CAN PBB-TE BRIDGE THE GAP TO NEXT-GENERATION CARRIER ETHERNET?

As carriers drive their networks towards a converged next-generation platform, new technologies are entering the marketplace and creating significant impact on network development strategies. One of the most recent and most discussed technologies is Provider Backbone Bridging – Traffic Engineering (PBB-TE).

This paper explores the PBB-TE debate, examining the benefits and challenges it presents to carriers. Focusing on PBB-TE’s extension to the network Ethernet Demarcation Device, this paper considers the financial implications of early adoption and how PBB-TE could actually reduce costs and enable carrier’s to gain greater control of their next-generation network.

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Introduction

Architected as a possible replacement to circuit switched transport networking technologies, such as SONET/SDH, PBB-TE has the significant advantage of being based on Ethernet. Although still in its infancy, carriers in Europe and the US are producing RFPs that include PBB-TE functionality. If adoption is as strong as initial interest, many analysts believe that PBB-TE will become a technology standard in many of the world’s largest carrier infrastructures. Leading the charge is BT, who is including PBB-TE in their 21st Century Network plans. As the leading supplier of Ethernet Access Devices (EAD), ADVA Optical Networking is uniquely positioned to provide valuable industry insight.

BACKGROUND

PBB-TE as outlined in the draft IEEE802.1Qay is the latest in a series of IEEE standards that have been developed to build carrier class capabilities into Ethernet technology. 802.1Qay builds on earlier work within 802.1ad Provider Bridging, 802.1ah Provider Backbone Bridging and 802.1ag Connectivity Fault Management. Other recent standards such as 802.3ah "Ethernet in the First Mile" (EFM) and ITU-T Y.1731 "OAM Functions and Mechanisms" have also contributed greatly to Carrier Ethernet’s capabilities.

While carrier services are migrating rapidly from Frame Relay (FR), ATM and TDM Leased Lines towards Ethernet equivalents, it is not the ability to natively support Ethernet services that is driving PBB-TE to be the carrier Ethernet transport network of choice, although this is a huge benefit. It is in fact, the same fundamental reasons why Ethernet was so successful in the Enterprise space, namely low cost of Ethernet components and the ability to flexibly support a full range of services in an industry standard based way.

PBB-TE makes use of relatively simple though very high performance Ethernet switches in its core. While considerably more advanced than the average LAN switch they nevertheless benefit from the same fundamental low cost model when compared with traditional SONET/SDH cross connects or IP/MPLS routers of similar throughput.

IMPORTANCE OF THE TRANSPORT LAYER

In traditional carrier networks the service offered was very closely tied to the infrastructure providing it, e.g. TDM Leased Lines offered over a TDM/PDH or SONET/SDH network and FR offered over FR/ATM networks. IP/MPLS has been deployed by many carriers as an attempt to provide a unifying service layer but the experience of the largest carriers has shown that there are management and scaling problems preventing it being deployed to the customer premise.

Conversely, Ethernet and WDM appear to offer a more universal base on which to build a transport infrastructure as increasingly more infrastructural components are offered with Ethernet interfaces as standard and technologies develop to emulate legacy services over that new infrastructure.

The transport layer is an important layer in a carrier network. It provides an abstraction layer between the higher layer switching nodes (often based on IP/MPLS routers) and the physical fiber infrastructure. It allows the virtualization of the links between the routers (e.g. providing logical mesh around topology rings), while making the most efficient use of the fiber resources and switching nodes (e.g. bypass transit traffic at a lower layer). The transport layer allows these links to be protected against failure. It provides tools to isolate faults quickly across complex virtual links between routers which can often pass over several operators’ networks and large distances.

1 Source: Infonetics 2007
**Ethernet services and Ethernet transport**

When discussing PBB-TE we need to make a clear distinction between Carrier Ethernet services and Carrier Ethernet transport.

::Carrier Ethernet services are services the carrier sells to its customers in order to interconnect the customers' sites at the Ethernet layer. They are most often point-to-point services emulating a link in an Ethernet network (E-LINE) but are increasingly multi-point in nature emulating an Ethernet switch joining the various sites (E-LAN).

