OpEx Benefits of the Fujitsu Ethernet Tag Switching Implementation of Connection-Oriented Ethernet

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This study was commissioned by Fujitsu Network Communications, Inc.

About Fujitsu Network Communications Inc.

Fujitsu Network Communications Inc. is an innovator in Connection-oriented Ethernet and optical transport technologies, and is a market-leading provider of SONET, WDM, and packet optical networking solutions. Fujitsu enables its customers to migrate to fully converged packet optical networks that improve performance and profitability. Many of the world's largest carriers have deployed Fujitsu network elements across the globe. Fujitsu maintains a longstanding and highly-regarded position as a market leader by providing best-in-class data networking solutions optimized for Ethernet aggregation, transport and service delivery. For more information, please see: http://us.fujitsu.com/telecom .

Executive Summary

Connection-Oriented Ethernet holds great promise for creating a single aggregation and transport metro infrastructure. It provides the flexibility and scalability of Ethernet with the performance, reliability and security of SONET/SDH.

Ethernet tag switching is Fujitsu's branding of an Ethernet-centric implementation of Connection-Oriented Ethernet. Ethernet tag switching is similar to VLAN Tag Switching using IEEE 802.1ad frame format (Q-in-Q). Fujitsu's Ethernet tag switching implementation has solved the Q-in-Q scaling limitation. The OAM (Operations, Administration and Maintenance) standards used in Ethernet tag switching have been in place for many years.

Ethernet tag switching uniquely allows service providers to enjoy deterministic performance, efficient aggregation and 50 ms protection switching capabilities in a manner that is most easy to operationalize in their transport networks:

- Simple, circuit-like Ethernet Virtual Connection (EVC) provisioning
- Management-plane-driven to fit into the existing OSS and operational structure of the metro aggregation network
- Software structure that facilitates simpler software upgrades in the highly distributed metro environment
- SONET/SDH like network protection/restoration
- Minimizes the number of network layers to streamline OSS integration and ongoing management of EVCs
- Integrates directly into next-generation Packet-Optical Transport Systems (P-OTS) to eliminate additional network elements, cabling, and management complexity

MPLS-TP, an MPLS-centric implementation of Connection-Oriented Ethernet, is in the early stages of standardization by the IETF and ITU-T. MPLS-TP's strength, as with MPLS, is multi-service applications. Much of the remaining MPLS-TP standardization work is in the OAM area. The IETF is focusing on an MPLS-centric approach for MPLS-TP OAM. The ITU-T is focusing on using an Ethernet-centric approach that is used by all other Carrier Ethernet implementations including Ethernet tag switching, PBB-TE, Provider Backbone Bridging (PBB) and Provider Bridging (Q-in-Q). Because of these differences in approaches, there will be two incompatible standards for OAM for MPLS-TP.

This paper compares the operational expenses on transport platforms of a typical Connection-Oriented Ethernet network implemented using Ethernet tag switching versus one using MPLS-TP. The Ethernet tag switching implementation is shown to be 32% lower cost over five years than the MPLS-TP implementation of Connection-Oriented Ethernet. Most of the savings occur in the first three years because Ethernet OAM procedures are well established and standardized while those for MPLS-TP are not yet complete and MPLS itself is not well understood or used within service provider transport/transmission organizations.

Introduction

Transport networks must be highly scalable and packet-centric to flexibly and cost effectively meet the requirements of services and applications including:

- Metro Ethernet aggregation for handoff to service edge networks including Internet, Video, Telephony, Storage, Cloud services and the MPLS core
- Mobile and broadband backhaul
- Commercial business Ethernet services
- High availability and high security applications

It also is necessary that the transition to highly scalable and packet-centric transport be made in a way that does not compromise the quality and operational efficiency of existing SONET/SDH metro transport networks. In particular network operations procedures should be similar to those used on existing SONET/SDH networks and smooth for operations personnel who are trained in SONET/SDH technology.

