Capital and Operational Economic Benefits of MSA Pluggable Transceivers with Integrated OTN OAM and FEC

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1. Abstract

This paper, using a simple reference network, demonstrates how a carrier can save operational and capital expenses, by completely eliminating DWDM transponders in the network. Most of today's optical transport networks are built using transponders that maps a client short reach signal from an IP router or an Ethernet switch into a DWDM wavelength, suitable for transport on a ROADM based DWDM network. A transponder performs two main functions. One, to create a tightly spaced optical wavelength with ITU-Grid specification and two, to provide ITU-T based end to end, optical performance and monitoring capability. It is conceivable that a module, which can be directly plugged on to switch/router and that can perform both of the above functions, will add immense value to the network operators. The economic value of such a proposition is demonstrated in this paper.

2. Introduction

ITU-T defines **Optical Transport Network (OTN)** [1] as a set of Optical Network Elements connected by optical fiber links, able to provide functionality of transport, multiplexing, switching, optical link management, supervision and survivability of optical channels carrying client signals. OTN relies on ITU-T the G.709 digital wrapper specification to transparently encapsulate client signals and provide complete optical OAM&P capabilities. OTN also provides the additional benefit of Forward Error Correction (FEC) to boost the network optical performance by at least a factor of 4 (6dB coding gain).

Today, most of the client interfaces, such as router ports, generate native, short reach signals which must be adapted into DWDM wavelength before being transported, across the network. This adaptation is done by transponders in one of two ways: using either SONET/SDH or OTN as the transport mechanism. SONET/SDH based transponders maps the Ethernet payload via GFP/LCAS into SONET frames at considerable complexity and cost. More importantly, because of the limited payload bandwidth of SONET, especially at 10 Gbps where the 10.3 Gbps Ethernet payload must be throttled down and have its inter-packet gap frames removed to accommodate the 9.96 Gbps SONET payload, all Ethernet transparency is lost at considerable cost to the carriers to provide Ethernet services. OTN based transponders transparently wrap the Ethernet payload into a G.709 OTN frame. Transponders do, however, add substantial increase in the network operational and capital expenses; and in the case of SONET based transponders, traffic transparency is further compromised.

The ideal solution is to have the switch/router generate optical signal that can be directly transported on a WDM platform, thus eliminating the extra layer provided by the DWDM transponder. In order to make such proposition viable, the switch/router optical transceivers must meet two fundamental criteria:

1. Provide carrier-grade transport specific performance monitoring functions such as fault alarming and isolation, maintenance signaling and loopback conditions for network troubleshooting
2. Provide the necessary high grade optical performance to meet the network transport loss and other impairments budget.

ITU-T OTN as described above meets both criteria with the added benefits of transporting Ethernet traffic transparently. OTN enabled interfaces support a common set of alarming and maintenance functions, which surpasses SONET capabilities, without compromising on Ethernet transparency or payload throughput.

Since a typical switch router has a multitude of ports per line card, the cards must be designed to be flexible, to ensure a low initial first cost and incremental upgrade costs until the full line card capacity is reached. As a corollary, inventory management and cost becomes extremely undesirable, thus leading router vendors today to select modular MSA pluggable optical interfaces instead of fixed optics. This will enable the development team to design and develop one card which can accommodate any pluggable transmit/receiver, at any desired reach, performance or wavelength.

Lastly the DWDM optical interface from the router port must be suitable for long distance DWDM transmission by operating at a low OSNR rate to overcome the noise from optical amplifiers. SONET/SDH encoded transport networks do not have Forward Error Correction, which limit their OSNR and thus transmission distance. On the other hand, G.709 and G.975 defines Forward Error Correction protocols to provide >8.5dB extra coding gain for transmission reach over thousands of kilometers.

Now, the only remaining factor is to establish a clear business case accounting for the cost of deploying such a solution. The remainder of this paper is dedicated to evaluating the economic value proposition of a pluggable module with integrated OTN, FEC and DWDM.