::Carrier Ethernet transport is the use of Ethernet infrastructure to interconnect the carrier's own systems e.g. interconnecting DSL Access Multiplexers (DSLAMs) to a Broadband Routing and Access Server (BRAS) to support a broadband access service.

In reality, one of the main customer groups for Carrier Ethernet services is other carriers themselves, who use these Carrier Ethernet services to plug gaps in their own carrier Ethernet transport networks. Likewise, Carrier Ethernet transport networks are often (but not always) used as the technology to deliver Carrier Ethernet services.

**DIFFERENT OPERATION REQUIREMENTS**

Public services (e.g. internet based) allow users to peer over the service provider’s network between ad-hoc locations/systems. In such a network, there must be a seamless interaction between the control/routing protocols in the customer and provider networks i.e. a peering relationship that lends itself to a connectionless routing model such as IP.

Private services (e.g. Carrier Ethernet services) are connecting pre-defined locations. They must be provided as a client layer running on top of the carrier’s network (server layer). In this respect, the service must be completely transparent to the customer’s traffic and there must be no interaction between the control/OAM/monitoring functions of the two layers. To obtain a true client/server model the server layer must encapsulate or at least maintain/rebuild the client packets. In many cases, the links between the routers providing an IP-based service can be considered private services provided by the transport organization to the data organization.

In traditional networks, these different operating modes drove the need for different network layers to address the full complement of private (client/server) and public (peered) services. This requirement does not go away in the Next-Generation Network (NGN), though the nature of the technologies best suited to provide these layers has changed. IP/MPLS, Ethernet/PBB-TE and WDM/Fiber layers each add considerable and unique value in building a fully scalable converged NGN. The exact mix of technologies will always depend on a carrier’s service portfolio, existing network and size/reach/location. The mix of technologies is also likely to vary in different parts of the network (access/metro/core).

**CONNECTION ORIENTED PACKET SWITCHED (CO-PS)**

As bandwidth demands have increased and the payload mix has moved from constant bit-rate TDM voice to high-bandwidth variable data the Connection Oriented Circuit Switched (CO-CS) SONET/SDH networks have become significantly less efficient for building next-generation transport networks. However, connection oriented networks offered a number of operational benefits that still hold true for NGNs:

::Switching/Routing nodes need to be linked to each other via point-to-point or point-to-multipoint traffic flows (connections).

::Connections create an ability to deterministically manage resources over large geographic areas for large numbers of users.

::Once provisioned, connections are not re-routed except during engineering works – so their performance (especially their delay) does not vary over time.

::Circuits provide implicit guarantees for end-to-end bandwidth allocation (due to bandwidth reservation).

::Carriers have developed, fine-tuned and proven their operational processes for circuits over many years with huge investments in human skills and OSS systems.

These attributes of connections and circuits are the essential building blocks that allow solid QoS mechanisms to be built. PBB-TE aims to emulate the functionality of CO-CS networks such as SONET/SDH by using packet switching technology (Ethernet) to create a CO-PS alternative.

In order to achieve CO-PS and provide end-to-end QoS the following principles have to be adopted:

::In order to provide a truly transparent client/server service there should be no need to inspect the customer's content. The implementation needs to be engineered end-to-end for worst case traffic i.e. a flow that is sensitive to packet order, latency, jitter and packet loss.

::To prevent congestion in the core and minimize the jitter and drop it may be advantageous to shape (smooth/slightly delay) the traffic on entry.
to the connection to distribute the packets in time rather like the time-slots used in TDM systems. This helps to mimic a circuit (a bandwidth constrained connection).

By knowing which connections are provisioned over a link, port or NE and knowing the capacity of that link/port/NE it then becomes possible to engineer the loading at each point in the network and hence guarantee the QoS performance under worst case conditions. This is something that is simply not possible on Connection Less Packet Switched (CL-PS) networks such as IP or “MAC Learning” Ethernet.

