

Autonomous Client Discovery in Backbone Edge Bridges for Multipoint PBB-TE Networks

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Abstract— This paper discuss how to complement provider backbone bridge – traffic engineering (PBB-TE) networks with multipoint connections to implement a deterministic and simple-to-use multipoint network. We propose the learning and multicasting mechanisms for unknown destination and source addresses of clients, while the connection-oriented property or determinism of PBB-TE networks is maintained. Pre-determined Ethernet switched paths created by the B-components of IB type BEBs (IB-BEBs) are only used for delivering multicast frames to other IB-BEBs in the multipoint PBB-TE networks. The ingress I-components of IB-BEBs take charge of learning and multicasting for unknown destination client addresses. The egress I-components of IB-BEBs take charge of learning and multicasting for unknown source client addresses. Since provider instance ports (PIPs) of the I-component are internally connected with customer backbone ports (CBPs) of the B-component, the frames of unknown destination address flooded at PIPs are encapsulated by B-TAG in the B-component and deliver to other IB-BEBs through pre-determined Ethernet switched paths (ESPs).

Keywords— Provider Backbone Bridge - Traffic Engineering, autonomous client discovery, multipoint, determinism, MAC learning, multicast

I. INTRODUCTION

Provider Backbone Bridge –Traffic Engineering (which is being standardized in IEEE under the name PBB-TE) is connection-oriented Ethernet technology that provides deterministic (i.e. predictable) routing and QoS [1]. Deterministic routing forces traffic over a predetermined path so that all packets on that path will experience the same delay. This is an absolute necessity for real-time traffic such as Voice-over-IP, video conferencing and Internet protocol television (IPTV) services [2]. On the other hand, one of the major criticisms of PBB-TE is focus on point-to-point connections. To provide virtual private networks and IPTV services, PBB-TE needs to extend a function in order to support multipoint connections.

IP and enterprise Ethernet are connectionless networks that were designed from the beginning to be multipoint [3]. Adding and removing clients of these networks are simple tasks to perform. However, this is also a disadvantage as it is

difficult to predict which route traffic will take through the network at any given time. Traffic might follow an undesirable route or lead to congestion on some routes while others are underutilized. For connection-oriented behaviour in large networks, PBB-TE adds both traffic engineering and determinism to Ethernet. But this mechanism is not multipoint by nature. It is therefore necessary to complement PBB-TE with further technology and capabilities to implement a deterministic and simple-to-use multipoint network.

For any-to-any multipoint networks, it is important challenge to create a multipoint PBB-TE network architecture that is simple to establish and manage, where traffic can be controlled, but where it is possible to add and remove clients without these changes unduly affecting the operation of the network.

There are two methods to realize multipoint PBB-TE networks. First approach is the virtual private LAN service (VPLS) based on PBB-TE [4], [5]. In this method, PBB-TE tunnels are used instead of multiple protocol label switching (MPLS) label switched paths (LSPs) to implement connectivity between VPLS nodes. In order to flood frames of unknown destination MAC addresses, the method is in need of a control plane called provider network controller. Secondly, Provider link state bridging (PLSB) has been suggested as an Ethernet-focused any-to-any multipoint method [6]. PLSB is a new approach that replaces spanning tree protocol with a more sophisticated control protocol based on intermediate system to intermediate system (IS-IS) signalling.

In this paper, we propose the mechanism that autonomously discovers clients in edge nodes of the PBB-TE networks, where provide traffic engineering capabilities and determinism. The mechanism uses a self MAC-learning method that is carried out by backbone edge bridges (BEBs) based on the incoming frame's source MAC address. If the PBB-TE networks have autonomous client discovery functions, it becomes simpler and easier to manage or configure the networks.

