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LETTER

Interoperability Experiment of VLAN Tag Swapped Ethernet and Transmitting High Definition Video through the Layer-2 LSP between Japan and Belgium

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SUMMARY The first global interoperability experiment of GMPLS controlled Ethernet with VLAN tag swapping between two different implementations is successfully demonstrated. High definition video streaming is realized through a newly established Layer 2 Label Switched Path (L2-LSP). The results of this experiment can be applied to designing reliable Layer 2 networks.

key words: *VLAN tag swapping, Ethernet label switching, GMPLS, interoperability*

1. Introduction

Wide area Ethernet is attractive for the next generation Internet backbone architecture, especially for carrier environments. This is because Ethernet is the most common networking technology and it's cost effective. In addition, the link bandwidth has been increasing: starting from 10 Mbps about 30 years ago, and reaching up to 100 Gbps nowadays. Ethernet became applicable to Wide Area Network (WAN) although it originated from Local Area Network (LAN) technology.

Providing an Ethernet Virtual Line (EVL) between customers is a basic service component. EVL is provisioned as an Ethernet Virtual LAN (VLAN) path. The Ethernet VLAN path can be established with VLAN technologies, especially with tag-based VLANs, which is standardized in IEEE 802.1Q [1]. The VLAN ID/tag is part of the Ethernet header. Wide area Ethernet using Ethernet Label Switching (ELS) [2] also forwards frames according to the value of its VLAN tag.

VLAN configuration of all switches along the Ethernet VLAN path is required when setting up or tearing down the path. Generalized Multi-Protocol Label Switching (GMPLS) [3] is a set of network control protocols to provide a next generation high performance transport network, and can be used for automatically configuring these switches in path provisioning. Therefore, we are proposing to employ GMPLS protocols for automatic Ethernet VLAN path provisioning. To increase the scalability of Ethernet, an automatic VLAN configuration technique is an important challenge especially for WAN.

In addition, the scalability of VLAN technology is an issue in wide area Ethernet. In the conventional VLAN tag-based Ethernet network (IEEE 802.1Q), a VLAN tag must be globally unique in a whole network. In other words, different Ethernet VLAN paths cannot reuse the same VLAN tag. In addition, only 12 bits are assigned to the field of VLAN tag. These imply that wide area Ethernet cannot support over 4096 Ethernet VLAN paths. That number of paths is not sufficient in WAN. We have proposed an effective network architecture to increase network scalability [4].

This paper presents experimental results of GMPLS controlled Ethernet VLAN path provisioning with VLAN tag swapping between Japan and Belgium. We successfully demonstrated the following things: 1) Interoperability between two different VLAN tag swapping based Ethernet implementations; one has been developed by Keio University, and the other has been developed by Ghent University, 2) International Q-in-Q frame [5] transmission between Japan and Belgium, 3) High definition video streaming through the established Ethernet VLAN path.

2. Wide Area Ethernet Architecture

In this section, two types of wide area Ethernet architecture are discussed. One is a centralized model, and the other is a decentralized model.

Figure 1 shows the architecture of the centralized model. It has a Path Computation Element (PCE) based architecture. A PCE has responsibilities of resource management and path calculation in a domain. When an L2-LSP is requested, a layer-2 switch demands the PCE responsible for the corresponding domain to set up a path. The PCE calculates a path coordinating with PCEs in other domains. Finally, the PCE reserves an available VLAN tag for the new path.

Figure 2 shows the architecture of the decentralized model. It employs GMPLS control protocols such as OSPF-

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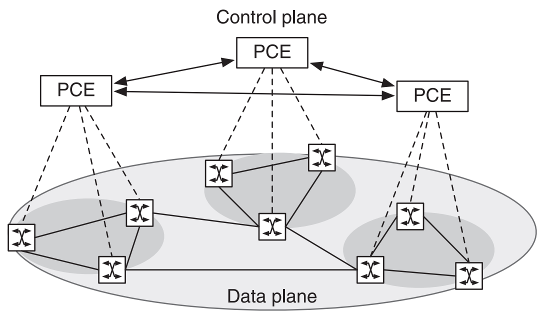


Fig. 1 Centralized wide area Ethernet.

