

# **An Economic Analysis of PWE3 Deployment in the Access Network**

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MANAGEMENT CONSULTANTS TO THE NETWORKING INDUSTRY  
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February 2005





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## Executive Summary

In January 2001, the Multiprotocol Label Switching (MPLS) working group of the Internet Engineering Task Force (IETF) published the first proposed standard for MPLS deployment within the Core Internet. Since the accomplishment of that first milestone, MPLS has become the basis for a growing number of related technologies and enhancements to existing protocols, such as Label Distribution Protocol (LDP), Resource Reservation Protocol (RSVP) and Psuedowire Emulation End-to-End (PWE3). As development of these MPLS-based technologies continues, so do the many services that capitalize on their traffic engineering abilities. More importantly, these enhancements to MPLS also extend the portions of the network in which these technologies can be effectively employed.

MPLS-based technologies such as PWE3 offer service providers an opportunity to optimize their access networks and differentiate themselves in a highly competitive marketplace. The current drive toward consolidation in the marketplace, as evidenced by the recent SBC-AT&T and Verizon-MCI mergers, suggests that major changes are forthcoming in the telecommunications industry. The key to survival in this environment is the ability of the service provider to offer a wide range of services, including but not limited to corporate data services, local and long distance telephony, Internet access and IPTV, to Enterprise as well as Residential customers.

While a significant amount of literature exists on the economics and optimization of Layer-3 architectures in support of Managed IP services, it is important to note that this body of work often ignores the traditional economics and benefits of existing network deployments. Such deployments often involve SONET-based transport and ATM or Frame Relay (FR) virtual circuits and a relative “mish-mash” of Layer-3 protocols to perform routing and forwarding functions. PWE3, based on the *Martini* and *Dry Martini* standards, is a relatively new development incorporating the notions of virtual circuits and edge-to-edge networking into a consistent and deterministic MPLS core domain. This concept, which we refer to as Layer 2.5 over MPLS, proposes a method of **network transition** that can bring more efficiency and service interworking into the areas of traditional TDM, ATM, Frame Relay and Ethernet services.

In addition to permitting the provisioning of traditional Layer 1 and Layer-2 connections through an MPLS network, other benefits of the Layer 2.5 approach include advanced traffic engineering and the ability to measure and manage traffic forwarding rates, through the concept of *strict aggregation*. This last feature is of particular importance given the increased competition in the access market, as the provision of a packet-enabled interface becomes the key enabler to add or bundle additional revenue producing managed services.

In order to appropriately meet the expectations of an increasingly knowledgeable Enterprise customer, all Managed Services in the future will be sold with specific Service Level Agreements (SLAs), which aim to provide customers with a guaranteed benchmark of network performance and reliability upon which they can rely on in support of their business critical applications and communications. SLAs typically state specific forwarding performance guarantees and several other maintenance-related parameters (such as maximum network

downtime) or special service-specific parameters (such as CIR/EIR, UNI service definitions, VPN setup rates, etc.).

Given this backdrop, the objective of this White Paper is the following:

**To establish and analyze the economic benefits of using PWE3 in the access network to provide packet based services for business customers.**

A model was developed by *Network Strategy Partners, LLC* that compares the economics of PWE3 in the access network with TDM services (Nx64, T1, and DS3). The results of our work definitively demonstrate the following economic benefits of Dry Martini PWE3 in the access portion of the network:

- **Increased Revenue opportunity due to the concurrent support of new Ethernet service offerings**
- **Lower total cost of ownership per Mbps**
- **Lower OPEX per Mbps**
- **Lower access transport costs per Mbps**
- **Better cash flows**
- **Higher gross margins per Mbps**

The specific assumptions, results and analysis of each of the categories above are presented in detail within the following sections of this White Paper.

**Based on the results from this paper's analysis, Network Strategy Partners would make the following recommendations to Service Providers:**

- 1) *Using Layer 2.5 switches for aggregation and MPLS backhaul of traditional data services to Gigabit Ethernet-enabled Layer 3 edge routers is the most cost-effective approach to transitioning the network.*
- 2) *The Layer 2.5 approach provides greater flexibility in access technology choices, significant service differentiation (QoS), operations advantages (OAM&P), and reduces the complexity of provisioning new services. Given the competitive nature of today's marketplace, it is imperative for Service Providers to use a more differentiated and cost-effective aggregation and backhaul architecture to reach sustainable profitability.*

## Introduction - Why Pseudo Wires and Dry Martini?

The telecommunications industry is in the early stages of a major paradigm shift created by the development of new wireline and wireless technologies, industry consolidation and the emergence of Enterprise computing requirements (such as any-to-any connectivity) that facilitate competitive advantage for the business customer. The enablement of a packet interface, supported by a packet-enabled network, has created an opportunity for emerging service providers to enter ILEC markets with a diverse portfolio of managed services supported by lower operational expenses. In order to maintain customer share and service differentiation, incumbent carriers are realizing that they must offer new Ethernet based services while continuing to support legacy data services such as point-to-point serial connections and frame relay. The critical success factors in this evolution are the following:

- Leveraging the existing TDM network
- Reducing OPEX
- Reducing CAPEX

For business customers, Ethernet is emerging as the preferred interface for future managed services. Early deployment of Ethernet services has been primarily targeted at on-net fiber customers. Providing Ethernet service to off-net customers has proved to be more challenging. For this reason, a Layer 2.5 approach utilizing PWE3 technologies has emerged as a leading integrated approach to combining new Ethernet and IP services with legacy services on the existing TDM infrastructure.

The PWE3 working group is developing a set of standards to emulate legacy services such as leased lines, frame relay, and ATM over both IP/MPLS networks and non-IP networks. Dry Martini is the PWE3 standard for creating connection-oriented virtual circuits over non-IP networks such as SONET. Dry Martini provides a mechanism for transporting Ethernet, frame relay, leased lines, and ATM over virtual circuits encapsulated within SONET bandwidth or T1 circuits. The PWE3 approach in the access is proving adept at supporting flexible use of existing TDM bandwidth and facilitates statistical multiplexing gain.

