# A Comparative study on Metro Ethernet Technologies

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***Abstract* - The most widely installed Local Area Network (LAN) technology, Ethernet, is deployed in a Metropolitan Access Network (MAN) as pure Ethernet, Ethernet over Synchronous Digital Hierarchy (SDH) etc. First evolution in carrier grade Ethernet was Virtual LAN (VLAN) and it's extended version known as Provider Bridge (PB) technology is now widely used for the deployment of large scale MAN. The main challenging tasks faced by network operators are scalability, security, operations, administration and management (OAM) these networks. Newer technologies such as Provider Backbone Bridge (PBB) and Virtual Private LAN Service (VPLS) are choices for upgrading PB networks. The techniques for migrating from existing technologies can be of In-service migration and also by Partial VLAN service migration. The comparison study on these network technologies will give an idea about the benefits and need for the deployment of newer technologies. Upgraded network technologies will reduce the recurring cost of service deployment while offering much flexibility in offering value-added data services. Evaluating the network parameters and comparing them will help the network service providers to enhance their services with the newer technology. The merits and some demerits of these novel technologies are also pointed out by the comparison study.**

## I. INTRODUCTION

Ethernet has been widely used in LANs for years, and it is an inexpensive and scalable solution for small network environments. Metro Ethernet is a network that covers a metropolitan area using Ethernet Interface to provide Internet service and to connect businesses to a larger service network. Metro Ethernet is offered by a wide variety of service providers around the world, the number of subscribers continues to grow rapidly by the thousand. IEEE 802.1Q Virtual LANs (VLAN) and IEEE 802.1ad Provider Bridging (PB) are used by broadband network providers as well as many enterprises for the large deployment of Ethernet networks. The day by rapidly increasing demand for end to end Ethernet services, which lead to the need of new Ethernet deployments and leads to the growth of the Ethernet footprint on the core network side, some of the end-to-end Ethernet services may need to span the core network over a Virtual Private LAN Service (VPLS). This leads to significantly larger contiguous Ethernet service domains [1]. According to the growing scale of deployment, weaknesses of flat Ethernet networks, most importantly limited scalability and lack of data security are becoming a concern on the core network side, some of the end-to-end Ethernet services may need to span the core network over a Virtual Private LAN Service (VPLS). This leads to need for significantly larger contiguous Ethernet service domains.

VLAN services in Provider Bridging are limited to 4096 as VPNs which support PB networks by means of grouping traffic into Service VLANs (S-VLAN). Provider Edge Bridges (PEB) will add an additional VLAN tag called the Service (S)-tag into the header of the customer Ethernet frames. The S-VLAN Identifier (S-VID) in the S-tag limits the number of provided services. PB network operators can take merit of operating and managing the customer VLAN space in data frame, as well for customers that do not use VLAN tagging, e.g. for residential customers of broadband access networks. The applicability of this method is limited in practical scenario.

### A. *IEEE 802.1Q VIRTUAL LANS (VLAN)*

The development of IEEE STD 802.1D-1993 was resulted from the MAC Bridge standardization activities which introduced the concept of Filtering Services in Bridged Local Area Networks, and mechanisms whereby filtering information in such LAN's may be acquired and held in a Filtering Database. IEEE Std 802.1q specifies how the MAC Service is supported by Virtual Bridged Local Area Networks, the principles of operation of those networks, and the operation of VLAN-aware Bridges, including management, protocols, and algorithms. IEEE STD 802.1d-1998 edition, a revision of IEEE STD 802.1d-1993, extended the concept of Filtering Services to define additional capabilities [3]. This standard, first published as IEEE STD 802.1q-1998, makes use of the concepts and mechanisms of LAN Bridging that