Connection-Oriented Ethernet on packet optical transport platforms meets these requirements by combining the packet capabilities of Ethernet with the transport capabilities of SONET/SDH. Specific Ethernet capabilities include:

- Layer 2 aggregation
- Statistical multiplexing
- Flexible bandwidth granularity
- Cost effectiveness

Specific SONET/SDH capabilities include:

- Deterministic and precise QoS
- Bandwidth reserved per STS/STM (Synchronous Transport Signal/Synchronous Transport Module)
- 99.999% availability
- Highest security (like a Layer 1 service)

Ethernet tag switching is an Ethernet-centric implementation of Connection-Oriented Ethernet that is optimized for Ethernet/IP service delivery and transport. It is explicitly designed to simplify OAM and reuse existing Carrier Ethernet standards especially the service OAM so as leverage the procedures and knowledge of transport operations personnel and there by minimize OpEx.

MPLS-TP is an emerging set of standards for an MPLS-centric implementation of Connection-Oriented Ethernet and is optimized for multi-service transport. Due to its focus on multi-service transport—versus Ethernet only—it has both Ethernet and MPLS OAM layers and is more complex than the Ethernet tag switching implementation of Connection-Oriented Ethernet. This results in additional, unnecessary OAM complexity for transporting Ethernet and IP services when compared to the Ethernet Tag Switching implementation of Connection-Oriented Ethernet. MPLS-

TP standards are not complete, particularly in the OAM area. There also is disagreement between the ITU-T and IETF regarding OAM standardization. This directly affects operations expense (OpEx).

This paper analyzes the OpEx categories affected by the approach to Connection-Oriented Ethernet implementation. The categories are:

- **OSS System Integration and Software**: Systems integration activities and associated software expense required to link Connection Oriented Ethernet systems with the service provider's OSS (Operations Support Systems).
- **Network Management Equipment and Software**: License fees for network management software and the cost of network management equipment—primarily servers—used to operate the network management software.
- **Training**: Labor charges tied to the number of hours per year NOC (Network Operations Center) and field-service personnel spend in attending training sessions on Connection Oriented Ethernet technologies.
- **Testing and Certification Operations**: The number of hours NOC personnel spend annually on testing and certifying all new Connection Oriented Ethernet hardware and software releases before they are released into the network.
- **Network Care**: The NOC activities associated with managing a transport network including fault management, performance management, and configuration management.
- **Network Upgrades and Patches**: The process of adding software patches and upgrades to the Connection Oriented Ethernet transport network.

An OpEx model is used to compare OpEx for Ethernet tag switching versus MPLS-TP. The general assumptions and those specific to each OpEx category are discussed in the following section. The whitepaper then summarizes the OpEx results and presents conclusions.

OpEx Model Assumptions

The following sections present general OpEx modeling assumptions and those specific to each OpEx category.

General Assumptions

This model uses a bottom-up approach to calculating OpEx using estimates for the hours required for different types of labor to carry out specific tasks. Three categories of labor are considered in this model:

- **Hands-on-Technician**: Technicians working in Central Offices doing physical equipment configuration and maintenance. This includes cabling, replacing cards, and maintaining facilities.
- **Tier 1 Engineer**: First level engineers working in Network Operations Centers and Central Offices. These engineers work on software configuration, provisioning, and first level fault management activities.

- **Tier 2 Engineer**: Advanced engineers working in Network Operations Centers. These engineers work on software configuration, performance management, and escalated fault management activities.

Operation and management of the transport network is often separated from operation and management of the router network. The three largest network operators in the U.S., for example, maintain transport or transmission organizational entities that are distinctly separate from their router organizations. NTT in Japan does so as well. Some operators in Europe go so far as to maintain a subsidiary transmissions company. The transport and routing organizations require different technical skills, training and certifications. More technical training and certifications are required for managing routers than transport equipment in most cases. MPLS technology due to its multiservice and multi-layer capabilities is a more sophisticated and complex technology, and requires higher levels of training and multiple technical certifications. For that reason many service providers maintain higher pay scales for technicians and engineers with MPLS training and certifications. In contrast, training and understanding of Ethernet is a base-level requirement for most technicians and engineers. Therefore, higher labor rates are defined for personnel with MPLS expertise than for personnel with Ethernet expertise[1]. This is reflected in Table 1.

