Cost and flexibility advantage of a multi haul DWDM platform

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Abstract: A capital expenditure freeze and intense price pressure in the long haul DWDM market requires new approaches to system design that offer a low cost flexible solution to carriers. This paper describes the concept of a multi haul DWDM platform combining traditional long haul with ultra long haul system features. A cost comparison of a typical national ring network shows that a multi haul platform provides a solution at a competitive cost to traditional long haul systems for low traffic levels and a low incremental upgrade cost advantage typical of an ultra long haul system.

1. Introduction

During the late 1990's, claims that Internet traffic was growing at unprecedented rates led many carriers to rapidly build-out their networks. To provide a rapid expansion in bandwidth and make the best use of fibre capacity, carriers deployed DWDM transmission technology in their core networks. Recent deployments include ultra long haul (ULH) systems capable of transmitting signals at distances greater than 3000km without regeneration [1]. Because ULH systems require fewer regeneration sites than traditional long haul (LH) systems the incremental upgrade cost to meet future traffic demands in the network is lowered. However the use of advanced technologies such as low-noise amplifiers, dynamic gain equalisation, re-configurable optical add/drop multiplexers (R-OADM) and return-to-zero (RZ) modulation makes the initial cost of a ULH system high compared to a traditional long haul (LH) system which uses cheaper amplifiers, no gain equalisation, non return-to-zero (NRZ) modulation and fixed optical add/drop multiplexers (F-OADM).

Network operators want the low initial cost offered by traditional LH systems to meet today's low traffic demands and the low per wavelength upgrade cost offered by ULH systems to meet future requirements [2]. However they are often reluctant to deploy a mixture of platforms in their network due to issues such as separate sparing, training, management and system proving requirements. System vendors are responding by developing multi-haul (MH) platforms, which combine the features of LH and ULH systems in a common modular platform. Table 1 briefly summarises the typical architecture of each type of line system, the remainder of this paper demonstrates the cost savings and flexibility advantage when deploying a multi haul platform in a typical national ring network.

System type	*Transponders*	*Optical Add/Drop*	*Amplifiers*	*Application*
LH	NRZ	F-OADM (8 channel add/drop)	LH	Short links (<600km) with high proportion of terminating traffic
ULH	RZ	R-OADM (100% add/drop)	ULH (low noise)	Long links (<3500km) with high proportion of transit traffic
MH	NRZ RZ	F-OADM R-OADM	LH ULH	All core network applications

Table 1. Summary of DWDM system architectures

2. Example network designs

The example network is shown in fig. 1 and consists of 8 nodes, which is representative of a typical national ring network. Fig. 2 is the traffic demand matrix for the first planning period, where 1+1 represents 1 × OC-192 wavelength between the nodes in each direction around the ring; during the second planning period the traffic demand is simply doubled.

Together with the traffic requirements, engineering rules stating the maximum number of amplified fibre spans of a particular length which can lie between regeneration points for various transponder and amplifier types determine the location of regeneration and optical add/drop sites. In the most challenging cases, for example long links containing spans of highly irregular lengths, or to reduce the number of amplifier sites in a link as much as possible, computer simulations are used to verify that transmission impairment margins are acceptable. Fig. 3 (a) and (b) show the possible connections and the transponder types required for long haul and ultra long haul amplifiers in the example network.

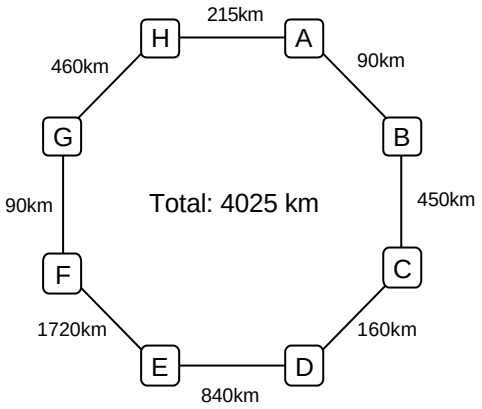


Figure 1. Example national ring network

	A	B	C	D	E	F	G	H
A								
B								
C		1+1						
D	1+1							
E								
F	1+1		1+1					
G	1+1		1+1		1+1	1+1		
H	1+1	1+1	1+1	1+1	1+1	1+1	1+1	