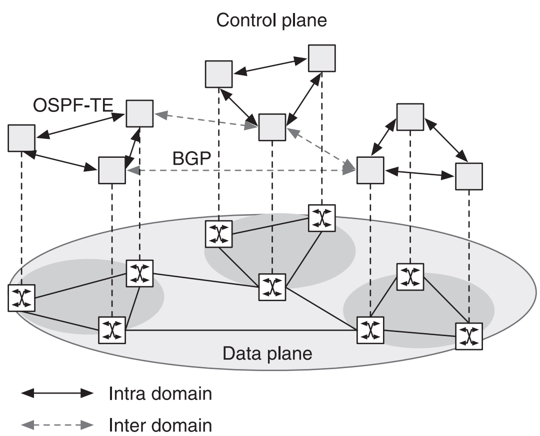


Fig. 2 Decentralized wide area Ethernet.

TE, BGP, and RSVP-TE instead of PCEs. The resource information is distributed by OSPF-TE within a domain, and the information is shared among layer 2 switches in a domain. The resource information between other domains is advertised by BGP. When an L2-LSP is ready to set up, RSVP-TE signaling from the source switch is carried out towards the destination. A path is calculated in the source switch according to the current network information, and then an available VLAN tag is reserved as triggered by signaling.

The above architectures are compared. One of the advantages of the centralized model is complete management of network resources. In the centralized model, a PCE manages all of network resources within the domain, and information about the current network resources can be received without delay. On the other hand, the lack of scalability is one of the largest drawbacks in the centralized model. Managing all network resources is a heavy task when the number of nodes in a domain increases. High performance PCEs are required. In addition, a PCE is single point of failure. The centralized model is weak against failures.

Therefore, the decentralized model is assumed in this paper. In this model, it is desirable that network resources are locally managed. However, a VLAN tag must be globally unique in the conventional network. To extend scalability of Ethernet, we have introduced VLAN tag swapping [4]. Figure 3 shows an example of VLAN tag swapping.

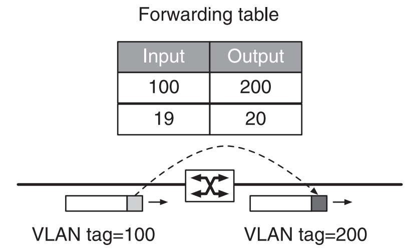


Fig. 3 VLAN tag swapping.

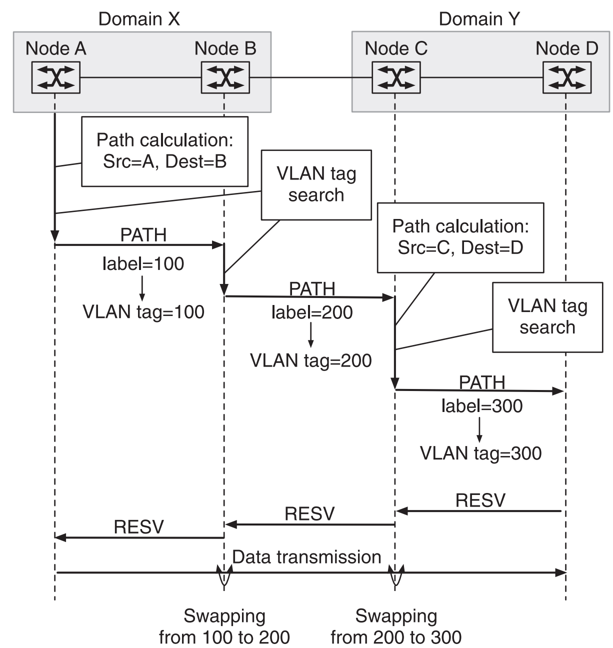


Fig. 4 Signaling sequence of L2-LSP establishment.

The VLAN tag of an incoming frame is replaced with another VLAN tag for the corresponding outgoing frame. In this example, two configurations are stored in the forwarding table. The VLAN tag of the incoming frame is 100. It matches the first configuration of the forwarding table, therefore the VLAN tag of the outgoing frame becomes 200. In wide area Ethernet with VLAN tag swapping, a VLAN tag must be unique in a link, and the same VLAN tag can be reused in the other links (link local labeling). Therefore, the scalability increases, and the restriction of the number of connections is virtually eliminated.