3. Network Model and Assumption

This section will describe the architecture used for the analysis along with all relevant assumptions. It should be noted that this paper does not provide the analysis steps or the network equipment count, but simply report the results and conclusions.

3.1. Architecture Alternatives

The present mode of operation is shown in Figure 1, where a transponder is placed between the client system and a DWDM network with either a fixed or reconfigurable optical ADM (ROADM). Figure 2, shows the simpler architecture when the OTN functionalities are integrated into the router via the MSA pluggable transceiver.

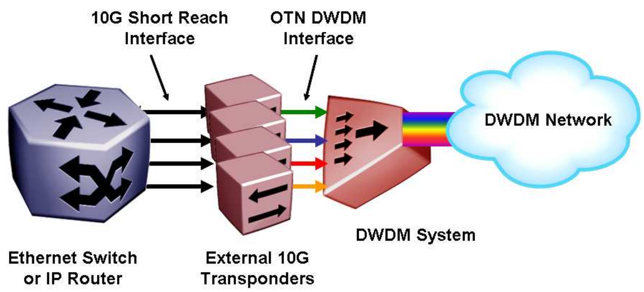

Figure 1: Present Mode of Operation

The client could be an IP router, Ethernet switch (VPLS, ELINE), a multi-service provisioning platform (MSPP), digital cross connect, SAN system, etc., with a typical Short Reach interface. These optical SR interfaces could transport client signals up to 10 km and in some cases up to 80 km but do not provide any of the necessary transport OAM functions described above. In order to be transported across the DWDM transport network it must be converted to an impairment tolerant DWDM optical interface. This function, along with optical performance management and alarming, is performed by the transponder placed between the client and the network.

Alternatively, as shown in Figure 2, a pluggable device can directly be placed on the client, which has all the necessary OTN OAM&P in addition to long reach capability such as FEC and thus can be directly transported on to the WDM ROADM network.

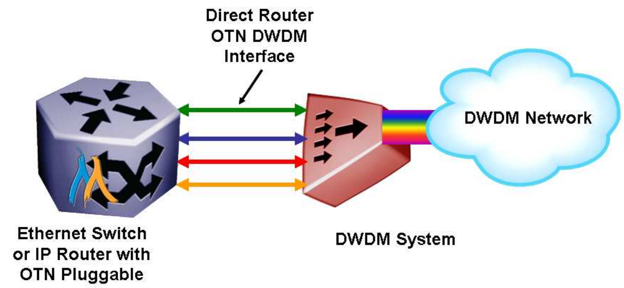

Figure 2: Client with Pluggable Module

3.2. Reference Networks

Figure 3 shows the reference network used for this analysis. It can be seen that the network is a combination of ring and linear systems, and the 10G demand traverses across the network. There are total of nine traffic generating terminals and one amplifier. Though amplifiers do not affect the cost savings at the transponder location, it is included for normalization purpose.

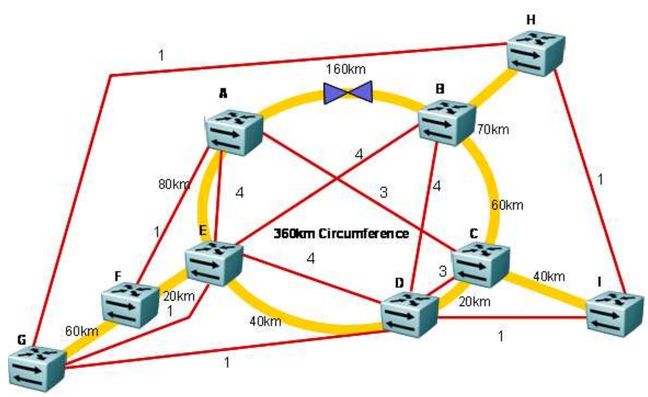

Figure 3: Reference Network

Figure 4 provides the distribution of the 10G demand across the reference network. It should be noted that 45% of the demand traverses greater than 200Kms but over 80% of the demand is under 300Kms.

