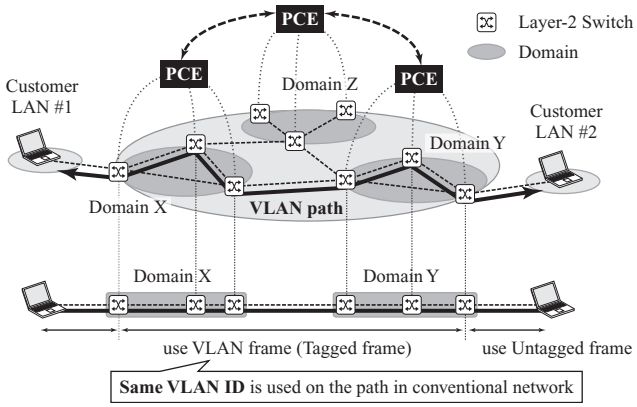

Fig. 1 GMPLS layer-2 switch capable network architecture

2. Layer-2 Network Architecture

In this section, a multi-domain wide area layer-2 network architecture is discussed. Figure 1 shows the GMPLS controlled network architecture assumed here. A nation-wide network which consists of several domains is considered. A Path Computation Element (PCE) addresses all node resource information that includes link resources, switch resources, and VLAN tag resources of each domain. When setting up a new VLAN path, first, the ingress node sends a message to the PCE to request a path computation, second, it obtains explicit route information which includes node-IDs of switches and VLAN IDs of links, final, it makes a GMPLS RSVP-TE PATH message, and sends the message to downstream.

In conventional wide area Ethernet, the same VLAN ID value must be used at all Ethernet switches along with a VLAN path. This is because; the Ethernet standard [4] does not allow assigning different VLAN IDs along with a VLAN group. However, the range of the VLAN ID value is limited to 12 bits, and the assumed network size including number of nodes and paths is quite large. This VLAN ID limitation is quite hard to apply to the multi-carrier wide area networks.

To solve this problem, the VLAN tag stacking technology (Q-in-Q) and the MAC encapsulation technology (MAC-in-MAC) were developed. GMPLS can be applied to control a Q-in-Q network and a MAC-in-MAC network. However, to set up an end-to-end (user-to-user) VLAN path if demanded, complicated multi-layer GMPLS signaling technique is required. To avoid the multi-layer signaling, we challenged to establish a VLAN tag swapping path with swapping function at domain border nodes. The swapping function enables to assign a VLAN ID independently per domain. Therefore, the PCE easily searches the unused VLAN ID only within the domain. It can create scalable VLAN network architecture.

We developed a VLAN tag swapping function on a prototype layer-2 bridge/switch. To control and make the VLAN tag swappable switches and conventional unswappable switches interworking, label usage of GMPLS RSVP-TE is extended.

3. Establishing a new VLAN path

In this section, operations of each node and PCE to establish a VLAN path with domain tag swapping is discussed. First, establishing a VLAN path within only one domain without domain tag swapping is discussed. Secondly, two methods to establish a VLAN path in multi-domain with domain tag swapping function are discussed.

3.1 Establishing a VLAN path within only a domain

Figure 2 shows an operating sequence diagram of each node and PCE to establish a path within only a domain. To establish a new path, there are two processes. The first process is a path computation request process triggered by ingress node to obtain explicit route information from PCE. The information includes both node-IDs of switches and VLAN IDs of links along the path, which are necessary for establishing a VLAN path. The second process is signaling process with RSVP-TE, sending PATH message to downstream to set up configuration of layer-2 switches. After the message passes all nodes along a path, all switches and links are reserved with the VLAN IDs.