were introduced by IEEE STD 802.1d and it defines additional mechanisms that allow the implementation of Virtual Bridged Local Area Networks. VLANs aim is to offer the benefits such as to facilitate easy administration of logical groups of stations that can communicate as if they were on the same LAN, also to facilitate easier administration of moves, adds, and changes in members of these groups, traffic between VLANs is restricted ,i.e., bridges forward unicast, multicast, and broadcast traffic only on individual LANs that serve the VLAN to which the traffic belongs, VLANs maintain compatibility with existing bridges and end stations. If all Bridge Ports are configured to transmit and receive untagged frames, bridges will work in plug-and-play IEEE Std 802.1d mode. End stations will be able to communicate throughout the network. 4 bytes are inserted into the header of an Ethernet packet. This consists of 2 bytes of Tag Protocol Identifier (TPID) and 2 bytes of Tag Control Information (TCI). TPID is the tag protocol identifier, which indicates that a tag header is following and contains
the user priority, canonical format indicator (CFI), and the VLAN ID. User priority is a 3-bit field that allows priority information to be encoded in the frame. Eight levels of priority are allowed, where zero is the lowest priority and seven is the highest priority. The CFI is a 1-bit indicator that is always set to zero for Ethernet switches. CFI is used for compatibility between Ethernet and Token Ring networks. If a frame received at an Ethernet port has a CFI set to 1, then that frame should not be bridged to an untagged port.

*B. IEEE 802.1AD PROVIDER BRIDGING (PB)*

IEEE 802.1ad standard defines the architecture and protocols to offer the equivalent of separate Local Area Networks (LAN's) [2], Bridged Local Area Networks or Virtual Bridged Local Area Networks to a number of users, while requiring no cooperation between the users, and minimal cooperation between each user and the provider. A Provider Bridge is a system that comprises a single Service-VLAN aware bridge component. Each port of the Service-VLAN aware bridge connects to either a Provider Network Port; or a Customer Network Port. Each Customer Network Port can connect either directly to a customer system; or to a Customer-VLAN aware Bridge component that provides one or more Provider Edge Ports. A Provider Bridge may comprise a number of Customer-VLAN aware Bridge components. In order to improve scalability, equipment vendors added support for a second VLAN tag. The resulting "Q-in-Q" or "Double Tagging" mechanism has been formalized in the IEEE 802.1ad Provider Bridging revision to 802.1Q.
The inner tag field or C-Tag carries the customer VLAN Identifier (C-VID), which identifies a customer VLAN (C-VLAN). The outer tag field, or S-Tag, carries the S-VID, which identifies a service VLAN (S-VLAN). This tag is used to identify a service instance and defines a topological partition of the network based on the topology of this service instance. Spanning tree protocol is used to prevent loops in each S-VLAN (and independently, to prevent loops in each C-VLAN). S-VLAN provides customer separation and also isolation of customers from a carrier's network. However, the S-VLAN tag is itself too limited for large-scale carrier networks.

*C. PROVIDER BACKBONE BRIDGING (PBB)*

PBB (also known as MAC-in-MAC) encapsulation adds layer-networking support to Ethernet. MAC-in-MAC encapsulation is now being formalized in the 802.1ah 'Provider Backbone Bridges' draft standard. From a technical perspective, PBB is both flexible and efficient. It has the ability to support services such as E-Line, E-LAN and E-Tree as defined by the Metro Ethernet Forum (MEF). It is designed to efficiently handle many multipoint services simultaneously. PB Ethernet frames are encapsulated and forwarded in the backbone network based on extra newly added Backbone-Destination Address (B-DA), Backbone-Source Address (B-SA), and Backbone-VLAN-ID (B-VID) fields within the PB frame structure. MAC-in-MAC encapsulation support improves upon the separation and isolation features introduced in 802.1ad: it supports complete isolation of individual client-addressing fields as well as isolation from address fields used in the operator's backbone. 802.1ah also introduces a new 24 bit tag field; the I-SID service instance identifier. This 24-bit tag field is proposed as a solution to the scalability limitations encountered with the 12 bit S-VID defined in Provider Bridges. 802.1ah Provider Backbone Bridges operate the same way as traditional Ethernet bridges. Service is still connectionless, flooding is used when destination MAC addresses are not recognized, and spanning tree is used to prevent loops. VLAN tags are reserved on a network, rather than a per-port basis PBB overcomes the VLAN capacity challenge of 4094 per network by using an I-SID which performs the same function of a VLAN but allows for 16.7 million individual services on the network by using a PBB MAC address, called a B-MAC, to forward frames. All other technologies use customer frames to forward frames, which becomes inefficient as the number of multipoint customers on a network grows. Benefits of PBB network includes: It imposes no change to Ethernet switching process in the core bridges, supports Ethernet private line (E-Line), Ethernet Transparent (E-LAN) and Ethernet Tree (E-Tree) services, provides a clear point between the customer and provider domain, learns customer MAC addresses only through the backbone edge bridges (BEB), supports up to $2^{24}$ service instances, achieves additional PBBN scaling and interconnection using hierarchical and peer PBBN features etc

