A Total Cost of Ownership (TCO) Analysis and Comparison of Multiservice Edge Network Architectures

NETWORK STRATEGY PARTNERS, LLC
MANAGEMENT CONSULTANTS TO THE NETWORKING INDUSTRY
www.nspllc.com

February, 2006

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Executive Summary

In 2004, frame relay and ATM generated more than $25 billion in revenue for service providers worldwide. In the United States, Frame Relay and ATM still represent (for Tier 1 carriers) the largest and most profitable revenue stream with respect to data services. However, as service providers begin to introduce managed IP services (such as IP-VPNs) and begin the migration of this multiservice traffic to IP/MPLS backbones, questions begin to arise as to the most economic and reliable means to transition this traffic while maintaining customer service-level agreements (SLAs) and supporting the deployment of new managed data services in response to emerging Enterprise data paradigms.

A recent survey of several major carriers indicates that by the end of 2006, 27% of Layer 2 traffic will migrate from native ATM networks to IP/MPLS core backbones. In response to this planning requirement, three distinct transition approaches have been developed and/or implemented.

These transition approaches can be simply described as follows:

The "Upgrade Approach" - Upgrade the installed base of legacy ATM switches. At a minimum, this includes enhancements to the MPLS control plane, support for service interworking and line card upgrades for new services such as PWE3 virtual leased lines (VLLs).

The "Layer 2.5 Approach" - Install a new breed of multiservice edge switch. Only one vendor, Hammerhead Systems, offers a platform engineered specifically for Layer 2.5 migration, but several vendors are developing capabilities to meet this opportunity head-on.

The "Layer 3 Approach" - Install a multiservice edge router (MSER). Although these products lack a Layer 2 control plane and specific migration capabilities, MSER vendors position these platforms for the termination of both legacy and new services at the MPLS edge.

The objective of this document is to provide an in-depth economic analysis comparing these three implementations for aggregating and grooming a portfolio of data services including Ethernet, IP VPNs, Frame Relay, and ATM at the edge of a Service Provider's network. *Network Strategy Partners, LLC* analyzed the Total Cost of Ownership (TCO) of each implementation, comprised of CAPEX and OPEX, based on modeling a hypothetical mid-sized network's growth over a five-year period.

With five-year revenue forecasts for each of the above services, Network Strategy Partners compared the TCO and ROI of six 'real-world' edge device alternatives: the Hammerhead Systems HSX 6000 Layer 2.5 Aggregation Switch, the L2 Incumbent Legacy, the L2 Incumbent Upgrade, the MSER1, the MSER2, and the MSER3. Each of these alternatives are solutions proposed by leading vendors in the marketplace.

The high level results of this analysis are presented in Figure 1. [1]

Key Financial Statements Among 6 Technical Solutions - Cumulative Financials over a 5 year period

	Hammerhead	L2 Incumbent Legacy	L2 Incumbent Upgrade	MSER1	MSER2	MSER3
5year total capital cost	$ 31,576,290	$ 66,257,940	$ 55,783,620	$ 74,297,790	$ 46,151,760	$ 70,726,740
(% to Hammerhead Solution)	100.00%	209.83%	176.66%	235.30%	146.16%	223.99%
5year total network operation expenses	$ 38,709,981	$ 94,532,365	$ 58,451,058	$ 69,362,566	$ 69,362,566	$ 56,634,825
(% to Hammerhead Solution)	100.00%	244.21%	151.00%	179.19%	179.19%	146.31%
5year Total Cost Of Ownership	$ 70,286,271	$ 160,790,305	$ 114,234,678	$ 143,660,356	$ 115,514,326	$ 127,361,565
(% to Hammerhead Solution)	100.00%	228.76%	162.53%	204.39%	164.35%	181.20%
5year cumulative cash flow from operations	$ 190,829,355	$ 100,325,320	$ 146,880,948	$ 117,455,269	$ 145,601,299	$ 133,754,060
(% to Hammerhead Solution)	100.00%	52.57%	76.97%	61.55%	76.30%	70.09%
5year Total Return On Investment	**704.34%**	**251.42%**	**363.30%**	**258.09%**	**415.48%**	**289.11%**

Figure 1

Based on our analysis contained in the body of this paper, Network Strategy Partners can definitively reach the following three conclusions:

1) **Using Layer 3 MSERs for edge aggregation is consistently the most capital-intensive (CAPEX) and incurs the highest operating costs (OPEX) for a Service Provider. These conclusions occurred in all scenarios studied.**

2) **The Hammerhead HSX 6000 is the most cost-effective edge aggregation solution – by a very significant margin, for both CAPEX and OPEX -- among the alternatives for all scenarios analyzed in this paper.**

3) **The Hammerhead HSX 6000 TCO is significantly lower than the MSER alternatives in all scenarios analyzed in this paper.**

Network Strategy Partners reached it's conclusions by evaluating and comparing two general approaches to building an edge aggregation infrastructure: edge switches backhauling to routers, and an all-router network. For the edge switch approach, carrier edge switches such as the Hammerhead HSX 6000 are used to terminate Frame Relay, ATM, and Ethernet services. IP VPN services are aggregated on these edge switches and backhauled over an MPLS network to an MSER located closer to the network core. In the all-router approach, Layer 3 MSERs are used at the edge of the network to terminate Frame Relay, ATM, Ethernet, and IP VPN services. The Layer 3 routers are interconnected via an MPLS core network.

This study modeled a mid-sized hypothetical network with 50 PoPs and 10 Super-PoPs, and analyzed the following scenarios:

- *Aggregation* of Frame Relay, ATM, Ethernet, and IP VPN services;
- *Aggregation* of Frame Relay, ATM, and Ethernet services;

[1] These are the results of a *new aggregation* strategy being employed by the service provider. This is a cap and grow strategy that is more fully described in the section of this paper entitled "New Aggregation: Frame Relay, ATM, Ethernet, & IP VPN".

- *Aggregation* of Frame Relay and ATM services only; and
- *Migration* of Frame Relay, ATM, Ethernet, and IP VPN services.

For the purposes of using this paper in evaluating a 'greenfield build' scenario, the reader can utilize the Migration scenarios. In a 'greenfield build,' our assumption is the incumbent will use their Next Generation switch.

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 IP VPN traffic to MSERs in the core is the most cost-effective approach to transitioning the network.*

2) *The Layer 2.5 approach provides greater flexibility in access technology choices ("creative access"), significant service differentiation (QoS/CoS) 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 profitability sooner.*

The body of this paper presents the details of Network Strategy Partners' assumptions, economic analysis, and results.

Introduction

Today, legacy data services such as Frame Relay and ATM dominate the data services market and generate the vast majority of service providers' data revenues and margins. However, the emergence of "any-to-any" connectivity requirements and new productivity applications has triggered exponential demand for IP based data services. As a result, this activity has driven a core transition to IP/MPLS. In order for carriers to remain competitive in this dynamic marketplace, it is essential that carriers reduce capital expenses and operational expenses while maintaining the agility to support new and emerging services. However, cost reductions and new service offerings *cannot* come at the expense of disrupting or discontinuing legacy data services.

One of the major challenges facing Service Providers today is architecting the network edge such that it supports new IP and Ethernet services as well as legacy Frame Relay and ATM services. An additional challenge is migrating legacy traffic from the legacy ATM core network to the new IP/MPLS core network.

A recent survey of several major carriers indicates that by the end of 2006, 27% of Layer 2 traffic will migrate from native ATM networks to IP/MPLS core backbones. In response to this planning requirement, three distinct transition approaches have been developed and/or implemented.

These transition approaches can be simply described as follows:

The "Upgrade Approach" - Upgrade the installed base of legacy ATM switches. At a minimum, this includes enhancements to the MPLS control plane, support for service interworking and line card upgrades for new services such as PWE3 virtual leased lines (VLLs).

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The "Layer 3 Approach" - Install a multiservice edge router (MSER). Although these products lack a Layer 2 control plane and specific migration capabilities, MSER vendors position these platforms for the termination of both legacy and new services at the MPLS edge.

These different approaches are compared in a variety of different scenarios. In each scenario service revenues, gross profits, capital expenses, operating expenses, cash flows, Return on Investment (ROI), Total Cost of Ownership (TCO), and payback periods are contrasted for each of the alternatives. In all the scenarios analyzed, the Layer 2.5 edge aggregation architecture has proven to be the lowest cost approach for offering both legacy and emerging data services. Furthermore, the Hammerhead HSX 6000 proves to be the best economic solution with significant capital and operations cost advantages over the alternative solutions.

Architecture Overview

The analysis set forth in this white paper is based on a financial model developed by *Network Strategy Partners, LLC*. This model is flexible and can be configured to analyze different types of networks, different levels of service demand, different pricing models, and supports multiple network architecture alternatives and sizes. For the purposes of this white paper we have modeled a mid-sized generic network with 50 POP's and 10 Super-POP's. Our assumptions for service growth and pricing are presented in the next section.

The results presented in this paper are based on the alternative architectures described earlier. The following paragraphs will describe each of these architecture alternatives in detail so as to provide a better understanding of our economic analysis.

The first alternative, the Layer 2.5 Hammerhead HSX 6000, is depicted in Figure 2.

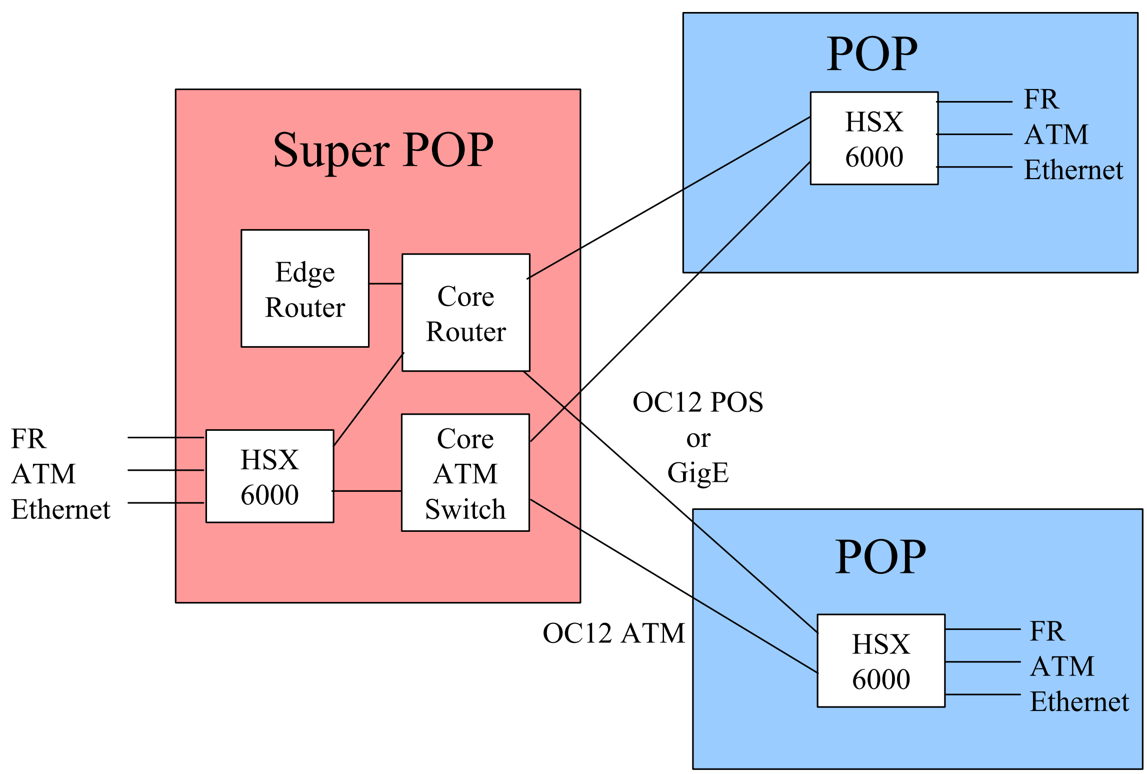

Figure 2

In our economic model, we assume that the network consists of two types of Carrier Points of Presence: POP's and Super-POP's. In each POP there are one or more HSX 6000 switches that can terminate Frame Relay, ATM, and Metro-Ethernet traffic. The HSX 6000 connects to both the ATM and IP/MPLS core and performs service interworking between Frame Relay, ATM, and Metro-Ethernet. The ATM core is used for transport of legacy traffic and service interworking . The IP/MPLS core is used in support of new managed IP services (such as IP-VPNs). Over time, legacy PVC's are migrated from the ATM to the IP/MPLS core.

