Total Cost of Ownership Comparison: Ethernet Transport vs. VPLS and MPLS in the Metro Network

Network Strategy Partners, LLC

MANAGEMENT CONSULTANTS TO THE NETWORKING INDUSTRY

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TABLE OF CONTENTS

Executive Summary

In carrier metro networks, SONET/SDH transport is giving way to MPLS/Gigabit Ethernet and 10 GE transport as new business models are emerging built upon residential Triple Play, Ethernet mobile backhaul, and enterprise Carrier Ethernet services. Ethernet Transport is an architecture that allows carriers to use Ethernet instead of MPLS in the metro network. Ethernet Transport significantly reduces the Total Cost of Ownership (TCO) of the metro network.

The TCO of three architectural alternatives are compared using a model metro network that is typical for metro areas. It consists of three large Central Offices, four medium Central Offices and three small Central Offices that offer Triple Play services to residential households, Carrier Ethernet services to enterprises and Carrier Ethernet services used for backhaul to mobile wireless operators. The large Central Offices each contain 20,000 households and 1,000 enterprise establishments; the medium Central Offices each contain 6,400 households and 192 enterprise establishments; and the small Central Offices each contain 2,400 households and 72 enterprise establishments. The architectural alternatives are:

1. Ethernet Transport using the Extreme Networks BlackDiamond Ethernet Transport Switch product family

2. VPLS using a multiservice router built upon highly scalable IP/MPLS services infrastructure

3. MPLS using an Ethernet Switch/Router with IP/MPLS ports featuring Carrier Ethernet services

The analysis shows that Ethernet Transport has lower TCO than the VPLS and MPLS alternatives over a five-year study period. Specifically,

- Ethernet Transport has 61% lower TCO than a VPLS architecture

- Ethernet Transport has 63% lower TCO than a MPLS architecture

Figure 1 summarizes the TCO analysis.

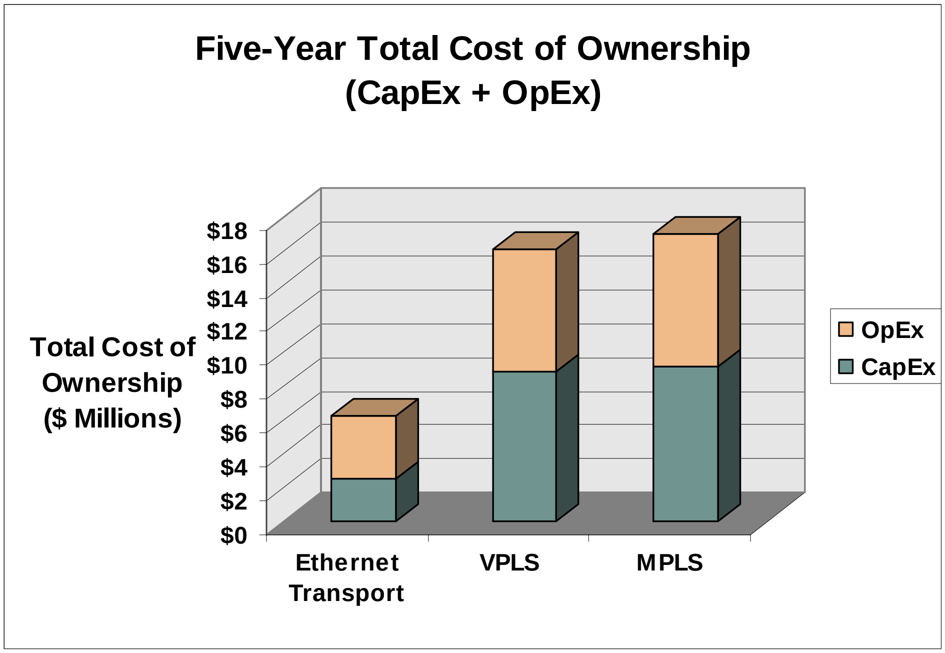

Figure 1
Five-Year Total Cost of Ownership

The substantial cost advantage of Ethernet Transport over VPLS and MPLS results from savings in both initial capital expenditures as well as long-term operational expenditures. Ethernet Transport's use of much simpler and widely used Ethernet technology enables disruptive price points for 10 Gigabit Ethernet (10 GE) switching, the building block for next generation metro networks. VPLS and MPLS equipment are much more expensive because they utilize specialized and complex VPLS/MPLS technology versus Ethernet Transport's use of standard Ethernet.

At the same time, the relative operational simplicity of Ethernet Transport provides ongoing savings across several areas including reduced training costs, reduced service provisioning times, and reduced maintenance complexity. The VPLS and MPLS architectures, furthermore, use a distributed control plane that both embeds costly capabilities into each network element and increases operational complexity.

Introduction

Carriers are creating new business models built upon residential Triple Play, Ethernet mobile backhaul, and enterprise Carrier Ethernet service offerings. As these new services are introduced SONET/SDH transport has given way to MPLS and VPLS protocols and Gigabit Ethernet and 10 GE transport layer 2 interfaces. A new architecture, Ethernet Transport, uses standard and emerging Ethernet protocols including VLAN, VMAN (QinQ), PBB, and PBB-TE that allow a carrier to use Ethernet instead of MPLS in the metro network. Ethernet Transport holds the potential to significantly reduce the cost of building, operating and maintaining a metro network for two primary reasons.

1. Ethernet technology is mass produced and well down the manufacturing experience curve as compared to MPLS and VPLS technology.

2. Ethernet Transport is much less complex from both design and operations perspectives as compared to MPLS and VPLS.

This paper presents a Total Cost of Ownership (TCO) analysis that compares Ethernet Transport versus two alternative architectures for building and operating a metro network that carries residential Triple Play, Ethernet mobile backhaul, and enterprise Carrier Ethernet services. The alternative architectures are:

1. Ethernet Transport using the Extreme Networks BlackDiamond Ethernet Transport Switch product family

2. VPLS using a multiservice router built upon highly scalable IP/MPLS services infrastructure

3. MPLS using an Ethernet Switch/Router that employs Carrier Ethernet IP/MPLS ports

Figure 2 shows the process for estimating Total Cost of Ownership.