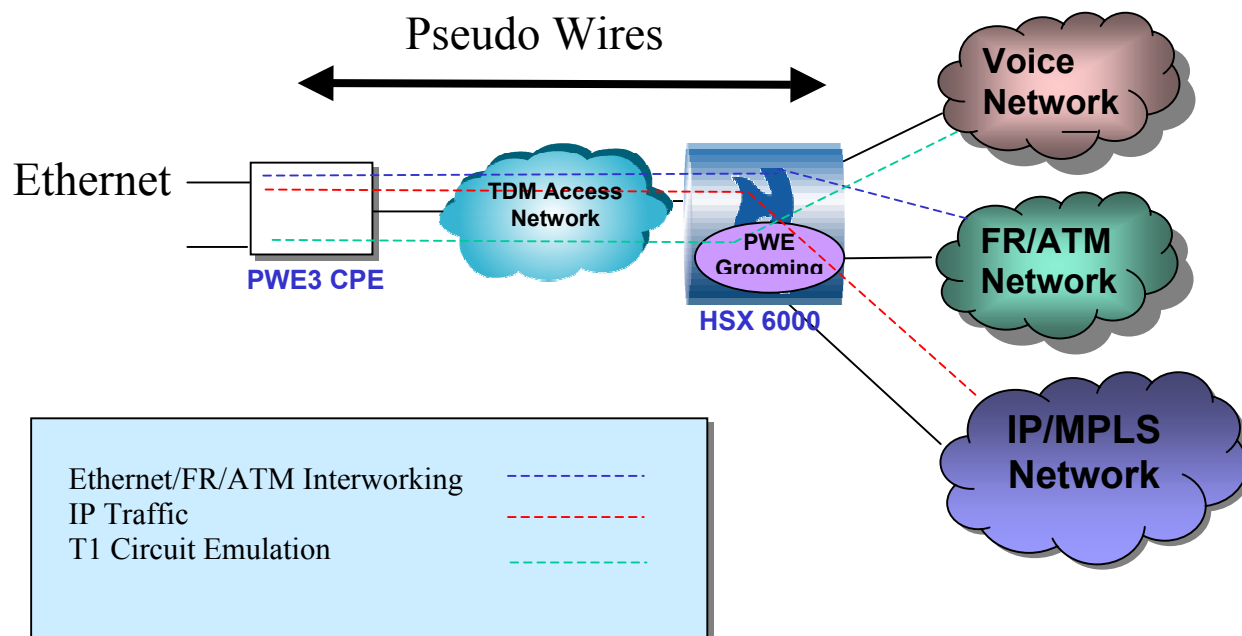


Figure 1

The diagram in Figure 1 provides an example of how *Dry Martini* Pseudo Wires can be used in the legacy TDM access network to integrate Ethernet, frame relay, ATM, and leased line services. In this example an end customer site uses PWE3 CPE with Ethernet and T1 circuit interfaces. The PWE3-enabled CPE creates Pseudo Wires supporting Ethernet virtual circuits (EVC's) and circuit emulated NX64 or T1 lines. These circuits are carried over NXT1, DS3, or Gigabit Ethernet transport to the Central Office. In the Central Office a Hammerhead HSX 6000, offered through Fujitsu Network Communications FASST<sup>1</sup> program, is used as a PWE3 Digital Cross Connect. It grooms the PWE3 circuits handing off voice circuits to the Class 5 switches, Internet traffic to routers, and frame relay/ATM traffic to core ATM switches. The HSX 6000 also has the capability of supporting service interworking between Ethernet, frame relay, and ATM virtual circuits. This allows service providers to create a seamless migration path between legacy frame relay, ATM, and emerging metro Ethernet services.

Some of the benefits of deploying PWE3 in the access network are:

- Ethernet services can be offered over the existing TDM network
- PWE3 provides a standard virtual circuit technology across TDM, IP, and MPLS transport networks
- PWE3 technology extends from the access network to the MPLS core allowing for smooth migration of legacy services to MPLS

A network utilizing a Layer 2.5 PWE3 aggregation approach has significant economic benefits over the current TDM based access networks:

<sup>1</sup> FASST (The Flexible Architecture for Subscriber Service Termination) is the vehicle that executes Fujitsu's vision for transitioning and migrating network smoothly and without compromise.

- Ethernet service offerings increase Carrier revenues while minimizing customer churn
- Transport Costs per Mbps are lower for PWE3 aggregation solutions
- Operations Costs are significantly lower as compared to legacy DCS
- Circuit provisioning is less expensive for PWE3 aggregation solutions
- Capital Expenses for the PWE3 Aggregation solution is less than that of the legacy DCS
- Utilization of the existing TDM network (particularly the 12,000 foot local loop) obviates the need for building a new access network

The next section of this paper presents the architecture framework for the business model and details some of the basic assumptions of our analysis. The following sections present the results of the model and explore some of the economic drivers for deploying PWE3 in the access network.

## Architecture and Assumptions

The results presented in this paper are generated from an economic model comparing PWE3 in the access network with the present mode of operations (PMO). Our focus is entirely on voice and data business services. Some of our basic assumptions are:

- If the Carrier continues the present mode of operations (PMO) then Ethernet services are NOT offered over the legacy TDM network
- If the Carrier uses PWE3 in the access network then Ethernet, frame relay, and voice services are offered over the PWE3 access network
- Bandwidth growth is assumed to be primarily supported by 1) adding new customers or 2) growth in Ethernet traffic
- There is no bandwidth growth for existing customers in the legacy voice and frame relay networks
- New customers are served using PWE3 and some existing customers are converted to PWE3

The PWE3 access solution is compared with the PMO using a generic network architecture that could apply to many Carriers. The architecture used to analyze the present mode of operations (PMO) is illustrated in Figure 2. In the PMO customers are separated into two fundamental groups: single tenant customers and multi-tenant customers. Single tenant customers are in a standalone facility where the Carrier has no other customers. These customers are served by CPE providing access to network services across the TDM network. Multi-tenant customers are located in buildings where the Carrier serves multiple customers in the same building. These customers are served by CLE equipment in the building. In the PMO the services offered are voice, frame relay, and/or ATM over NX64, T1, NXT1, or DS3 circuits.