Each Super-POP also hosts an HSX 6000 that connects directly to the core ATM and IP/MPLS switches over either OC-12 ATM or Gigabit Ethernet. In this architecture an edge router located in the Super-POP provides IP VPN services. VPN traffic is backhauled to the edge router using Frame Relay, ATM, or Ethernet over MPLS. The RFC 2547bis IP VPN is then initiated at the edge router and carried across the IP/MPLS network.

The second alternative ("ATM Upgrade Approach") is depicted in Figure 3.

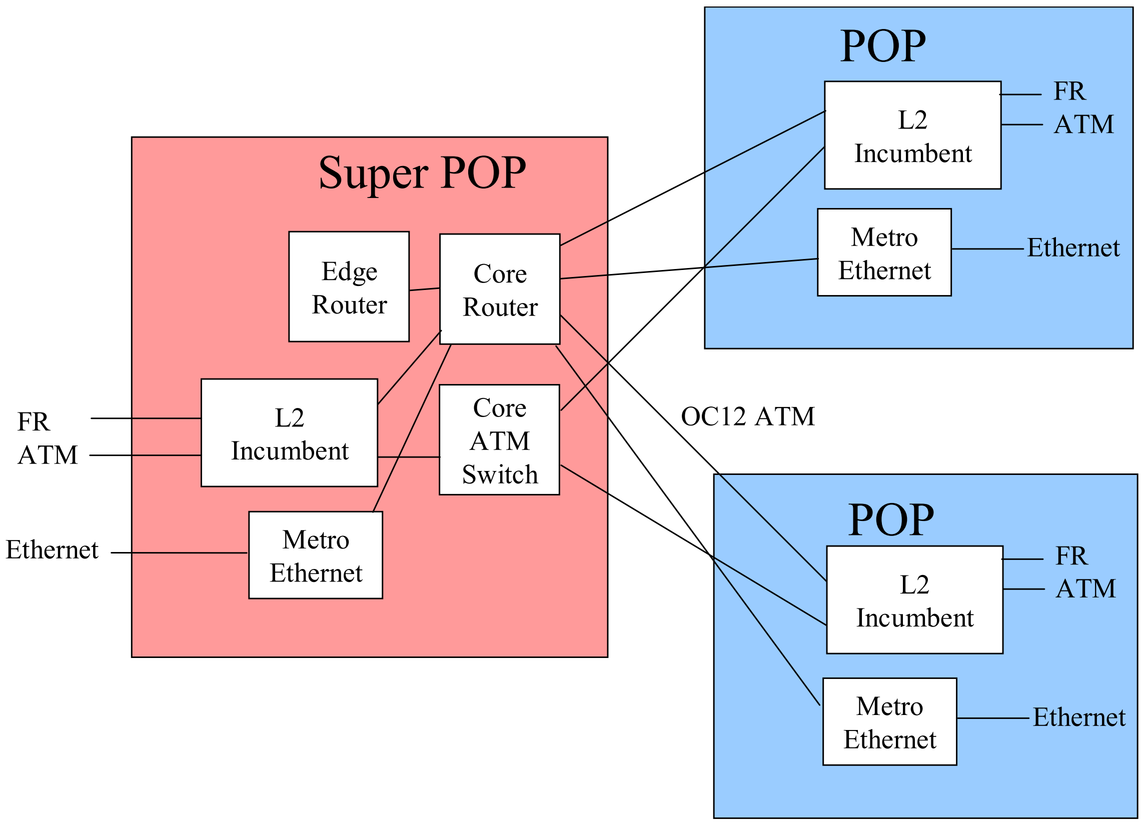

Figure 3

This model is used to represent the Incumbent L2 Incumbent Legacy and Upgrade architectures. The multiservice Layer 2 switches are used to terminate Frame Relay and ATM traffic. Additionally, Layer 2 Ethernet switches are required to terminate Metro Ethernet traffic at the network edge because the Incumbent switches are not capable of providing Ethernet Services. These switches are connected to the ATM core and are also connected to the IP/MPLS core using ATM OC-12 interfaces. It is assumed that the migration from ATM to MPLS will use ATM interfaces to MPLS routers. In this scenario, the edge router in the Super-POP also provides VPN services.

The final set of alternatives studied in this paper (Layer 3 multiservice edge router) is presented in Figure 4. In this architecture Layer 3 multiservice edge routers terminate all edge services: Frame Relay, ATM, Ethernet, and RFC 2547bis IP VPN. The edge router connects to the legacy ATM network via an ATM OC-12 and it connects to the IP/MPLS network via either a Gigabit

Ethernet connection or a OC-48 POS connection. Legacy Frame Relay, ATM, and Metro-Ethernet services are carried over MPLS LSP's. IP VPN's are provisioned at the network edge.

Each of the architecture models described above is used in the TCO analysis.

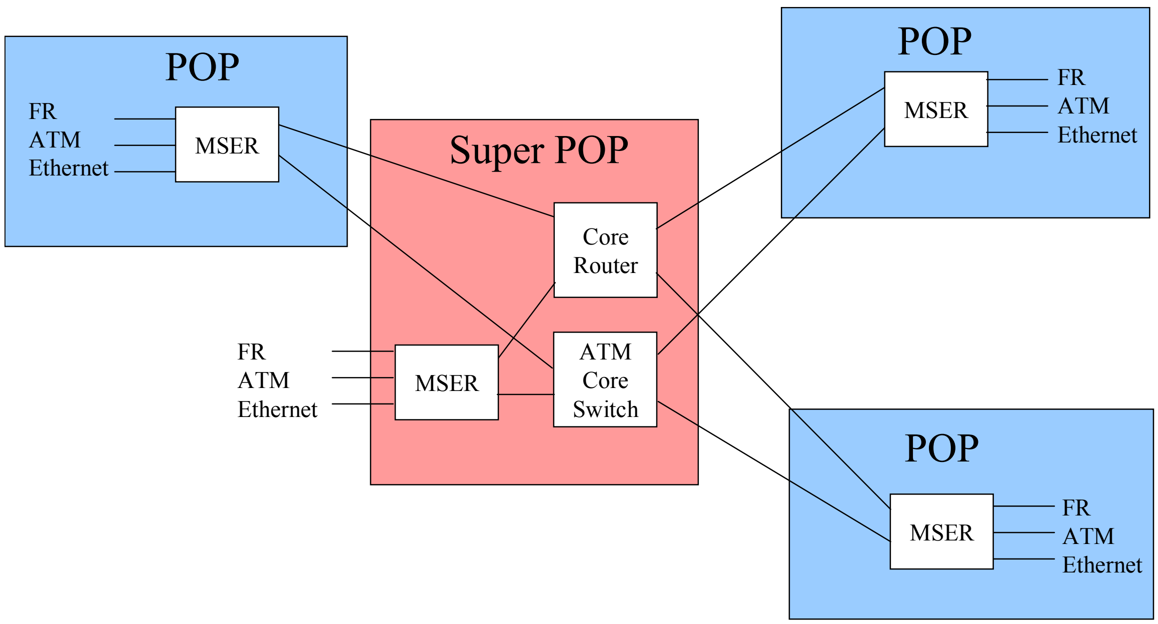

Figure 4

Service Profiles

Some of the key financial metrics presented in this study (such as ROI, payback period, and discounted cash flows) are closely tied to the service revenue model. Over a five-year period there is a high degree of uncertainty associated with service revenue growth rates. Some analysts have projected low levels of Frame Relay growth and high levels of Ethernet and VPN growth while other analysts have projected higher levels of Frame Relay growth due to a large-scale migration of circuit voice to VoIP. Today there are a large number of T1 voice circuits that could migrate to T1 Frame Relay circuits as enterprises and SME's migrate to VoIP. However, for the purposes of this white paper we have decided to take a *very conservative position* on Frame Relay and ATM growth rates as specified in Table 1. *It should be stressed that if Frame Relay revenues grow at an annual rate higher then 2%, then the financial results for the Layer 2.5 aggregation solution will improve*. Ethernet and IP VPN growth rates are more aggressive and are based on Network Strategy Partners' engagements with Service Providers and the Metro Ethernet Forum.

Service	Price Depreciation Rate	Revenue Growth Rate
Frame Relay	10%	2%
ATM	10%	-5%
Metro Ethernet	15%	16%
IP VPN	12%	42%

Table 1

The assumptions for access line demand are combined with pricing assumptions to calculate service revenues.