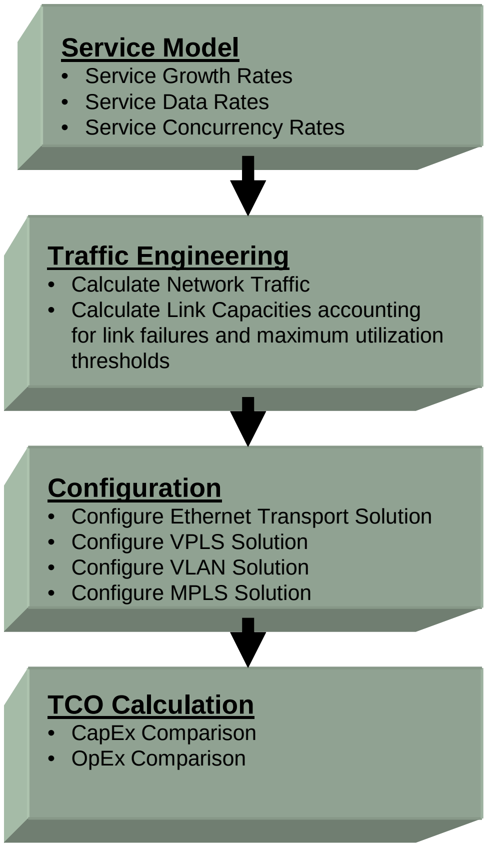

Figure 2
TCO Estimation Process

The TCO estimation process begins by creating a service model that describes the residential Triple Play, Ethernet mobile backhaul, and enterprise Carrier Ethernet services including expected service penetration and data rates. Traffic engineering is then performed to estimate bandwidth requirements for each network node and link. The equipment configurations needed to meet the projected traffic requirement are then made for each architectural alternative. Finally, CapEx and OpEx (TCO) are estimated.

The following sections define each of these modeling steps.

Modeling Scenario

Figure 3 shows a network schematic of the typical Metro Network used to estimate TCO.

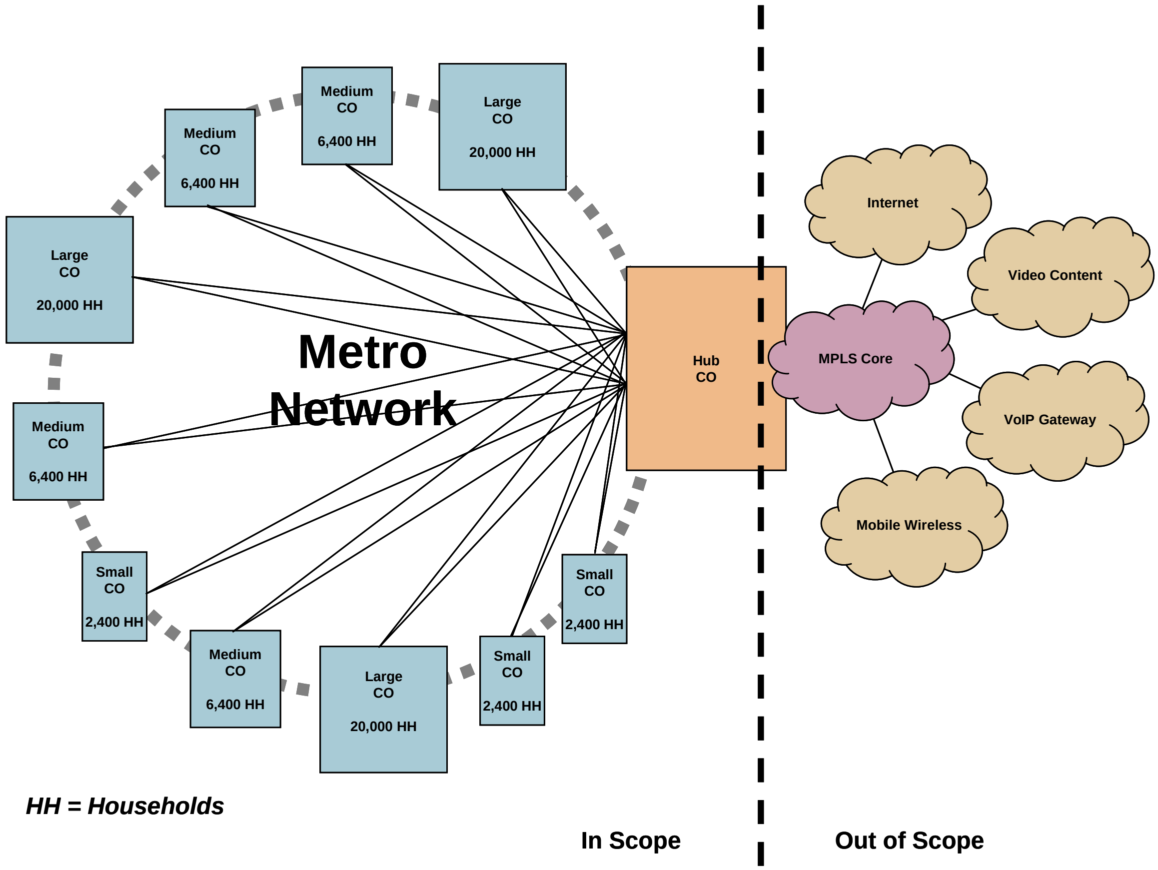

Figure 3
Overview of Modeling Scenario

The model metro network aggregates the traffic from ten Central Offices. The number of households (HH) for each Central Office is shown on the figure. The offices are interconnected with a physical DWDM fiber-optic ring while a logical dual tree of 10 Gigabit Ethernet connections provides Ethernet transport from the Ethernet switch in each Central Office to interconnected dual routers in the Hub Central Office. The Hub in turn is connected to an MPLS Core Network which is then connected to a Video Head End and the Internet. The MPLS Core Network, BRAS for Internet Services, Wireless Base Station, and Video Head End are outside of the scope of the analysis.

Figure 4 shows the detail for a single Central Office.