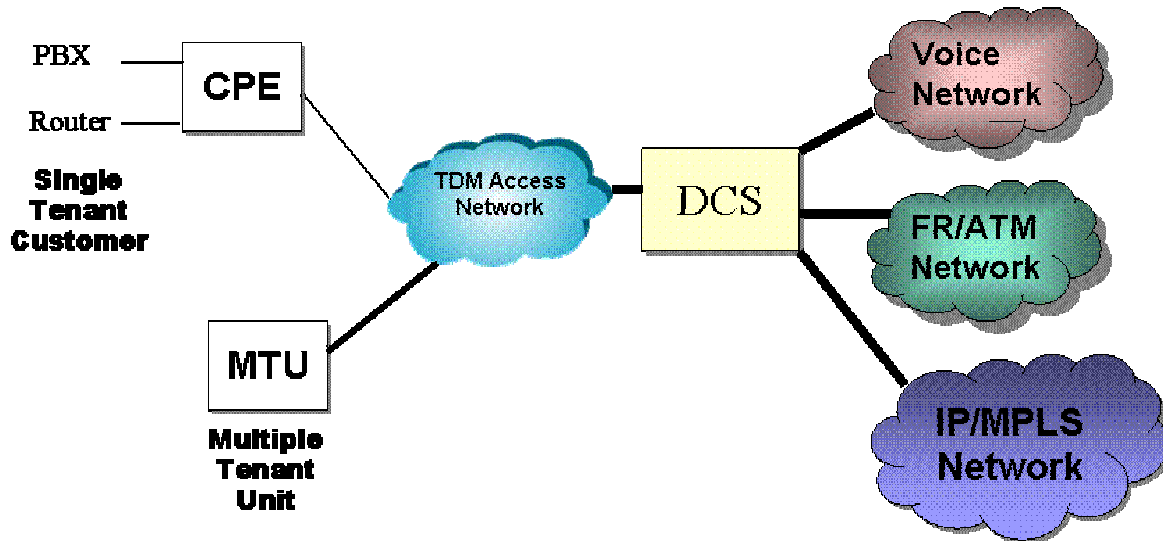


Figure 2

The high level architecture for our PWE3 scenario is depicted in Figure 3. In this scenario the network provides both new PWE3 based services and legacy TDM services. New customers are served by PWE3 CPE or CLE connecting single-tenant or multi-tenant customers to the network. Legacy customers are either 1) converted to PWE3 or 2) continue on the legacy TDM network. Customers served by PWE3 CPE have Ethernet service for data and NX64 or T1 service for voice. All circuits are carried over the TDM network using Dry Martini PWE3 encapsulation. PWE3 circuits are aggregated and switched by the HSX 6000.

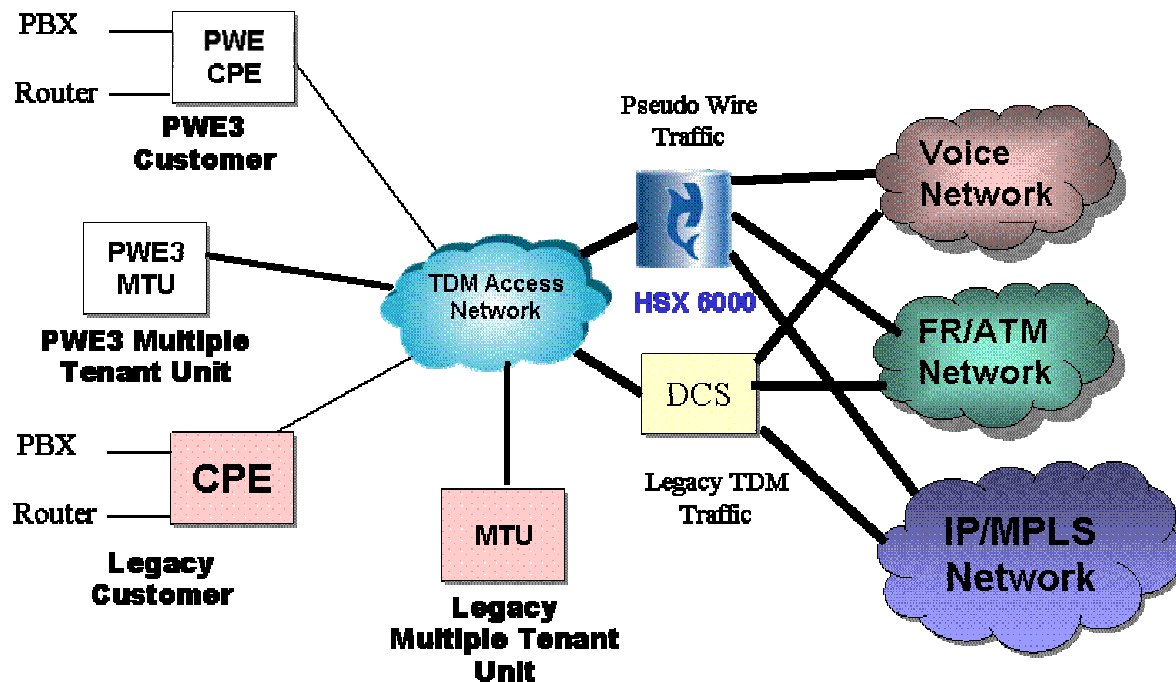


Figure 3

For the PMO scenario and the PWE3 scenario both on-net and off-net customers are modeled. On-net customers are directly connected to the Carrier’s network and transport charges are modeled at cost. Off-net customers require leased lines to provide access to the last mile . These transport charges are modeled at a Carrier wholesale price level

In order to account for the diversity of customers served by the network, our model accounts for several types of customers. These customers are label type A, B, C, and D. The following diagrams and paragraphs describe the attributes of these customers.

**Customer Type A**

Customer Type A, depicted in Figure 4, is a small to medium business with voice and data communications services. In the *PMO scenario*, this customer uses an NX64 or T1 circuit to multiplex voice and frame relay. A TDM IAD is the CPE used on the customer premise to mix circuit and frame relay traffic. In the *PWE3 scenario*, Customer Type A uses a PWE3 CPE device with an Ethernet interface for data and a DSX interface for voice. PWE3 virtual circuits are transported to the HSX 6000 layer 2.5 switch over NX64, T1, NXT1, or DS3 circuits depending on bandwidth growth associated with Ethernet services.