Labor Tier	Loaded Labor Rates ($/hour)	
	Ethernet Tag Switching	MPLS-TP
Hands-on Technician	$ 30	$ 40
Tier 1 Engineer	$ 60	$ 80
Tier 2 Engineer	$ 90	$ 120
Labor Inflation Rate	3%	

Table 1.   Fully loaded labor rates for three tiers of technicians and engineers

Most of the OpEx calculations are made by assigning the number of hours required for each labor tier on a per transport system chassis basis. Total expense is then found by pricing out the hours using the unit labor costs shown in Table 1 and then multiplying by the number of transport systems chassis in service for a given year. In this study it is assumed that there are 100 transport systems in the transport network with an annual growth rate of 15%.

OSS System Integration and Software Expense

The processes and procedures used by service providers for managing transport networks are tightly coupled to OSS systems. New transport technologies require OSS software enhancements and system integration. Ethernet is well established in most networking organizations so OSS integration expenses will be modest. MPLS-TP standards are not yet fixed and MPLS itself will be entirely new in most transport organizations. Consequently the introduction of MPLS-TP to the transport systems operation will require substantial OSS systems integration and software deployment. Ethernet tag switching, therefore, requires less OSS integration expense than MPLS-TP.

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[1] Labor rates are Network Strategy Partners' estimates based on its work for service providers.

There are multiple stages of work required to integrate a new system into a service provider's OSS. The stages of work are:

- **Business Process Design**: In this first step the fundamental business processes used to operate and maintain the network are defined and documented.
- **OSS Software Specification**: After the business processes have been defined, functional and design specifications are written for the OSS software enhancements.
- **OSS Software Coding**: After the software specifications are reviewed and accepted then the software enhancements to the OSS are coded.
- **OSS Software Test and Integration**: After the software is coded it must be integrated and tested in the overall OSS system.

The assumptions used in this model for the OSS integration labor hours are depicted in Table 2. The data was collected by Network Strategy Partners from experienced OSS system integration practitioners. Most OSS system integration work requires Tier 2 labor because business process design, software specification, and coding are done by Tier 2 level engineers. However, testing is carried out with a combination of Tier 1 and Tier 2 engineers.

OSS System Integration and Software - For entire network	Ethernet Tag Switching (Labor Hours)			MPLS-TP (Labor Hours)		
	Hands-on	Tier 1	Tier 2	Hands-on	Tier 1	Tier 2
Business Process Design	-	-	5,600	-	-	8,400
OSS Software Specification	-	-	1,400	-	-	2,100
OSS Software Coding	-	-	5,600	-	-	8,400
OSS Software Test and Integration	-	2,800	2,800	-	4,200	4,200

Table 2.   Labor hours required for OSS System Integration and Software Expense

Total OSS integration and software expense is compared for Ethernet tag switching and MPLS-TP in Figure 1. All OSS expenses are incurred in Year 1 of the analysis.
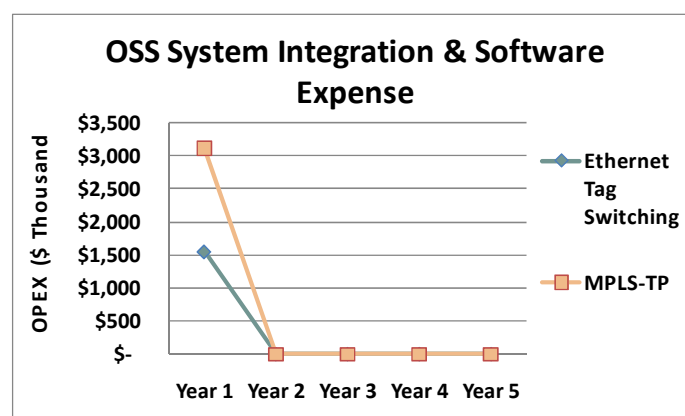

Figure 1.   OSS Integration and Test Expense comparison of Ethernet tag switching and MPLS-TP

Network Management Equipment and Software

Network management equipment and software expense includes the license fees for network management software and the cost of network management equipment—primarily servers—used to operate the network management software. License fees include an initial fee to install the software and a recurring fee that covers the cost of keeping the management software up-to-date. Software pricing includes a fixed fee and a charge for each network element under management.

