Characterization of the economic impact of stranded bandwidth in fixed OADM relative to ROADM networks

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Abstract: Carriers are generating business cases for deploying ROADM networks based on the elimination of wavelength blocking in FOADM networks. We quantify the real cost of stranding bandwidth in FOADM networks and determine optimum network size depending on the traffic patterns.

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1. Introduction

The recent marketing of Reconfigurable Optical Add Drop Multiplexer (ROADM) systems by numerous vendors has led numerous carriers to undertake studies to quantify the Capital Expenditure (CapEx) and Operational Expenditure (OpEx) benefits of ROADM system technology. The OpEx benefits of a ROADM system over previous generations of DWDM transport are considerable and an attractive aspect of the value proposition, however OpEx is historically very difficult to quantify [1], and in addition uncertainty exists regarding whether a carrier will ever realize these savings. Therefore, the business cases for a ROADM typically focus on CapEx savings over existing solutions.

The CapEx savings for a ROADM system over existing SONET and MSPP systems are well understood to be dominated by the elimination of the OEO regeneration "Pass-Thru" tax that increases the cost to transport bits through a node. However previous generation systems based on Fixed Optical Add Drop Multiplexing with thin film filters is an alternative means to achieve these savings with Thin Film Filters (TFFs) that are widely accepted to be lower in cost than the ROADM subsystems that replace them. While the FOADM systems do enable CapEx savings via transparent optical bypass, the fixed nature of the optical elements requires that a carrier preplan the drop capacity at every node if they are unwilling to break network connectivity as would be needed to reconfigure FOADM TFFs if the planning were incorrect. Differences in actual traffic patterns from that expected in the planning phase leads to wavelength blocking in the network and the requirement that additional common equipment be deployed before the original equipment capacity is exhausted. The financial penalty of this is explored and quantified.

2. Methodology

In order to properly study the effects of wavelength blocking on banded fixed optical add/drop module (FOADM) DWDM systems, a statistical approach was used to sample the behavior of many networks and calculate various blocking effects. There has been a recent acceptance of the viability and cost effectiveness of core ROADM systems in today’s traffic heavy metro core networks. Logical mesh traffic patterns in these networks are particularly well serviced by full wavelength flexibility at most nodes. In light of this recent shift toward ROADMs, it is important to understand the cost drivers in the more prevalent backhaul and hub networks. In general, these networks have lower terminating traffic at each node, referred to as “edge” nodes in the following discussions. We examine the sensitivity of FOADM systems to traffic growth and planning errors in small to moderate backhauled rings with low to moderate traffic that has dedicated protection. This represents a major cross section of the rings migrating from legacy SONET/MSPP rings to DWDM rings.

Monte Carlo simulations were used to calculate the various blocking and associated costs. We present here the effects in banded systems and ROADM systems, but this technique is valuable for studying the actual deployment costs of any architecture, including combinations of banded and ROADM systems, tunable
filter based systems, etc. In all systems it was assumed that in deploying a service, no existing service could be disrupted or even switched to protection. All additions must qualify as “hitless”.

3. System Details

The FOADM system used was a 32 wavelength, 100 GHz channel spaced system using industry standard 4 skip 0 banding filters. At hub locations, a complete 32 wave demultiplexer and multiplexer were assumed. For comparison, a 32 wave core reconfigurable optical add/drop module (ROADM) system with full wavelength flexibility was use. In this system, there was no difference between the hub nodes where 100% drop was expected and other nodes in the system. Specific costs for all components in the common equipment layer were assumed, capturing the relative cost differences between core ROADM systems and banded FOADM systems, along with the associated difference in optical amplification. The overall behavior of the cost studies is not changed by significant changes in the costs of the various components.