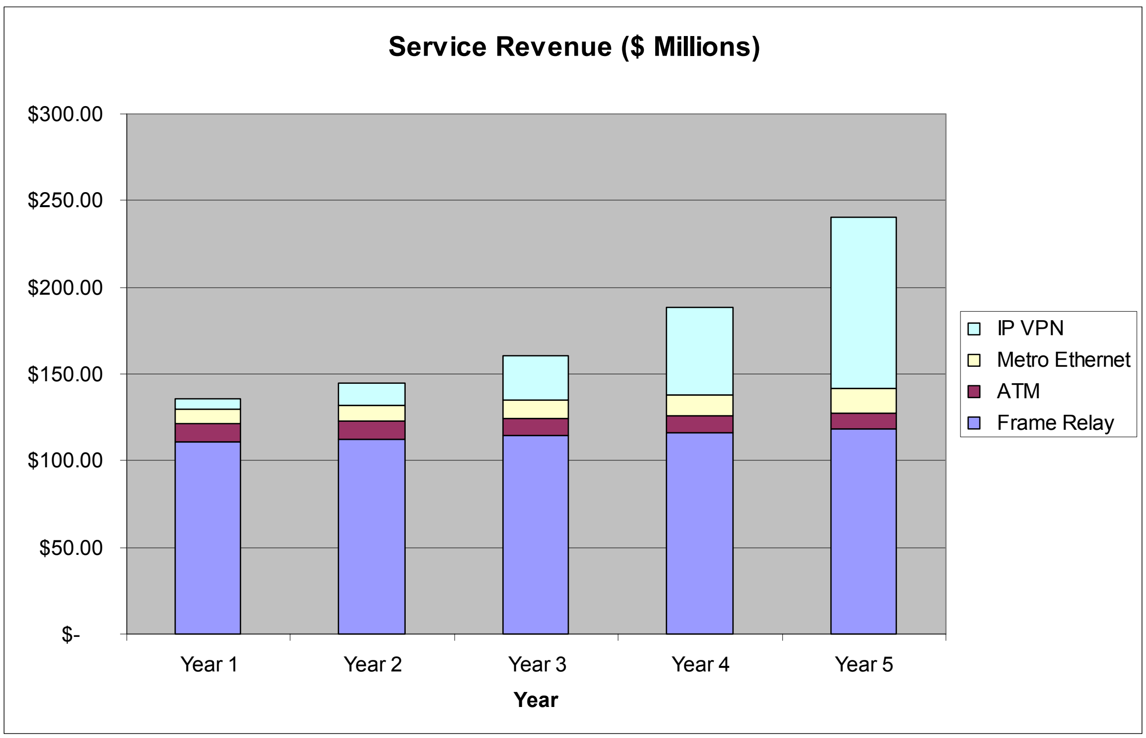

Figure 5

The chart in Figure 5 represents the service revenues from Frame Relay, ATM, Metro Ethernet, and IP VPN over a five-year period allocated to the edge equipment ROI calculation. In this model *it is assumed that 50% of the total revenues from these services will be allocated to calculate the ROI on the network edge*. The other 50% of the revenues are allocated to other network resources such as the core network. In this projection, Frame Relay revenue remains relatively static, ATM revenue is shrinking, and Ethernet and IP VPN's revenues are growing.

The distribution of revenue is presented in Figure 6. In this scenario IP VPN's will become the largest revenue generating service by year 5.

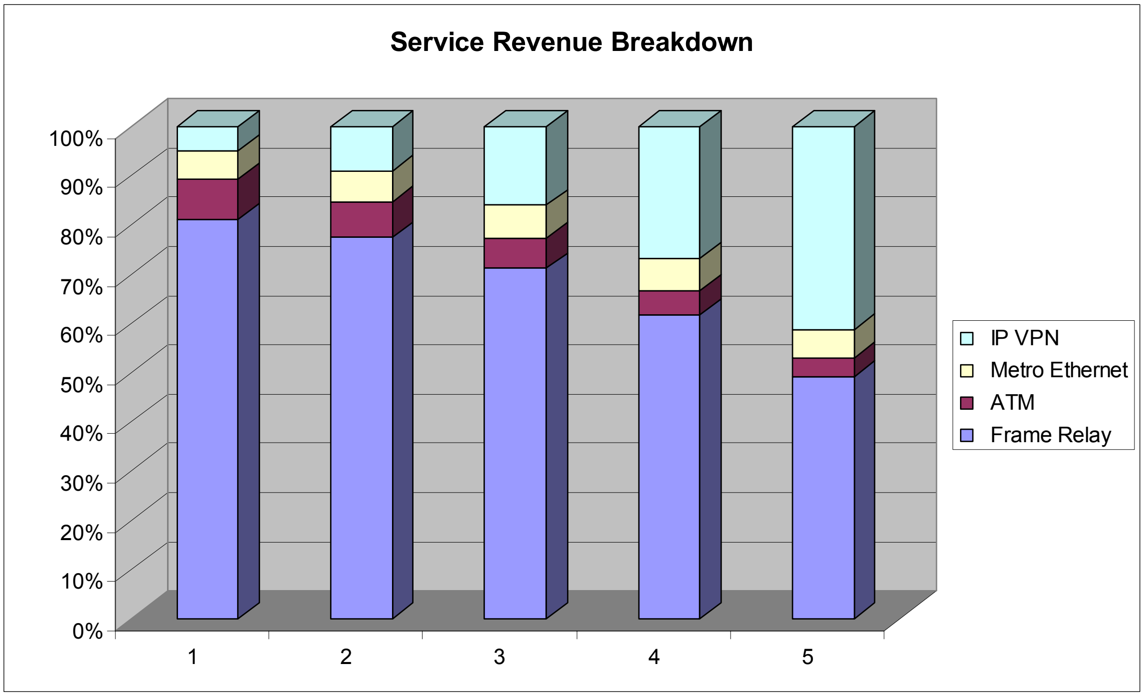

Figure 6

Economic Comparison of Edge Architectures

The economics of the six alternatives are compared in several different deployment scenarios. NSP evaluated two different deployment approaches for new edge platform deployments in existing networks:

1. *New Aggregation*
2. *Replace and Migrate*

In the *new aggregation* model the old switches are run in maintenance mode and new services are turned up on the new platforms. In the *replace and migrate* model, old switches are swapped out and replaced by new equipment. All services are migrated to the new network. The deployment scenarios considered in this paper include both *new aggregation* and *replace and migrate*.

Additionally we will consider deployment scenarios with the following service combinations:

- Frame Relay and ATM only
- Frame Relay, ATM, and Ethernet

- Frame Relay, ATM, Ethernet, and IP VPN

New Aggregation: Frame Relay, ATM, Ethernet, & IP VPN

In this deployment scenario a *new aggregation* strategy is being employed by the service provider. All the services (Frame Relay, ATM, Ethernet, and IP VPN) are offered in accordance with the service profiles and revenue models discussed earlier. Given the set of assumptions specified in the architecture and service profile sections above, we used our economic model to create a five-year forecast. The results depicted in Figure 7 are cumulative revenues and expenses over the five-year period.

	Hammerhead	L2 Incumbent Legacy	L2 Incumbent Upgrade	MSER1	MSER2	MSER3	*Assumptions*
Allocated Revenue							
Frame Relay	$ 571,354,218	$ 571,354,218	$ 571,354,218	$ 571,354,218	$ 571,354,218	$ 571,354,218	
ATM	$ 50,240,690	$ 50,240,690	$ 50,240,690	$ 50,240,690	$ 50,240,690	$ 50,240,690	
Metro Ethernet	$ 53,933,097	$ 53,933,097	$ 53,933,097	$ 53,933,097	$ 53,933,097	$ 53,933,097	
IP VPN	$ 194,857,414	$ 194,857,414	$ 194,857,414	$ 194,857,414	$ 194,857,414	$ 194,857,414	
Cumlative Allocated Revenue	**$ 870,385,419**	**$ 870,385,419**	**$ 870,385,419**	**$ 870,385,419**	**$ 870,385,419**	**$ 870,385,419**	*50% Allocation*
Cost of Revenue	**$ 609,269,793**	**$ 609,269,793**	**$ 609,269,793**	**$ 609,269,793**	**$ 609,269,793**	**$ 609,269,793**	*30% Gross Margin*
Cumulative Allocated Gross Profit	**$ 261,115,626**	**$ 261,115,626**	**$ 261,115,626**	**$ 261,115,626**	**$ 261,115,626**	**$ 261,115,626**	
Capital Cost							
Hammerhead	$ 16,837,500	$ -	$ -	$ -	$ -	$ -	
L2 Incumbent Legacy	$ -	$ 41,140,000	$ -	$ -	$ -	$ -	
L2 Incumbent Upgrade	$ -	$ -	$ 31,952,000	$ -	$ -	$ -	
MSER1	$ 3,650,000	$ 3,650,000	$ 3,650,000	$ 57,962,500	$ -	$ -	
MSER2					$ 39,384,000	$ -	
MSER3					$ -	$ 54,830,000	
MPLS Core Router	$ 1,100,000	$ 1,100,000	$ 1,100,000	$ 1,100,000	$ 1,100,000	$ 1,100,000	
Core ATM Switch	$ 6,111,000	$ 6,111,000	$ 6,111,000	$ 6,111,000	$ -	$ 6,111,000	
Metro Ethernet Edge Switch	$ -	$ 6,120,000	$ 6,120,000	$ -	$ -	$ -	
Installation	$ 2,769,850	$ 5,812,100	$ 4,893,300	$ 6,517,350	$ 4,048,400	$ 6,204,100	
Spares	$ 1,107,940	$ 2,324,840	$ 1,957,320	$ 2,606,940	$ 1,619,360	$ 2,481,640	
Cumulative Capital Cost	**$ 31,576,290**	**$ 66,257,940**	**$ 55,783,620**	**$ 74,297,790**	**$ 46,151,760**	**$ 70,726,740**	
Network Operations Expenses							
Capacity Planning	$ 326,538	$ 1,033,846	$ 630,000	$ 350,769	$ 350,769	$ 263,077	
Network Administration	$ 1,505,769	$ 3,627,692	$ 2,416,154	$ 5,261,538	$ 5,261,538	$ 3,946,154	
Service Provisioning & Configuration	$ 2,362,500	$ 6,853,846	$ 4,257,692	$ 4,361,538	$ 4,361,538	$ 3,271,154	
NOC Support	$ 11,994,231	$ 33,552,692	$ 21,091,154	$ 26,169,231	$ 26,169,231	$ 19,626,923	
Field Support	$ 8,048,077	$ 23,365,385	$ 14,538,462	$ 14,953,846	$ 14,953,846	$ 11,215,385	
Environmental	$ 5,570,879	$ 21,097,369	$ 10,111,087	$ 10,576,483	$ 10,576,483	$ 7,932,362	
Financial Penalties for Flash Cut Outages	$ -	$ -	$ -	$ -	$ -	$ -	
EMS Service Migration Expenses	$ 185,000	$ -	$ 570,000	$ 570,000	$ 570,000	$ 570,000	
Training	$ 1,454,227	$ -	$ 257,601	$ 1,532,908	$ 1,532,908	$ 1,149,681	
OSS Service Migration Expenses	$ 5,441,574	$ -	$ 1,360,394	$ 1,360,394	$ 1,360,394	$ 5,441,574	
Hardware Support	$ 1,578,815	$ 4,317,200	$ 2,789,181	$ 3,714,890	$ 3,714,890	$ 2,789,181	
OSS Support	$ 242,371	$ 684,335	$ 429,335	$ 510,969	$ 510,969	$ 429,335	
Cumulative Expenses	**$ 38,709,981**	**$ 94,532,365**	**$ 58,451,058**	**$ 69,362,566**	**$ 69,362,566**	**$ 56,634,825**	
Cumulative Cash Flow	**$ 190,829,355**	**$ 100,325,320**	**$ 146,880,948**	**$ 117,455,269**	**$ 145,601,299**	**$ 133,754,060**	
TCO	**$ 70,286,271**	**$ 160,790,305**	**$ 114,234,678**	**$ 143,660,356**	**$ 115,514,326**	**$ 127,361,565**	
ROI ([Revenue-Expenses]/Capital)	**704%**	**251%**	**363%**	**258%**	**415%**	**289%**	
Payback Period in months	**3.09**	**7.46**	**5.50**	**7.79**	**5.21**	**7.49**	

Figure 7

This analysis shows that over a five-year period the edge switch architecture is far more cost effective than the edge router from both a CAPEX and OPEX perspective. Also amongst the edge switch solutions studied, the Hammerhead HSX 6000 is the most cost effective solution. The cumulative TCO is presented in Figure 8 and the CAPEX for each of the alternatives over a five-year period is presented in Figure 9.