Ethernet Element Management System (EMS) software is mature and widely deployed. It is nearly a commodity and therefore moderately priced[2]. EMS software for MPLS-TP is evolving because the standards are not yet in place. There is a very small market for MPLS-TP EMS, furthermore, as compared to Ethernet EMS, and MPLS-TP management is more complex than Ethernet management. MPLS-TP management software's small market, immaturity, and complexity as compared to Ethernet make fees for MPLS-TP EMS higher than Ethernet EMS. Figure 2 compares network management equipment and software expense for Ethernet tag switching and MPLS-TP.
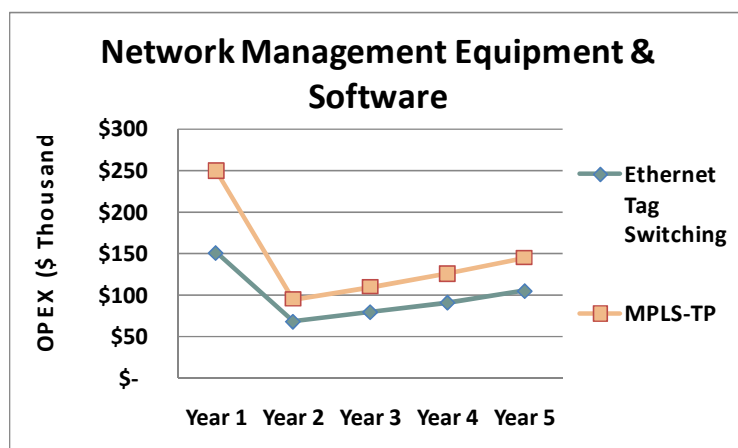

Figure 2.   Network Management Equipment and Software Expense comparison of Ethernet tag switching and MPLS-TP

Network management equipment and software expenses are higher for both technologies in the first year of operations and lower for subsequent years. Expense gradually increases in years 2 through 5 as additional network elements are added to the network.

Training

Training expense is calculated by projecting the number of hours of training per year required for each technology and labor classification and then multiplying each category by it corresponding hourly labor rate. More training is required in the first year of network deployment than in subsequent years. Table 3 shows the training hour projections and the percentage of hours of training required in years 2 through 5 as compared to year 1[3].

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[2] Software license fees were provided by Fujitsu.

[3] The estimates of training hours required are derived from interviews of NOC personnel by Network Strategy Partners. They also are derived from discussions with Network Strategy Partners' clients during construction of many TCO and ROI models—see whitepapers at www.nspllc.com for publicly available models.

Training	Ethernet Tag Switching			MPLS-TP		
	Hands-on	Tier 1	Tier 2	Hands-on	Tier 1	Tier 2
Number of People trained	20	10	5	20	10	5
Per Person Hours of Training Year 1	50	40	40	70	60	60
Total Hours of Training in Year 1 (Calculated)	1,000	400	200	1,400	600	300
Year N training vs Year 1 training	50%	50%	50%	70%	70%	70%
Total Hours of Training in Year 2-5 (Calculated)	500	200	100	980	420	210

Table 3.   Labor hours required for training for Ethernet tag switching and MPLS-TP

Fewer training hours are required for Ethernet tag switching than MPLS-TP because most transport organizations are already experienced with Ethernet while everyone will need MPLS-TP training once its standards are complete. In addition, MPLS-TP has more features and complexity than Ethernet and will require more training time. In addition, more follow-on training will be required for MPLS-TP for the next several years until the standards are completed[4].
Figure 3 shows training expenses for Ethernet tag switching and MPLS-TP over the next five years.

Figure 3.   Training Expense comparison of Ethernet tag switching and MPLS-TP

The figure shows substantially higher training expenses for MPLS-TP for the first three years. MPLS-TP training expenses, however, will reach parity with Ethernet tag switching expenses by year 4. Both technologies will be equally well understood and stable by then and little or no difference in the cost of ongoing training will exist.

