THE FUTURE OF SUBMARINE SOLUTIONS

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Abstract: The paper will provide a review of the current submarine market and of its segmentation. Over the past three years, the submarine suppliers have segmented the market in between unrepeatered, regional, transoceanic and offshore. Thus the paper will go over each segment while discussing the technology and product suite used for each.

Where is the submarine technology now going and when will the next technology breakthrough happen? The paper will detail and explain how the submarine market is likely to evolve from 2007 to 2010. The technology and trade offs will be discussed in light of the market driving forces. Thoughts will be shared as to the nature of the submarine solutions past 2010.

1 INTRODUCTION

The suppliers started to more finely segment the market in 2002-2003 following the severe downturn experienced by the whole industry. This was aimed at better addressing the cost reduction expected from different kind of customers, each with their set of requirements. In particular, the market was calling for a trimmed down version of the long haul repeatered systems for short haul applications. There was also a case of increasing the customer base by using the proven submarine telecom technology to serve a new sector, offering offshore connectivity to the world of science as well as to the Oil and Gas industry.

2 TRANSOCEANIC SOLUTIONS

2.1 Solution overview

Traditionnaly, the transoceanic solution call for 2 to 8 fiber pairs and a large bandwidth, ranging from about 3 Tb/s to about 10 Tb/s. This solution has to be designed for a 25 year lifetime and offer a full set of features over distances up to 12000 km. They truly are the core of the global fiber grid and can be best described as the highest end solutions of the submarine market.

2.2 Overview of the available technology

These solutions operate at 10 Gb/s and can provide the customers with a versatile choice of modulation formats such as NRZ, RZ and RZ-DPSK.

The submarine line terminal equipments benefit from a plug and play approach with tunable cards over the full terminal bandwidth. On top of the usual SDH and/or SONET client interfaces, they can now offer LAN and WAN 10Ge interfaces.

The repeater are based upon the EDFA technology with 980 nm redundant pumps so as to ensure very high reliability.

The cable design can be a 17 mm or 20 mm design although the 17 mm design can now be arguably considered the true industry benchmark in light of the solutions deployed the last 3 years. The fibers can be of the NZDSF type or they can belong to the dispersion slope matched category (better known under the +D/-D nickname).

The branching units boast a latched capability so that the BU electrical state can only be modified through an optical command originated from any of the three legs.

2.3 Tradeoffs

The main cost and performance tradeoffs revolve around the capacity management over the life of the system and around the capacity versus distance.

- Potential versus used capacity

As one increases the number of fiber pairs, one increases the capex (more fibers, more costly repeaters) for unlit capacity. Therefore this is an expense versus potential capacity while adding wavelengths is an expense for used capacity (pay as you grow). It's been observed that most systems deployed in the past have been upgraded beyond their initial design capacity, stemming from on-going improvements in terminal equipment. On this ground, the best value for money seems to be a 2 fp to 4 fp solution that strikes the best compromise between CAPEX and future proofness. This is where the market is headed, moving away from the 6 fp to 8 fp requested in 1999-2001.

- Capacity versus distance

At some point, if one wants to increase the upgrade potential, there is the case to resort to the +D/-D instead of the NZ-DSF. While +D/-D is a high capacity solution enabler for ranges above 9000 km [1], +D/-D could also be used for shorter range solutions, maybe from 6000 km. As this fiber is more expensive than the NZ-DSF, more widespread adoption would drive its cost down and make it an even more attractive proposition. The modulation format needs also be taken into account since it also bears an impact on the wet plant cost. Simply put, there is no simple answer and this has to be studied on a case by case basis for the costs versus performances tradeoffs. Nonetheless, the choices will revolve around combinations such as +D/-D & DPSK, +D/-D & RZ, NZ-DSF & RZ and NZ-DSF & DPSK.

3 REGIONAL SOLUTION

3.1 Solution overview

The regional solution is a 1 to 2 fp solution built around a narrow bandwidth, offering up to about 0,6 Tb/s. ranging from

It can enable affordable regional connectivity over distances up to about 2000 + km. This solution is still designed for a 25 year lifetime but only provides for a limited set of feature since the hardware breakdown structure has been trimmed down for cost effectiveness. It quality and reliability are the same as those of the transoceanic solution.