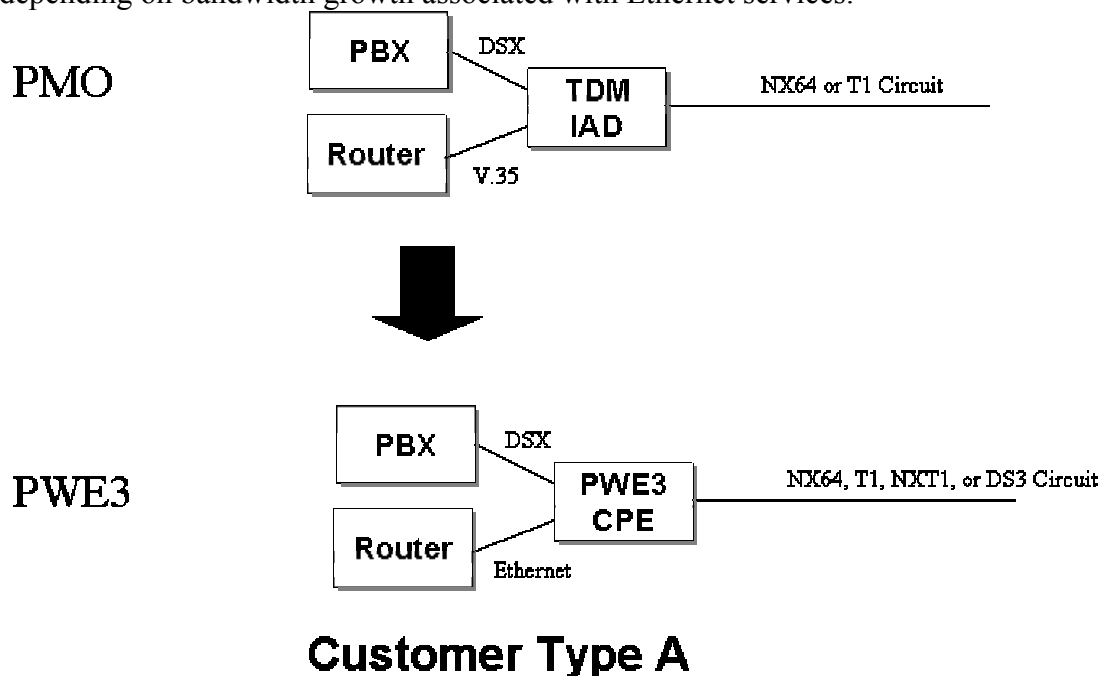


Figure 4

**Customer Type B**

Customer Type B, depicted in Figure 5, is a medium to large business that uses multiple T1’s in the PMO scenario for voice and data.

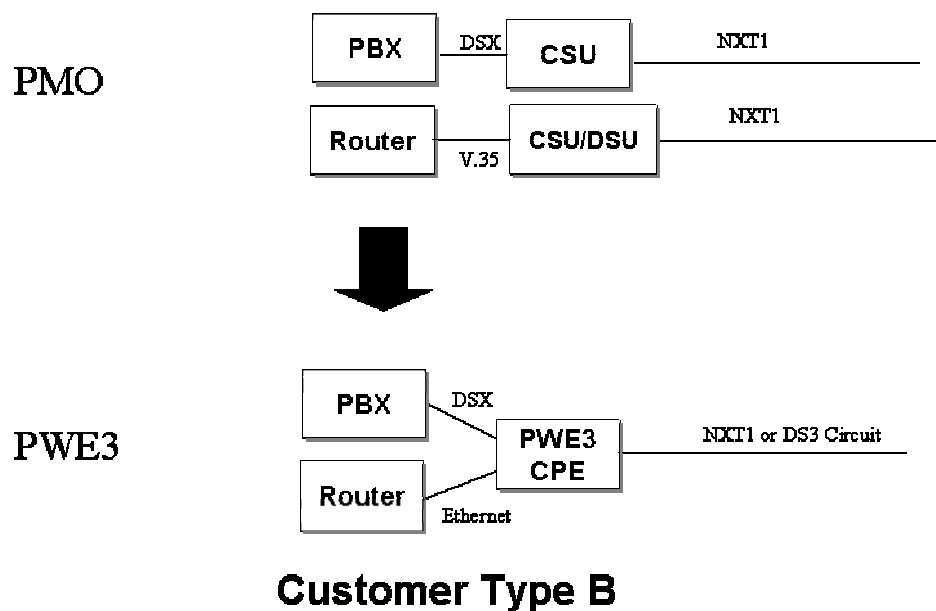


Figure 5

In the *PMO scenario* this customer uses separate T1 lines for voice and data. CPE equipment includes CSU's for voice and DSU/CSU's for frame relay. Traffic is carried to the central office on one or more T1 lines. In the *PWE3 scenario* Ethernet and voice are aggregated in a PWE3 CPE device and transported on Pseudo Wires over NXT1 or DS3 circuits. The bandwidth used to transport traffic is based on rates of growth for Ethernet services.

### Customer Type C

Customer Type C, Depicted in Figure 6, is a large customer using ATM DS3 in the *PMO scenario* to integrate voice and data. On the customer premise it is assumed that an ATM switch provides aggregation of voice and data and connects directly to the DS3 port on the Carrier's SONET ADM. It is assumed in the *PWE3 scenario* that large customers will be served by using PWE3 encapsulation on top of a gigabit Ethernet pipe.

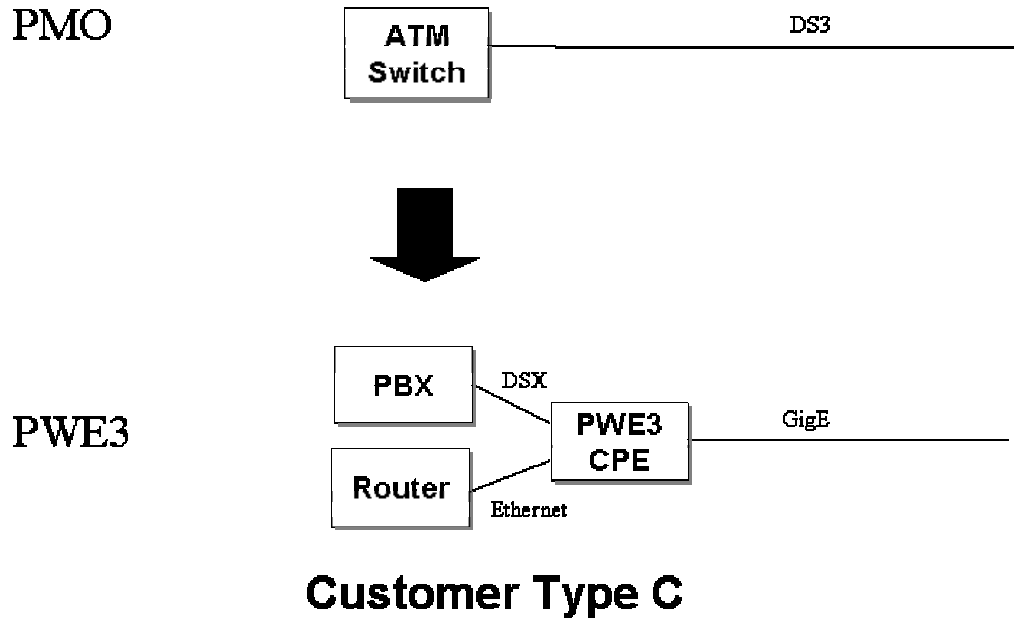


Figure 6

**Customer Type D**

Customer Type D, depicted in Figure 7, is a small business customer using DSL for data. As Ethernet services are rolled out and demand for bandwidth grows, this type of customer can be served with a PWE3 CPE device carrying Ethernet over NX64 or T1 lines.