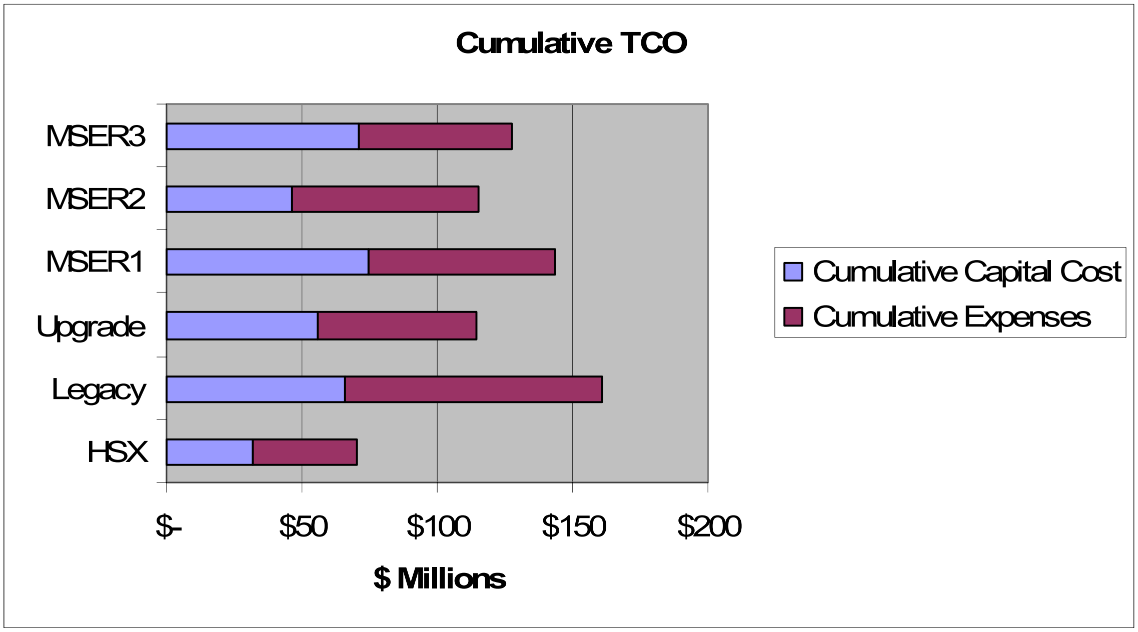

Figure 8

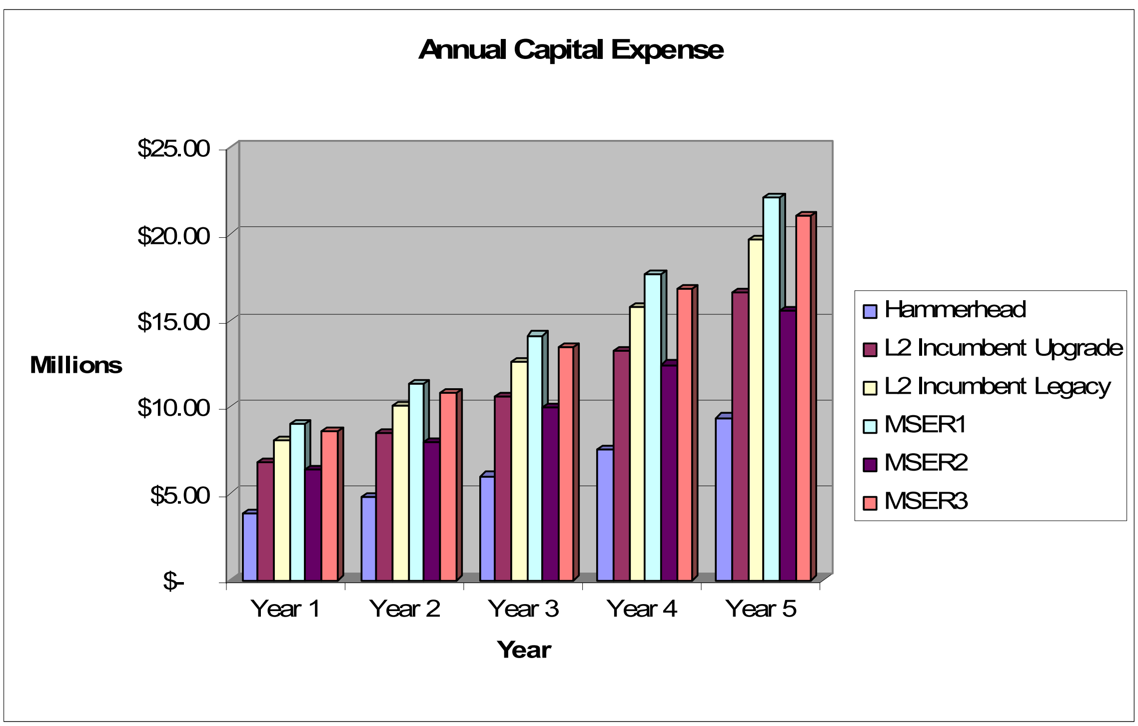

Figure 9

There are two drivers of Total Cost of Ownership: CAPEX and OPEX. The primary reasons that edge switch CAPEX is less then MSER CAPEX is that the cost of multiservice interfaces on high-speed edge router platforms are more expensive. This cost factor tends to make MSERs more expensive on a per port basis then edge switches. The incumbent switch, while less expensive then the MSER, is more expensive than the other alternatives because of its architectural limitations in switch fabric size and its 1-to-1 mapping between the processor and the physical interface ports. The HSX 6000 has the lowest CAPEX due to its bandwidth pooling architecture, high port densities, scalability, and low cost per port.

These results also show OPEX to be lower for the edge switch solution and lowest for the HSX 6000. Because routers are more complex devices to configure, operate, and troubleshoot, the router's OPEX tends to be higher than the switch's OPEX. The skill level required to successfully operate MSERs tends to be higher, which often translates to larger salary costs in the Network Operations Center (NOC). The complexity also tends to lead to more service outages, which impacts SLAs and the revenue streams associated with the services affected by the unplanned outages.

For the switching functions in networks, the administration, operations, and provisioning are typically handled by less expensive employees than those required to support MSERs. The architecture of the HSX 6000 also provides significant savings in that the platform can support higher port densities due to bandwidth pooling and the utilization of Universal Service Modules ("Any service, any port"). *The HSX 6000 is the only edge device on the market with bandwidth pooling, which supports the most efficient aggregation economics, especially with a mix of low-speed Frame Relay traffic and higher-speed ATM and Gigabit Ethernet traffic.*

In order to provide a deeper understanding of the economic analysis and results, the following paragraphs will provide a detailed description of each of the line items presented in Figure 7.

Allocated Revenue

The Allocated Revenue section of the model calculates the gross profit that will be used to calculate the cumulative cash flows, ROI, and payback period for capital investments. The top line revenue calculation is described in detail in the Service Profiles section of this paper. The key facts are that the revenue numbers are calculated based on unit demand, pricing, and a 50% allocation of total revenues to edge capital. Therefore the revenues projected in Figure 7 are 50% of the total revenues generated from the services specified in the demand matrix. The model also assumes a gross margin of 30% to calculate the cost of revenue and the gross profit. Cost of revenue is made up of multiple components including sales, marketing, transport costs, and access charges. The gross profit numbers are then used to calculate cumulative cash flow, ROI, and payback.

Capital Cost

Capital costs are calculated by configuring network elements in the POP's and Super-POP's and adding up the costs of all the components, using the published US list prices of the corresponding bill of materials (BOM) created by the assumed configuration. . These costs include edge switches, line cards, switch fabric modules , software and the line cards in core routers/switches necessary to accommodate new traffic. Each component of the CAPEX is described in the following paragraphs.

Edge Switch

There are three line items in Figure 7 for edge switches: Hammerhead HSX 6000, L2 Incumbent Legacy, L2 Incumbent Upgrade, MSER1, MSER2, and MSER3. In each of the scenarios these line items constitute the capital expense for all edge switching equipment. In all the reviewed scenarios, the capital cost of the HSX 6000 is significantly lower than the presented alternatives.

Multiservice Edge Router (MSER)

This line item specifies the CAPEX of a multiservice edge router. In the Layer 3 solution, MSERs are used to terminate both Layer 2 and Layer 3 services. The other three alternatives use edge switches to terminate Frame Relay, ATM, and Ethernet services. IP VPN services are backhauled to an MSER in a Super-POP, which does the IP VPN processing. This MSER is deployed as a 'one-armed router' (also known as a "router on a stick" approach) connected to a core router via one or more Gigabit Ethernet interfaces. The financial analysis in Figure 7 demonstates that this is a much more cost-effective way to provide IP VPN services then terminating IP VPN's at the edge of the network. *This is because it is more expensive to terminate a large number of T1 and sub-T1 interfaces on an edge router as compared to aggregating those services on a switch and then backhauling those services over a MPLS-enabled Gigabit Ethernet trunk which terminates on the MSER.*

MPLS Core Router

This line item specifies the CAPEX required in the IP/MPLS core network to accommodate new edge devices. It only accounts for line cards required to support new interfaces. It assumes that an IP/MPLS core network is already in place so it *does not* account for the costs of building the core network. The reason that the L2 Incumbent Legacy and L2 Incumbent Upgrade switches result in higher IP/MPLS core costs than Hammerhead is that those switches *must* use ATM interfaces to the MPLS core routers while the HSX 6000 uses Gigabit Ethernet interfaces. ATM interfaces are more expensive then Gigabit Ethernet and therefore the core routing line card expenses are higher for the Incumbent solutions.

Core ATM Switch

This line item is similar to the Core MPLS switch line item except that these are the line cards associated with the legacy ATM network. In the *new aggregation* model, all new traffic is connected to the IP/MPLS network so these costs are zero. In the *replace and migrate* model, , these costs are compared for the alternative solutions.

Metro Ethernet Switch

The L2 Incumbent Legacy and L2 Incumbent Upgrade do not support Gigabit Ethernet for Ethernet services. Therefore it is necessary to use separate Metro Ethernet switches to provide these services. These are the capital expenses associated with these switches.

Installation

These are the installation costs associated with all of the capital equipment. These costs include all the costs associated with truck rolls, site preparation, wiring, environmental preparation, chassis installation, and card installation. The installation costs were calculated as a percentage of CAPEX.

Spares

These are the costs associated with spare line cards for all capital equipment. Spares costs were calculated as a percentage of CAPEX.

Network Operations Expenses

Network operations expenses are calculated using a model that has been refined by Network Strategy Partners over a series of projects with both vendors and service providers. The various components of the operations expense are calculated using data from equipment configurations as well as data from the Network Strategy Partners database. In each of the operations expense categories, the number of employees, skill levels, and salary grades are calculated and differentiated between the switch and router architectures. The operations expenses considered in this model are *only those expenses related to the network edge*. Operations expenses associated with the network core, transport, access, and other network components are *not* considered in this paper because our objective is only to compare and contrast edge aggregation alternatives.

The components of OPEX are described in the following paragraphs.