### D. VIRTUAL PRIVATE LAN SERVICE (VPLS)

Multiprotocol Label Switching (MPLS) is the technology of choice for service provider core networks. MPLS provides a full suite of control protocols and data-handling capabilities that make the transformation of both Layer 2 and Layer 3 services possible. Carriers are aggressively deploying Virtual Leased Lines (VLL) and Virtual Private LAN Services (VPLS) in regional metro areas. These standards-based point-to-point and multipoint Ethernet services can be deployed to transform legacy architectures, simplifying the overall network structure and improving profitability, while maintaining all the benefits of MPLS service delivery and management. This approach extends all the benefits of MPLS to metro areas and beyond, and enables service providers to deliver end-to-end uniform services, irrespective of the underlying physical transport and network access technologies. VPLS delivers an Ethernet service that can span one or more metro areas provides connectivity between multiple sites, if these sites were attached to the same Ethernet LAN. In contrast to the current Ethernet service offering that is delivered upon a service provider infrastructure composed of Ethernet switches, VPLS uses the IP/MPLS service provider infrastructure. VPLS architecture is widely deployed and proven, and it is the fastest-growing architecture in service provider networks, delivering scalable, reliable and flexible Layer 2 multipoint Ethernet services to carriers' customers. It has become the de-facto architecture to deliver multipoint Ethernet services in carriers' networks. VPLS provides support for different types of service delivery options through the addition of control and data plane hierarchy. The resulting model, referred to as hierarchical VPLS (H-VPLS), adds a new dimension to the base model by allowing flexible service connectivity. The most popular deployment models include full and partial mesh, with hub-and-spoke ring topologies interconnecting VSI instances. This flexibility addresses the real deployment needs of carriers who require highly reliable Layer 2 services. From the service provider's point of view, use of IP/MPLS routing protocols and procedures, instead of the Spanning Tree Protocol, and MPLS labels instead of VLAN ID, significantly improves the scalability of the VPLS service.

## II. QUALITY COMPARISON

Spanning tree protocols (STP) are used in Ethernet networks to ensure a loop-free topology for any bridged Ethernet network. The main purpose of these protocols is to ensure loop-free operation of the networks and broadcast radiation. Two protocols: Rapid Spanning Tree Protocol (RSTP) and Multiple Spanning Tree Protocol (MSTP) are the portable software implementation of the Spanning Tree algorithm, and include Rapid Spanning Tree and Multiple Spanning Tree support. The software for this is portable to several RSTP or MSTP, dynamically

| Non-Functional Requirements | Network Technology | | |
|---|---|---|---|
| | *PB* | *PBB* | *MPLS* |
| Resilience | STP/RSTP, ERP | Global Protection, Fast re-route | Global Protection, Fast re-route |
| Security | VLAN isolation | Circuit – based, MAC proof | Circuit – based |
| Multicast | Ethernet multicast | For Point-to-Point only | Problematic, inefficient |
| QoS | DiffServ & guaranteed | DiffServ & guaranteed | DiffServ & guaranteed |
| Legacy Services | No | No | Yes |
| Scalability | Via VLAN stacking | VLAN & MAC scalability solved | Increased complexity |
| Equipment cost | Low | Low | High |
| Operation & Management | STD OAM 802.1ah/ 802.3ag | STD OAM 802.1ah/ 802.3ag | MPLS OAM, BFD |

determine the

TABLE I. NETWORK TECHNOLOGY COMPARISON

Leading operating systems and switch hardware using well-defined external interfaces. As with PB, PBB networks use a Spanning Tree Protocol (STP), e.g., topology of the PBB network and MAC address learning to dynamically build a forwarding database. RSTP/MSTP includes provisions for supporting Link aggregation and Port authentication.