II. MULTIPOINT PBB-TE NETWORK

PBB-TE is connection-oriented Ethernet technology that allows the use of Ethernet as a carrier class transport network. As shown in Figure 1, the PBB-TE network comprises a set of

IB type backbone edge bridges (IB-BEBs) and backbone core bridges (BCBs), which are interconnected by a set of Ethernet switched paths (ESPs) [1]. Each ESP is identified by a backbone destination address (B-DA), a backbone source address (B-SA), and a backbone VLAN ID (B-VID). The IB-BEB has the special capability to encapsulate Ethernet frames of customer equipments. The MAC header encapsulation function of the IB-BEB supports complete isolation of individual client addressing fields from address fields used in the operator's backbone, then, services could be independent of transport layer. The BCB acts as transit nodes. The packets are forwarded in the backbone network based on the B-VID and the B-DA. A service is identified by an I-SID service instance identifier that is proposed as a solution to the scalability limitations. ESPs are provisioned in a PBB-TE network by an external management or control plane. Spanning tree protocols and the MAC learning function for ESP-MACs are disabled. The forwarding is based on the static forwarding database (FDB) table entries configured by an external management or control plane.

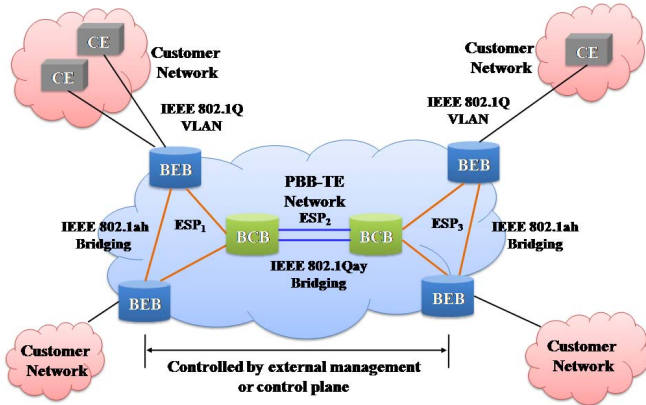


Figure 1. Multipoint PBB-TE network

To provide multipoint connections in the PBB-TE networks as shown in Figure 1, we have added the function that autonomously discovers clients without any help of control plane in the I-component of the IB-BEB.

III. NORMAL OPERATION OF BACKBONE EDGE BRIDGE

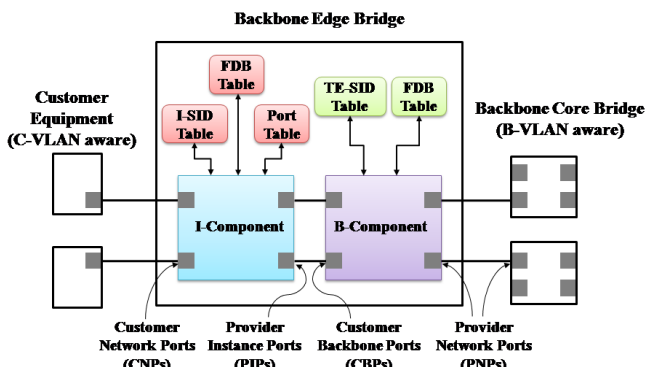


Figure 2. Structure of the IB type backbone edge bridge (IB-BEB)

A. I-component

As shown in Figure 2, an IB type BEB comprises an I-component and a B-component. The I-component of an IB-BEB supporting PBB-TE is responsible for encapsulating frames received from customer equipments and allocating each frame to a backbone service instance and for decapsulating frames received from the network via backbone service instances. The allocation of customer frames to backbone service instances is done at provider instance ports (PIPs). At the PIP, the customer frame is encapsulated by an I-TAG, which includes the backbone service instance identifier (I-SID), and a set of source and destination backbone MAC addresses. The source backbone MAC address is the PIP MAC address configured to take the same value as the customer backbone port (CBP) MAC address.