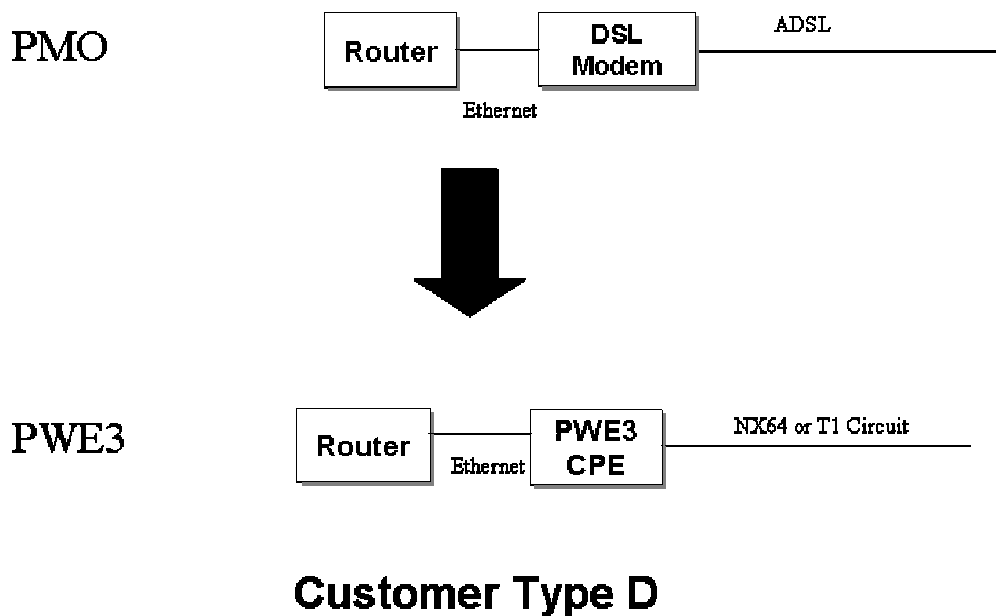


Figure 7

**Multiple Tenant Unit (MTU)**

An MTU is a building where a Carrier serves multiple customers. The PMO for an MTU is presented in Figure 8. In this example, there could be multiple customers in an MTU. Those customers could be customers of the types described earlier. NX64, T1, NXT1, and DS3 circuits are aggregated using an M13 MUX and are transported over to SONET network to the central office using DS3's. MTU's could be either on-net or off-net. If the MTU is off-net then DS3's are leased from the LEC.

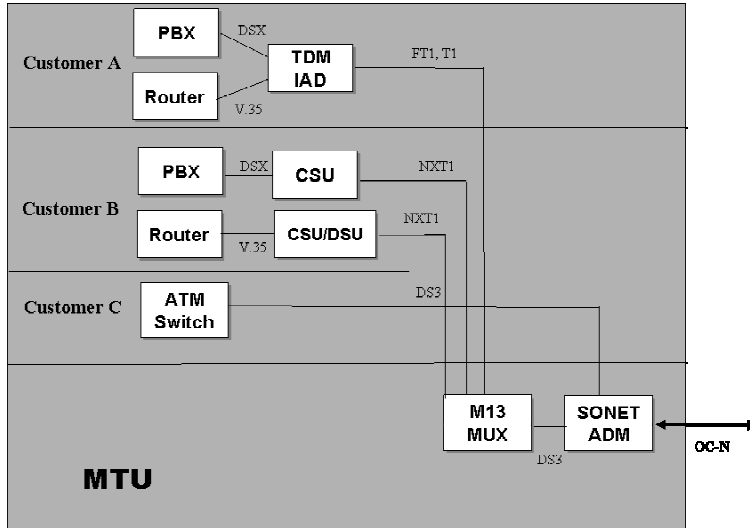


Figure 8

The PWE3 scenario for an MTU is depicted in Figure 9. In this scenario multiple customers are served by PWE3 CLE located in the central wiring closet of the MTU. Routers connect to CLE using Ethernet and PBX's connect using DSX interfaces. All traffic is carried over Pseudo Wires riding on top of Gigabit Ethernet.

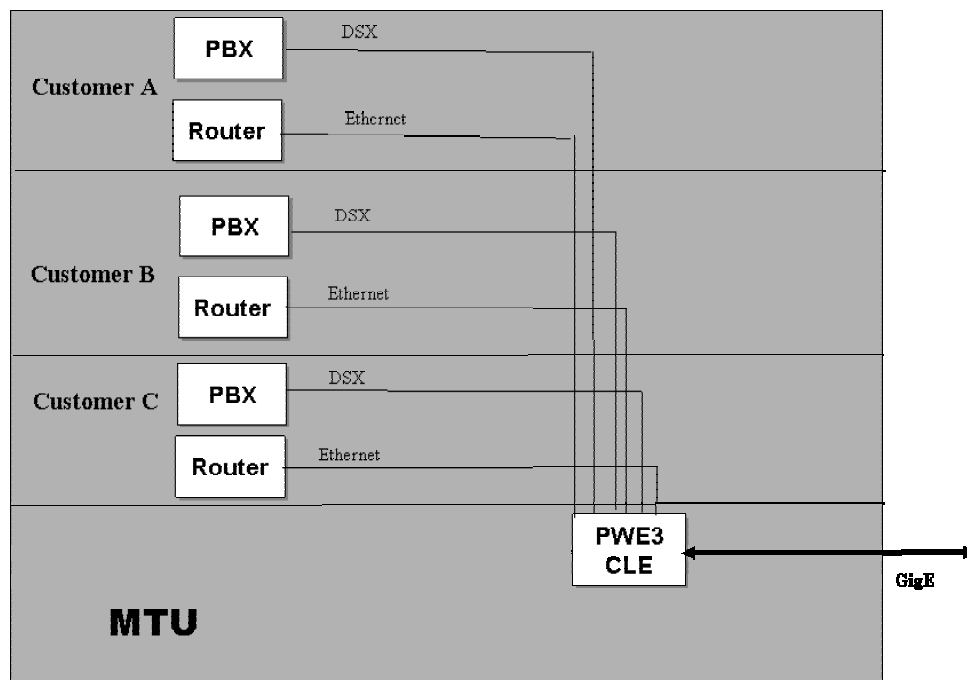


Figure 9

**Network Size and Composition**

The network modeled in this whitepaper consists of:

- 1000 Single Tenant Customers
- 100 Multiple Tenant Customers

The customers in the network are composed of Customer Types A, B, C, and D described above. Table 1 presents the distribution of customers in the network and also presents the rate of conversion of existing customers to PWE3.