Figure 4 shows the signaling sequence when the L2-LSP is established. There are 4 nodes, divided into 2 domains. Source routing is employed. First, Node A explicitly designates the path within Domain X and implicitly designates the path within Domain Y. A node checks availability of the VLAN tag of the incoming link and searches for an unused VLAN tag of the outgoing link when it receives a signaling message. Then, it manages a new mapping entry from label to VLAN tag. In the figure, Node B dynamically searches for an unused VLAN tag, then VLAN tag 200 is found as an unused VLAN tag. After all the entire procedure of establishing a new path is completed, data transmission can happen through the VLAN tag swapped path.

3. Experiments

3.1 Experimental Setup

Figure 5 shows the experimental setup of the international interoperability experiments between Japan and Belgium. There are 6 Ethernet switches (keio01, keio02, keio13, keio14, gent01, and gent02) and 2 end users (user01 and user02). The switches are controlled and configured by GMPLS protocols, and they contain VLAN tag swapping functionality. The data plane of all switches is based on the Click Modular Router framework [6]. The data plane of keio01, keio02, keio13, and keio14 is developed by Keio University, and that of gent01 and gent02 is developed by Ghent University. Figure 6(a) and Fig. 6(b) show the schematic diagram of the configurations of Click Modular Router in keio13 and keio01, respectively.

Two switches, keio13 and keio14, are placed in Keio University, Tokyo, Japan, and the other 4 switches are placed in Ghent University, Ghent, Belgium. The switches in Japan work as edge switches and the switches in Belgium work as core switches. The ingress edge switch accepts untagged Ethernet frames and encapsulates them into Q-in-Q VLAN tagged frames for transmission to the core switches as shown in Fig. 6(a). Every core switch then swaps the outer VLAN (S-VID) to forward it towards its next hop. Finally the egress edge switch removes the Q-in-Q VLAN tag.

3.2 Path Establishment

RSVP-TE establishes an L2-LSP between keio13 and keio14. Figure 7 shows the established L2-LSP in the experiment. The number below a link describes the value of the VLAN tag assigned to the link. For example, the VLAN tag of the link between keio13 and keio01 is 9, and that of the link between keio01 and keio02 is 10. In this case, the VLAN tag is swapped from 9 to 10 at keio01.

Each switch manages used tags and available tags. When reserving a path, each switch is looking for an available tag on the output port. In Fig. 7, it is assumed that the left port is port 0, and the right port is port 1 for all nodes. The first available tag of port 1 is used for a new L2-LSP at keio01. After the tag is assigned for a new L2-LSP, the configuration of the forwarding tables occurs automatically. In this case, the shaded entry (Input port, Input tag, Output port, Output tag) = (0, 9, 1, 10) is added. Similarly, all the other switches are configured, and finally the L2-LSP is established between keio13 and keio14.

3.3 High Definition Video Transmission and Numerical Results

A high definition video stream was transmitted through an L2-LSP, which is established by RSVP-TE. Figure 8 shows the sender, the receiver of a high definition video stream, and the edge switches, which are placed in Keio University, Japan. The sender corresponds to user01 in Fig. 5, and the receiver corresponds to user02 in Fig. 5. The core switches are located the ilab.t testbed in Ghent University, Belgium as shown in Fig. 9.

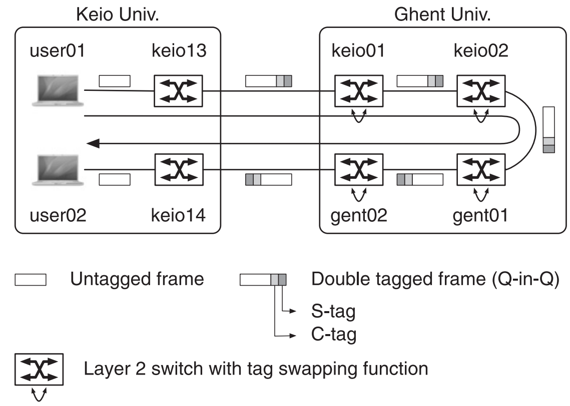
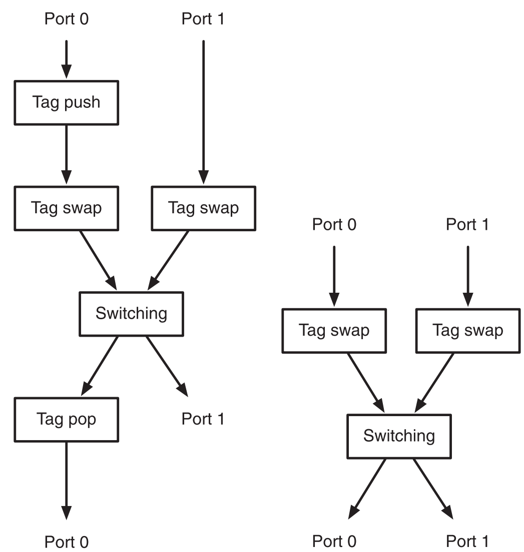