The normal forwarding operation of the I-components of IB-BEBs explains in left side of the figure 5. First of all, the I-component allocates the received frame to an appropriate I-SID by performing a lookup of an I-SID table based on customer VLAN identifiers (C-VIDs). Next, it gets a destination backbone address and a PIP as output port from the I-SID table. It gets a source backbone address from the port table connected by the founded PIP, and then, adds an entry which includes the I-SID, the B-DA, the B-SA, and the PIP into the multicast table associated with ESPs created by the B-component of the BEB. The encapsulated frames by I-TAG send to the B-component via PIPs. Figure 3 shows linkage between lookup tables in the I-component. For this reason, even though multicast frames for unknown destination address are flooded at PIPs, the multicast frames could be delivered to other BEBs in the PBB-TE networks through the ESPs created by the B-components of the BEBs.

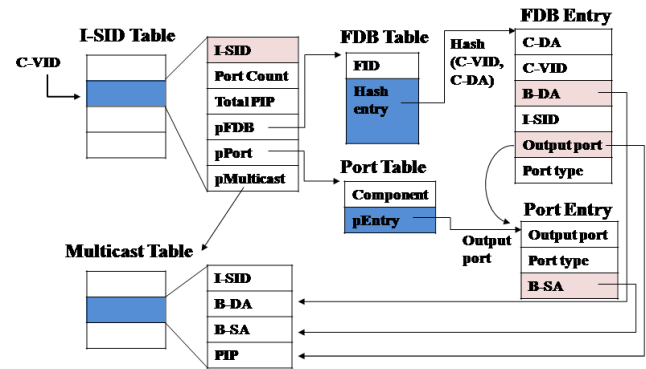


Figure 3. Linkage between lookup tables in the I-component of the proposed mechanism

For realization of any-to-any multipoint PBB-TE networks, we added the autonomous discovery function of clients to the I-component of the IB-BEB. The proposed mechanism is not only by signalling of a control plane but also by self-learning of data planes. Since the B-component of the IB-BEB provides deterministic connections by external management system, MAC address learning and flooding shall not be performed in

the B-component. However, pre-determined ESPs are only used for delivering frames of destination client addresses to other IB-BEBs. The ingress I-component which receives Ethernet frames from customer equipments is responsible for learning and multicasting unknown destination addresses of clients. The egress I-component which receives 802.1ah backbone frames from backbone networks is responsible for learning and multicasting unknown source addresses of clients.

B. B-component

The B-component relays each encapsulated customer frames from an I-component to one or more provider network ports (PNPs) and from a PNP of the IB-BEB to one or more I-components. The mapping of backbone service instances to TE service instances is done by performing a lookup of TE-SID table at the CBP. As shown in Figure 4, the B-component performs a lookup in the FDB table that is connected by the TE-SID table to determine the PNP using B-VID and B-DA. The external PBB-TE management or control plane forms a topology of CBP rooted trees, from each CBP belonging to a PBB-TE network to any of other CBPs in this network.

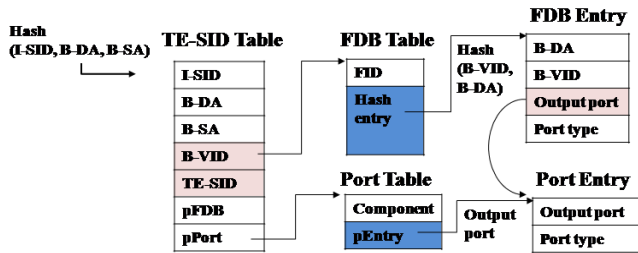


Figure 4. Linkage between lookup tables in the B-component of the proposed mechanism

IV. AUTONOMOUS CLIENT DISCOVERY IN IB-BEB

Normal forwarding operation of the IB-BEB, that is, FDB entries for customer MAC addresses exist in the FDB table of the I-component, has been explained in the third section. For PBB-TE networks, the conventional BEB has discarded unknown customer frames whose destination and source addresses don't exist in the FDB table of the I-component.

However, this paper proposes the learning mechanism for destination and source addresses of unknown customer frames while the connection-oriented property or determinism of PBB-TE networks has been maintained like that.