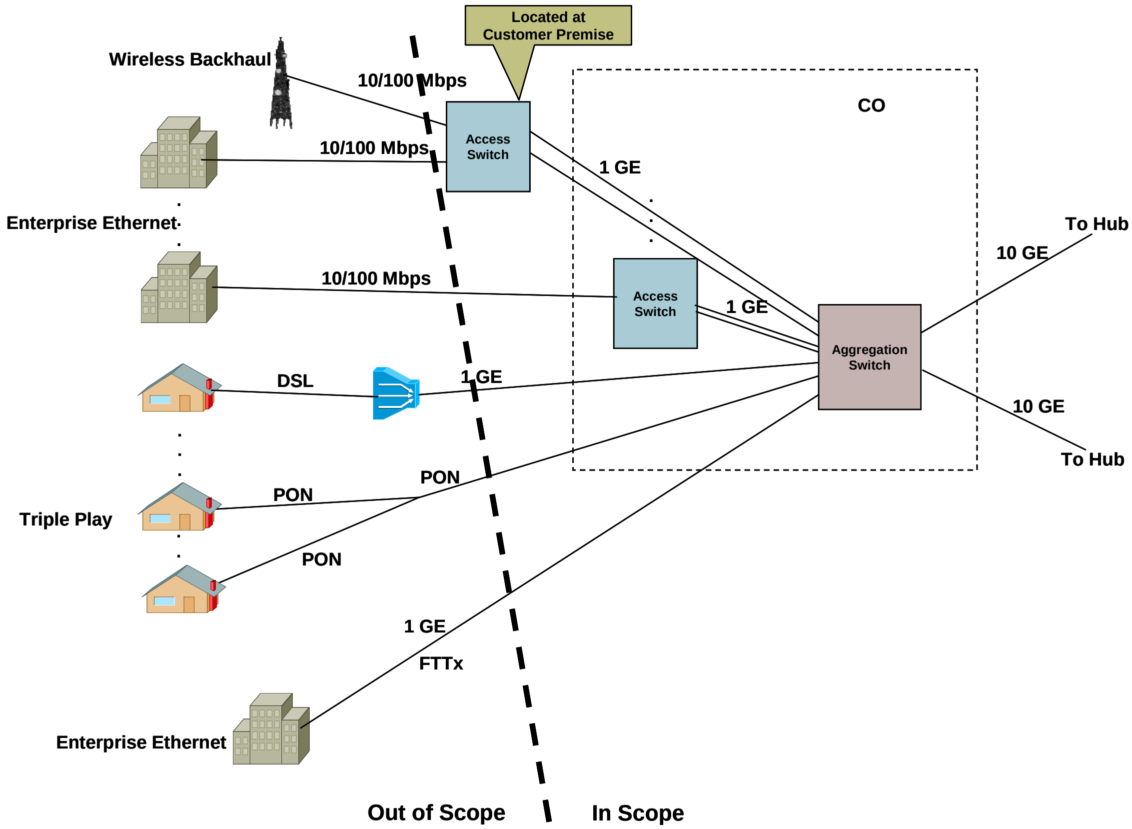

Figure 4
Network Detail for a Single Central Office

An Aggregation Switch is used to connect the Central Offices to the Metro Network. In addition, the Ethernet Transport, VLAN and MPLS architectural alternatives use a separate Access Switch to connect individual subscribers to the Aggregation Switch. The VPLS architectural alternative combines the Access and Aggregation switching functions in a single system (Chassis).

IP DSLAMs with multiple 1 GE backhaul links are used to connect Triple Play subscribers to the Aggregation Switch. (The design also can be used for PON and other FTTx solutions.)

Enterprise and Wireless Backhaul (Carrier Ethernet) services are provided at 10/100 Mbps and 1GE port speeds. Traffic throughput may be limited by a Committed Information Rate (CIR) that is below the port speed—see service discussion below.

Figure 5 shows the network schematic for the Hub Central Office.

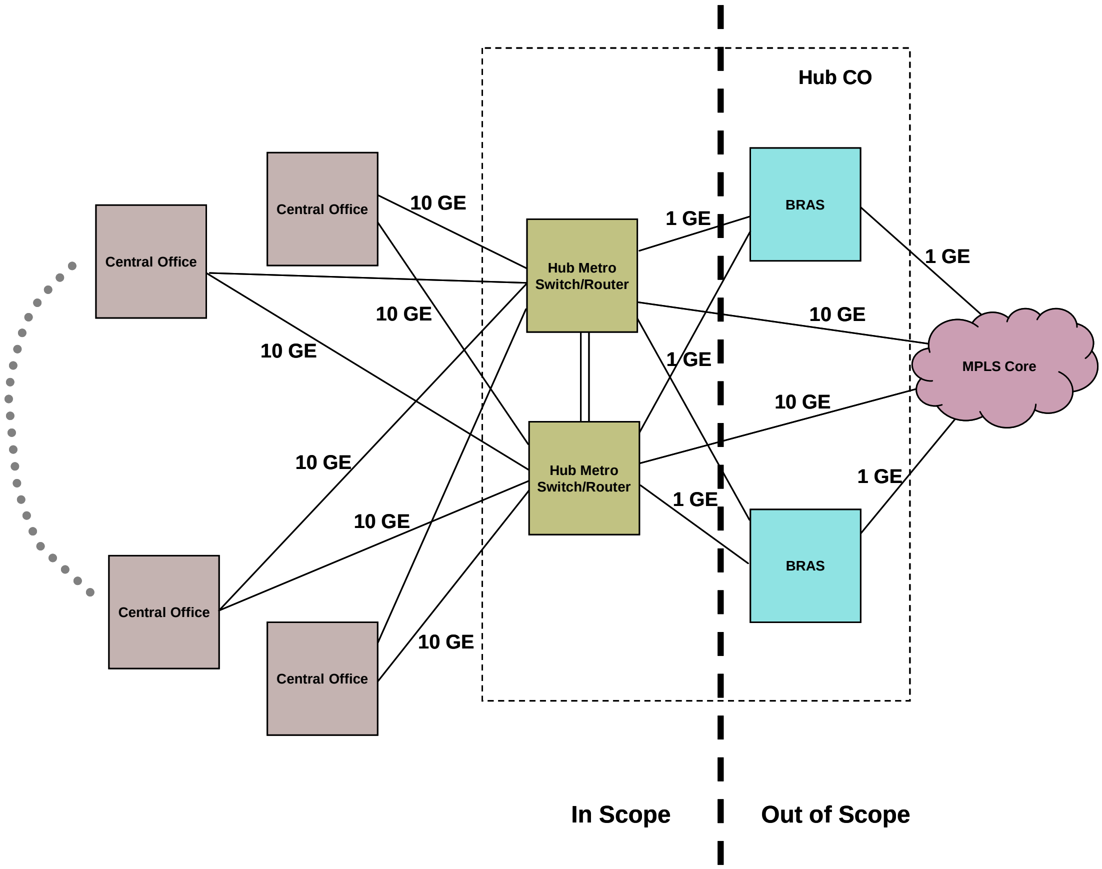

Figure 5
Network Detail for Hub Central Office

The Hub Central Office provides the interface between the Metro Network and the MPLS Core. Dual Aggregation Switch/Routers are used to provide network resiliency. Each end-office is connected to each Hub Switch/Router with one or more 10 GE circuits. VoIP and High Speed Internet traffic is sent to dual BRAS using 1 GE links while Video and Carrier Ethernet traffic go directly into the MPLS Core Network over 10 GE links. The BRAS and MPLS Core Network are out of the scope of this analysis.

Carrier Ethernet Services and Traffic Projections

Two types of Private Line service and Ethernet LAN service are modeled. Carrier Ethernet service definitions use the Metro Ethernet Forum's standards.[1]

- E-Line – An Ethernet service type that is based on a Point-to-Point Ethernet Virtual Connection. Two E-Line services are defined:

[1] See MEF 6 – Ethernet Service Definitions – Phase I, Metro Ethernet Forum, June 2004 for the technical specification of E-Line and E-LAN service types.

- EPL (Ethernet Private Line) – This is a very simple point-to-point service characterized by low Frame Delay, Frame Delay Variation and Frame Loss Ratio.
- EVPL (Ethernet Virtual Private Line) – This is a point-to-point service wherein service multiplexing (more than one Ethernet virtual circuit) is allowed.

- E-LAN – An Ethernet service type that is based on a Multipoint-to-Multipoint Ethernet Virtual Connection.