It also provides comprehensive management capabilities. Since an IB-BEB forwards frames to PB and PBB networks, it has to learn customer and backbone MAC addresses. However, since an IB-BEB is at the edge of the Service Provider network, it only learns customer MAC addresses of the local traffic. Ethernet OAM (Operations, Administration and Maintenance - IEEE 802.1ah) provides carriers with the ability to diagnose last mile link problems. Ethernet CFM [4] (Configuration Fault Management - IEEE 802.1ag, ITU Y.1731) finds and fixes faults in large scale layer 2 Carrier Networks.

Quality of Service (QoS) guarantee is provided by Differentiated Services (Diffserv) architecture on an aggregate of flow. Diffserv can be used to provide service differentiation in a network for different classes of traffic. The ingress router classifies the incoming traffic into classes and also performs the policing of the traffic. The traffic classes are called Behaviour Aggregates. A classified packet is marked using a set of markings known as Differentiated Services Code Point (DSCP). The markings can be stored in the DS field in the IP header of a packet. Based on the marking in a packet, a router in a Diffserv domain treats the packet according to the scheduling and queuing rules associated with its class.

An important area in which VPLS strongly differentiate itself from other Layer 2 VPN technologies is support for Quality of Service (QoS). There are two primary methods of controlling QoS in the network. First method is to assign a Class of Service (CoS) value for the VPLS instance at configuration time. First method is to assign a Class of Service (CoS) value for the VPLS instance at configuration time. In this method, the ingress PE router overrides the priority of an incoming frame and selects a tunnel LSP with a CoS value that matches what was configured for the VPLS instance. The second method deals with assigning a distinct CoS value for each MPLS frame entering the network. In this method, a common LSP tunnel is used for traffic between two PE's, irrespective of the VPLS instance to which it belongs. Discrimination between different traffic types in the MPLS network is done by using different EXP bits in the MPLS frame. The EXP bits are set by mapping the 802.1p CoS value from the incoming tagged Ethernet frame to desired EXP bits. If the incoming frame is untagged, the router can also be configured to assign a priority to the port to determine the CoS value for an incoming untagged Ethernet frame.

The external control plane of PBB simplifies network management by eliminating the vendor – specific modules within the control plane environment used by MPLS. This reduces the cost of each network element and improves the manageability of the Metro networks. It also improves quality of service through deterministic path selection and increase reliability with SONET/SDH speed failover to pre–provisioned backup paths. The VPLS has much higher capital expense than the Ethernet Transport alternative. This cost difference is due to the VPLS uses IP/MPLS embedded features in their line-card as compared to the widely deployed Ethernet L2/L3 features of the Ethernet transport line-cards. Ethernet vendors can profitably support price levels that are less than half of those of highly specialized VPLS line-cards.

## III. PARAMETER COMPARISON

Provider backbone Bridges (PBB's) offer an effective scalable solution for the Internet Service Providers (ISP) to build large bridged communication

| Parameters | PB | Ethernet over MPLS | VPLS over MPLS |
|---|---|---|---|
| Scalability | Low-L2 core n/w | Low- requires p-to- p mesh b/w sites | High- Shared core, p-to-mp |
| Convergence | High-L2 across n/w | Medium- L2 with multiple sites | Low- MPLS backbone |
| Latency | High-L2 forward across core | Low- forward across LSP | Low- forward across LSP |
| Latency Variation | High-L2 forward across core | Low- forward across LSP | Low- forward across LSP |
| Cost | Low- shared core Infra structure | Low- shared core Infra structure | Low- shared core Infra structure |
| Provisioning operations | Complex - L2 core n/w | Complex -requires p-to-p mesh b/w site | Simple- shared core infra structure, auto discovery support |

networks. The PBB primarily focus on improving two main areas with provider Ethernet bridged networks:

TABLE II. PARAMETER COMPARISON

The MAC address table scalability and Service instance scalability. To obviate the above two limitations, PBB introduces a hierarchical network architecture with associated new frame format that extend the work completed by Provider Bridge (PB's). VPLS is typically used to link a large number of sites together. Scalability is therefore an important issue that needs addressing.

