Leveraging Capital Investment by Retrofitting 40Gb/s Wavelengths on Existing 10Gb/s DWDM Systems

R. Saunders and L. Ceuppens
StrataLight Communications Inc., 2105 S. Bascom Avenue, Suite 300, Campbell, CA 95008, USA
Phone: +1/408/961-6259, Fax: +1/408/626-7100, email: ross@stratalight.com

Abstract: Retrofitting 40Gb/s wavelengths multiplies by four times the effectiveness of the remaining capacity on existing DWDM systems. This pushes out the time frame required for overbuilding the network, minimizing the cost of incremental capacity and maximizing a carrier's return on optical transport investment.

OCIS codes: (060.2330) Fiber optics communications; (060.4250) Networks

1. Introduction

When telecom carriers consider the deployment of next-generation long-haul transport technologies there are typically financial requirements for rapid payback and a reduction of network operating costs, both presenting significant network design hurdles. Tight carrier CAPEX spending constraints and a drop in bandwidth demand forecasts [1] resulted in very little field deployment of next-generation technology, such as 10Gb/s ULH. Optical technology advancements over the last few years have focused on providing low incremental cost of bandwidth by increasing reach between regenerators and reducing the cost per bit at high fill rates. However, the upfront cost of deploying a next generation network (i.e. all the line equipment, EDFAs, OADMs, MUX/DEMUXes, DCMs, etc) is significant. This high upfront fixed infrastructure capital investment causes the payback period to be excessively long, particularly in low demand growth scenarios where little capacity is enabled at the outset. As a result, most carriers have continued to add incremental capacity to their installed base of DWDM systems, filling unused channels with more 10Gb/s wavelengths, rather than overbuild with next generation equipment.

At some point, the installed DWDM network infrastructure runs out of unused channel capacity and the carrier will be forced to make a large capital investment and overbuild the network, lighting new fiber to meet new capacity demands. An attractive alternative to sequentially filling unused 10Gb/s channel slots with 10Gb/s wavelengths on existing DWDM systems is to fill unused channels with 40Gb/s wavelengths, deferring the point in time at which new overbuilds would be needed, reducing capital spending and greatly reducing the cost of incremental capacity by avoiding high fixed infrastructure costs [2,3,4]. By installing 40Gb/s wavelengths directly into the existing 10Gb/s DWDM optical MUX/DEMUX ports the remaining unlit capacity is leveraged fourfold. This can significantly postpone the time at which the carrier is forced to overbuild the network.

To make the most out of the installed transport infrastructure (in many cases systems with a high number of unlit wavelengths), the new technology deployed at the terminal sites should be designed to interoperate with the existing DWDM system, without the need for any line system (fixed infrastructure) upgrade. In essence, not just the optical fiber but the entire DWDM system (including mux/demux filters, EDFAs, OADMs, DCMs and transmission fiber) should be thought of as a transparent optical pipe capable of carrying an arbitrary mix of 10Gb/s and 40Gb/s wavelengths simultaneously. In this manner, next generation line cards can simply be connected into the mux/demux filter ports at the terminal/OADM sites. This concept is shown in Fig.1.

The benefits of retrofitting 40Gb/s wavelengths to existing 10Gb/s DWDM systems can be summarized as:

1. Increase capacity of installed transport system with minimal disruption to the network; the cost of incremental scales linearly with the need for the new capacity (variable cost);
2. Defer capital investment in new DWDM overbuilds;
3. Support new services, e.g. OC-768c IP router interconnection;
4. Reduce operational expenses (fewer wavelengths to turn-up and maintain, reduced space and power);
5. Capital preservation, increase the useful lifetime of existing DWDM system.