Carrier Ethernet Traffic Projections

The hypothetical network used by the TCO model is derived from demographic data and current market research reports.[2] Traffic for the metro network shown in Figure 3, Figure 4 and Figure 5 is projected for each year of a five-year study period. Separate demand models are used for the small, medium and large Central Offices to reflect the varied demographic mix across a typical metro area[3]. The large office is typical of what would be found in the city at the center of a metro area, while the medium office is typical for the first ring of suburbs and the small office would be found at the periphery of the metro area.

The traffic projection begins by estimating service penetration rates for each type of Central Office and for each Carrier Ethernet service. For example, Table 1 shows the penetration rates assumed for the large Central Offices.

Service	Penetration Rates				
	Year 1	Year 2	Year 3	Year 4	Year 5
E-Line (EPL)	1.8%	3.2%	4.5%	5.6%	6.5%
E-LINE (EVPL)	1.4%	3.2%	5.7%	8.0%	10.8%
E-LAN	1.9%	3.6%	4.8%	6.4%	7.8%
Total	**5.0%**	**10.0%**	**15.0%**	**20.0%**	**25.0%**

Table 1
Carrier Ethernet Service Penetration Rates for Large Central Office

EPL services have been available for some time. They are used for Internet access services or when offered at Gigabit speed as a means of connecting a data center used for

[2] See *State and Metropolitan Area Data Book: 2007*, U.S. Census Bureau as well as published reports of Heavy Reading, Network World and Vertical Systems Group
[3] The demand models combine demand for Carrier Ethernet services used by enterprises and those used by mobile operators for backhaul.

web hosting to a Tier 1 Internet peering point—CIR is generally set at the port speed. EVPL service also is point-to-point or point-to-multipoint; however, service multiplexing allows the total bandwidth to be subdivided into several virtual circuits. This creates multiple opportunities to offer differentiated services over the same physical connection. For example, separate virtual circuits can be created to support Internet access, an enterprise private data network and video conferencing services. The projection calls for much faster development of EVPL service as it supplants the early EPL offerings. E-LAN service also has been available as Transparent LAN Service (TLS) for a long time. However, the modern service should grow rapidly now that carrier-class Ethernet is being realized and national and international connectivity can be supported through next-generation L2/L3 core networks. E-LAN services feature any-to-any connectivity and are offered with a rich variety of QoS alternatives.

The traffic projection then is completed by forecasting the port type and data rate for each service and for each size Central Office. Table 2 shows the distribution of Carrier Ethernet customer ports by type and speed as well as the total bandwidth flowing into or out of the Large Central Office.

Service	Port Speed (Mbps)	CIR (Mbps)	Bandwidth in/out Large Central Office (Mbps)				
			Year 1	Year 2	Year 3	Year 4	Year 5
E-Line (EPL)	10	10	140	240	320	390	440
	100	100	400	800	1,200	1,600	2,000
	1,000	1,000	2,000	2,000	3,000	3,000	2,000
E-LINE (EVPL)	10	3	30	60	96	123	150
	100	30	150	360	690	1,080	1,620
	1,000	300	300	600	900	1,200	1,500
E-LAN	10	3	39	66	81	99	108
	100	20	120	260	400	580	780
	1,000	150	150	300	300	450	600
Total Bandwidth in/out Large Central Office			**3,329**	**4,686**	**6,987**	**8,522**	**9,198**

Table 2
Carrier Ethernet Bandwidth in/out Large Central Office

The table shows that a large Central Office will require about 9 Gbps of bandwidth by the fifth year to accommodate expected service penetration rates and data rates for Carrier Ethernet services.

Similar tables are created for the medium and small Central Offices and then used to project traffic demand for all ten Central Offices and subsequently calculate the traffic on the metro network and the traffic between the metro network and the MPLS Core network.

The medium Central Office has 32% of the large Central Office's residential subscribers while the small Central Office has 12% of the large Central Office's residential subscribers.

Triple Play Services and Traffic Projections

Four types of Triple Play services are modeled:

- Broadcast IPTV – this is subdivided into Standard Definition (SDTV) and High Definition (HDTV)
- Video on Demand – also subdivided as SD VoD and HD VoD
- High Speed Internet – HSI
- VoIP – Voice over IP

Service demand is projected by applying penetration rates to the number of households in each Central Office. Table 3 shows the penetration rates.

Service	Percent of Households				
	Year 1	Year 2	Year 3	Year 4	Year 5
SDTV	8%	11%	12%	13%	12%
HDTV	2%	5%	8%	13%	18%
SD VoD	5%	6%	8%	8%	8%
HD VoD	2%	4%	8%	12%	18%
VoIP	20%	30%	35%	40%	45%
High Speed Internet	30%	40%	50%	60%	70%

Table 3
Triple Play Service Penetration Rates[4]

Average service data rates are used together with service penetration rates to project the Triple Play traffic requirement. Table 4 shows the rates.

Service	Average Data Rate
SDTV & SD VoD	2 Mbps
HDTV & HD VoD	9 Mbps
VoIP	32 Kbps
High Speed Internet	250 Kbps

Table 4
Average Service Data Rates

Several additional factors also are used to calculate traffic requirements and to estimate DSLAM port requirements. These include the number of households served per DSLAM, the number of broadcast TV channels, the number of television sets per household and the service concurrency rate during the busy period. The total downstream traffic that must be delivered from the metro network to each Central Office is projected

[4] The Triple Play Service Penetration Rates are based upon Network Strategy Partners' Triple Play studies conducted on behalf of carriers and systems vendors and those published at www.ftthcouncil.org

by combining these factors. (Though the calculations use a DSLAM configuration the architecture does not require DSL—it also supports PON OLTs and other FTTx configurations. The TCO results will be nearly identical.) Figure 6 shows the projection for a Medium-sized Central Office.