Figure 2. Traffic demand matrix for example network

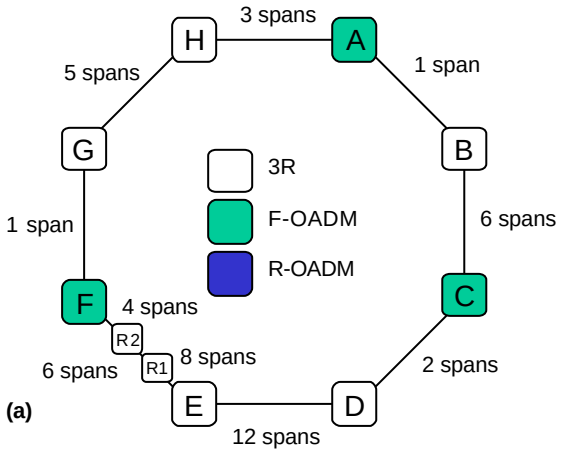
(a)

clockwise from	to A	B	C	D	E	F	G	H
A		NRZ	NRZ	-	-	-	-	-
B	-		NRZ	NRZ	-	-	-	-
C	-	-		NRZ	-	-	-	-
D	-	-	-		NRZ	-	-	-
E	-	-	-	-		-	-	-
F	-	-	-	-	-		NRZ	NRZ
G	NRZ	-	-	-	-	-		NRZ
H	NRZ	NRZ	-	-	-	-	-	

(b)

clockwise from	to A	B	C	D	E	F	G	H
A		NRZ	NRZ	NRZ	RZ	-	-	-
B	-		NRZ	NRZ	RZ	-	-	-
C	-	-		NRZ	NRZ	-	-	-
D	-	-	-		NRZ	-	-	-
E	RZ	RZ	-	-		RZ	RZ	RZ
F	NRZ	NRZ	RZ	RZ	RZ		NRZ	NRZ
G	NRZ	NRZ	RZ	RZ	RZ	-		NRZ
H	NRZ	NRZ	NRZ	NRZ	RZ	-	-	

Figure 3. (a) Connections possible using NRZ transponders and LH amplifiers (b) connections possible using NRZ and RZ transponders with ULH amplifiers (note that mixing of NRZ and RZ transponders is only possible using the multi-haul platform)



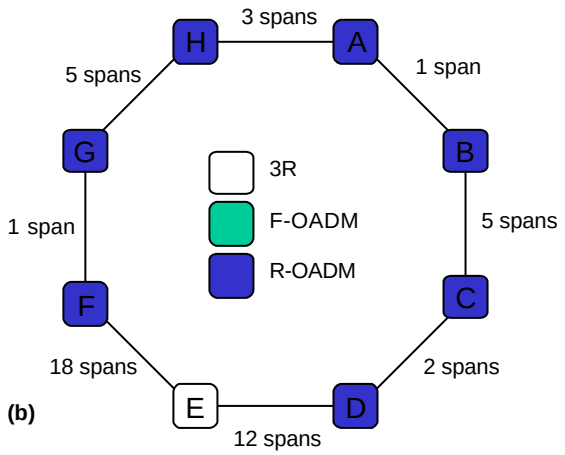


Figure 4. (a) Long haul network design (b) ultra long haul network design

For a design based on a long haul platform the link E to F is simply too long therefore extra regeneration sites need to be introduced at positions R1 and R2 shown in fig. 4 (a). From this basis 3R regeneration sites and low cost F-OADMs are placed according to traffic requirements and the capabilities of the system. Using a ULH platform, link E to F is feasible using RZ transponders and two gain equalising network elements along the link. According to fig. 2 site H has the heaviest traffic requirement, however if this site were to be chosen as a regenerator further regeneration would be required at E to reach site F and G in the clockwise direction. In choosing E as the single regeneration point within the network all sites can be reached except C and D in the clockwise direction, which satisfies the requirements since no traffic is expected between these nodes, all nodes apart from E are R-OADMs. Due to the improved noise performance of ULH amplifiers, link B to C can be achieved in 5 as opposed to 6 spans.