**PBB-TE technology**

PBB-TE is built from a number of existing components. Indeed, one of the most striking characteristics is that it mostly takes away unnecessary features from Ethernet to leave a minimalist but complete set of tools for building a CO-PS transport network. In the process it delivers a highly resilient, deterministic and secure network that can be managed by the same systems used for the SONET/SDH infrastructure.

**PBB-TE CONNECTIONS**

PBB-TE uses the MAC in MAC (802.1ah Provider Backbone Bridging) encapsulation to implement connections (see Figure 2).

Each end-point (port) on the network has a MAC address. Every packet ingression into the network is encapsulated with an additional Ethernet header. As shown in Figure 1, the Source Address (SA) is the MAC address of the ingress port and the Destination Address (DA) is the MAC address of the egress port at the remote-end of the connection. The VLAN-ID (VID) is used to identify different connections between the two end-points. These are known as the B-DA, B-SA and B-VID and together they define the circuit ID between the end-points and this is maintained end-to-end across the network without modification. By allowing multiple connections between the same two end-points diversely routed protection paths can be set up.

An additional field (the I-SID) can be used to identify separate traffic flows multiplexed within the connection without needing to inspect the customer’s VLAN tags directly, except at the edge of the network where the mapping takes place.

**Figure 1: Protected PBB-TE circuits**

**Figure 2: Carrier Ethernet encapsulation schemes**
TRADITIONAL (CONNECTIONLESS) ETHERNET SWITCHING

The heart of an Ethernet switch is its forwarding table. Each entry in the forwarding table lists a MAC address and a port number. This tells the switch which port must be used to forward packets destined to a particular device (MAC address). When the switch receives a packet it looks up the packet’s DA in the table and if it finds a match it will forward the packet as directed. Where there is no entry in the forwarding table (or in the case of broadcast traffic) the switch will flood the packet on all ports to ensure it reaches its destination (N.B. broadcast traffic is generally the result of discovery protocols required to make Ethernet “plug and play” within the enterprise environment).

Traditional Ethernet switching only allows one path between any two points on the network. As there is only one path across the network the forwarding tables hold one entry per MAC address (depending on VLAN implementation).

Protection is provided by adding redundant connections between switches. A protocol called Spanning Tree is then used to disable some of the links to ensure the “no loops” rule is maintained. If a fault occurs, Spanning Tree brings up one of the previously disabled links.

VLANs are built by restricting the switch so it will only forward a packet to a port that is a member of the VLAN shown in the packet’s VLAN-ID field (VID). Each MAC address is only ever a member of one VLAN.

There are two ways to configure the forwarding table:

1. Dynamically by allowing the switch to self-learn which ports to forward traffic through for each DA (the usual mode of operation) or

2. Static entries provisioned from a management system – the PBB-TE approach.

PBB-TE (CONNECTION ORIENTED) ETHERNET SWITCHING

In PBB-TE, the dynamic “MAC learning” function is disabled and all forwarding table entries are provisioned statically from the management system or a control plane. The network only forwards traffic within defined connections. This allows flooding to be disabled and any broadcasts and unknown DAs to be dropped, making it much more stable and secure in WAN environments. The connection oriented management platforms and processes that carriers have traditionally used for SONET/SDH can be adapted relatively easily to configure the Ethernet switch instead of traditional Digital Cross Connects (DXC) allowing the existing systems, process and people to operate the new networks.

Unlike connectionless Ethernet where there is only one forwarding table entry per MAC address, with PBB-TE there could be several connections terminating at the same MAC address (differentiated by B-VID). To support this, the switch must provide Independent VLAN Learning (IVL) that requires separate instances of the forwarding table for each VLAN.