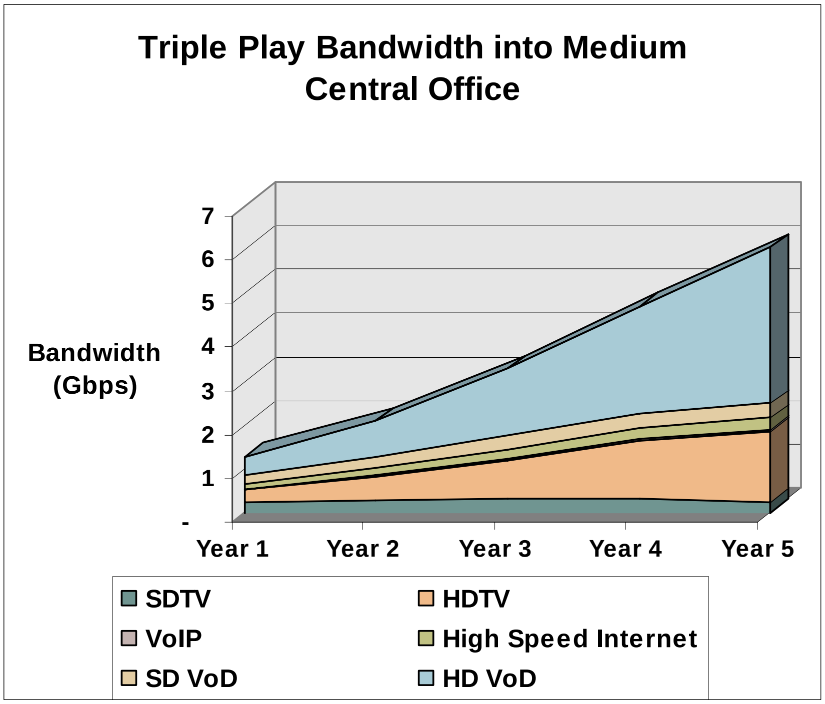

Figure 6
Triple Play Bandwidth Into Medium Central Office

High Definition Video on Demand contributes the majority of the bandwidth onto the metro network with broadcast HDTV contributing much of the remainder. High Speed Internet service contributes only a small portion of total bandwidth because substantial oversubscription is used with this service. VoIP requires an inconsequential amount of total bandwidth.

Figure 7 shows the total bandwidth on the metro network.

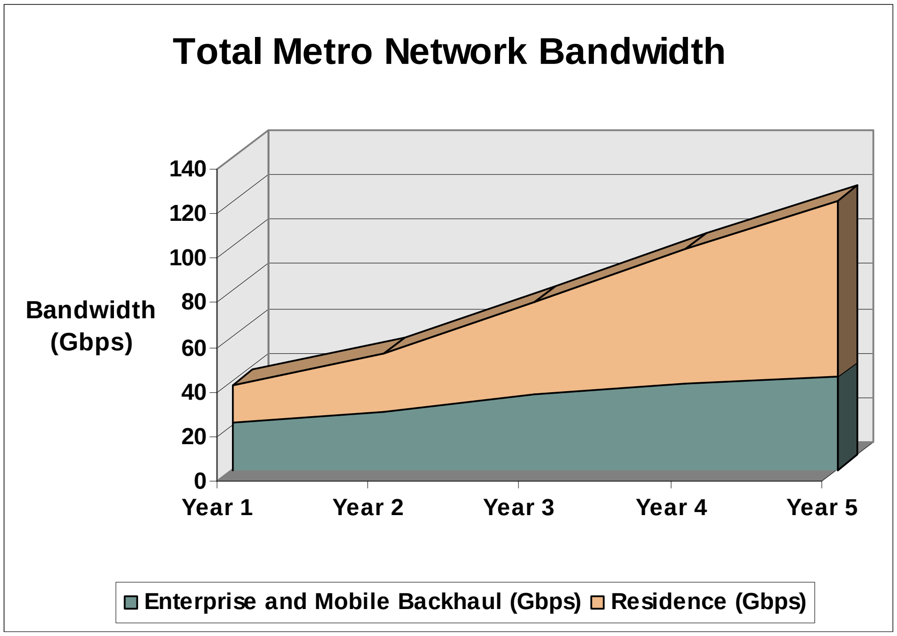

Figure 7
Total Metro Network Bandwidth

Metro network bandwidth grows to more than 100 Gbps. The projected rapid growth of residential High Definition video services is the largest growth source.

Ethernet Transport

The Ethernet Transport architectural alternative uses the Extreme Networks BlackDiamond 20808 Ethernet Transport Switch which is equipped with 1 GE and 10 GE port line-cards and incorporates the VLAN, VMAN (QinQ), and PBB/ PBB-TE[5] protocols. An external control plane that abstracts network services across a multi-vendor transport network is implemented using the Soapstone Networks Resource and Service Control System.

The BlackDiamond 20808 has high capacity with 120 Gbps per slot bandwidth, 64 10 GE ports per chassis, and 192 10 GE per rack. It incorporates carrier-class reliability features including hitless fail-over and separation of the management and fabric modules. It is purpose-built for Metro Ethernet Transport and as such supports:

- Hardware-based QoS
- Scalable Multicast Streams
- PBB/PBB-TE
- VPLS

[5] Separately licensable future upgrde

- E-NNI and Cross Connect

The BlackDiamond 20808 also supports Ethernet OA&M which reduces time-to-repair.

The external control plane (PBB-TE) 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 Network. It also improves quality of service through deterministic path selection and increases reliability with SONET/SDH speed failover to pre-provisioned backup paths.

The Extreme Networks BlackDiamond 12804 Ethernet Switch is used as the metro aggregation switch in the small and medium Central Offices because these locations do not require the high scale of the BlackDiamond 20808.

The Extreme Networks Summit X250e Ethernet Switch, a stackable 24 port Fast Ethernet switch with 1 GE optical uplinks, is used as an Access Switch for 10/100 Mbps Carrier Ethernet service delivery.

VPLS

The VPLS architectural alternative uses a multiservice router family built upon a highly scalable IP/MPLS service infrastructure. An Ethernet Service Switch is used in each end-office to perform the Access Switch and Aggregation Switching functions. This switch supports 10/100 Mbps, 1 GE and 10 GE optical ports. It provides E-Line, E-LAN, Virtual Private Wire Services (VPWS) for wireless backhaul, and VPLS services.

A Service Router (multiservice router) that implements IP/MPLS is used as the Hub Aggregation Switch/Router. It offers very high scale and a rich set of routing features.

MPLS

The MPLS architectural alternative uses an Ethernet Switch/Router that uses MPLS line cards to deliver any combinations of Ethernet Layer 2 switching, bridging, VPLS, Ethernet over MPLS, and Layer 3 IP/MPLS routing. A stackable 24 port Fast Ethernet switch with 1 GE optical uplinks is used as an Access Switch for 10/100 Mbps Carrier Ethernet service delivery.

The Ethernet Switch/Router equipped with the MPLS line cards is used in the Central Offices as well as the metro network hub. This extends full IP/MPLS capabilities to each end-office.

Total Cost of Ownership Comparisons

Figure 8 compares Total Cost of Ownership over the five-year study period for the three alternatives.