If the customer demands to establish a VLAN path, ingress node A sends a message to PCE-X to request a path computation between source node A and

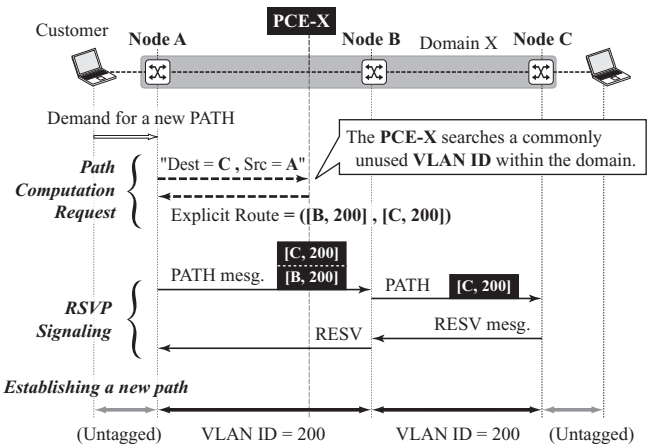

Fig. 2 A sequence diagram of operations to establish within a domain

destination node C. PCE-X computes a route, searches an unused VLAN ID within domain X, and replies to request node A with the explicit route information such as [B,200], [C,200]. [B,200] means to setup the VLAN path till node "B" with VLAN ID "200" and [C,200] means till node "C" with VLAN ID "200". Node A makes an RSVP-TE PATH message for the signaling, it includes the route information as Explicit Route Object (ERO) which consists of the pairs of node-ID and VLAN ID. All nodes read the ERO and sets up the configuration of the layer-2 switch suitably. In Fig.2, Ingress node A sends the message to node B, and this transit node B reads, updates, and forwards the message to next node C. After receiving the message, egress node C returns an RESV message to upstream. All nodes receive the RESV message, and setup the configuration of each switch. While the message reaches to ingress node A, the new path is established with VLAN ID=200 within domain X.

3.2 Establishing a VLAN path on Muti-Domain

In this section, two methods to establish a path are proposed as shown in figure 3.

3.2.1 Method 1: signaling after the interworking

In method 1, both path computation request process and RSVP-TE signaling process are divided. First, ingress node A sends a path computation request message to PCE-X to achieve an explicit route from source A to destination F. Note that node F is not on domain X, therefore a route which is across several domains is required. After receiving the computation request, PCE-X determines a sequence of domains to be traversed by interworking. PCEs are communicating with each other; they already know which domain every egress node belongs to, thus PCE-X knows where node F is.