Testing and Certification Operations

All new hardware and software releases must go through a testing and certification process before being released into the network. Service providers already have trained engineers, acquired test equipment, created test automation, and regression testing for Ethernet. MPLS-TP is new and any

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[4] Lack of agreement between the ITU-T and IETF could delay this standardization even longer.

deployments that exist today are pre-standardization implementations. In those service providers where transport operations are separate from routing operations MPLS experience of any kind is unlikely to exist in the transport organization. This will make MPLS-TP testing and certification operations more expensive than Ethernet tag switching operations for the next several years. Once the MPLS-TP standards are completed and the necessary training, test environment and testing procedures are established there should no longer be a large cost difference between Ethernet tag switching testing and certification expense and that of MPLS-TP.

The default assumptions for testing and certification are presented in Table 4[5]. There are three primary functions:

- Test case development – writing the test cases
- Test case automation – automating the test cases with automated testing tools
- Executing the test cases

Test case development and automation are carried out by Tier 2 labor. Test case execution is carried out by Tier 1 labor. It is assumed that two major releases per year are deployed in the network.

Test & Certification	Ethernet Tag Switching (hours per			MPLS-TP (hours per release)		
	Hands-on	Tier 1	Tier 2	Hands-on	Tier 1	Tier 2
Test case development	0	0	600	0	0	700
Test case automation	0	0	200	0	0	300
Test case execution	0	800	0	900	625	0

Table 4.   Labor hours required for Test and Certification for Ethernet tag switching and MPLS-TP

The five-year test and certification expenses for Ethernet tag switching and MPLS-TP are compared in Figure 4. Test and certification expenses are on-going expenses because two new releases are deployed in the network each year.
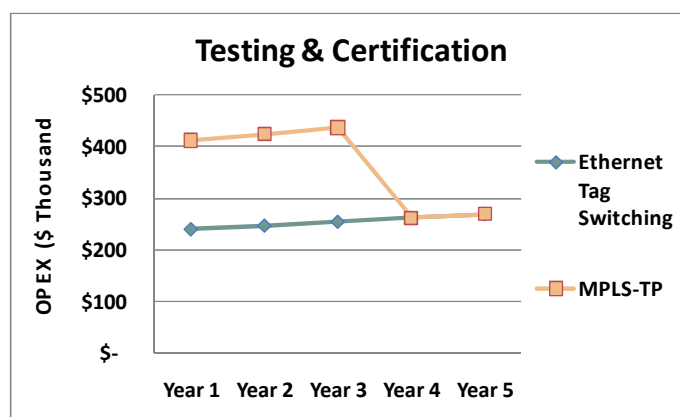

Figure 4.   Testing and Certification Expense comparison of Ethernet tag switching and MPLS-TP

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[5] Labor hours required for testing and certification were obtained through interviews of test lab staff by Network Strategy Partners, development of OpEx expense models by Network Strategy Partners for many clients, and a survey of the quality and operational issues for Next Generation networks in North America by Network Strategy Partners.

The figure shows substantially higher cost for testing and certification of MPLS-TP as compared to Ethernet tag switching in the first three years. This is caused by the need to establish new testing procedures for MPLS-TP and expected changes to its standards as final details are resolved. By the fourth year no difference in testing and certification expense is anticipated.

Network Care

This category includes most of the NOC activities associated with managing a transport network. This includes provisioning, configuration management, fault management, and performance management.

The main functions of network care are:

- Configuration management
- Fault management
- Performance management

MPLS-TP network care expenses will be higher than those of Ethernet tag switching for the next several years. Many NOCs already manage switched Ethernet networks, MPLS-TP standards are not yet firm, and MPLS is inherently more complex than Ethernet

Configuration management should require more time for MPLS-TP than for Ethernet tag switching because there is more to configure under MPLS than in Ethernet. No labor hour difference is expected in the fault management function. More hours are required for MPLS-TP performance management than for Ethernet tag switching during the first several years because MPLS-TP performance management standards are being created now. Labor hours for network care are presented in Table 5[6].