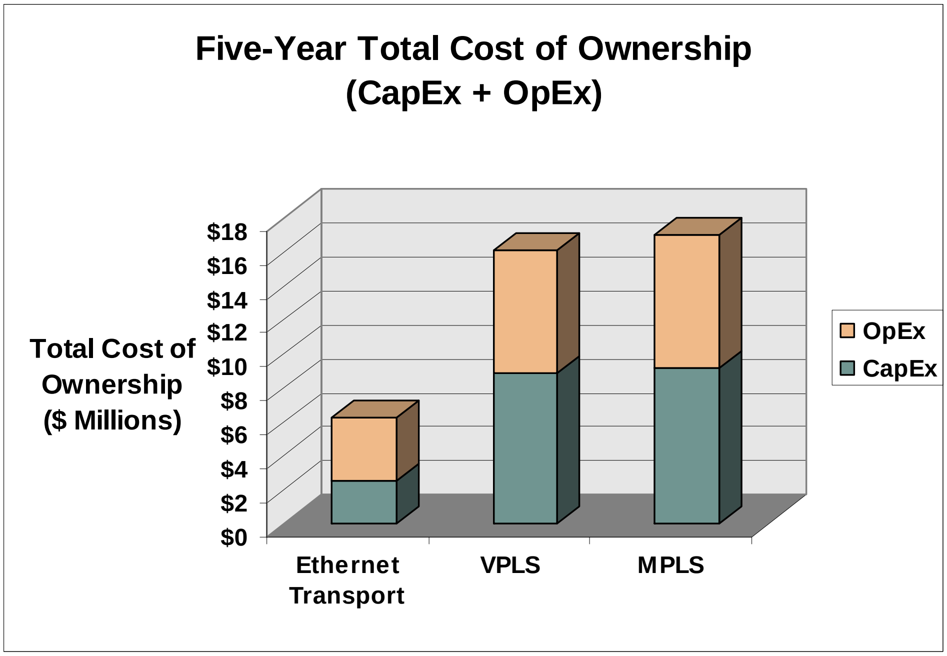

Figure 8
Five-Year Total Cost of Ownership

TCO for Ethernet Transport is much less than for the VPLS (61%) and MPLS (63%) alternatives. Both CapEx and OpEx are lower for Ethernet Transport than for the VPLS, MPLS and VLAN alternatives.

Figure 9 shows a functional breakdown of Capital Expense for the three alternatives over five-years.

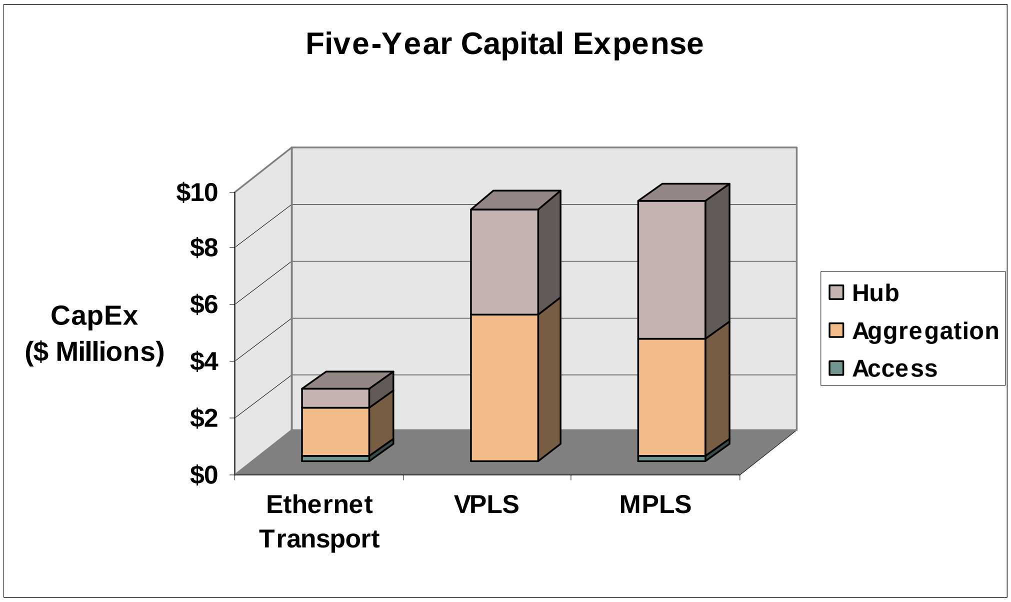

Figure 9
Five-Year Capital Expense Breakdown

The VPLS and MPLS alternatives have much higher capital expense than the Ethernet Transport alternative. This cost difference is due to the VPLS and MPLS alternatives' use of IP/MPLS embedded features in their line-cards as compared to the widely deployed Ethernet L2/L3 features of the Ethernet Transport line-cards. The volume of production of Ethernet line-cards is two orders of magnitude greater than that of the VPLS and MPLS line-cards. Consequently Ethernet Transport vendors can profitably support price levels that are less than half of those of the highly specialized (and relatively low volume) VPLS and MPLS line-cards.

Low port density in the Hub VPLS and MPLS switches has a compounding effect on the total CapEx of the Hub due to the use of dual switch/routers—see Figure 5. The dual switch/router design requires that a fixed number of ports be dedicated to provide interconnection between the chassis. The required ports in each chassis must be at least:

- Two 10 GE ports between dual chassis for redundancy
- One 10 GE port to the MPLS Core
- Two 1 GE ports to each BRAS

This creates a diminishing returns situation when more than two chassis are required to satisfy the connectivity requirements of the metro network. In the case where dual chassis cannot meet the port requirements from the end-offices; the network must be split in two so that two sets of dual routers are required to satisfy the port requirements. However, the same five ports listed above must be provisioned in each chassis.

Therefore, the number of required ports is spread over a smaller number of end-office ports. This results in increased fixed costs per end-office port. The addition of two more chassis also increases fixed costs as each additional chassis must be equipped with supervisor cards, power supplies, and other common equipment.

Figure 10 illustrates the metro network design that results when additional sets of hub chassis are required to accommodate all the Central Offices on a single metro network. Visual comparison of Figure 10 with Figure 3 or Figure 5 shows the many additional chassis, ports, and network links that are required when the network is divided to accommodate the smaller chassis.