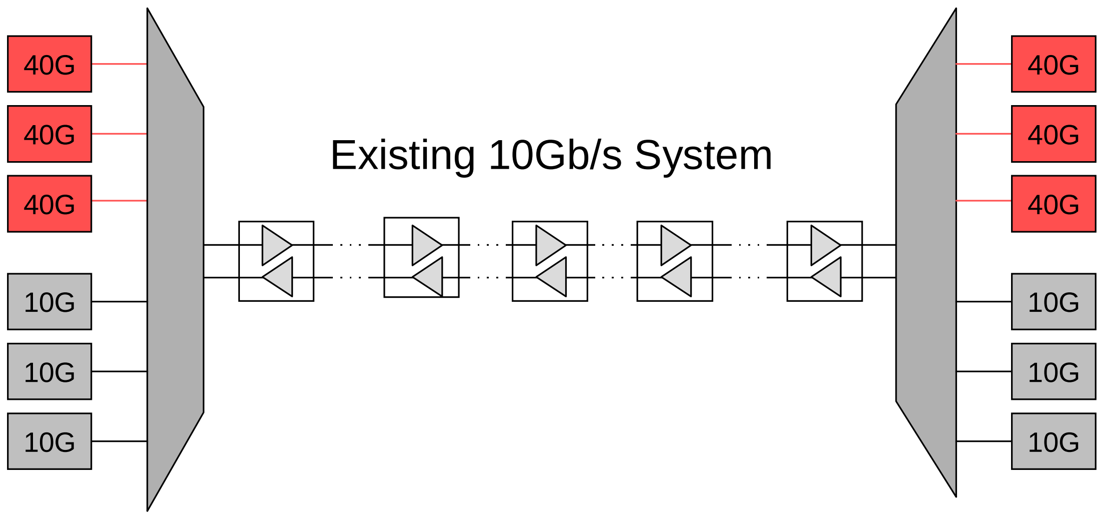

Fig.1: 40Gb/s Retrofit to Existing 10Gb/s DWDM Systems

2. Technical Challenges

The scenario for a 40Gb/s upgrade to existing 10Gb/s DWDM systems faces several technological challenges, such as: (i) squeezing 40Gb/s spectrum through 10Gb/s DWDM optical filters (typically with 50GHz channel spacing); (ii) meeting 10Gb/s dispersion tolerance windows (typically > 300ps/nm) to avoid replacing line DCMs; (iii) co-propagate alongside existing 10Gb/s channels without inducing crosstalk penalties; (iv) tolerance to polarization mode dispersion; (v) higher OSNR required and (vi) large input/output power dynamic range to meet MUX/DEMUX interface specs. Two critical technologies are required to overcome these challenges; (i) the use of enhanced FEC to overcome the higher OSNR required at 40Gb/s and (ii) an advanced modulation format to spectrally compress the 40Gb/s signal to be compatible with the existing 10Gb/s DWDM optical filters and increase dispersion tolerance.

3. Route Model Assumptions

To analyze the economic implications of retrofitting 40Gb/s wavelengths to existing DWDM systems, a model was developed which compared 3 different scenarios:

1. Present Mode of Operation (PMO), i.e. carry on deploying 10Gb/s wavelengths on existing LH system;
2. Deploy 10Gb/s ULH overbuild systems;
3. Retrofit 40Gb/s wavelengths on existing system (modified PMO).

The cost assumptions used in the model are:

- Price per 10Gb/s transponder = $25,000
- Price per 40Gb/s transponder = $75,000
- 10Gb/s PMO reach = 450km
- 10Gb/s ULH reach = 1,800km
- 40Gb/s retrofit reach = 900km
- Price per Optical Line Amplifier (OLA) = $80,000
- Price per terminal common optics = $120,000
- Route length = 1500km
- Remaining unlit wavelengths = 10

To show the relative economics of each solution, it is worth considering a simple point-to-point route. In this example, it is assumed that the route is 1,500km in length and there are 10 wavelengths unused on the installed DWDM system. The incremental cost of adding more capacity is shown in Fig. 2.