Although not particularly expansive, this reference network is considered so that a lower bound on the potential savings can be established by eliminating the transponders in networks. Though the economic benefit comes from the nodes, the distance normalizes the overall cost of the network thus projecting a realistic cost structure.

The system design is not elaborated in this paper but it should be noted that the design considers appropriate number of working and protection systems. Some systems are protected as 1:N or 1:1. Regardless, same assumptions are used to compare the two solutions.

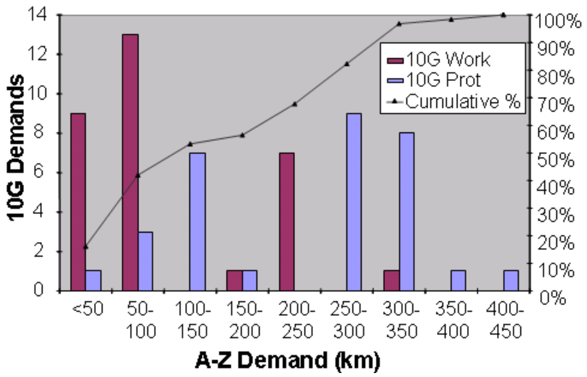

Figure 4: Reference Network

3.3. Impact of Transponder

This section demonstrates the proportion of the transponder cost with respect to the overall transport cost.

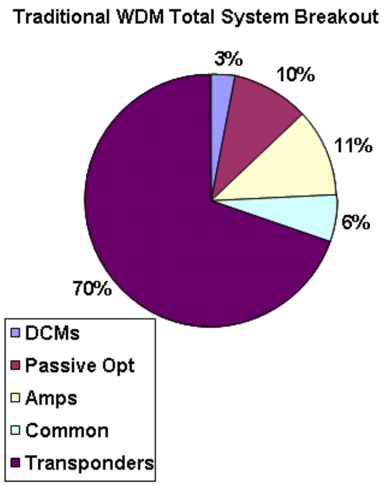

Figure 5: Reference Network

It can be seen that 70% of total transport capital cost is contributed by the transponders. Dispersion Compensation, passive optics at DWDM, amplifiers, interfaces, contribute to the remaining 30%.

3.4. Scope of the Analysis

This analysis focuses on attacking the largest portion of the overall transport cost by eliminating transponders from the network.

The comparison has two parts:

1. Capital Expense (CAPEX) Savings
2. Operations Expense (OPEX) Savings.

CAPEX includes cost of transponders, short reach interfaces on the client, cost of the pluggable long reach modules and common equipment cost.

OPEX captures cost of floor space, power consumption, installation, testing, and commissioning. The following section tabulates the cost assumptions used for the analysis.

3.5. Cost Assumptions

The analysis uses a normalized cost of transponders, amplifiers, dispersion compensation, short reach interfaces and all related common equipment. The same set of cost assumptions are used to compute the cost of network with and without transponders and only the relative merits are reported.

Figure 7 shows a table that summarizes the variables considered in evaluating the operating expenses. The unit price for each of the variable is listed in the table.

These assumptions are applied to all the Reference Networks, in the exact manner.

Parameter	Value
Bay Foot Print sq ft/w aisles	12
Foot Print Real Estate Cost per sq. ft/ year	$75
Electricity (per KWh)	$0.130
Skilled Loaded labor (per hour)	120
Install Loaded Labor (per hour)	75
Shelf Eqpt/Common Install (hrs per shelf)	3
Card Inst and Turn-up (hrs per card)	0.5
Card Inst and Turn-up (hrs per card)	0.75
Client Connection test (hrs per card)	0.75
System Node Turn-up (hrs per node)	1.5
System Node Turn-up (hrs per node)	2
System Node Turn-up (hrs per node)	0.5
Wavelength Commission (hrs per wave)	1

Figure 6: OPEX Cost Assumptions

4. Results

This section summarizes the results of the analysis done using the reference network and the assumptions stated in the previous section.

The following section shows the CAPEX reduction and savings, when using a pluggable module and the next section highlights various operational advantages including the cost savings.