	Ethernet Tag Switching (Hours per Chassis per Year)			MPLS-TP (Hours per Chassis per Year)		
Network Care	Hands-on	Tier 1	Tier 2	Hands-on	Tier 1	Tier 2
Configuration Mgt	1	30	10	2	35	12
Fault Mgt	4	5	20	4	5	20
Performance Mgt	0	5	10	0	7	12

Table 5.   Labor hours required for Network Care for Ethernet tag switching and MPLS-TP

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[6] Estimates developed by Network Strategy Partners derived from discussions with NOC personnel operating in the Pacific Rim and North America.

A comparison of the total operational expenses for network care is presented in Figure 5
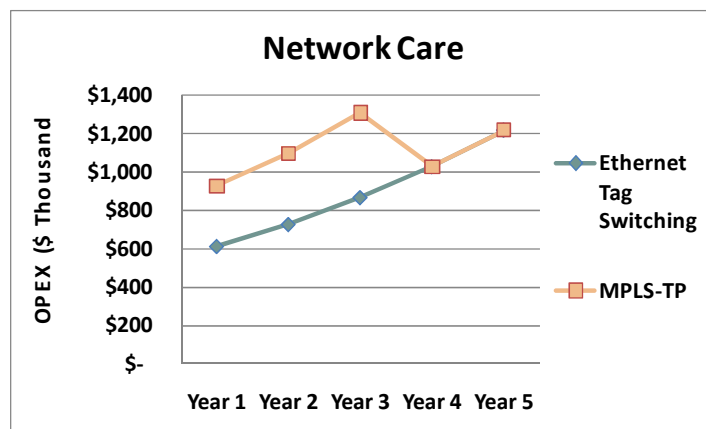

Figure 5.   Network Care Expense comparison of Ethernet tag switching and MPLS-TP

The figure shows that network care expenses are higher for MPLS-TP during the first three years. This is caused by the extra work required to configure an MPLS-TP network and to work created by the need to adapt network care procedures while MPLS-TP standards move to their final form. By the fourth year no difference in network care expenses for the two technologies is expected. Network care expense, however, should steadily increase as more transport equipment is added to a growing network.

Network Upgrades and Patches

All network technologies are continuously evolving as new capabilities are added to IP networks and as changes are made to cope with performance issues and new security threats. Consequently network upgrades and patches are frequently required. Four releases per year of upgrades and patches are projected for Ethernet tag switching and six rounds for MPLS-TP. More upgrades and patches are expected for MPLS-TP in the first three years due the large amount of unfinished standards activity. Despite the number of patches and upgrades released by network equipment vendors, service providers typically group them into one or two annual maintenance periods to reduce network downtime and to increase network stability.
Over the first three years MPLS-TP upgrades and patches should require more hours of work because changes will more extensive and the network operations staff will need more time to work with the new technology.

Table 6 shows the hours required for each upgrade or patch[7].

	Ethernet Tag Switching (Labor Hours per Upgrade or Patch per Chassis)			MPLS-TP (Labor Hours per Upgrade or Patch per Chassis)		
Network Upgrades & Patches	Hands-on	Tier 1	Tier 2	Hands-on	Tier 1	Tier 2
Network Upgrade or Patch	0	1	2	0	2	3

Table 6.   Network Upgrade and Patch hours per upgrade of patch for Ethernet tag switching and MPLS-TP

Figure 6 shows the network upgrades and patches expense comparison over five years.
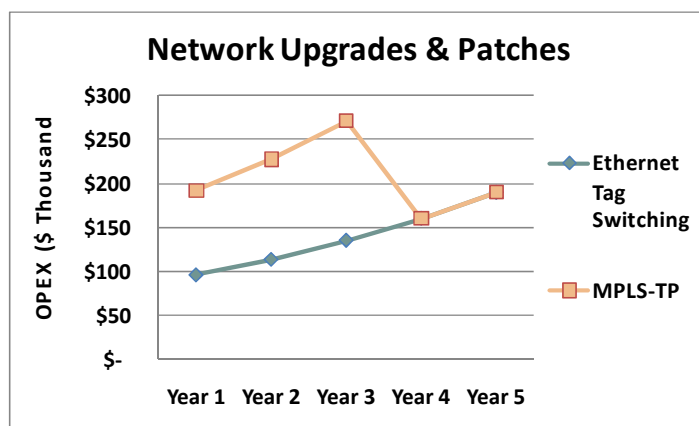