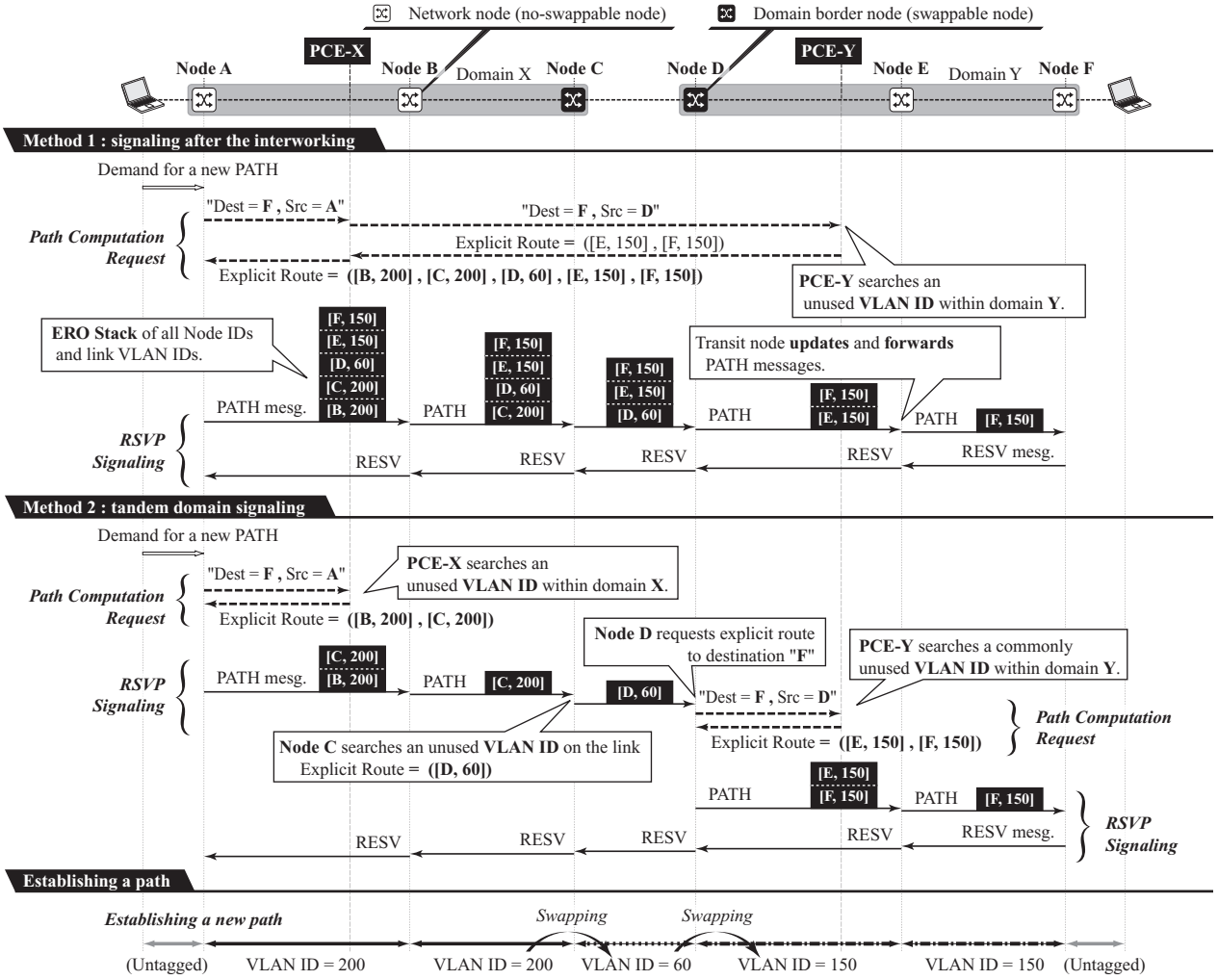

Fig. 3 A sequence diagram of operations to establish a new path on multi-domain

Firstly PCE-X computes a route from ingress node A to node C which is gateway node to next domain-Y. Secondly PCE-X also sends a path computation request message to next PCE-Y to obtain a route from node D to destination F. Finally PCE-X determines the explicit route information from A to F, and replies that information to request node A.

Due to supporting domain tag swapping function on border node, different VLAN IDs per domain can be used. In the figure, VLAN ID=200 is allocated in domain X, VLAN ID=150 is in domain Y, VLAN ID=60 is in the inter-domain link. After path computation request process, node A makes the PATH message, and sends to downstream. By receiving the PATH message, all nodes obtain the information of VLAN ID, and then control the layer-2 switch.

In this method, routing and signaling process are divided. After receiving PATH message, transit nodes should only read ERO, and forward the message to downstream nodes. However, this method has a disadvantage; resource information of all nodes and links in other domains may gather in all ingress nodes. It causes network operator confidentiality problem.

3.2.2 Method 2: tandem domain signaling

Method 2 is tandem domain signaling. In this method, a PCE only computes a route within its own domain. Every time PATH message reaches a next domain, the domain border node sends a path computation request message to the PCE.

In this method, it is assumed that only reachability information to every nodes on another domain are informed to ingress node with OSPF-TE. Therefore, ingress node A knows that node C is the gateway to the shortest route to destination F.

In Fig.3, after the customer demands to establish a new path, ingress node A sends a request message to PCE-X to request path computation between source node A and gateway node C. PCE-X computes a route from A to C, searches an unused VLAN ID within domain X, and makes the explicit route information to