Fig. 5 Experimental setup of demonstration.



(a) keio13 (b) keio01

Fig. 6 Click configuration.

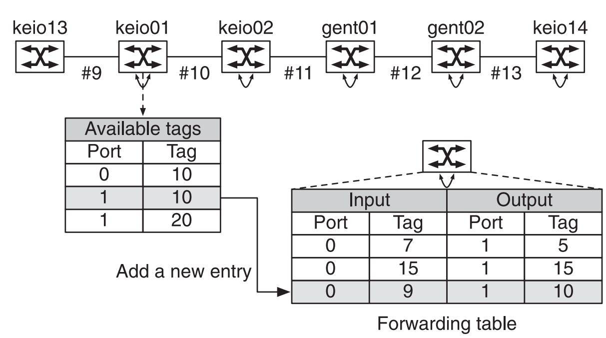


Fig. 7 Changing configurations of a switch when signaling is occurred.

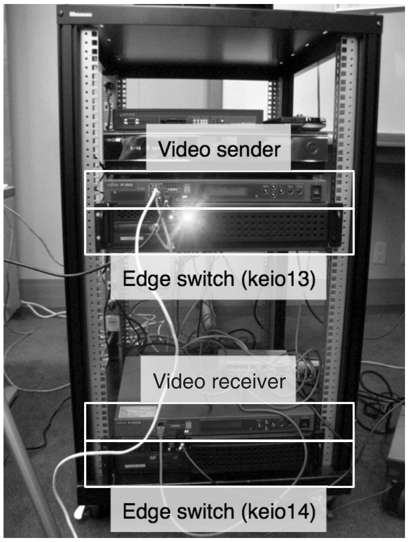


Fig. 8 High definition video sender, receiver, and 2 edge switches placed in Keio University, Japan.

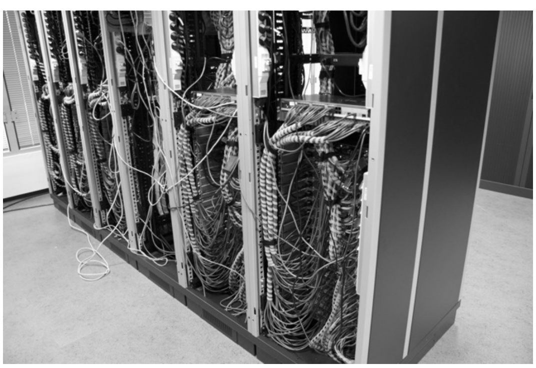


Fig. 9 4 Core switches placed in the ilab.t testbed in Ghent University, Belgium.

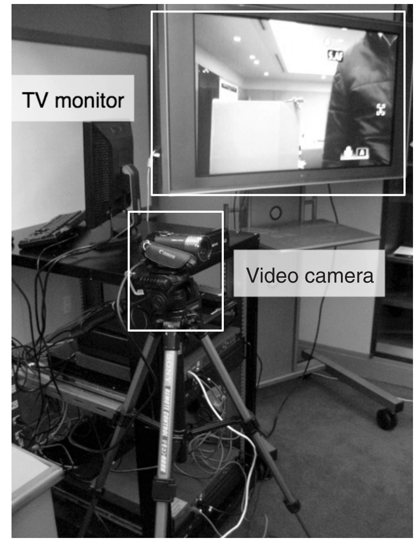


Fig. 10 High definition video captured by video camera is displayed on TV monitor.