A. Multicasting for unknown destination customer addresses at PIP

Figure 5 shows multicasting procedure for an unknown destination customer addresses in the ingress I-component. If the ingress I-component receives an unknown customer frame from customer equipment attached by a CNP, that is, destination and source addresses of customers don't exist in the FDB table of the I-component, () it sends the frame to

the egress I-component as an exception packet. The egress I-component, and then, will perform learning process for unknown source customer address. To learn unknown destination customer address, multicast I-tagged frames which include the unknown destination customer address deliver to other IB-BEBs through pre-determined ESPs. Where, multicast I-tagged frames are created using the multicast table associated with pre-determined ESPs. PIPs of the I-component are internally connected with CBPs of the B-component in the PBB-TE network. For this reason, even though multicast I-tagged frames for unknown destination address are flooded at PIPs, the multicast frames could be delivered to other BEBs in the PBB-TE networks through the ESPs created by the ingress B-component.

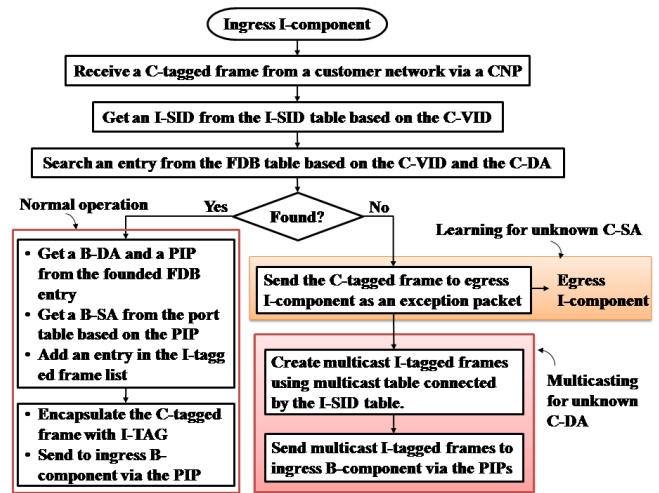


Figure 5. Multicasting procedure for an unknown destination customer addresses in the ingress I-component

B. Learning for unknown source customer addresses at CNP

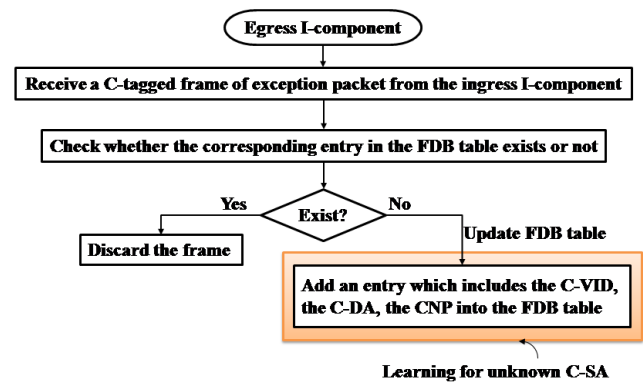


Figure 6. Learning procedure for unknown source customer addresses in the egress I-component

The egress I-component receives a C-tagged frame as an exception packet from the ingress I-component. It checks if there is a corresponding entry in the FDB table by performing a lookup of FDB tables based on the C-VID and the C-DA of the received frame. If there is no corresponding entry in the FDB

table, the egress I-component updates the FDB table by adding an entry which includes the C-VID, the C-DA, and the CNP of the received frame into the FDB table. Learning procedure for unknown source customer addresses in the egress I-component shows in the Figure 6.

C. Delivering multicast frames to other IB-BEBs via pre-determined ESPs

The ingress B-component delivers multicast frames received from the ingress I-component to other IB-BEBs through the pre-determined ESPs. The FDB table of the ingress B-component was explicitly configured by an external management or control plane. Multicast I-tagged frames received from the ingress I-component are encapsulated by the B-TAG. This operation is the same as the normal behaviour of the B-component and independent of unknown destination customer addresses. That is, connection-oriented ESPs, which have previously created, are only used to deliver multicast frames to other IB-BEBs without changes of the ESPs. Therefore, the connection-oriented property or determinism of PBB-TE networks could be maintained.