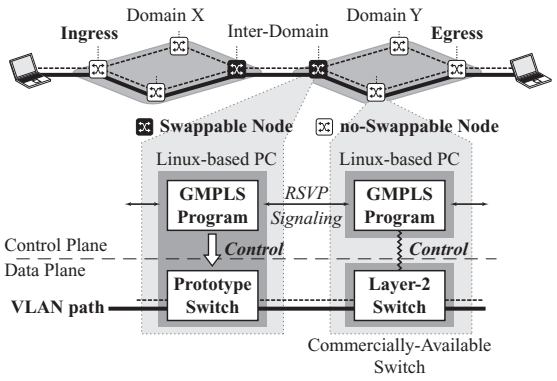

Fig. 4 An experimental network diagram

establish the new path. PCE-X replies the information to requesting node A, and ingress node A starts RSVP-TE signaling. When the PATH message reaches to node C, the node C searches an unused VLAN ID on the next link, the resource information of the link is managed by the nodes on both sides of the link. Node C adds the ERO to the message, and sends the message to downstream node D. The message reaches to domain border node D, node D send a request message to PCE-Y. PCE-Y computes a route from D to F, searches an unused VLAN ID within domain Y, and makes the explicit route information to establish the new path. Node D adds the ERO to the message and sends the message to downstream node E. After that, the PATH message reaches to egress node F, and comes back to ingress node A as a RESV message, and the new path is established.

This method allows PCE to compute a route without interworking between PCEs, and the computation will be done independently. Also all resource information such as VLAN IDs is secured within each domain.

4. Experiments and Results

4.1 Experimental Network

Figure 4 shows an experimental network diagram. This network emulates multi-AS interworking in a wide area layer-2 network shown in Fig.1. There are two domains in the network, and each domain has four nodes. Two swappable nodes which support VLAN tag swapping function located at domain border compose the GMPLS program and the prototype layer-2 switch program running on a Linux PC. Six un-swappable nodes compose the GMPLS program and the commercially available Ethernet switch. GMPLS RSVP-TE and OSPF-TE are running in all nodes. When proper PATH and RESV messages are received, all switches are configured and an end-to-end VLAN path is successfully established.

4.2 Multi-domain VLAN path signaling having tag swapping function

In this experimentation, we challenge to establish a VLAN tag swapping path by the two methods discussed in section 3. Implemented RSVP-TE program is extended to designate ERO including not only the router-IDs but also the labels defined in [5]. The VLAN IDs for each link are addressed by the generalized label which was already shown in [6]. It is assumed that each node is able to obtain explicit route information computed by PCE before RSVP-TE signaling.

The implemented VLAN path control mechanism with the domain tag swapping function is successfully demonstrated at iPOP 2008 Exhibition [7]. Both signaling methods and interoperability were confirmed.

5. Conclusion

For the first time we successfully demonstrated, VLAN path signaling with the domain tag swapping. Multi-domain VLAN path signaling, two signaling method were proposed. The first is the method after PCE interworking and the other is the tandem domain method. These control and transport method can apply to future wide area layer-2 network.

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References

[1] Akira Arutaki, *“Wide Area Ehternet Technology Overview (in Japanese),”* IEICE book, ISBN:4-88552-211-0, June. 2005.

[2] E. Mannie. (Editor), *“Generalized Multi-Protocol Label Switching (GMPLS) Architecture,”* IETF RFC 3945, Oct. 2004.

[3] D.Papadimitriou, et.al, Internet Draft, draft-ietf-ccamp-ethernet-traffic-parameters-04.txt, Apr 2008, work in progress.

[4] IEEE Std 802.1Q, *“IEEE Standards for Local and Metropolitan Area Networks Virtual Bridged Local Area Networks,”* May 2003.

[5] L. Berger (Editor), *“Generalized Multi-Protocol Label Switching(GMPLS) Signaling Resource ReserVation Protocol-Traffic Engineering(RSVP-TE) Extensions,”* IETF RFC 3473, Jan. 2003.

[6] D. Ishii et al, *“An Experiment of Controlling Gigabit Wide Area Ethernet by GMPLS supporting Layer-2 Switching Capability”*, Proc.OFC/NFOEC2008, OThB5, Feb. 2008.

[7] K. Kikuta et al *“GMPLS VLAN Path Establishment using Inter-domain VLAN Tag Swapping,”* http://www.pilab.jp/ipop2008/, June 2008.