Figure 6.   Network Upgrade and Patch Expense comparison of Ethernet tag switching and MPLS-TP

Though there is substantially higher network upgrade and patch expense for MPLS-TP in the first three years no difference in expenses is expected after this initial adoption period. Network upgrade and patch expenses increase continuously as the network grows in size.

OpEx Comparison Results

The OpEx analysis shows that the Ethernet tag switching implementation has 32% lower OpEx than the MPLS-TP implementation.

Figure 7 compares the operational expense (OpEx) cost elements over a five-year study period for the typical network used in this study.

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[7] Estimates are derived from a Network Strategy Partners survey of operations staff located in the U.S. concerning quality issues in Next Gen Networks. Frequent patches are a major quality concern.
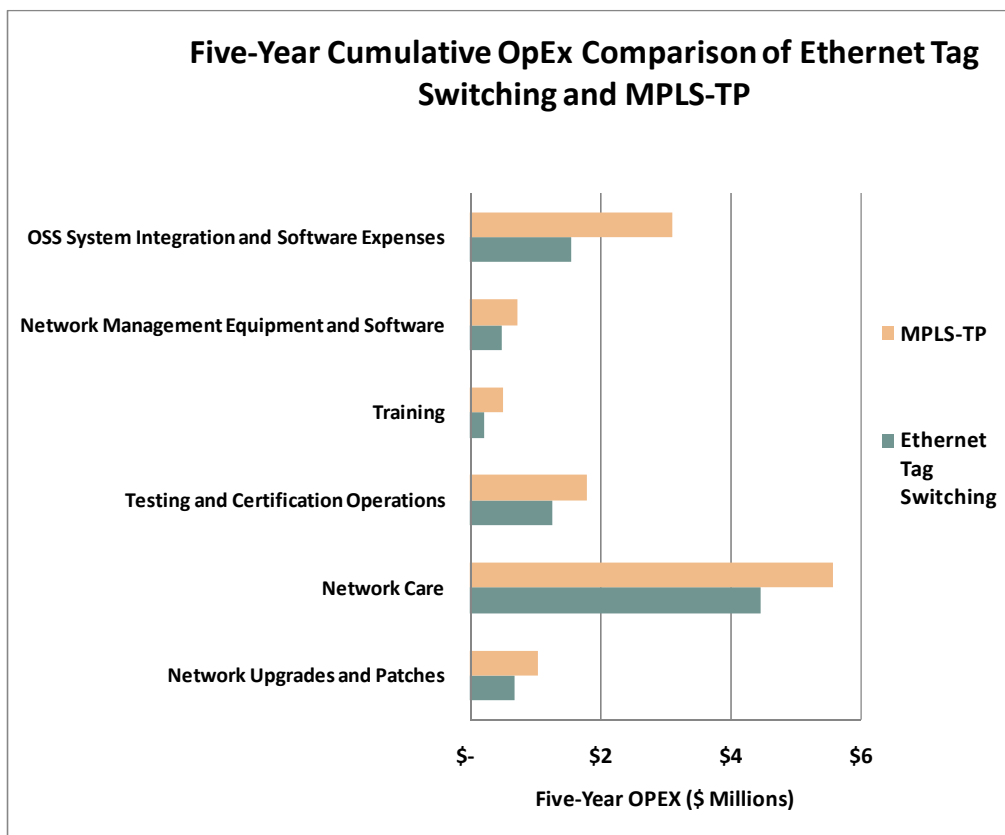
Figure 7.   Percentage of savings comparison of Ethernet tag switching and MPLS-TP