Customer Type	Distribution	% Converted to PWE3
Customer Type A	60%	50%
Customer Type B	7%	75%
Customer Type C	4%	100%
Customer Type D	29%	25%

Table 1

**Results**

The results of our work definitively demonstrate the following economic benefits of PWE3 deployment in the access portion of the network::

- Increased Revenues driven by the support of an Ethernet service offering



- Lower total cost of ownership per Mbps
- Lower OPEX
- Lower access transport costs per Mbps
- Better cash flows
- Higher gross margins per Mbps

The following sections provide a detailed analysis of each of the economic benefits.

## Revenues

Figure 10 compares revenue growth between the PWE3 scenario and the PMO scenario. In the PMO scenario, revenues tend to grow due to new customer acquisition. It is assumed in our model that there is no growth of legacy voice, frame relay, and ATM services; therefore this significantly limits future revenue growth for existing customers. In contrast, in a PWE3-enabled network Ethernet services are used to stimulate revenue growth among existing customers. In this scenario, revenue growth is based on acquiring new customers and providing new services to existing customers. For example, if a customer using a 64 Kbps frame relay service with 32 Kbps CIR moves to a 100 Mbps Ethernet service, then we assume that the CIR for the Ethernet service could grow to 1 Mbps over a 5-year period. This is a fairly conservative grow rate for CIR over Ethernet. If the growth rate and the adoption of new services is higher, then the business case will improve proportionally.

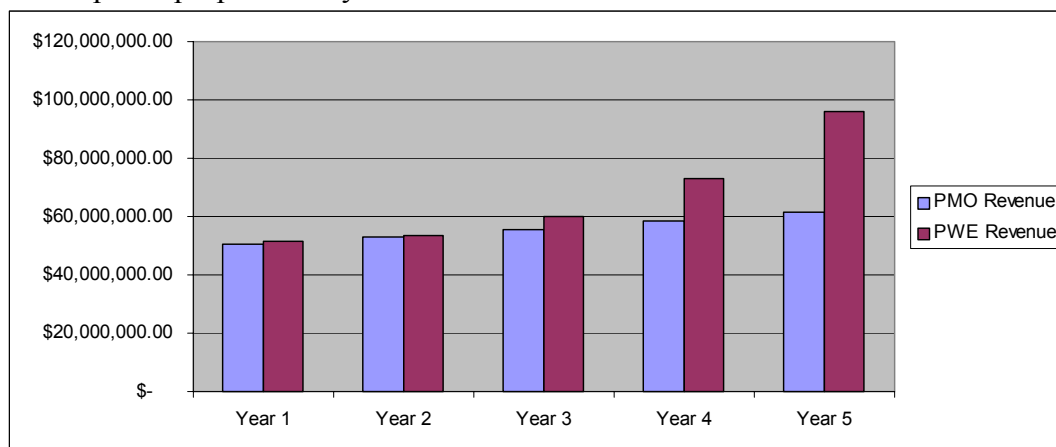


Figure 10

## Total Cost of Ownership (TCO)

Our economic modeling demonstrates that the PWE3 scenario has a lower total cost of ownership (TCO) than the PMO. The TCO consists of capital and operational expenses. Capital expenses are needed for CPE and network equipment required for network growth. Operations expenses fall into two categories:

- Transport expenses
- Network operations expenses

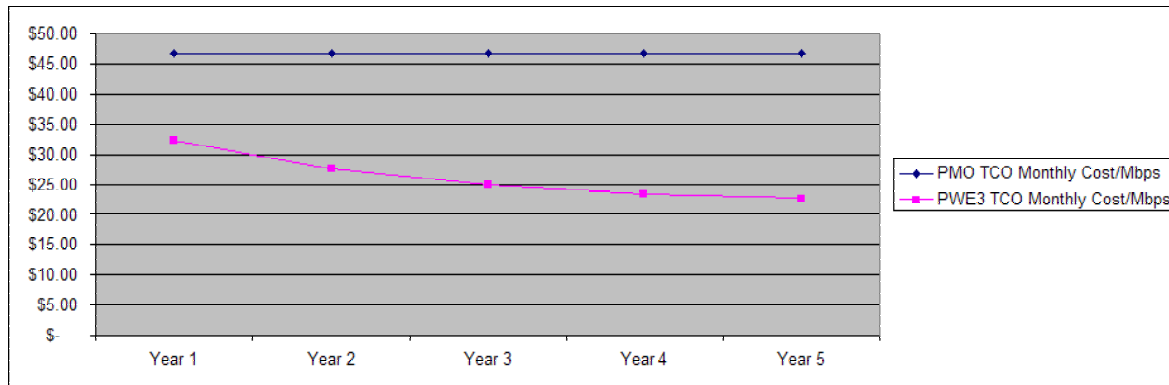
Transport expenses consist of the costs for both on-net and off-net transport. If the end customer is on-net, then transport is modeled at cost. If customers are off net, then wholesale transport (DS1 or DS3) must be leased from a LEC.

Network operations expenses consist of:

- Service provisioning
- Network administration
- Capacity planning
- Technical support in the Network Operations Center (NOC)
- Field support
- Environmental expenses

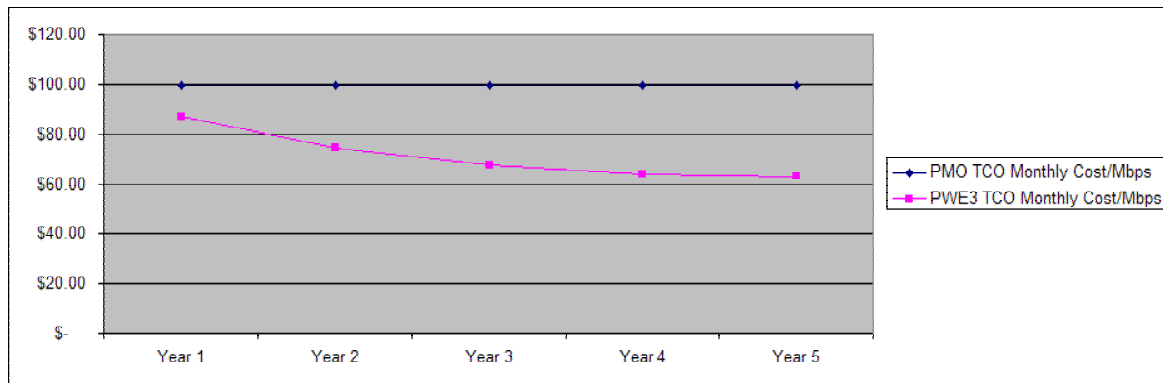
Both revenue and network capacity are growing more quickly in the PWE3 scenario than the PMO scenario, thus comparing total TCO for each scenario is not meaningful. Therefore, to ensure a fair comparison of the two scenarios, we have compared the TCO per Mbps delivered across the network. We believe that this metric is equivalent to normalizing the data. The TCO per Mbps is compared for on-net customers in

**Figure 11** and off-net customers in Figure 12. In both cases the total cost per Mbps is increasingly lower for the PWE3 scenario in each year of the rollout.