They can be best used to eliminate a regional capacity bottleneck and gain access to an internation hub node of the global fiber grid.

3.2 Technology overview

These solutions operate at 10 Gb/s. The submarine line terminal equipment benefit from a plug and play approach with tunable cards over the full terminal bandwidth. But the feature set is limited: optical channel protection is not available, there is a single modulation format, supervision is optional. On top of the usual SDH and/or SONET client interfaces, they can now offer LAN and WAN 10Ge interfaces.

The repeater is a long span repeater whose design has been optimized for a narrow bandwidth in order to offer spans in excess of 100 km. The design is still based upon the EDFA technology with 980 nm redundant pumps so as to ensure very high reliability.

The cable design is a 14 mm design with a limited voltage range while the fibers fall into the NZDSF type.

3.3 Tradeoffs

There are not any real tradeoffs to be run for the regional solution since the cost reduction has been built in as a design criterion. Consequently, there is no room left to maneuver and flexibility is minimal, apart from the supervision which can be procured as an option. This is the best endeavor at a cost optimized solution which can still guarantee the reliability and quality of a transoceanic solution.

4 UNREPEATERED SOLUTION

4.1 Solution overview

The unrepeatered solution call for 2 to 12 fiber pairs, bandwidth to 10 Tb/s and they are designed to bridge gaps of about 450 + km without repeaters. They are generally sought after when the distance doesn't warrant a repeatered solution and the high voltage coming with it. A unrepeatered solution is somewhat simpler than a repeatered solution and is often considered as trouble free since there is no active electronics in the sub sea line.

4.2 Technology overview

These solutions operate at 10 Gb/s and can be equipped at 40 Gb/s if the range allows it. The submarine line terminal equipment benefit from a plug and play approach with tunable cards over the full terminal bandwidth. There is a choice in the modulation format in order to offer the best performances. On top of the usual SDH and/or SONET client interfaces, they can now offer LAN and WAN 10Ge interfaces while channel spacing is typically 50 GHz.

The cable design is a 14 mm design whose optical core is inherited from the repeatered cable technology so as to offer maximal reliability and a wide operating range. The fibers belong to the G.652 or G.654 types whose effective areas generally fares at 70 square microns or 110 square microns to tackle the high power level typical of the unrepeatered transmission. The optical attenuation is very much of the essence and the fibers are selected for premium attenuation levels (e.g 0.172 dB/km), well below those of the terrestrial cables (0.25 dB/km)[2].

There is a requirement to use very powerful optical sources (1 Watt and above) in many schemes that can rely contra propagating, codirectional propagating as well as remote optically pumped amplifier (ROPA) pumping. These sources rely on high order Raman technology and it is also to be noted that the integrated optical station must comply to the IEC60825 standard to protect station staff from optical safety hazards.

The following table provides a snapshot of the typical solution that can be implemented on a industrial basis with 5 dB margin.

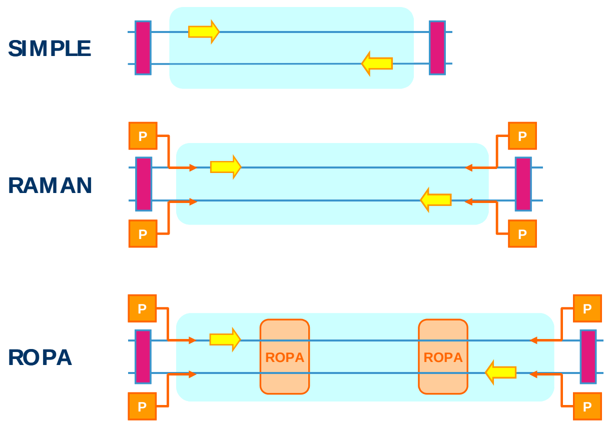

Figure 1: Unrepeatered solution scheme

Distance	Technology (5 dB margin)
Up to 420 km	Raman
Up to 470 km	ROPA

Table 1 :Typical unrepeatered distances with Raman and ROPA

4.3 Tradeoffs

The usual unrepeatered tradeoff is understand if ROPA should be used or not.