Capacity Planning

Network capacity planning is an engineering function. It involves analyzing measured statistical data and using capacity planning tools to estimate the need for more transmission bandwidth, switches, line cards, and physical capacity.

Network Administration

Network Administration is an operational process associated with maintaining switches and routers with the correct software revisions and the correct configurations. Administration also includes performance and fault monitoring.

Service Provisioning & Configuration

As customers order new services the operations group needs to provision circuits and configure routers. This is the process of provisioning and configuration on a large scale to add new customers and services to the network.

Network Operations Center (NOC) Support

NOC support is the operations costs associated with running a Network Operations Center. The NOC is a 24x7 call center that deals with level 1 and level 2 support. Level 3 support is usually escalated outside the NOC. NOC support includes both technician level and engineering level staff.

Field Support

Field support costs are associated with truck rolls. These costs include field technicians as well as field engineers providing service to remote central offices.

Environmental

Environment costs include floor-space, power, cooling, and battery backup. These costs are calculated using the network configurations.

Financial Penalties for Flash Cut Outages

The migration of PVC's from the ATM network to the IP/MPLS core network is a complex activity. The HSX 6000 is designed as a migration platform to allow for the smooth migration of PVC's without incurring network outages. The HSX 6000 uses a dual ATM and MPLS control plane, and a bridge-and-roll software feature to facilitate non-disruptive ATM PVC to MPLS migration. The other solutions studied in this paper all require service outages to allow for PVC migration. These are the penalties paid on SLA's for migration-related PVC outages.

EMS Service Migration Expenses

As new platforms are added to the network Service Providers must incur an Element Management System (EMS) migration expense. This is the expense associated with integrating a new EMS into the OSS infrastructure. The only platform that does not incur this expense is the L2 Incumbent Legacy. Hammerhead's Pegador EMS uses standards-based interfaces (SNMP, CORBA, and XML), and, unlike the Incumbent or MSER, has one integrated solution supporting both legacy and Ethernet services to simplify EMS migration. Therefore, EMS migration costs are less for the HSX 6000 than the MSER's.

Training

Adding new platforms to a network requires training of engineers, technicians, and operators. This is the expense associated with integrating each of the new platforms. The L2 Incumbent Legacy, of course, does not incur training expenses.

OSS Service Migration Expenses

While part of the expense of integrating a platform into the network is accounted for in the section on EMS expenses, the greater component of cost is associated with full integration with the Service Provider's own OSS, and may include costs to integrate with NMA, TIRKs, and multiple other systems. For the purposes of this analysis it is assumed that there is no cost associated with OSS integration for the L2 Incumbent Legacy and that the L2 Incumbent Upgrade and the MSER's already have some level of integration. The HSX 6000 requires complete OSS integration and, thus incurs the highest OSS migration expense.

Hardware Support

This is the expense the Service Provider incurs with hardware support contracts.

OSS Support

This is the expense the Service Provider incurs with OSS support contracts.

The following sections present different *new aggregation* and *replace and migrate* scenarios. The line items in each of these tables are the same as those described above.

New Aggregation: Frame Relay, ATM, & Ethernet

In this deployment scenario a *new aggregation* strategy is employed for Frame Relay, ATM, and Ethernet services. It is assumed that IP VPN services are *not* offered in this scenario. The Frame Relay, ATM, and Ethernet services are offered in accordance with the service profiles and revenue models discussed earlier. Given the set of assumptions specified in the architecture and service profile sections of this paper, we used our economic model to create a five-year model. The results, depicted in Figure 10, are cumulative results over the five-year period.

	Hammerhead	L2 Incumbent Legacy	L2 Incumbent Upgrade	MSER1	MSER2	MSER3	Assumptions
Allocated Revenue							
Frame Relay	$ 634,838,020	$ 634,838,020	$ 634,838,020	$ 634,838,020	$ 634,838,020	$ 634,838,020	
ATM	$ 49,790,289	$ 49,790,289	$ 49,790,289	$ 49,790,289	$ 49,790,289	$ 49,790,289	
Metro Ethernet	$ 78,890,354	$ 78,890,354	$ 78,890,354	$ 78,890,354	$ 78,890,354	$ 78,890,354	
IP VPN	$ -	$ -	$ -	$ -	$ -	$ -	
Cumlative Allocated Revenue	**$ 763,518,663**	**$ 763,518,663**	**$ 763,518,663**	**$ 763,518,663**	**$ 763,518,663**	**$ 763,518,663**	*50% Allocation*
Cost of Revenue	**$ 534,463,064**	**$ 534,463,064**	**$ 534,463,064**	**$ 534,463,064**	**$ 534,463,064**	**$ 534,463,064**	*30% Gross Margin*
Cumulative Allocated Gross Profit	**$ 229,055,599**	**$ 229,055,599**	**$ 229,055,599**	**$ 229,055,599**	**$ 229,055,599**	**$ 229,055,599**	
Capital Cost							
Hammerhead	$ 10,237,500	$ -	$ -	$ -	$ -	$ -	
L2 Incumbent Legacy	$ -	$ 20,136,000	$ -	$ -	$ -	$ -	
L2 Incumbent Upgrade	$ -	$ -	$ 15,526,000	$ -	$ -	$ -	
MSER1	$ -	$ -	$ -	$ 37,262,500	$ -	$ -	
MSER2					$ 26,697,000	$ -	
MSER3					$ -	$ 31,670,000	
MPLS Core Router	$ 1,100,000	$ 1,100,000	$ 1,100,000	$ 1,100,000	$ 1,100,000	$ 1,100,000	
Core ATM Switch	$ 1,413,000	$ 1,413,000	$ 1,413,000	$ 1,413,000	$ -	$ 1,413,000	
Metro Ethernet Edge Switch	$ -	$ 6,120,000	$ 6,120,000	$ -	$ -	$ -	
Installation	$ 1,275,050	$ 2,876,900	$ 2,415,900	$ 3,977,550	$ 2,779,700	$ 3,418,300	
Spares	$ 510,020	$ 1,150,760	$ 966,360	$ 1,591,020	$ 1,111,880	$ 1,367,320	
Cumulative Capital Cost	**$ 14,535,570**	**$ 32,796,660**	**$ 27,541,260**	**$ 45,344,070**	**$ 31,688,580**	**$ 38,968,620**	
Network Operations Expenses							
Capacity Planning	$ 242,308	$ 909,231	$ 505,385	$ 306,923	$ 306,923	$ 263,077	
Network Administration	$ 726,923	$ 2,727,692	$ 1,516,154	$ 4,603,846	$ 4,603,846	$ 3,946,154	
Service Provisioning & Configuration	$ 1,557,692	$ 5,789,423	$ 3,193,269	$ 3,816,346	$ 3,816,346	$ 3,271,154	
NOC Support	$ 7,476,923	$ 27,789,231	$ 15,327,692	$ 22,898,077	$ 22,898,077	$ 19,626,923	
Field Support	$ 5,296,154	$ 19,730,769	$ 10,903,846	$ 13,084,615	$ 13,084,615	$ 11,215,385	
Environmental	$ 3,641,844	$ 17,578,052	$ 6,591,770	$ 9,254,423	$ 9,254,423	$ 7,932,362	
Financial Penalties for Flash Cut Outages	$ -	$ -	$ -	$ -	$ -	$ -	
EMS Service Migration Expenses	$ 185,000	$ -	$ 570,000	$ 570,000	$ 570,000	$ 570,000	
Training	$ 918,000	$ -	$ 188,678	$ 1,341,294	$ 1,341,294	$ 1,149,681	
OSS Service Migration Expenses	$ 5,780,155	$ -	$ 1,445,039	$ 1,445,039	$ 1,445,039	$ 5,780,155	
Hardware Support	$ 726,779	$ 3,112,950	$ 1,377,063	$ 2,267,204	$ 2,267,204	$ 1,377,063	
OSS Support	$ 153,000	$ 569,463	$ 314,463	$ 447,098	$ 447,098	$ 314,463	
Cumulative Expenses	**$ 26,704,778**	**$ 78,206,812**	**$ 41,933,359**	**$ 60,034,865**	**$ 60,034,865**	**$ 55,446,417**	
Cumulative Cash Flow	**$ 187,815,251**	**$ 118,052,127**	**$ 159,580,980**	**$ 123,676,664**	**$ 137,332,154**	**$ 134,640,562**	
TCO	**$ 41,240,348**	**$ 111,003,472**	**$ 69,474,619**	**$ 105,378,935**	**$ 91,723,445**	**$ 94,415,037**	
ROI ([Revenue-Expenses]/Capital)	**1392%**	**460%**	**679%**	**373%**	**533%**	**446%**	
Payback Period in months	**1.25**	**3.26**	**2.43**	**4.34**	**2.93**	**3.80**	

Figure 10

In this scenario there is significantly less equipment deployed. This is because the revenue model for Frame Relay, ATM, and Ethernet has remained the same but IP VPN revenue and access line requirements have been subtracted. Because IP VPN revenue was projected to grow at a high rate, a significant amount of the capital equipment deployed for IP VPN is not needed.

One of the interesting results is that if IP VPN services are removed, then the ROI and the payback periods for all solutions are significantly better then in the previous scenario. ***This is a reflection of the assumed volatility of IP-VPN pricing over the 5-year period. Therefore, the CAPEX investment in support of IP-VPNs tends to be high while the corresponding margin for these new services (which drives ROI) tend to grow smaller over the period.***

In this scenario the Hammerhead solution is significantly less expensive then the alternative solutions. One of the reasons for this is that the Incumbent solutions require Ethernet switches for Ethernet services, therefore leading to extra CAPEX and OPEX. As discussed earlier, the MSER expenses are high because of higher port costs and OPEX for routers. The CAPEX and OPEX of the alternatives are compared in Figure 11 and five year CAPEX for the alternatives is depicted in Figure 12.