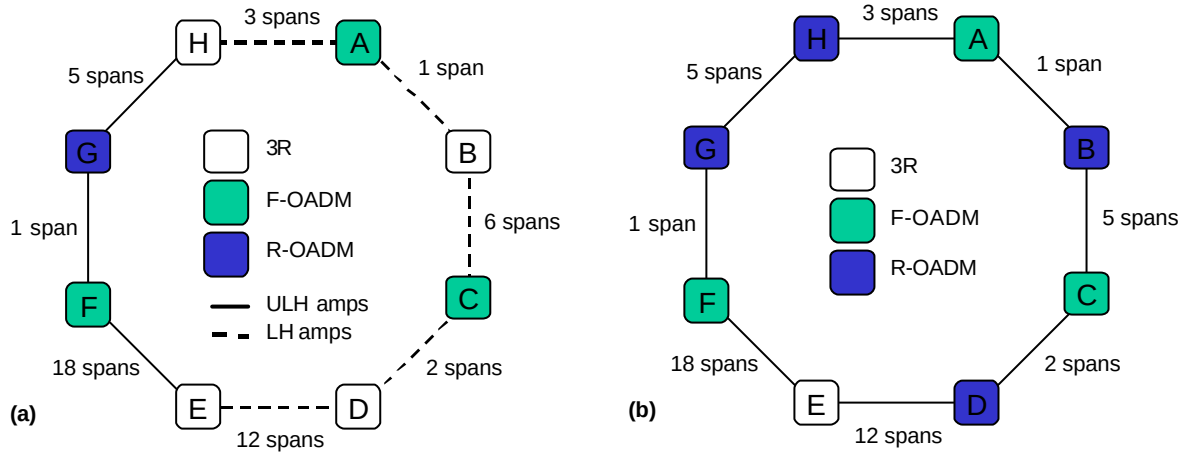


Figure 5. (a) Low initial cost multi haul network design MH1 (b) low per wavelength cost multi haul network design MH2

Using the multi haul platform two approaches can be taken to the network design lowering initial cost or lowering total cost of ownership, the final choice will depend on the priorities of the carrier. Solution MH1 shown in fig. 5 (a) mixes LH and ULH amplifier sections and requires only four regeneration sites compared to the seven regeneration sites required in an LH only design. An R-OADM is required at node G due to the traffic requirement in the second period exceeding the 8-channel limit of a F-OADM; all other nodes can be lower cost F-OADMs.

The MH2 solution shown in fig. 5 (b) is based on the ULH solution with one regeneration site and uses ULH amplifiers throughout. Three of the add/drop nodes can use the low cost F-OADMs the remaining nodes require R-OADMs to provide gain equalisation functionality and to meet traffic requirements. According to the rules of fig. 3 (b), lower cost NRZ transponders can be used for shorter reach connections, producing further savings over the ULH design. Fig. 6 summarises the total number of transponders required for each solution over the two planning periods.