D. Receiving a frame replied from destination IB-BEB via a pre-determined ESP

In the opposite direction of the ingress B-component, the egress B-component receives a B-tagged frame replied from the destination IB-BEB through the pre-determined ESP. Like the FDB table of the ingress B-component, the FDB table of the egress B-component was explicitly configured by an external management or control plane. After performing a lookup of the FDB table, the received B-tagged frame is decapsulated into an I-tagged frame. And then, the egress B-component sends the I-tagged frame to the egress I-component via a CBP.

E. Learning for unknown destination customer addresses at PIP

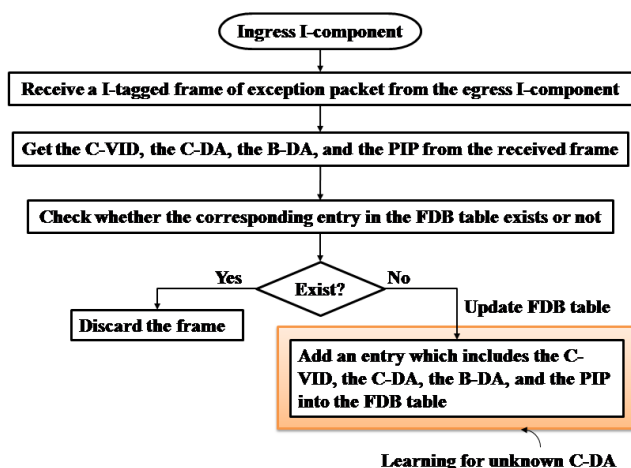


Figure 7. Learning procedure for unknown destination customer addresses in the ingress I-component

If the egress I-component receives the replied frame from the egress B-component via a PIP, it sends the frame to the ingress I-component as an exception packet. If there is no corresponding entry in the FDB table, the ingress I-component updates the FDB table by adding an entry which includes the C-VID, the C-DA, the B-DA, and the PIP of the received frame in the FDB table.

V. DISCUSSION

This paper has been proposed the mechanism that autonomously discovers clients without any help of control plane in the PBB-TE networks providing traffic engineering capabilities and determinism.

The features of the proposed mechanism are as follows. First is that it takes place at provider instance ports (PIPs) that an unknown destination client address multicast to other IB type backbone edge bridges (IB-BEBs) in the PBB-TE network. Since PIPs of the I-component are internally connected with CBPs of the B-component, the frames of unknown destination address flooded at PIPs are encapsulated by B-TAG in the B-component and deliver to other IB-BEBs through pre-determined ESPs. Second is that the learning for the unknown source client addresses take place at customer network ports (CNP). Third is that the replied frame for the unknown destination client address is received at a PIP and learned by updating the FDB table of the ingress I-component.

Moreover, the multicast frames for an unknown destination client address are not only flooded with all FDB entries of FDB tables for a basis but also flooded with the multicast table connected by an I-SID for a basis. This point can therefore avoid that multicast I-tagged frames allocated to the same ESP are duplicated. The multicast table is created and managed by the I-SID separately. Eventually, multicast frames can be delivered to only PIPs belonging to the corresponding I-SID.

The proposed mechanism has many advantages. PBB-TE networks are capable of supporting multipoint services such as IP-TV while they provide connection-oriented behaviour for real-time traffic. Learning, multicasting, and association with the pre-determined ESPs for unknown destination and source addresses of clients are autonomously performed in the data plane. Therefore, a management plane is not necessary for autonomous discovery of clients. It is sufficient that a control plane such as GMPLS controls only ESPs. External management or control plane becomes simpler and easier to operate. Since the duplicated I-tagged frames allocated to the same ESP are removed and multicast frames are delivered to only PIPs belonging to the corresponding I-SID, traffic load occurred by flooding of unknown client frames could be reduced. The more clients attached to CNPs of the I-component than ESPs created by the B-component in the IB-BEB, this advantage is the more effective in view of the throughput performance of the IB-BEB.