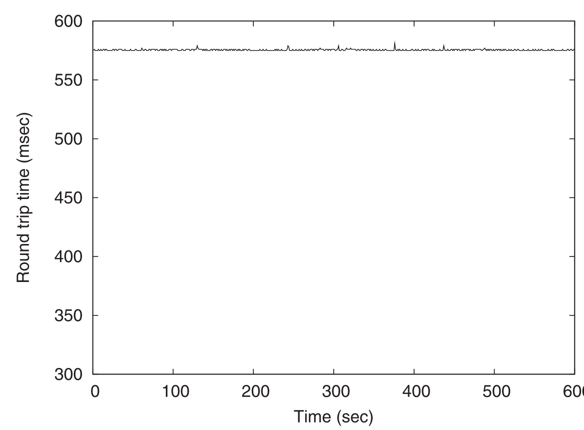


Fig. 11 Round trip time between user01 and user02.

Figure 10 shows the experiment of transmitting high definition video. The video stream was captured by a video camera attached to the sender, and the TV monitor is attached to the receiver. The high definition video stream from the camera is transmitted through the established L2-LSP. The video is successfully displayed on the TV monitor at high definition quality as shown in Fig. 10.

The round trip time and the UDP bandwidth between two users (user01 and user02) are measured. Figure 11 shows the round trip time measured by ping for 10 minutes. An ICMP packet is sent every 1 second from user01. The average round trip time is 575.5 msec and the standard deviation is 0.64 msec. This result indicates that tag swapping does not affect stability of the round trip time. Figure 12 shows the UDP throughput measured by iperf [7] for 10 minutes. user01 is the source node and the transmissions rate of the source node are 10 Mbps, 15 Mbps, and 20 Mbps, respectively. The measured throughput is satisfactory for high definition video transmission.

The number of VLAN paths supported in the conventional system is at most 4096. On the other hand, our proposed system can support at least 4096 VLAN paths. The value varies with the number of hops of the paths through the network. 4096 VLAN tags can be used on each link in our proposed system, and there are 5 links in this experiment. The maximum number N of VLAN paths allowed in this experiment is expressed as follows:

$$N = \max(x), \text{ such that } \sum_{i=0}^{x} h_i \leq 4096 \times 5 \qquad (1)$$

$$\approx \frac{4096 \times 5}{\bar{h}} \qquad (2)$$

where i is the index number of a VLAN path, h_i is the number of hops of the VLAN path i, and $\bar{h}$ is the average number of hops of the VLAN paths. The VLAN tag search time is $O(1)$ with the number of nodes n since a hash table is used for the forwarding table in our implementation.

From this experiment, we verified the interoperability between two different VLAN tag swapping based Ethernet

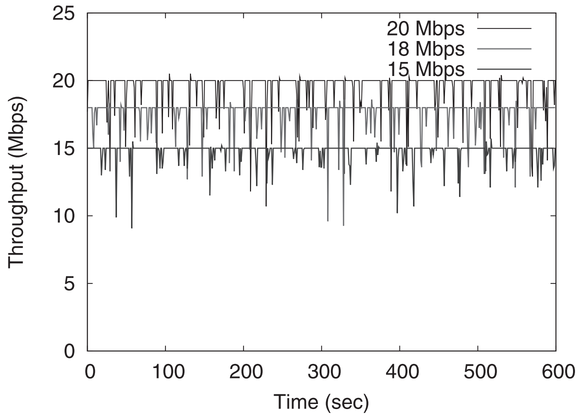


Fig. 12 UDP throughput between user01 and user02.

implementations. We successfully transmitted high definition video stream between Japan and Belgium with Q-in-Q frames. This result proves the feasibility of VLAN tag swapped based Ethernet, and proves that wide area Ethernet is realistic.

4. Conclusion

The scalability of Ethernet is a key issue in wide area Ethernet. To cope with the issue, VLAN tag swapping is an effective solution. In this paper, we reported on an interoperability experiment between two different implementations of Ethernet VLAN swapping in Japan and Belgium. In the experiment, a GMPLS controlled L2-LSP was established between Japan and Belgium, and high definition video was transmitted through the L2-LSP. We successfully demonstrated the interoperability of VLAN tag swapping and Q-in-Q frame transmission between the two countries. This result confirmed that VLAN tag swapping is a good solution for wide area Ethernet.

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