	LH	ULH	MH1		MH2	
	NRZ	RZ	NRZ	RZ	NRZ	RZ
Period1	234	86	124	30	34	52
Period2	468	172	248	60	68	104

Figure 6. Total transponder numbers for each solution and planning period

3. Network cost results

Total network costs are calculated for each design, applying a 10% reduction in the cost of upgrade equipment between the first and second planning period, fig. 7 shows the normalised results. For the first planning period the cheapest solution is the MH1 design using the multi haul platform, which results in a 17% cost saving compared to the solution using the ULH system, a 4% saving compared to the solution using the LH system and a 2% saving compared to the MH2 design. Significant savings are realised over the ULH design through the use of cheaper LH amplifiers and F-OADMs, however there is an increase in the proportion of cost spent on terminals and transponders due to more regeneration sites in the network. When considering both planning periods the cheapest solution is the MH2 design which saves 19% compared to the LH design, 14% compared to

the ULH design and 8% compared to the MH1 design. The MH2 design is efficient in saving over the LH design due to less transponders and regeneration in the network far outweighing the additional expense of ULH amplifiers and R-OADMs. For the same reasons the MH2 design proves cheaper than the MH1 design at the higher traffic level. Savings are realised over the ULH design from the use of cheaper NRZ transponders for short connections and cheaper F-OADMs on some nodes. These results demonstrate that a common multi haul platform can compete effectively on cost with traditional LH systems for low traffic requirements whilst enjoying the flexibility and low incremental upgrade cost advantage of ULH systems.

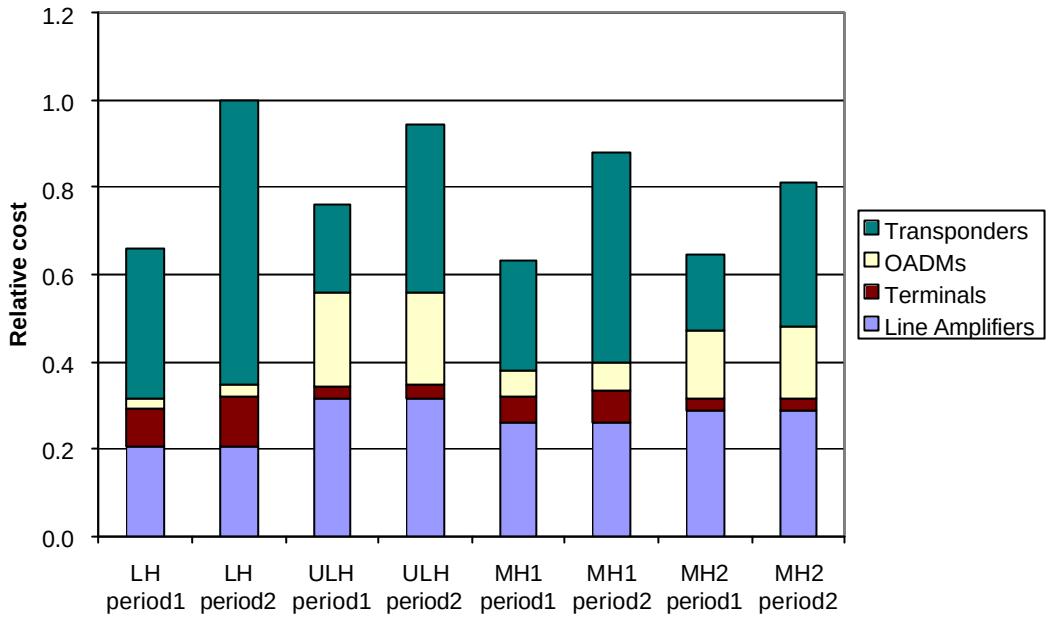


Figure 7. Total network cost for each system type and planning period

4. Summary

A multi haul DWDM platform offers a cost-effective, flexible and scalable solution for core network applications. Low first channel costs of LH systems can be combined on a common modular platform with the low incremental upgrade costs and flexibility offered by ULH systems. There are many other advantages to carriers in deploying multi haul platforms for core network applications. Integrated DWDM interfaces on SDH equipment can produce additional cost savings by eliminating transponders and back-to-back grey interfaces between SDH and DWDM equipment [3]. Multi haul platforms will further reduce operational costs for the carrier and reduce time to revenue by providing plug-and-play and automatic provisioning features usually found in ULH systems, a common platform will also reduce sparing, training, management and system proving costs.

Acknowledgements

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