4. Results

Initial results will study the blocking on a 6 node network. All traffic is bidirectional and protected from the hub to one of the 5 edge nodes. Figure 1 shows blocking probabilities for the 2 different systems. The independent variable is chosen as the number of wavelengths deployed on the network. The dependent variable is the percentage of networks that can not deploy the next desired service without either effecting service or deploying more common equipment. Examining the core ROADM first, we see that no networks see blocking until that last wavelength in the systems is used. At this point a network overlay is obviously required. This is the ideal situation. The 4 dashed curves represent different configurations of the same FOADM system. The uniform traffic scenario represents the best possible behavior of a banded systems where the distribution of traffic matches the expected distribution. The fact that this system sees blocking is due to 2 major effects. First, the traffic, while statistically uniform, still arrives with timing uncertainty. This means that one node could see the 5th demand before a different node sees its 4th demand. This makes blocking occur even in a perfectly planned network. In addition, this deployment suffers from the fact that there is no good way to deploy 4 skip 0 banding filters in a network with 5 edge nodes. In this ideal case, half of the networks are blocked at 22 deployed wavelengths out of a 32 wavelength system. Planning errors represented by additional, unplanned node growth in the next to traces indicate that matters only get worse in the real world. In the very realistic case of a new office complex spurring significant growth at one office (1 node overbuilt by a factor of 3) we see that half of the networks are blocked when only half the wavelengths are consumed. In perhaps a counter-intuitive conclusion, pre-planning for traffic

Figure 1: Blocking probability in banded FOADM networks for various planning errors.

Figure 2: Cost of network common equipment for multiple deployments taking wavelength blocking into account.
that doesn’t materialize is the worst case shown in Figure 1. In this case, extra filtering was deployed at a node as more traffic was expected to be serviced at that node. This was modeled as a planning error, with a resultant uniform traffic pattern. Blocking occurred quickly, and over 90% of the networks were blocked by the time half of the total wavelengths were deployed.

Blocking in FOADM systems is fairly well understood in the field, but perhaps the economic pain of that blocking is not fully realized. Figures 2 and 3 translate these effects into expected common equipment deployment costs in various networks. Figure 2 shows the significant cost penalties of wavelength blocking. In this case, we are examining the average cost of an edge node as we add wavelengths to our 6 node backhaul ring. Again, looking at the core ROADM system we see the benefits of flexibility. While starting with a high initial per node cost at an average of one wavelength deployed at each edge location, that cost does not grow as we load the system. Since every single deployment of our ring sees no blocking with a core ROADM, we never need deploy more common equipment until our ring is exhausted, and this happens on the shift from 6 wavelengths per node (30 total) to 7 (35 total). At this point we overlay a second core ROADM system everywhere, and the common equipment cost is doubled. Unfortunately, a similar effect is not observed in the FOADM based systems. They have the advantage of starting with a low node price with only 1 or 2 waves deployed, but as further waves are deployed, network overlays are needed to continue to serve the incoming demands. In the best case of uniform growth on a network that was planned for uniform growth, we start to see a non-trivial cost penalty at an average of 3 wavelengths deployed. If a field of rings were deployed, we would be overlaying networks on a small but non-negligible subset of those rings. In the case of uneven demand growth we see network blocking becomes so significant that the network costs rival or possibly exceed the costs associated with a core ROADM system.

Figure 3 explores the choice of node count in these networks. There is a tradeoff between available wavelengths, and hub node cost sharing in these networks. If wavelength blocking were not an issue, it would be advantageous to deploy larger rings. This is due to the fact that one hub node is used to service more edge nodes. The core ROADM systems is easy to understand: the larger the ring, the better (within limits) as the hub cost is shared and the ring sees no wavelength blocking. The behavior of the FOADM system is significantly different. Not only do we see that there is a real penalty for deploying rings with greater number of nodes, we cannot make good use of hub sharing. Additionally, planning errors once again limit the benefits of cost sharing the hub node. All of this points directly to the need for a low cost node with some flexibility that addresses wavelength blocking from a network common equipment cost perspective.

5. Conclusion
We have shown a means to evaluate the blocking probability in a banded FOADM system and compared that to the more flexible ROADM counterpart, which has no stranded bandwidth. The blocking results are also used to create lifecycle cost plots that quantify the cost of stranded bandwidth in a matter that enables it to be compared to more costly ROADM systems. These represent a generic analysis technique that can be used to optimize the cost of a network depending on the traffic pattern an equipment used to build it.

References