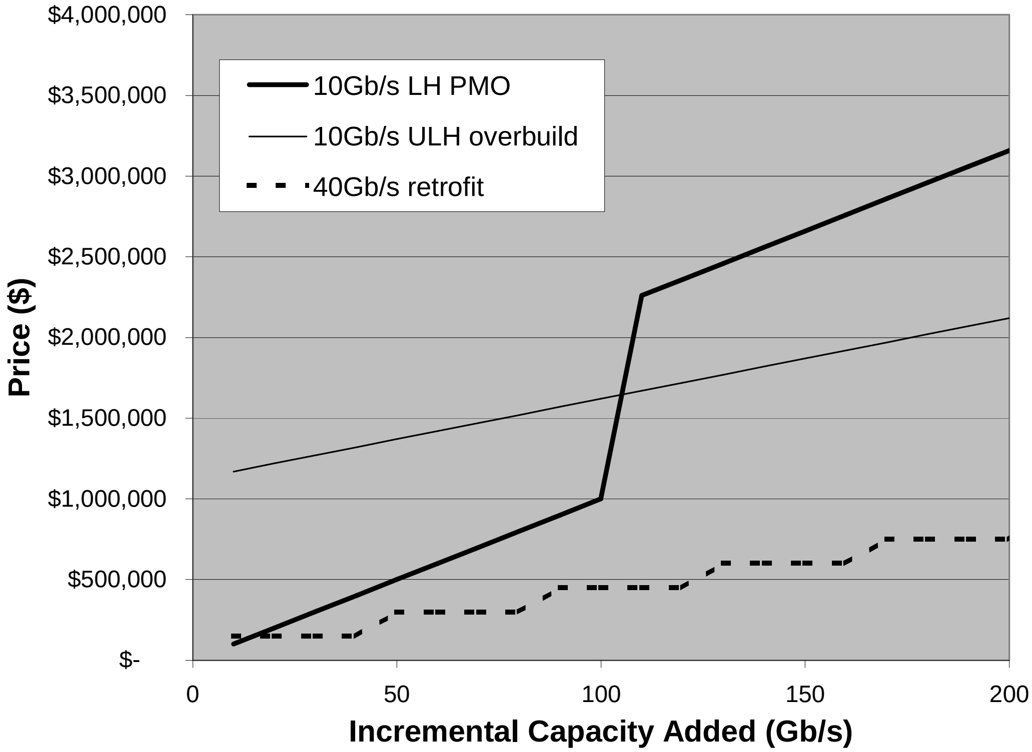

Fig. 2: Cost comparison of 10Gb/s LH PMO vs 10Gb/s ULH Overbuild vs 40Gb/s Retrofit over 1500km route

From the results in Fig. 2 it can be seen that 40Gb/s retrofit offers substantial network cost savings versus PMO or 10Gb/s ULH overbuild. The 10Gb/s LH PMO has 2 main economic disadvantages: (i) high incremental cost of capacity related to the cost of OEO regenerators and (ii) after 100Gb/s of additional capacity is deployed, a new overbuild is triggered with the subsequent additional cost of the common optical equipment (line amps, mux/demuxes, DCMs, etc.). The 10Gb/s ULH overbuild has a lower incremental cost of bandwidth but suffers from high initial capital required to deploy the new set of common equipment. It therefore takes some time for the carrier to reach payback and there is risk that demand growth will not materialize quickly enough to yield a timely ROI.

The 40Gb/s retrofit provides both a low upfront cost (no new common equipment required, just add 40Gb/s line cards) and low incremental wavelength cost since 40Gb/s price is less than 4 times the 10Gb/s price . In addition the new 40Gb/s equipment has increased reach compared to 10Gb/s PMO, so fewer OEO regenerators are deployed. The other major advantage is that a lot of new capacity can added as the 10 unlit wavelengths can now offer 400Gb/s of capacity, an increase of 300% over the PMO. This extra capacity enables the carrier to delay overbuilding their network with a new DWDM line system, providing significant short-term cash savings. In the example shown, deployment of an additional 200Gb/s of capacity costs $3.16m for 10Gb/s PMO, $2.12m for 10Gb/s ULH overbuild (33% savings) but only $750,000 for the 40Gb/s retrofit option (76% savings). The carrier could also consider rolling existing traffic from 10Gb/s wavelengths onto 40Gb/s wavelengths, thus making room for even greater increases in capacity. The 10Gb/s transponders could then be re-deployed on low demand growth network segments.

Another way of looking at the economics is to consider the ROI of deploying 10Gb/s ULH overbuilds or 40Gb/s retrofit versus the PMO. Using the assumptions above, the Net Present Value (NPV) of 10Gb/s ULH and 40Gb/s retrofit were compared vs PMO over a 3 year time horizon. One critical parameter that needs to be considered closely by the carrier is the NPV versus capacity growth rate. The results are shown in Fig. 3.