### On-Net TCO

Figure 11



## Off-Net TCO

Figure 12

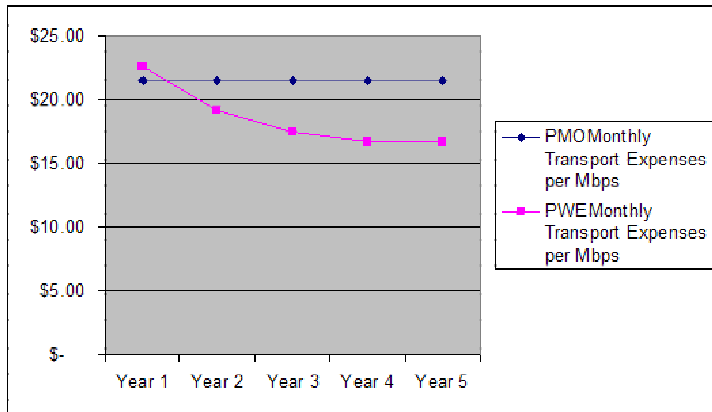
## Transport Expenses

Transport expenses are a significant component of the TCO. We have accounted for both on-net and off-net transport expenses for:

- T1
- Structured DS3
- Unstructured DS3
- Gigabit Ethernet
- DSL

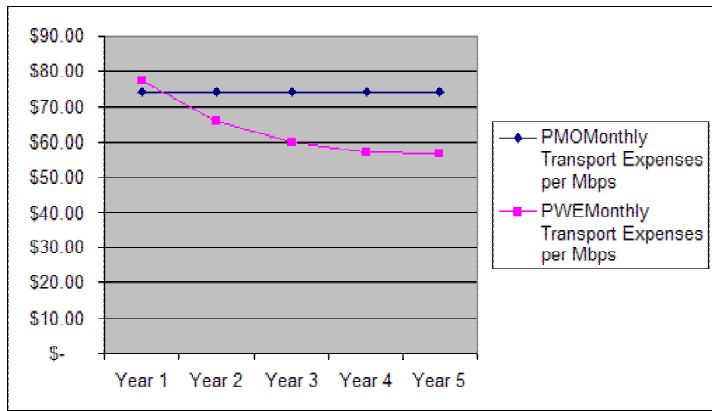
Figure 13 and Figure 14 present a comparison of on-net and off-net transport costs per Mbps for the PMO and PWE3 scenarios. For both on-net and off-net customers, transport costs per Mbps decrease sequentially in the PWE3 scenario. The primary reasons for the savings in transport expenses are:

- Unstructured DS3 circuits can be used to carry PWE3 traffic while structured DS3's must be used for TDM traffic
- The use of Unstructured DS3's result in a significant cost savings
- The use of Gigabit Ethernet transport significantly reduces operational costs as compared to multiple structured DS3 circuits
- Statistical multiplexing of the traffic provides a significant cost savings



### On-Net Transport Expenses

Figure 13



### Off-Net Transport Expenses

Figure 14

## Network Operations Expenses

Total network operations expenses for:

- Service provisioning
- Network administration
- Capacity planning
- Technical support in the Network Operations Center (NOC)
- Field support
- Environmental expenses

are presented in Figure 15.

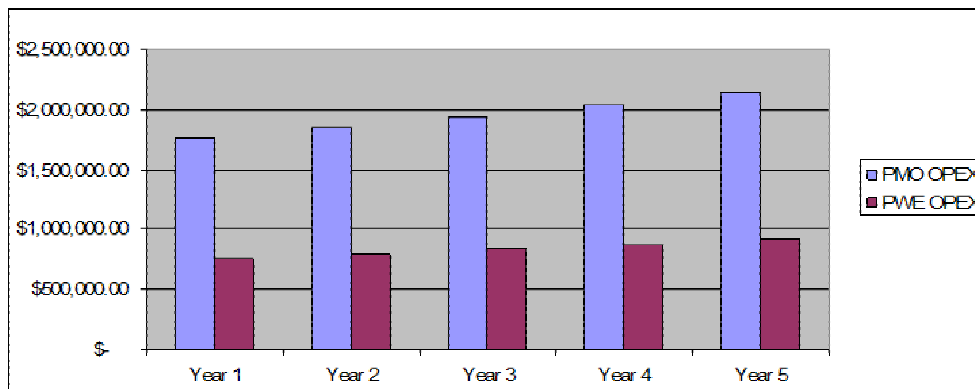


Figure 15

The significant cost savings are primarily due to the difference in operations and environmental costs of managing the Digital Cross Connect (DCS) vs. the Hammerhead HSX 6000. Provisioning, configuration, administration, and maintenance of a TDM DCS are labor-intensive processes. In contrast, circuit provisioning using PWE3 and MPLS in an HSX 6000 is an automated point and click process (similar to configuring a frame relay PVC). The environmental expenses consisting of:

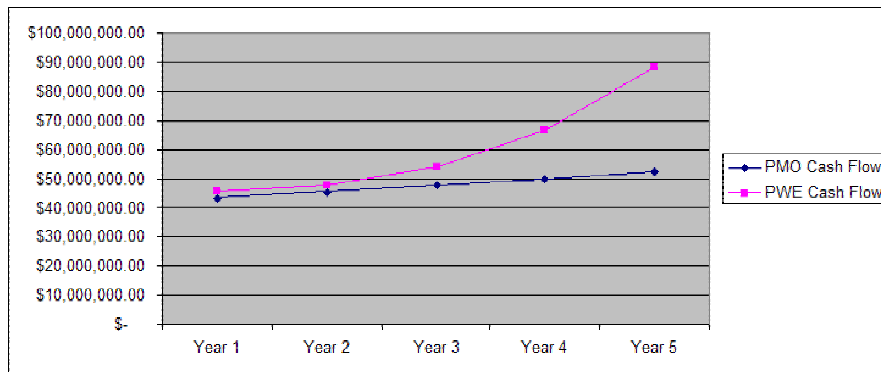
- Floor space
- Power
- Cooling
- Battery and generator backup

are also significantly lower for the HSX 6000 than the DCS. For a more detailed analysis of environmental costs, we would recommend that the reader review a companion White Paper

entitled *A Total Cost of Ownership (TCO) Analysis and Comparison of Edge Aggregation Network Architectures*, which NSP published in January of 2005.