4.1. CAPEX Savings

Figure 7 shows the total equipment cost savings with respect to the present mode of operations. The three groups represent each of the three scenarios and individual value presents the extent of savings.

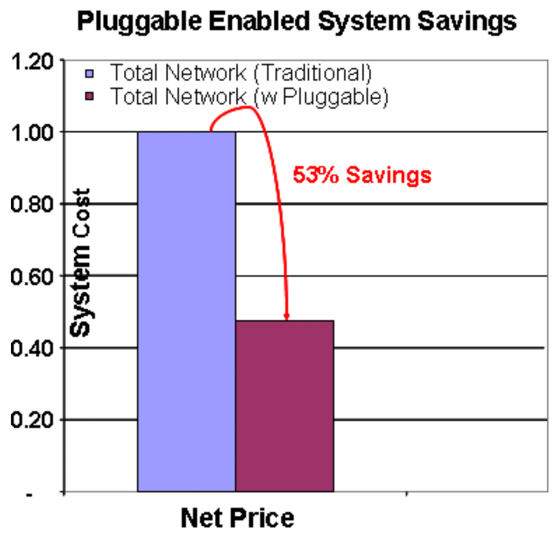

Figure 7: Capital Cost Saving

It can be seen that the there is a 53% reduction in the overall transport cost.

Figure 8 below shows the transport cost breakdown using the pluggable WDM system. It can be seen that the impact of transceiver is reduced to the 40% of the overall transport cost.

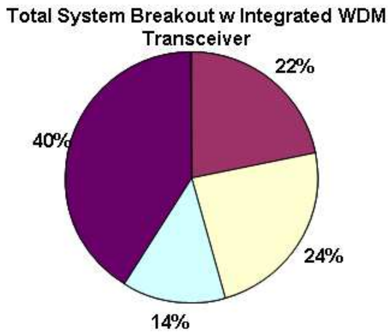

Figure 8: System Cost Breakdown

4.2. OPEX Savings

Operational advantages are captured from the following perspectives:

1. Floor space reduction.
2. Reduced power consumption.
3. Labor cost associated with installation and turn up.
4. Labor cost associated with repairs. If there are more modules and cards, number of repairs will proportionally increase.

Figure 9 shows the comparison of failure rates of the two options i.e. network with transponder and without.

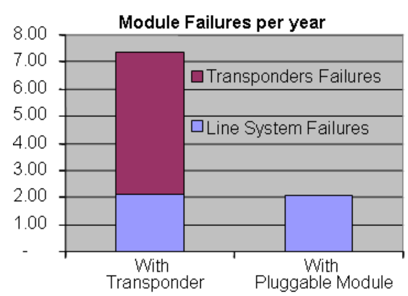

Figure 9: Module Failures

It should be noted that there is a 66% reduction number of module failures, contributing the increase in network availability from .997 to .999. The failure rate reduction results in OPEX savings and is captured in the overall cost savings.

The overall reduction in the number of modules also results in reduction the first installation and commissioning costs. This component is demonstrated in Figure 10 below, showing a 33% reduction in labor costs.

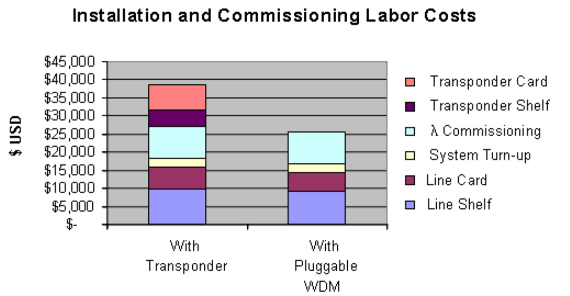

Figure 10: First Installs

Proportionately there is a reduction in power consumption. Figure 11 below, demonstrates a 60% reduction in power consumption. This is taken into account as a recurring cost savings in the overall OPEX savings.