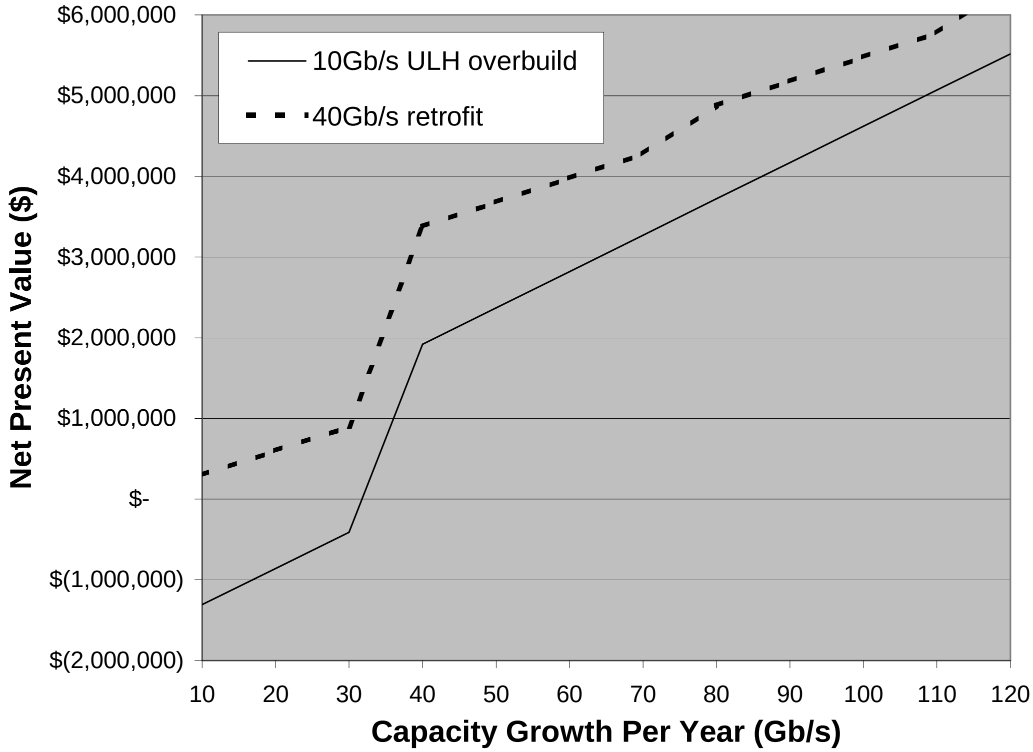

Fig. 3: NPV of 10Gb/s ULH Overbuild and 40Gb/s Retrofit vs PMO

One important observation from these results is that the 40Gb/s retrofit does not require a large capital investment and offers instantaneous payback. Even for low growth rates it offers savings versus PMO and therefore can be considered as a low risk option for the carrier. On the other hand, a ULH overbuild requires a high upfront capital outlay to pay for the new DWDM common equipment. If demand growth is high enough (and the ROI time horizon long enough) then the savings in OEO regenerators will pay for the upfront common equipment. In this example 1,500km route, the payback breakeven is at a growth rate of 30Gb/s per year. Note that payback breakeven would be later for a shorter route with fewer saved OEO regenerators and if more than 10 wavelengths remained unlit on the DWDM system.

The 40Gb/s retrofit option offers moderate cost savings versus PMO up till until the point were the last wavelength has been lit on PMO. After this point (30Gb/s/year in this example), the 40Gb/s retrofit offers substantial savings as adding more capacity does not trigger a DWDM overbuild, as is the case for PMO. This capital deferral is the key economic value proposition for 40Gb/s retrofits to existing 10Gb/s DWDM systems.

6. Summary and Conclusions

The benefits of retrofitting 40Gb/s wavelengths into existing 10Gb/s DWDM systems has been described. This option offers substantial savings for the carrier by deferring the capital outlay required for new DWDM overbuilds, significantly reducing the cost of capacity and the investment payback period. A 40Gb/s retrofit also enables new service interfaces, such as OC-768 interfaces from next-generation IP routers to be transported over the existing DWDM infrastructure, while accommodating quad 10 Gb/s client interfaces transparently.

By retrofitting 40Gb/s wavelengths to installed 10Gb/s DWDM systems, a carrier can pragmatically enable new services, increase remaining capacity by 300% future-proofing an existing network without incurring the significant cost of large scale network overbuilds.

References

[1] A. M. Odlyzko, “Internet traffic growth: Sources and implications,” http://www.dtc.umn.edu/~odlyzko/doc/itcom.internet.growth.pdf.

[2] C. Lima et al., “40Gb/s DWDM Optical Transport Systems: Practical Considerations”, session D2, NFOEC 2002, September 2002, Dallas, TX.

[3] L. Ceuppens et al., “Spectrally Efficient Modulation Enables Incremental Capacity Growth by Retrofitting 40Gb/s Channels into Existing 10Gb/s Networks”, NFOEC 2003, September 8-11, 2003, pp 516-525.

[4] Sprint press release, "Sprint Customers Experience Internet's Fastest Track", Overland Park, Kansas, June 2nd 2004, http://144.226.116.29/PR/CDA/PR_CDA_Press_Releases_Detail/1,3681,1112069,00.html