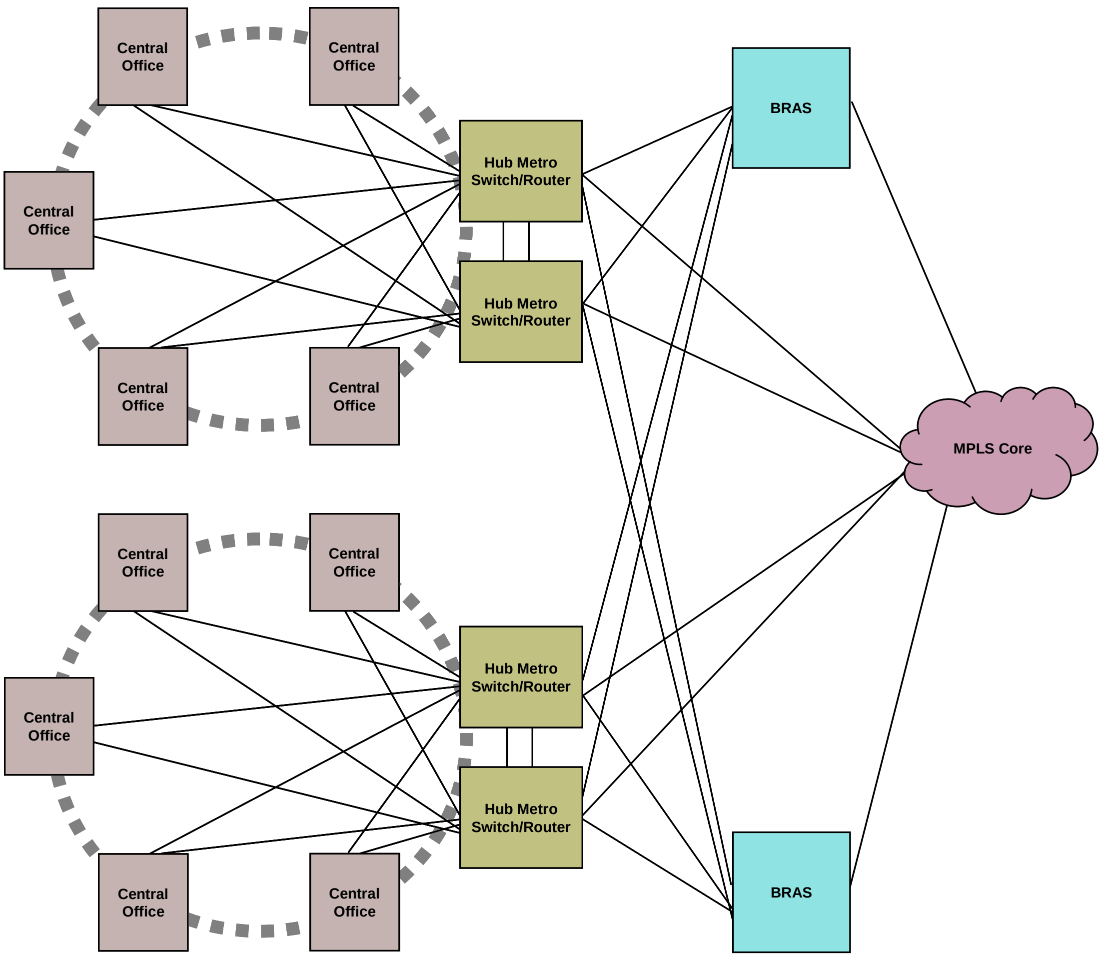

Figure 10
Division of Metro Network into Two Parts to Accommodate Smaller Switch Chassis

Operations Expense

Figure 11 details the components of operations expense.

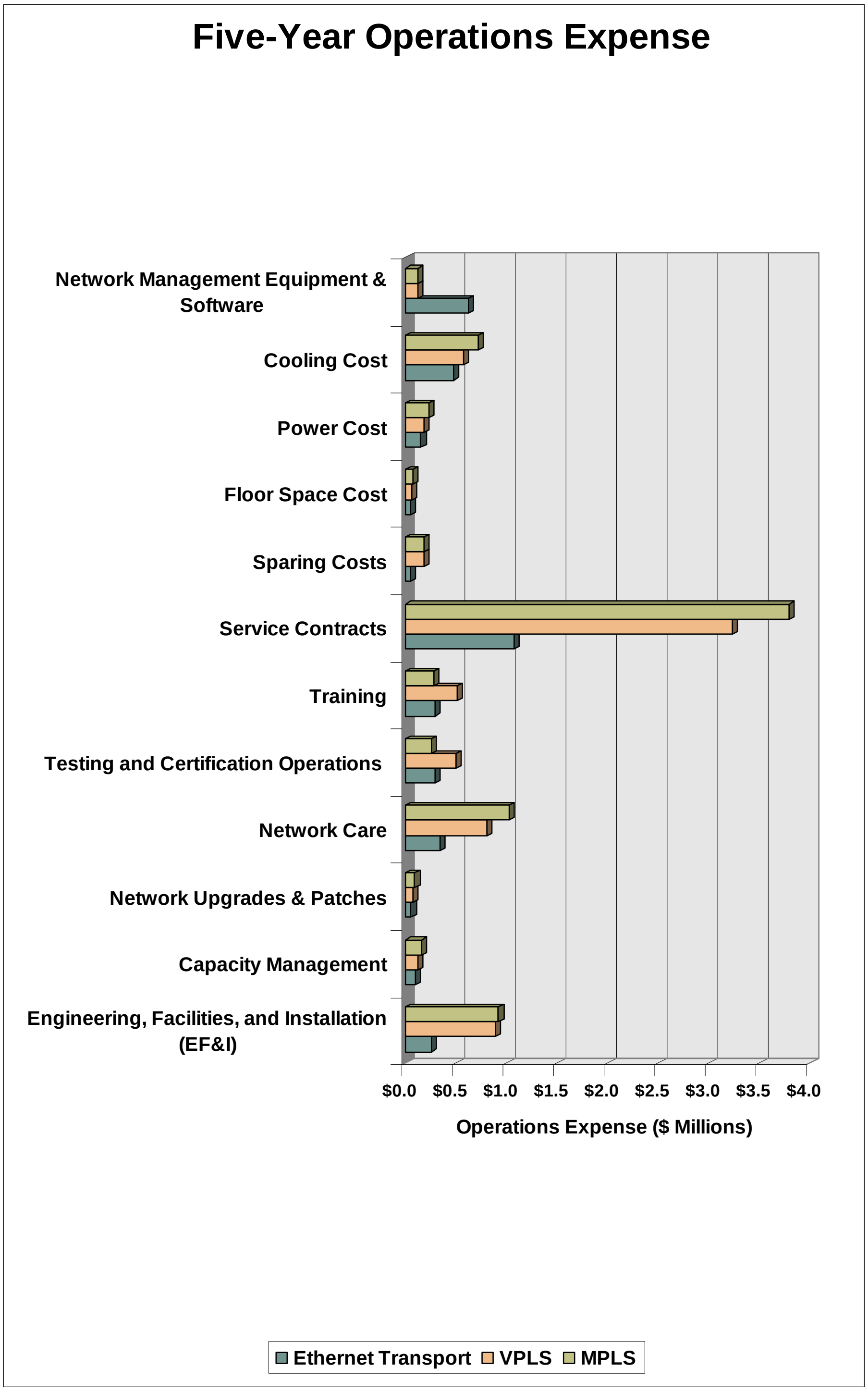

Figure 11
Five-Year Operations Expense Breakdown

Ethernet Transport OpEx over five-years is 48% less than that of VPLS, and 52% less than MPLS. Each OpEx component is defined and the source of savings produced by Ethernet Transport as compared to the VPLS, and MPLS alternatives is discussed in the following paragraphs. The paragraphs are ordered from largest to smallest savings contribution by Ethernet Transport versus VPLS and MPLS.

- Service Contract Expense – Annual fees charged by systems vendors for equipment service and support including software upgrades and maintenance is directly linked to CapEx because vendor contracts for service and software upgrades are priced proportionally to the sales price of the associated equipment. Consequently, VPLS and MPLS Service Contract costs are much higher than that of the Ethernet Transport alternative because the VPLS and MPLS equipment is more expensive.