Ethernet OAM mechanisms are used for monitoring and fault detection. These run in-band with the connections ensuring they are subject to the same forwarding components, transmission and disturbances as the client traffic. The exact use of OAM messages within PBB-TE is still under discussion in the IEEE working group; however, it can be seen that IEEE 802.1ag Connectivity Check Messages (CCM) can allow each connection to be monitored and errors detected in the forward direction, while ITU-T Y.1731 Remote Defect Indicator (ETH-RDI) can allow faults to be communicated in the reverse direction. Using these OAM functions, SONET/SDH like protection switching mechanisms can be created. A protection switch is performed by changing the B-VID to cause the packets to pass over the back-up connection (1:1) or by transmitting the traffic over both connections (transmitting every packet twice – once with each VID) and choosing the best connection at the destination (1+1). This basic architecture allows scope for a full range of 1+1, 1:1 and n:n protection schemes to be developed using reserved or shared protection bandwidth depending on the SLA required.

This native ability of PBB-TE to offer protection means that Spanning Tree is no longer required to block redundant paths.

The removal of MAC learning, flooding and Spanning Tree removes the LAN derived control plane problems that have been holding back Carrier Ethernet, leaving a very solid foundation on which to build highly dependable services. The level of churn with transport circuits is low – once provisioned they generally remain in service for long time periods and so manual provisioning is the norm. However, in time it is expected that a GMPLS control plane will be added to PBB-TE to support the Network Operation Center (NOC) engineers with automated control plane tools such as topology discovery, signaling and path identification.
**PBB-TE RESTRICTIONS**

Much of the initial criticism of PBB-TE has been focused on whether it will “scale” to support Multi-Point-to-Multi-Point (MP-2-MP) connectivity to address all the Ethernet service types defined by the MEF. However, PBB-TE is a transport layer connection oriented technology that forms part of a multilayer network. A converged network does not mean a single networking technology but a series of network layers providing clearly defined and delineated functions working in concert to offer the full set of functionality without duplication. The definition of a connection only allows for P-2-P or P-2-MP connectivity and PBB-TE is able to handle both these constructs very well. As with the previous generation of connection oriented transport (SONET/SDH), some simple connectivity services may be offered directly over the PBB-TE layer while others such as MP-2-MP services must be offered via a higher CL-PS layer (i.e. routed IP or bridged Ethernet) running on top of PBB-TE.

**WHY EXTEND PBB-TE TO THE EAD?**

ADVA Optical Networking provides next-generation EADs as part of the innovative Fiber Service Platform (FSP) product family. Many global carriers who use Ethernet as a transparent on-ramp to their various network cores based on Ethernet, IP and MPLS have chosen the FSP 150 as their preferred EAD. The FSP 150 is designed to interwork seamlessly with NGN cores based on PB, PBB, PBB-TE, T-MPLS and MPLS RSVP-TE.

The complexity of MPLS has meant that few carriers have extended it out to the customer premise except when MPLS is required as part of the stack for delivering specific technologies such as VPLS (PWE3) for Circuit Emulation. However, in the case of PBB-TE, ADVA Optical Networking sees considerable benefit in extending the core transport technology out to the EAD where PBB-TE’s fundamental strengths in QoS, protection and simplicity can be integrated with ADVA Optical Networking’s Etherjack® service demarcation functions to deliver enhanced service control and monitoring.

There are two approaches to performing the PBB-TE encapsulation: encapsulate at a Provider Edge (PE) device in the Central Office (CO) or encapsulate at the EAD at the Customer Premise (CP).

**ENCAPSULATION AT THE PE**

Traffic being transported between higher layer equipment (DSLAMs, IP/MPLS routers, BRAS etc.) needs to be encapsulated on entry to the PBB-TE network and where these nodes are co-located with the PBB-TE PE, the PE is best placed to perform the edge functions such as MAC-in-MAC encapsulation.

**ENCAPSULATION AT THE EAD**

The EAD is the demarcation point between the carrier service and the customer’s network. It provides the User Network Interface (UNI) functions to control the customer service and monitor end to end service performance. It also provides the Network Interface Device (NID) functions to detect faults, perform commissioning tests and monitor network performance.

One of the key benefits of Ethernet as an NGA service delivery technology is the ability to deliver multiple services over a single access tail (Ethernet Virtual Circuit, EVC) and deliver these to the customer via separate client interfaces on the EAD. This allows the up-selling of additional services and the migration of legacy services to Ethernet without the need to disturb the customer equipment or existing services running over it. Figure 3 shows a typical application scenario of EADs feeding into a PBB-TE network.