In PB technology QoS and scalability is provided through I-Tag. It can support up to 16 million instances also have seven levels of priority. Core and edge bridges can handle both legacy and PBB traffic. Core and edge devices only need to "learn" the edge MAC addresses to forward frames. Link errors are detected by 802.1ag CFM and error recovery is done within 50ms. PBB carries a comprehensive set of OAM capabilities from IEEE 802.1ag. PBB's connection-oriented features and behaviour, as well as its OAM approach is inspired by SONET/SDH networks. PBB is essentially designed for manually provisioned point-to-point Ethernet (transport) connections. PBB allows Ethernet transparent bridging and therefore enables automated establishment of Ethernet connectivity.

VPLS works on a mesh network design. This means that it works as a virtual LAN switch, providing a direct any-to-any connection between sites, rather than the hub-and-spoke model used by older WAN solutions. A mesh design offers two key benefits that are appealing for data centre interconnect: single-hop links and resiliency. By offering a single-hop, direct access between remote sites on the VPLS, latency issues common in hub and spoke designs are eliminated. Without the overhead of running inter-site data traffic with a router at headquarters serving as a go-between, VPLS offers performance improvement for tasks such as data centre synchronization and backup processes. Similarly, without the single point of failure of a centralized WAN hub, a VPLS network is more resilient to potential outages. In the event that one data centre loses its network link, the rest of the remote sites can go on unaffected. VPLS is a technology that provides any-to-any bridged Ethernet transport among several customer sites across a service provider infrastructure. All sites on the same VPN are connected to the VPLS service and belong to the same LAN bridging domain. Frames sent by workstations attached to the site LANs are forwarded according to IEEE 802.1 bridging standards. VPLS offers none of the layer 3 security or isolation features offered by layer 3 VPN technologies, including MPLS VPN and IPSec. The integrated PBB/VPLS solution combines the scalability benefits of PBB and the resiliency, traffic engineering and convergence benefits of VPLS and MPLS, enabling carriers to leverage their existing metro Ethernet infrastructure.

## IV. CONCLUSION

PBB is a Packet-based Transport Network (PTN) technology for Metro Ethernet with layered architecture, improved OAM, and QoS guarantee usually by Differentiated Services (Diffserv). As a convergence-layer solution, PBB is more cost effective than MPLS. Most services are moving to IP so it is often possible to restrict legacy services to the access network and provide a gateway to terminate legacy protocols, extract the IP payloads and transport them over a Carrier Ethernet network, for example, by using a VoIP gateway to convert legacy PBX voice traffic to VoIP. The legacy limitations of Ethernet can now be overcome via PBB technology, bringing the highly sought cost-effectiveness and simplicity of the technology to core carrier networks. The deployment of PBB provides carriers with the scalability, reliability and granularity of service they require while taking advantage of the wide acceptance and low operating costs of Ethernet. With improved standards, PBB is expected to become an optimal solution for next-generation metro PTNs.

Virtual Private LAN Service (VPLS) provides a framework for extending Ethernet LAN services, using MPLS label tunnelling capabilities, through a routed MPLS backbone without running protocols such as RSTP or MSTP across the backbone. Thus VPLS has been deployed on a large scale in service provider networks. PBB only supports point-to-point Ethernet services and does not satisfy some key packet transport requirements (multipoint- to-multipoint connectivity, multiservice support, scalability). On the other hand, VPLS not only meets all the requirements, but also provides the flexibility to start with a centralized/static provisioning model if needed and later migrate to a distributed/dynamic model. Main benefit of PBB is its MAC-in-MAC capability and VPLS will make use of it for MAC hiding. Collaboration of the better parts of the old, existing and proposing technologies can give rise to a fast, efficient and advanced communication network with QoS guarantee.

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