The figure shows that Ethernet tag switching has lower OpEx over five years than MPLS-TP in all categories. The biggest savings is realized in the OSS System Integration and Software expense category. Large service providers employ highly sophisticated OSS systems so as to reduce OpEx, improve their service response times and to leverage the operations staff. The interfaces between the network and associated network element management systems and the OSS itself are complex and highly refined from long use. The introduction of a new network element or change in the associated network element management systems disrupts these interfaces and requires major systems integration efforts. Consequently Ethernet tag switching has a much smaller impact on OSS Systems Integration and Software expense than MPLS-TP because Ethernet is already known and used by the transport organization. Completion of system integration efforts for MPLS-TP will be delayed until its standards are in place.

Network care expense has the second highest difference between Ethernet tag switching and MPLS-TP. Expense is higher for MPLS-TP because it will take several years for network operations personnel to fully refine their MPLS-TP network care procedures.
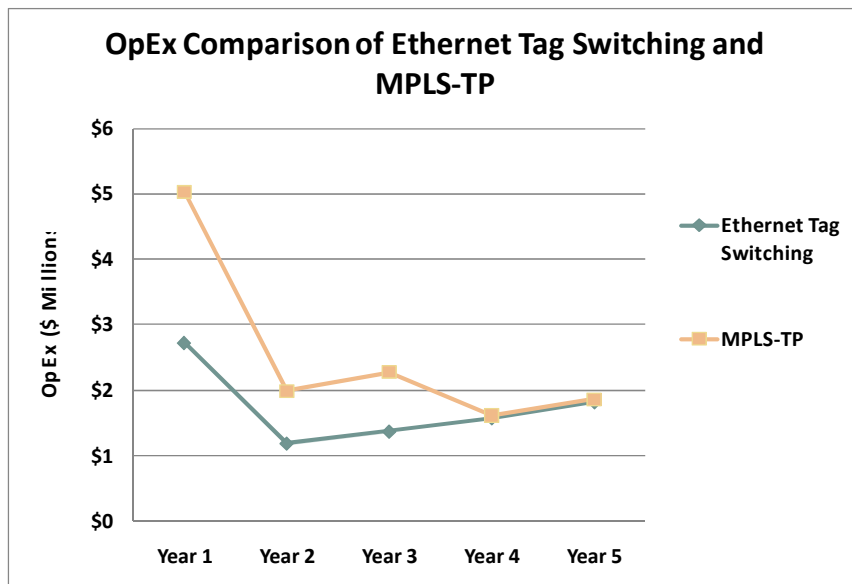
Figure 8. Five year summary of OpEx for Ethernet tag switching and MPLS-TP

Figure 8 shows that most of the OpEx savings occur in the first three years because Ethernet OAM procedures are well established while those for MPLS-TP are not yet complete. The OpEx difference between Ethernet tag switching and MPLS-TP will no longer be significant once the MPLS-TP standards are sufficiently complete and transport organizations are trained on its use and have testing and other network operations procedures in place.

Conclusion

Ethernet tag switching is Fujitsu's branding of an Ethernet-centric implementation of Connection-Oriented Ethernet. It was explicitly designed to simplify OAM and reuse existing Carrier Ethernet standards, especially in the area of service OAM, and leverage the procedures and knowledge of transport operations personnel to minimize OpEx.

MPLS-TP, an MPLS-centric implementation of Connection-Oriented Ethernet, is in the early stages of standardization by the IETF and ITU-T. Due to its focus on multi-service transport—versus Ethernet only—it has three OAM layers and is more complex than the Ethernet tag switching implementation of Connection-Oriented Ethernet. MPLS-TP standards are not complete, particularly in the OAM area.

An OpEx model is used to compare the OpEx of Ethernet tag switching versus MPLS-TP for a typical metro transport network. The Ethernet tag switching implementation is shown to be 32% lower cost than the MPLS-TP implementation of Connection-Oriented Ethernet. Most of the savings occur in the first three years because Ethernet OAM procedures are well established while those for MPLS-TP are not yet complete and MPLS itself is not well understood or used within service provider transport/transmission organizations.

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