**Figure 3: Application scenario of EADs feeding into a PBB-TE network**
Extending PBB-TE to the EAD allows each service to be separately encapsulated into its own PBB-TE connection right at the point of service demarcation, each with its own attributes and SLA parameters. PBB-TE can directly encapsulate a wide-range of client signals such as 802.3, 802.1Q, 802.1ad, 802.1ah, VPLS and PWE3. At the point of ingress the MAC-in-MAC frame encapsulation takes place, tunnels are created and protection paths are set up. Providing this mapping at the EAD greatly simplifies transport across the access network and prevents the need for complex 802.1ad/802.1Qay/MPLS RSVP-TE conversions at the PE.

PBB-TE relies on very strict control of bandwidth on ingress to the CO-PS paths. Without this the core resources could be overloaded causing congestion – with potential knock-on effects to other customers. As a result, it is essential to provide ingress policing and shaping at the demarcation point into the PBB-TE network. If a different technology was used in the access this would clearly lead to multiple points of ingress policing making it extremely difficult to justify dropped frames on the basis of a customer overdriving their SLA. It is far better to ensure all ingress policing takes place at the point of customer service demarcation where any discarded frames can be clearly aligned to the customer’s own abuse of the service.

Mapping Ethernet services into PBB-TE end-to-end from customer demarcation to customer demarcation provides a considerable level of control and uniformity across the network. It allows the low latency and deterministic qualities of the PBB-TE transport network to be applied to the end-to-end service with no discontinuities. It also allows end-to-end protection mechanisms, monitoring, fault management and PMs equipping Ethernet to deliver QoS analogous to a SONET/SDH based service. Deploying PBB-TE out to the EAD equips Ethernet services to be ready to displace transport based FR/ATM & TDM leased lines from the dominant position that they have held in recent years.

A further benefit is that as PBB-TE provides a true client/server model for the services it transports. It provides clearly defined connections with known performance characteristics. This dependability means that higher layers can be built over it with confidence. Service layer features can be built into the EAD to provide differentiated services over the clearly defined CO-PS transport interconnects. For example, the independent addressing of the server layer PBT-TE tunnels and the client layer customer traffic means these two layers can be switched independently. The PBB-TE tunnels are switched according to PBB-TE connection oriented principles while the service layer can be switched using the customer MAC addresses under normal 802.1D/802.1Q principles (with learning, flooding and Spanning Tree as required).

Conclusions

There are a number of approaches to building NGNs. There is considerable debate in the industry over which is the best approach – and this debate will always exist as new technologies emerge. However, the access network represents a considerable investment to carriers and one which is difficult to change once it has been deployed.

Supporting PBB-TE in the EAD thus allows a considerable amount of service flexiblity and scaling to be added into the network while leaving the PE devices and core switches to deal with aggregation, grooming, cross-connect and section based protection mechanisms.

As the world’s largest supplier of Ethernet access equipment ADVA Optical Networking has many customers that are utilizing EAD equipment with all the major core technologies. ADVA Optical Networking is committed to offering EAD solutions that not only support a wide-range of network cores but also allow operators to migrate their core technology without needing to upgrade their access network.

In the case of PBB-TE cores, ADVA Optical Networking sees considerable benefit in extending the core technology out to the EAD and ADVA Optical Networking’s PBB-TE capable EADs support upgrades from PB (QinQ) to PPB-TE with ease.
The right technology

ADVA Optical Networking has a long history of providing application-focused fiber-optic solutions that add value to, and remove cost from, transport networks. With a comprehensive portfolio of innovative Optical+Ethernet networking solutions, ADVA Optical Networking is an ideal partner for service providers seeking to roll out differentiated portfolios of high-speed services. Regardless of which type of service the service provider decides to offer, ADVA Optical Networking has the right solution from the customer premise to the metro core and beyond.