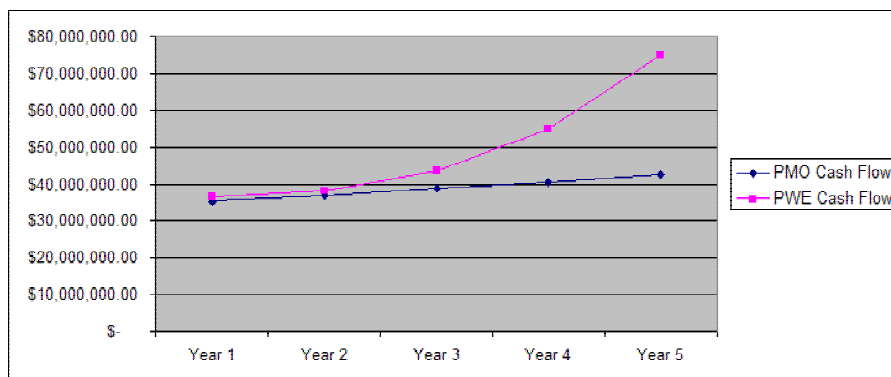
### Cash Flow

Because revenues are higher and TCO is lower for the PWE3 scenario, cash flows are sequentially better. The cash flows for the on-net case study are depicted in Figure 16 and the cash flows for the off-net case study are presented in Figure 17. Cash flows are better for the on-net case because the use of PWE3 in the access significantly reduces transport costs for those services.



**On-Net Cashflow**

Figure 16



**Off-Net Cashflow**

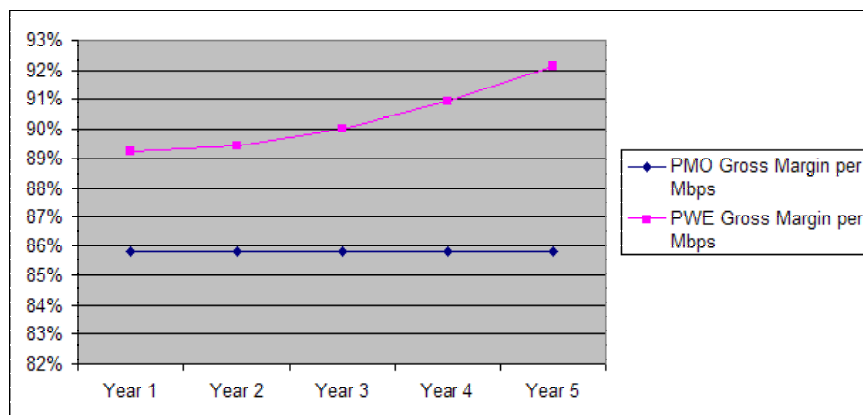
Figure 17

## Gross Margin per Mbps

The relative profitability of the PWE3 solution is compared with the PMO by using gross margin per Mbps as a metric. This is defined within the model as:

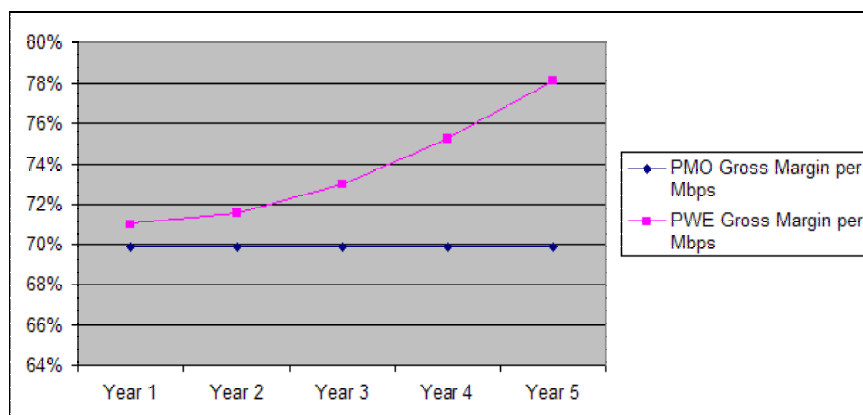
$$\text{Gross Margin per Mbps} = 1 - (\text{TCO per Mbps})/(\text{Revenue per Mbps})$$

The TCO per Mbps is the total cost of ownership for each Mbps of service delivered. This metric was presented earlier within this White Paper. The Revenue per Mbps is the revenue for each Mbps of service delivered. Because TCO per Mbps is decreasing and revenue is increasing, the gross margin per Mbps is sequentially increasing for the PWE3 scenario. These results are presented in Figure 18 and Figure 19 for the on-net and off-net case studies. Because transport is less expensive for on-net customers, gross margins per Mbps are higher for on-net customers and lower for off-net customers. In all cases where the PWE3 solution is deployed in the access portion of the network, the business case is significantly more profitable.



### On-Net Gross Margin per Mbps

Figure 18



## Off-Net Gross Margin per Mbps

Figure 19

## Conclusion

Carriers today are faced with the challenge of transitioning their networks to packet-enabled networks without creating service interruptions for existing data customers. A second challenge presented by transition is the carrier's ability to support new services (and collect additional revenues) over the existing access infrastructure. In this White Paper, we have demonstrated that the deployment of PWE 3 technology within the access portion of the network is a pragmatic solution to this challenge. Some of the benefits of deploying PWE3 in the access network are:

- Ethernet services can be offered over the existing TDM network
- PWE3 provides a standard virtual circuit technology across TDM, IP, SONET and MPLS transport networks
- PWE3 technology extends from the access network to the MPLS core supporting the transition strategy of "creative access" tied to a consistent and deterministic IP/MPLS core.

**Based on the results from this paper's analysis, Network Strategy Partners would make the following recommendations to Service Providers:**

- 1) *Using Layer 2.5 switches for aggregation and MPLS backhaul of traditional data services to Gigabit Ethernet-enabled Layer 3 edge routers is the most cost-effective approach to transitioning the network.*
- 2) *The Layer 2.5 approach provides greater flexibility in access technology choices, significant service differentiation (QoS), operations advantages (OAM&P), and reduces the complexity of provisioning new services. Given the competitive nature of today's marketplace, it is imperative for Service Providers to use a more differentiated*

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