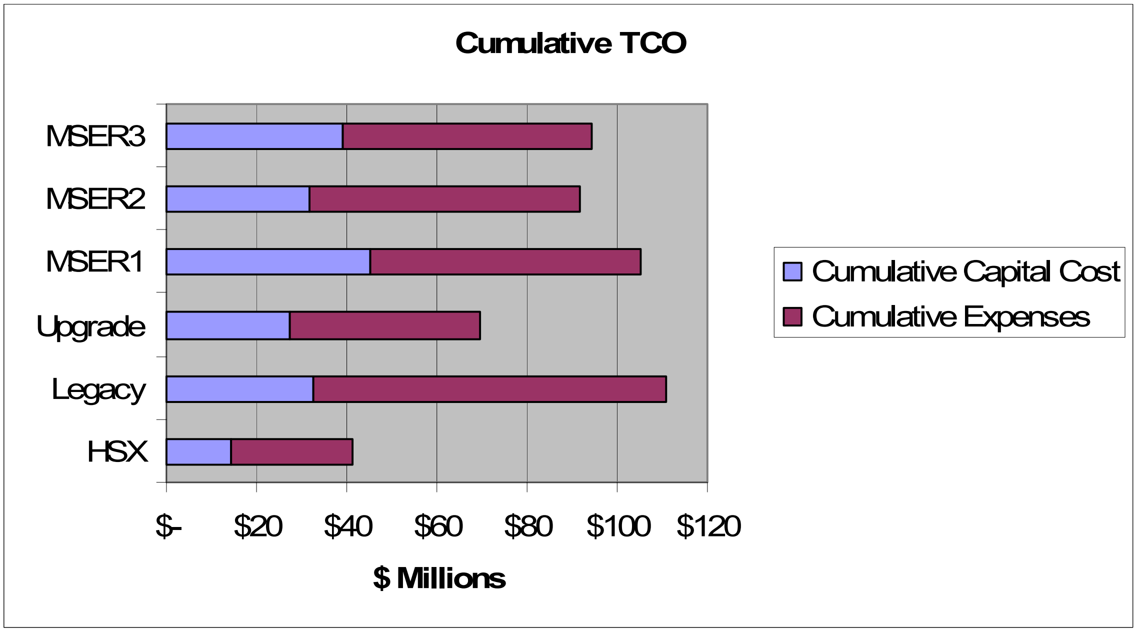

Figure 11

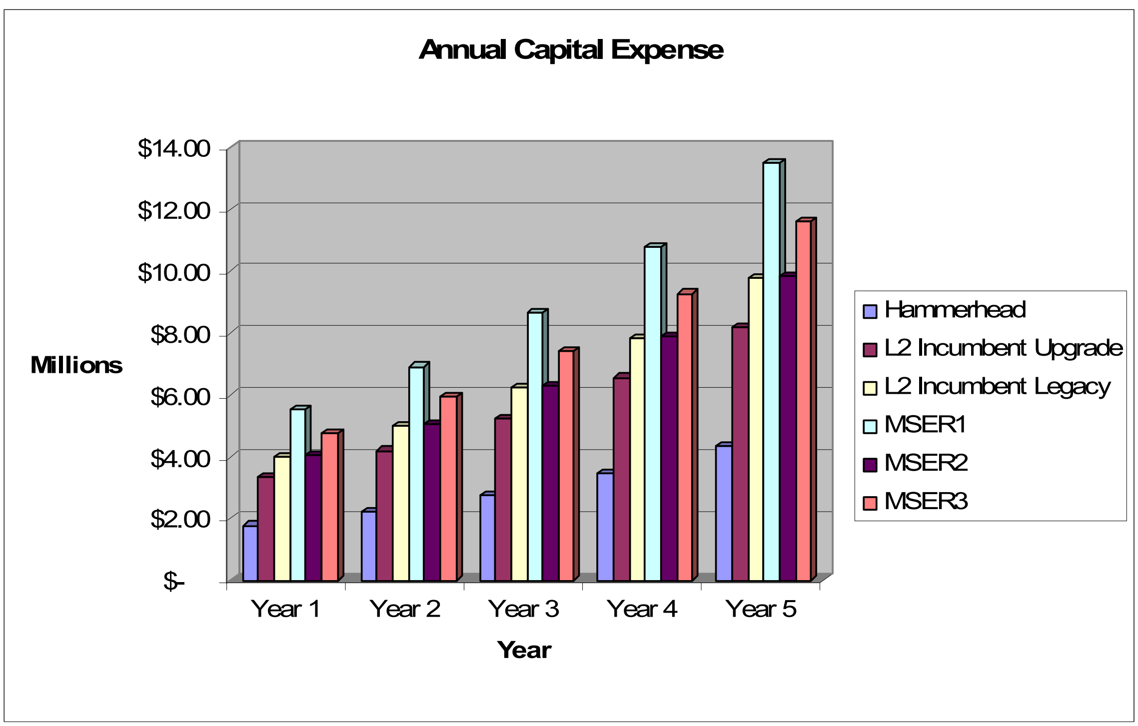

Figure 12

New Aggregation: Frame Relay & ATM

In this deployment scenario a *new aggregation* strategy is employed for Frame Relay and ATM services. It is assumed that Ethernet and IP VPN's are *not* offered. The Frame and ATM services are offered in accordance with the service profiles and revenue models discussed earlier. Given the set of assumptions specified in the architecture and service profile sections above, we used our economic model to create a five-year model. The results depicted in Figure 13 are cumulative results over the five-year period.

	Hammerhead	L2 Incumbent Legacy	L2 Incumbent Upgrade	MSER1	MSER2	MSER3	Assumptions
Allocated Revenue							
Frame Relay	$ 634,838,020	$ 634,838,020	$ 634,838,020	$ 634,838,020	$ 634,838,020	$ 634,838,020	
ATM	$ 49,790,289	$ 49,790,289	$ 49,790,289	$ 49,790,289	$ 49,790,289	$ 49,790,289	
Metro Ethernet	$ -	$ -	$ -	$ -	$ -	$ -	
IP VPN	$ -	$ -	$ -	$ -	$ -	$ -	
Cumlative Allocated Revenue	**$ 684,628,309**	**$ 684,628,309**	**$ 684,628,309**	**$ 684,628,309**	**$ 684,628,309**	**$ 684,628,309**	*50% Allocation*
Cost of Revenue	**$ 479,239,817**	**$ 479,239,817**	**$ 479,239,817**	**$ 479,239,817**	**$ 479,239,817**	**$ 479,239,817**	*30% Gross Margin*
Cumulative Allocated Gross Profit	**$ 205,388,493**	**$ 205,388,493**	**$ 205,388,493**	**$ 205,388,493**	**$ 205,388,493**	**$ 205,388,493**	
Capital Cost							
Hammerhead	$ 9,137,500	$ -	$ -	$ -	$ -	$ -	
L2 Incumbent Legacy	$ -	$ 20,426,000	$ -	$ -	$ -	$ -	
L2 Incumbent Upgrade	$ -	$ -	$ 15,526,000	$ -	$ -	$ -	
MSER1	$ -	$ -	$ -	$ 23,412,500	$ -	$ -	
MSER2					$ 17,376,000	$ -	
MSER3					$ -	$ 26,385,000	
MPLS Core Router	$ -	$ -	$ -	$ -	$ -	$ -	
Core ATM Switch	$ 1,413,000	$ 1,413,000	$ 1,413,000	$ 1,413,000	$ -	$ 1,413,000	
Metro Ethernet Edge Switch	$ -	$ -	$ -	$ -	$ -	$ -	
Installation	$ 1,055,050	$ 2,183,900	$ 1,693,900	$ 2,482,550	$ 1,737,600	$ 2,779,800	
Spares	$ 422,020	$ 873,560	$ 677,560	$ 993,020	$ 695,040	$ 1,111,920	
Cumulative Capital Cost	**$ 12,027,570**	**$ 24,896,460**	**$ 19,310,460**	**$ 28,301,070**	**$ 19,808,640**	**$ 31,689,720**	
Network Operations Expenses							
Capacity Planning	$ 242,308	$ 646,154	$ 242,308	$ 263,077	$ 263,077	$ 263,077	
Network Administration	$ 726,923	$ 1,938,462	$ 726,923	$ 3,946,154	$ 3,946,154	$ 3,946,154	
Service Provisioning & Configuration	$ 1,557,692	$ 4,153,846	$ 1,557,692	$ 3,271,154	$ 3,271,154	$ 3,271,154	
NOC Support	$ 7,476,923	$ 19,938,462	$ 7,476,923	$ 19,626,923	$ 19,626,923	$ 19,626,923	
Field Support	$ 5,296,154	$ 14,123,077	$ 5,296,154	$ 11,215,385	$ 11,215,385	$ 11,215,385	
Environmental	$ 3,641,844	$ 17,578,052	$ 6,591,770	$ 7,932,362	$ 7,932,362	$ 7,932,362	
Financial Penalties for Flash Cut Outages	$ -	$ -	$ -	$ -	$ -	$ -	
EMS Service Migration Expenses	$ 185,000	$ -	$ 570,000	$ 570,000	$ 570,000	$ 570,000	
Training	$ 918,000	$ -	$ 91,800	$ 1,149,681	$ 1,149,681	$ 1,149,681	
OSS Service Migration Expenses	$ 5,395,279	$ -	$ 1,348,820	$ 1,348,820	$ 1,348,820	$ 5,395,279	
Hardware Support	$ 601,379	$ 2,751,950	$ 965,523	$ 1,415,054	$ 1,415,054	$ 965,523	
OSS Support	$ 153,000	$ 408,000	$ 153,000	$ 383,227	$ 383,227	$ 153,000	
Cumulative Expenses	**$ 26,194,502**	**$ 61,538,002**	**$ 25,020,912**	**$ 51,121,836**	**$ 51,121,836**	**$ 54,488,537**	
Cumulative Cash Flow	**$ 167,166,421**	**$ 118,954,030**	**$ 161,057,120**	**$ 125,965,587**	**$ 134,458,017**	**$ 119,210,235**	
TCO	**$ 38,222,072**	**$ 86,434,462**	**$ 44,331,372**	**$ 79,422,906**	**$ 70,930,476**	**$ 86,178,257**	
ROI ([Revenue-Expenses]/Capital)	**1490%**	**578%**	**934%**	**545%**	**779%**	**476%**	
Payback Period in months	**1.11**	**2.55**	**1.74**	**2.87**	**1.97**	**3.36**	

Figure 13

This scenario is fairly similar to the previous example modeling Frame Relay, ATM, and Ethernet. Because Ethernet services are not offered in this example, revenues CAPEX, and OPEX are slightly lower. In this case Hammerhead performs better then the alternatives as depicted in Figure 14 and Figure 15. The primary reasons for Hammerhead's cost advantages are:

- Better port densities and lower costs per port
- Bandwidth Pooling
- Lower environmental costs due to better port densities
- Edge switch operational advantages over MSERs

Because Frame Relay's assumed revenue growth rate is 2% and ATM Revenue growth rate is – 20%, the CAPEX investment is fairly low compared to the other scenarios where VPN's and Ethernet were driving service growth. It should also be noted that OPEX is a larger component of the expense then CAPEX. This is because service growth and subsequent CAPEX is small over the period.