- Engineering, Facilities, and Installation Expense – Costs required to design, furnish (Add racks, cables, etc.) and install the equipment – is driven by the associated CapEx and consequently VPLS and MPLS are the highest expense alternatives while Ethernet Transport is the lowest cost alternative.

- Network Care Expense – The cost of provisioning, surveillance, monitoring, data collection, maintenance, and fault isolation – is driven by hours of Network Operations Center (NOC) and field service technician and engineering staff work and their respective labor rates. Hours of work in-turn is determined by the number of chassis under care and each alternative's approach to network management. VPLS and MPLS have higher network care expense than Ethernet Transport due to the underlying complexity of managing VPLS/MPLS technology. VPLS/MPLS provisioning requires highly-trained (and expensive) routing engineers with knowledge of protocols including LDP, RSVP-TE, ISIS, OSPF, BGP, etc. Ethernet Transport in contrast uses a transport provisioning process that is simpler and does not require such highly trained engineers and technicians. Using Ethernet Transport network problems are less complex to debug and much less configuration of complex protocols is required. Complex protocol configurations are the source of many real world problems in IP networks.

  Also, Ethernet Transport's use of an external control plane (PBB-TE) that abstracts network control on top of the actual network hardware simplifies the work of network managers as compared to all of the other alternatives. The external control plane approach also makes the network's behavior more predictable. This eliminates certain faults and reduces the work of fault isolation and clearing.

- Training Expense – The cost of training network technicians and engineers – is highest for the VPLS and MPLS alternatives because VPLS/MPLS is complex technology as compared to Ethernet Transport.

- Testing and Certification Operations Expense – This is the cost of performing testing and certification operations on each model of equipment used in the network. VPLS and MPLS costs are highest due to the complexity of the VPLS/MPLS technology while Ethernet Transport costs are lowest due to its simplicity and wide use.

- Sparing Cost – This is the cost to carry spare parts in inventory. This cost is highest for VPLS and MPLS due to their use of specialized and therefore high-cost VPLS/MPLS equipment.

- Cooling Cost, Power Cost, and Floor Space Cost – These are all environmental expenses and are determined by the power consumption of the equipment chassis. (Floor space requirements are determined by a maximum power consumption per square-foot limit.) Ethernet Transport has lower environmental expense than the other alternatives because it has higher port density and bandwidth scalability and therefore requires fewer chassis in the network.

- Capacity Management Cost – This is the cost of performing capacity management activities. Most of the cost is for the hours incurred by Hands-On-Labor Technician, NOC Tier 1 Support, and NOC Tier 2+ Support. Ethernet Transport enjoys a cost advantage over the other alternatives because fewer chassis are deployed in the Ethernet Transport network, and by the feature functionality of the PBB-TE control plane.

- Network Upgrades and Patches Expense – This is the cost to deploy network software upgrades and patches. Since work must be done on each chassis the Ethernet Transport alternative enjoys a cost advantage because fewer chassis are deployed in its network.

- Network Management Equipment and Software Expense – This is the cost of the network management equipment and software used in the NOC. It consists of an initial charge for software and associated equipment and a recurring charge for right-to-use fees and maintenance. This cost is higher for the Ethernet Transport alternative than for the other alternatives. Ethernet Transport uses an external control plane approach (Soapstone Networks Resource and Service Control System) whereas the other alternatives use a distributed management architecture where much of the management function is embedded in each network element and a rudimentary system is used at the NOC. This OpEx expense component only addresses the system used at the NOC. The cost of network management software embedded in each network element is included in the element's price and is not separately identified.

Table 5, Table 6, and Table 7 provide a tabular summary of the TCO analysis.

Capital Expense Difference	Ethernet Transport - VPLS	Ethernet Transport - MPLS
Access	$ 178,737	$ 15,789
Aggregation	$ (3,440,769)	$ (2,411,429)
Hub	$ (3,120,156)	$ (4,247,880)
Total Five-Year CapEx Difference	**$ (6,382,188)**	**$ (6,643,520)**

Ethernet Transport Capital Expense compared to VPLS/VLAN (%)	VPLS	MPLS
Access	N/A	10%
Aggregation	-66%	-58%
Hub	-83%	-87%
Total Five-Year CapEx Difference	**-71%**	**-72%**

Table 5
Capital Expense Difference (Ethernet Transport – Alternative)

Operational Expense Difference	Ethernet Transport - VPLS	Ethernet Transport - MPLS
Engineering, Facilities, and Installation (EF&I)	$ (638,219)	$ (664,352)
Capacity Management	$ (31,745)	$ (67,329)
Network Upgrades & Patches	$ (14,640)	$ (36,680)
Network Care	$ (469,826)	$ (689,094)
Testing and Certification Operations	$ (204,831)	$ 41,632
Training	$ (217,435)	$ 15,229
Service Contracts	$ (2,157,250)	$ (2,724,444)
Sparing Costs	$ (127,644)	$ (132,870)
Floor Space Cost	$ (9,937)	$ (25,704)
Power Cost	$ (29,943)	$ (77,458)
Cooling Cost	$ (94,022)	$ (243,217)
Network Management Equipment & Software	$ 504,905	$ 504,905
Total Five-Year Operating Expense Difference	**$ (3,490,587)**	**$ (4,099,382)**
% Difference	**-48%**	**-52%**

Table 6
Operations Expense Difference (Ethernet Transport – Alternative)

Five-Year Total Cost of Ownership Difference	Ethernet Transport - VPLS	Ethernet Transport - MPLS
Five-Year TCO (CapEx+OpEx) Difference	$(9,872,775)	$ (10,742,902)
% Difference	-61%	-63%

Table 7
Total Cost of Ownership Difference (Ethernet Transport – Alternative)

Conclusion

The Ethernet Transport architecture uses the Extreme Networks BlackDiamond product family that is optimized for metro Ethernet Transport and implements an external control plane via the PBB-TE protocol. The Ethernet Transport architecture has TCO that is 61% less than VPLS, and 63% less than MPLS.

The substantial cost advantage of Ethernet Transport over VPLS and MPLS is due to Ethernet Transport's use of much simpler and widely used Ethernet technology, its high port density, and its external control plane. VPLS and MPLS equipment are much more expensive than Ethernet Transport because they utilize specialized and complex VPLS/MPLS technology rather than standard Ethernet.

Ethernet Transport also has both performance and OpEx advantages over all the alternatives due to its use of an external control plane implemented via PBB-TE. The external control plane abstracts network control on top of the actual network hardware. This simplifies network management by eliminating the vendor-specific modules used by VPLS and MPLS. The result is a more controllable and deterministic network as compared to the other alternatives. This permits network operation at higher traffic utilization levels, simplifies service provisioning and reduces OpEx, especially network care expenditures.