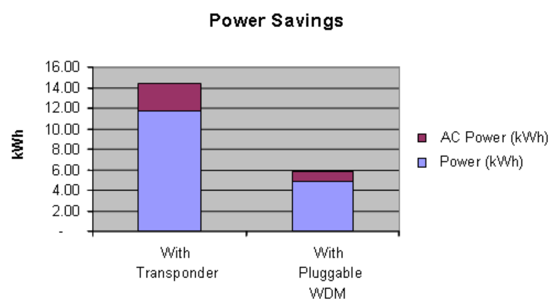

Figure 11: Power Consumption

The following figure combines all of the above factors and presents a comprehensive view of 44% OPEX savings for the first year.

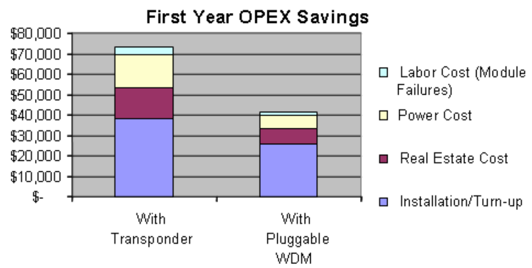

Figure 12: Consolidated First Year Cost

Beyond the first install cost, there is a significant operational savings due to the reduction in recurring costs. A savings of 56% is depicted in the following figure.

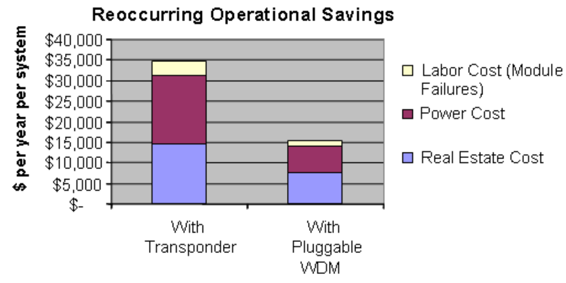

Figure 13: Reoccurring costs

Finally, if this savings is projected over ten years the importance of eliminating the transponder stands out. The following graph demonstrates $4.5M savings in operational costs, just for the fifteen systems considered in the hypothetical network.

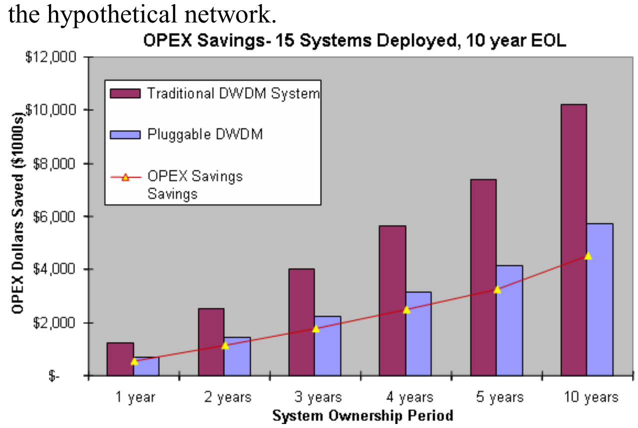

Figure 15: OPEX Savings Over 10 Years

5. Conclusions

It is evident from this analysis that network operators are bound to save tremendously both during the first install as well as on the on going basis. A 50% savings is seen in the CAPEX and about 50 to 60% savings is seen in the OPEX.

Beyond the tangible costs demonstrated there are several intangibles that should make the choice of growing the network with one less network element.

6. References

[1] ITU-T Recommendation G.709 *"Interfaces for the optical transport network (OTN))", G.709/Y.1331 (2003) Amend.1 approved on 2003-12-14*

7. About Menara Networks

Menara Networks develops innovative products and solutions that greatly simplify today's layered optical transport networks. Menara Networks modules and sub-systems enable optical networks with far superior performance and fewer network elements, which translates into simplified networks, faster service turn-up, and significant reduction in the network capital and operational expenditures. Our products allow our OEM customers to unlock the potential of their platforms by offering unique opportunities for expanded addressable markets and faster revenues.