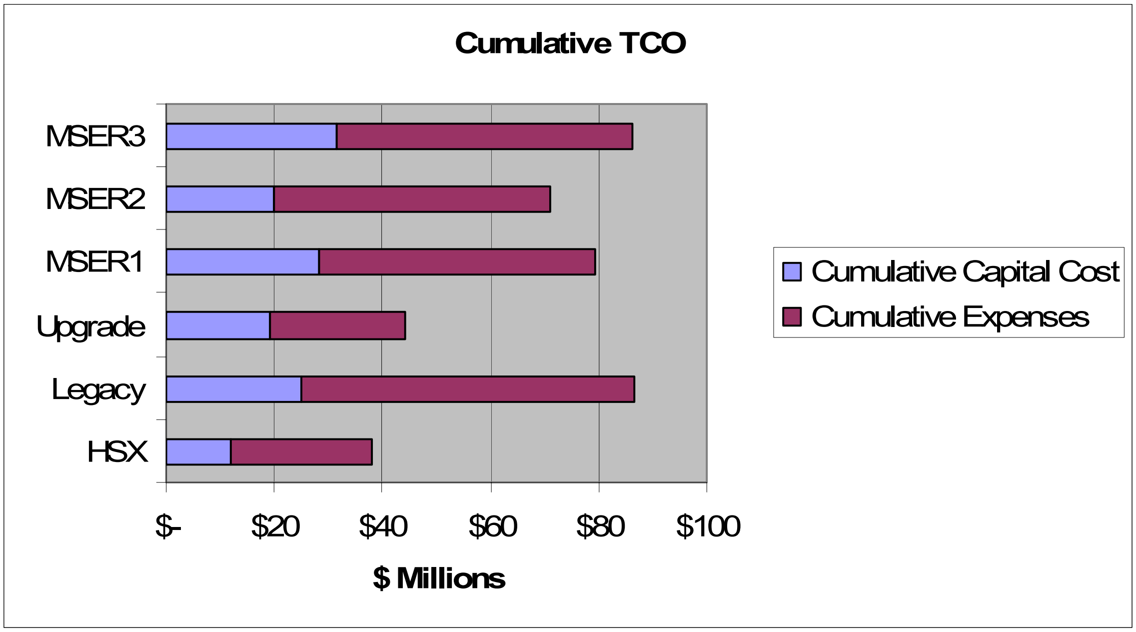

Figure 14

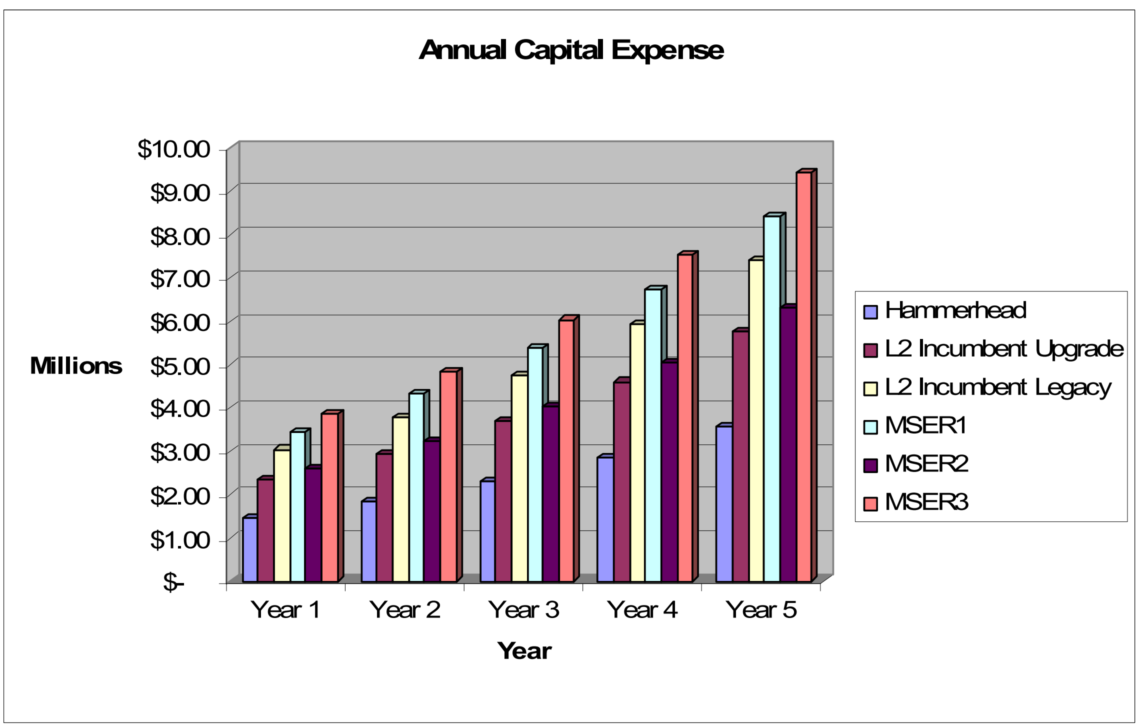

Figure 15

The Business Case for Migration

In the previous sections of this paper our analysis showed that in a *new aggregation* scenario the edge switch architecture is more cost effective then a Layer 3 MSER architecture. This section of the paper presents the business case for *replace and migrate.* In this scenario it is assumed that all the incumbent's (Lucent) legacy switches are replaced with HSX 6000's and that all four services (Frame Relay, ATM, Ethernet, and IP VPN) are supported. A five-year ROI analysis for the Hammerhead migration is presented in Figure 16.

Hammerhead Migration ROI	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Allocated Revenue						
Frame Relay	$ 110,451,120	$ 112,328,789	$ 114,238,379	$ 116,180,431	$ 118,155,498	$ 571,354,218
ATM	$ 11,053,512	$ 10,526,270	$ 10,024,177	$ 9,546,034	$ 9,090,697	$ 50,240,690
Metro Ethernet	$ 7,889,422	$ 9,127,875	$ 10,560,736	$ 12,218,522	$ 14,136,542	$ 53,933,097
IP VPN	$ 6,645,300	$ 13,058,015	$ 25,658,999	$ 50,419,933	$ 99,075,168	$ 194,857,414
Annual Allocated Revenue	**$ 136,039,354**	**$ 145,040,949**	**$ 160,482,291**	**$ 188,364,920**	**$ 240,457,906**	**$ 870,385,419**
Cost of Revenue	$ 95,227,548	$ 101,528,664	$ 112,337,603	$ 131,855,444	$ 168,320,534	$ 609,269,793
Annual Allocated Gross Profit	**$ 40,811,806**	**$ 43,512,285**	**$ 48,144,687**	**$ 56,509,476**	**$ 72,137,372**	**$ 261,115,626**
Cumulative Allocated Gross Profit	**$ 40,811,806**	**$ 84,324,091**	**$ 132,468,778**	**$ 188,978,254**	**$ 261,115,626**	
Capital Cost						
Hammerhead	$ 14,932,500	$ 1,726,612	$ 2,158,266	$ 2,697,832	$ 3,372,290	$ 24,887,500
Edge Router	$ 2,370,000	$ 274,038	$ 342,547	$ 428,184	$ 535,230	$ 3,950,000
MPLS Core Router	$ 3,750,000	$ 433,604	$ 542,005	$ 677,507	$ 846,883	$ 6,250,000
Core ATM Switch	$ -	$ -	$ -	$ -	$ -	$ -
Installation	$ 2,105,250	$ 243,425	$ 304,282	$ 380,352	$ 475,440	$ 3,508,750
Spares	$ 842,100	$ 97,370	$ 121,713	$ 152,141	$ 190,176	$ 1,403,500
Annual Capital Cost	**$ 23,999,850**	**$ 2,775,050**	**$ 3,468,813**	**$ 4,336,016**	**$ 5,420,020**	**$ 39,999,750**
Cumulative Capital Cost	**$ 23,999,850**	**$ 26,774,900**	**$ 30,243,713**	**$ 34,579,730**	**$ 39,999,750**	
Network Operations Expenses						
Capacity Planning	$ 44,708	$ 55,885	$ 69,857	$ 87,321	$ 109,151	$ 366,923
Network Administration	$ 198,235	$ 247,794	$ 309,743	$ 387,178	$ 483,973	$ 1,626,923
Service Provisioning & Configuration	$ 319,496	$ 399,370	$ 499,213	$ 624,016	$ 780,020	$ 2,622,115
NOC Support	$ 1,613,298	$ 2,016,622	$ 2,520,778	$ 3,150,972	$ 3,938,715	$ 13,240,385
Field Support	$ 1,088,185	$ 1,360,231	$ 1,700,289	$ 2,125,362	$ 2,656,702	$ 8,930,769
Environmental	$ 752,751	$ 940,939	$ 1,176,174	$ 1,470,217	$ 1,837,772	$ 6,177,853
Financial Penalties for Flash Cut Outages	$ -	$ -	$ -	$ -	$ -	$ -
EMS Service Migration Expenses	$ 185,000	$ -	$ -	$ -	$ -	$ 185,000
Training	$ 1,607,227	$ -	$ -	$ -	$ -	$ 1,607,227
OSS Service Migration Expenses	$ 5,441,574	$ -	$ -	$ -	$ -	$ 5,441,574
Hardware Support	$ 243,692	$ 304,615	$ 380,769	$ 475,961	$ 594,951	$ 1,999,988
OSS Support	$ 32,639	$ 40,799	$ 50,999	$ 63,748	$ 79,686	$ 267,871
Annual Expenses	**$ 11,526,806**	**$ 5,366,256**	**$ 6,707,820**	**$ 8,384,776**	**$ 10,480,969**	**$ 42,466,628**
Cumulative Expenses	**$ 11,526,806**	**$ 16,893,062**	**$ 23,600,883**	**$ 31,985,658**	**$ 42,466,628**	
Annual Cash Flow	**$ 5,285,150**	**$ 35,370,978**	**$ 37,968,054**	**$ 43,788,684**	**$ 56,236,382**	**$ 178,649,248**
Cumulative Cash Flow	**$ 5,285,150**	**$ 40,656,128**	**$ 78,624,182**	**$ 122,412,866**	**$ 178,649,248**	
Discounted Cash Flows	**$ 5,285,150**	**$ 33,686,646**	**$ 34,438,144**	**$ 37,826,312**	**$ 46,265,811**	**$ 157,502,062**
Cumulative Discounted Cash Flows	**$ 5,285,150**	**$ 38,971,796**	**$ 73,409,940**	**$ 111,236,251**	**$ 157,502,062**	
TCO	**$ 35,526,656**	**$ 8,141,307**	**$ 10,176,633**	**$ 12,720,792**	**$ 15,900,990**	**$ 82,466,378**
ROI ([Revenue-Expenses]/Capital)	**22%**	**152%**	**260%**	**354%**	**447%**	**547%**
NPV	**$ 157,502,062**					
Payback Period in months	**19.67**	**0.00**	**0.00**	**0.00**	**0.00**	

Figure 16

This analysis demonstrates the key financial metrics associated with the Hammerhead capital investment over a five-year period. The revenue assumptions associated with ROI and payback are the same as those discussed earlier, namely 50% of total revenue is allocated to edge equipment. Out of the allocated revenue 30% gross margins are used to calculate the gross profits used to compute ROI, Cash flows, NPV, and payback period. Given these fairly conservative assumptions, our model shows that a service provider can replace incumbent switches and migrate to an IP/MPLS network with a payback period of 19.67 months and an ROI of 547%.

Figure 17 gives a high level view of the business case for migration by presenting ROI and discounted cash flows on the same graph.