There are technologies available today that support the multipoint connectivity. The virtual private LAN service (VPLS) emulates Ethernet services using pseudowire

encapsulation and carries these services over MPLS tunnels. By creating a full mesh of pseudowires between service points in a VPN, the VPLS can support an Ethernet any-to-any service. The full mesh of pseudowires between all sites in the VPN results in packet replication at the service edge for multicast traffics and then inefficient utilization of link capacity. These are drawbacks of the VPLS.

As an alternative, the provider link state bridging (PLSB) was proposed. It configures the forwarding tables using the IS-IS protocol. Auto-discovery of service points is built into the PLSB protocol. PLSB distributes nodal and service information to all nodes in the network using IS-IS link state updates functions. However, the link-state protocols such as OSPF and IS-IS have a limit in supporting a large number of nodes.

On the other hand, the provider backbone bridge (PBB) uses multiple spanning tree protocol (MSTP) to establish rooted broadcast domains in a network, of which each domain is associated with a backbone virtual LAN (B-VLAN). Unknown MAC addresses are only broadcasted within the given B-VLAN.

Differences between the proposed mechanism and the previous works such as VPLS, PLSB, and PBB are as follows.

- a) The VPLS is based on MPLS transport network. The proposed mechanism is based on the PBB-TE transport network that works by adding a new MAC header to the Ethernet frame to be used in the backbone network while the original MAC header is used within the client infrastructure.
- b) The PLSB updates forwarding tables through IS-IS protocol. The proposed mechanism uses the self MAC learning method that extracts nodal and service information from the incoming frames and directly updates the forwarding tables in the data planes. The data plane do not need to communicate with the control plane, therefore, the proposed mechanism can update the forwarding tables much faster than the PLSB and handle a large number of nodes.
- c) The PBB network delivers the broadcast frames to backbone core nodes for multipoint service. However, it does not happen in the PBB-TE network because the PBB-TE disables flooding and learning to offer pre-determined paths, reserve bandwidth, deliver hard QoS, and offer 50 ms recovery. The proposed mechanism offers the key method which broadcasts and automatically learns unknown addresses of clients, and updates the FDB tables of the data planes in the edge node of the PBB-TE network. To realize these features, the structure of the conventional I-SID table of PBB, which is responsible for assigning each frame to a backbone service instance, has been modified. The modified I-SID table has supplemented the connection with newly added multicast table. The PBB broadcasts unknown frames to the nodes belonging to the same B-VLAN only. The proposed mechanism broadcasts unknown frames to the nodes

belonging to the same I-SID only. To resolve the problem of packet replication for multicast traffic, duplicative creation of entries with the same ESP in the multicast table has been removed. The proposed mechanism does not require to create the broadcast tree using protocols such as STP and IS-IS.

To realize the proposed mechanism, the I-SID table and the FDB table of the ingress I-component should be in sync with those of the egress I-component. That is, the ingress I-component and the egress I-component should be capable of receiving exception packets with each other.

VI. CONCLUSIONS

PBB-TE that provides traffic engineering capabilities and determinism is point-to-point connections by nature. To implement a deterministic multipoint PBB-TE network, however, it is necessary to complement the PBB-TE.

In this paper, we have proposed the mechanism which is capable of autonomously discovering clients without any help of control plane for supporting multipoint connections of the PBB-TE networks. Learning and multicasting functions for unknown destination client addresses have been added in the ingress I-component of the IB-BEB. Also, learning and multicasting functions for unknown source client addresses have been added in the egress I-component of the IB-BEB. Pre-determined ESPs created by the B-component of the IB-BEB are only used for delivering multicast frames to other IB-BEBs. This operation of the B-component is the same as the normal behaviour. Therefore, a deterministic multipoint network could be realized by autonomous discovery function of the I-component and connection-oriented function of the B-component.

The proposed mechanism could reduce traffic congestion due to flooding of multicast frames by delivering multicast frames to only PIPs belonging to the corresponding I-SID. Multipoint PBB-TE networks of the proposed mechanism could support real-time and multicast applications such as VPN and IPTV services, and management or configuration of the networks could become simpler and easier.

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