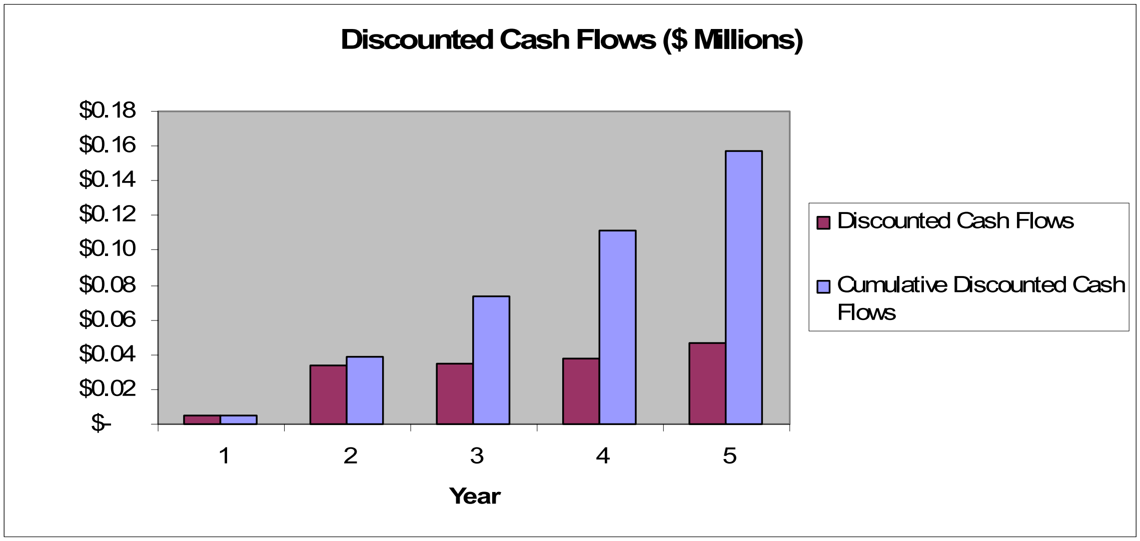

Figure 17

Now that the business case for replace and migrate is established, the alternative solutions are compared. Figure 18 compares each of the alternatives over the five-year interval. In the *replace and migrate* scenario, it is assumed that the Hammerhead HSX 6000, L2 Incumbent Upgrade, MSER1, MSER2, and MSER3 replace all the incumbent L2 Incumbent Legacy switches, connect to both the ATM and IP/MPLS networks, and migrate traffic to the IP/MPLS core network. The Incumbent alternative only adds new switches for *new services*, however, it also migrates PVC's to the IP/MPLS core using ATM trunks to connect to MPLS routers. The key point in this analysis is that ***over the five-year period the capital expense of replacing all L2 Incumbent Legacy's with HSX 6000's is less then the capital expense of keeping L2 Incumbent Legacy's in place and adding new L2 Incumbent Legacy hardware to support new services***. This is ***not*** true of any of the alternative solutions.

Figure 19 compares the five-year cumulative TCO for each of the four alternatives in the *replace and migrate* scenario. The HSX 6000 solution has the lowest CAPEX and OPEX of all the alternatives presented.

	Hammerhead	L2 Incumbent Legacy	L2 Incumbent Upgrade	MSER1	MSER2	MSER3	Assumptions
Allocated Revenue							
Frame Relay	$ 571,354,218	$ 571,354,218	$ 571,354,218	$ 571,354,218	$ 571,354,218	$ 571,354,218	
ATM	$ 50,240,690	$ 50,240,690	$ 50,240,690	$ 50,240,690	$ 50,240,690	$ 50,240,690	
Metro Ethernet	$ 53,933,097	$ 53,933,097	$ 53,933,097	$ 53,933,097	$ 53,933,097	$ 53,933,097	
IP VPN	$ 194,857,414	$ 194,857,414	$ 194,857,414	$ 194,857,414	$ 194,857,414	$ 194,857,414	
Cumlative Allocated Revenue	**$ 870,385,419**	**$ 870,385,419**	**$ 870,385,419**	**$ 870,385,419**	**$ 870,385,419**	**$ 870,385,419**	*50% Allocation*
Cost of Revenue	**$ 609,269,793**	**$ 609,269,793**	**$ 609,269,793**	**$ 609,269,793**	**$ 609,269,793**	**$ 609,269,793**	*30% Gross Margin*
Cumulative Allocated Gross Profit	**$ 261,115,626**	**$ 261,115,626**	**$ 261,115,626**	**$ 261,115,626**	**$ 261,115,626**	**$ 261,115,626**	
Capital Cost							
Hammerhead	$ 24,887,500	$ -	$ -	$ -	$ -	$ -	
L2 Incumbent Legacy	$ -	$ 39,400,000	$ -	$ -	$ -	$ -	
L2 Incumbent Upgrade	$ -	$ -	$ 59,012,000	$ -	$ -	$ -	
MSER1	$ 3,950,000	$ 3,950,000	$ 3,950,000	$ 95,507,500	$ -	$ -	
MSER2					$ 70,011,000	$ -	
MSER3					$ -	$ 83,490,000	
MPLS Core Router	$ 6,250,000	$ 13,900,000	$ 13,900,000	$ 6,250,000	$ 6,250,000	$ 6,250,000	
Core ATM Switch	$ -	$ -	$ -	$ -	$ -	$ -	
Metro Ethernet Edge Switch	$ -	$ 6,480,000	$ 6,480,000	$ -	$ -	$ -	
Installation	$ 3,508,750	$ 6,373,000	$ 8,334,200	$ 10,175,750	$ 7,626,100	$ 8,974,000	
Spares	$ 1,403,500	$ 2,549,200	$ 3,333,680	$ 4,070,300	$ 3,050,440	$ 3,589,600	
Cumulative Capital Cost	**$ 39,999,750**	**$ 72,652,200**	**$ 95,009,880**	**$ 116,003,550**	**$ 86,937,540**	**$ 102,303,600**	
Network Operations Expenses							
Capacity Planning	$ 366,923	$ 953,077	$ 710,769	$ 394,615	$ 657,692	$ 306,923	
Network Administration	$ 1,626,923	$ 3,385,385	$ 2,658,462	$ 5,919,231	$ 9,865,385	$ 4,603,846	
Service Provisioning & Configuration	$ 2,622,115	$ 6,334,615	$ 4,776,923	$ 4,906,731	$ 8,177,885	$ 3,816,346	
NOC Support	$ 13,240,385	$ 31,060,385	$ 23,583,462	$ 29,440,385	$ 49,067,308	$ 22,898,077	
Field Support	$ 8,930,769	$ 21,600,000	$ 16,303,846	$ 16,823,077	$ 28,038,462	$ 13,084,615	
Environmental	$ 6,177,853	$ 18,900,113	$ 12,308,343	$ 11,898,544	$ 19,830,906	$ 9,254,423	
Financial Penalties for Flash Cut Outages	$ -	$ 664,852	$ 664,852	$ 664,852	$ 664,852	$ 664,852	
EMS Service Migration Expenses	$ 185,000	$ -	$ 570,000	$ 570,000	$ 570,000	$ 570,000	
Training	$ 1,607,227	$ -	$ 288,201	$ 1,724,521	$ 2,874,202	$ 1,341,294	
OSS Service Migration Expenses	$ 5,441,574	$ -	$ 1,360,394	$ 1,360,394	$ 1,360,394	$ 5,441,574	
Hardware Support	$ 1,999,988	$ 4,564,200	$ 4,750,494	$ 5,800,178	$ 5,800,178	$ 4,750,494	
OSS Support	$ 267,871	$ 633,335	$ 480,335	$ 574,840	$ 574,840	$ 480,335	
Cumulative Expenses	**$ 42,466,628**	**$ 88,095,961**	**$ 68,456,080**	**$ 80,077,367**	**$ 127,482,102**	**$ 67,212,780**	
Cumulative Cash Flow	**$ 178,649,248**	**$ 100,367,464**	**$ 97,649,666**	**$ 65,034,709**	**$ 46,695,983**	**$ 91,599,246**	
TCO	**$ 82,466,378**	**$ 160,748,161**	**$ 163,465,960**	**$ 196,080,917**	**$ 214,419,642**	**$ 169,516,380**	
ROI ([Revenue-Expenses]/Capital)	**547%**	**238%**	**203%**	**156%**	**154%**	**190%**	

Figure 18

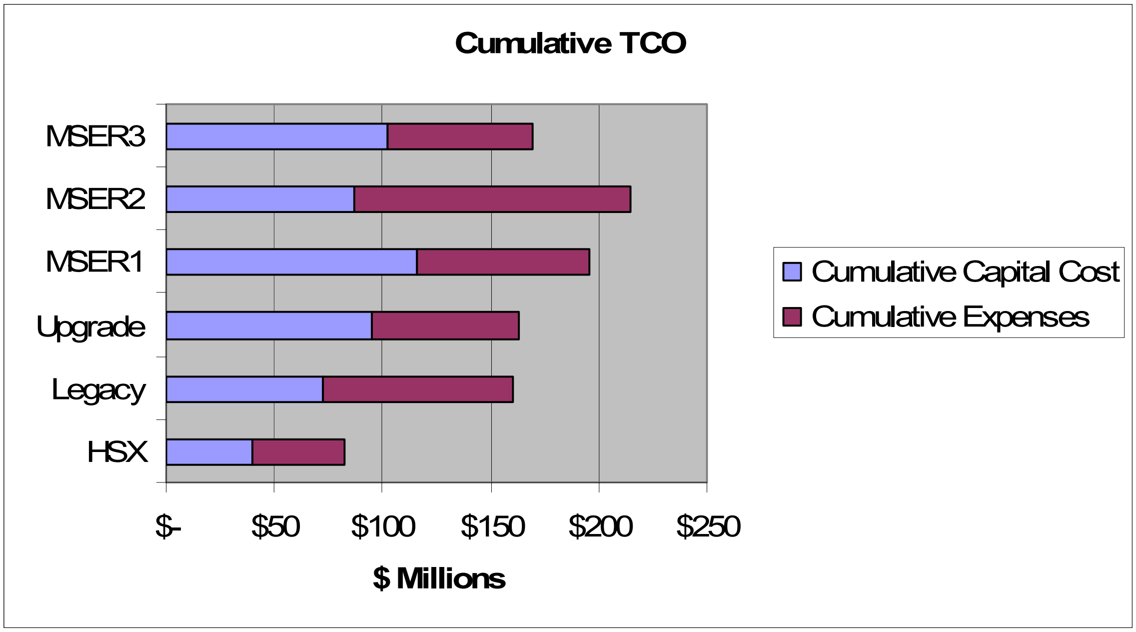

Figure 19

Conclusion

MSER vendors will exert considerable influence over the process of selecting the best approach for Layer 2 migration, given their incumbency within the core IP/MPLS network. However, we believe that service provider network planners will initially balance CAPEX between new platforms and existing multiservice edge switches to achieve risk mitigation (customer SLAs), operational integrity (the incumbents are entrenched within the network management layers) and cost effectiveness.

Based on our analysis contained in the body of this white paper, Network Strategy Partners can definitively reach the following three conclusions:

1) **Using Layer 3 MSERs for edge aggregation is consistently the most capital-intensive (CAPEX) and incurs the highest operating costs (OPEX) for a Service Provider. These conclusions occurred in all scenarios studied.**

2) **The Hammerhead HSX 6000 is the most cost-effective edge aggregation solution – by a very significant margin, for both CAPEX and OPEX -- among the alternatives for all scenarios analyzed in this paper.**

3) **The Hammerhead HSX 6000 TCO is significantly lower than the MSER alternatives in all scenarios analyzed in this paper.**

Based on these results from this white 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 IP VPN traffic to MSERs in the core is the most cost-effective approach to transitioning the network.*

2) *The Layer 2.5 approach provides greater flexibility in access technology choices ("creative access"), significant service differentiation (QoS/CoS) 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 profitability sooner.*

Given the results presented in this paper, Network Strategy Partners can conclusively say that the Layer 2.5 Hammerhead solution is the best economic choice for a Service Provider regardless of its service strategy and regardless of whether a *New Aggregation* or *Replace & Migrate* strategy is adopted.