The following figure shows the typical capacity versus distance behaviour with and without ROPA. Note that terminal equipment can be selected in a wide product range in order to cope with customer requirements in terms of initial cost and upgradability of the system.

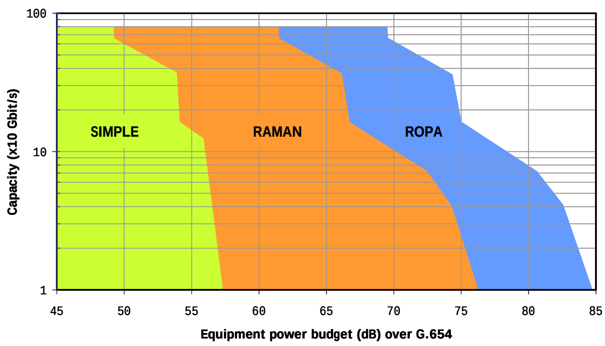

Figure 2: Typical capacity versus distance and solution scheme

From a cost standpoint, the ROPA bears a very limited impact. Moving from a “ROPAless” to a ROPA equipped solution will generally increase the cost by a few percent (2-3 %) for the same equipped capacity while providing for both more margin and more capacity with the same reliability.

The other typical tradeoff is that of the fiber type and fiber effective area in order to optimize the cost versus performances. There are no rules as this has to be studied on a case by case basis.

The final trade off is that of the boundary between a repeaterted and an unrepeaterted transmission. The following picture shows the relative cost in between a repeatered and an unrepeatered solution versus distance. It is self explanatory and shows that 450 + km is repeatered territory, 400 – km is unrepeatered territory and that 400-450 km is the range where studies need be performed to decide which one is best.

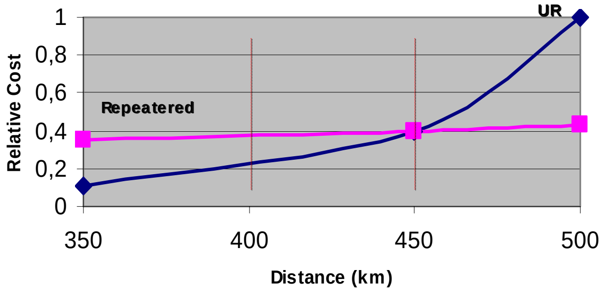

Figure 3: Relative cost of repeatered/unrepeatered versus distance

5 OFFSHORE SOLUTION

5.1 Solution overview

The architectures at stake can range between dry nodes to dry nodes (to yield deep water connectivity) and dry nodes to wet nodes (to yield sub sea connectivity) architectures. An significant benefit of the dry-wet solution is the availability of DC power distribution to the wet nodes (~10 kW/node). When combined with all electric subsea systems, this offers the opportunity for cost effective high reliability control systems in any offshore area [3].

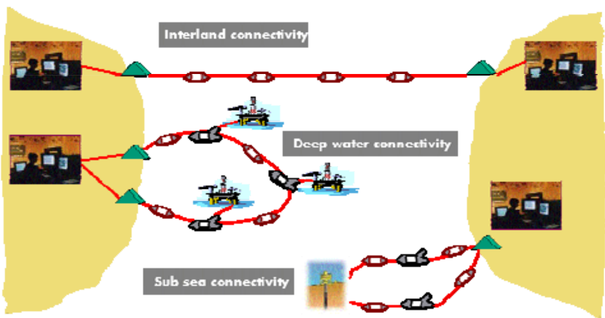

Figure 4 : Telecom solution and offshore solutions

5.2 Technology overview

The technology from the subsea communications sector is qualified and readily adapted to provide high capacity, high reliability communications to offshore surface and subsea structures. There are a few key pieces of technology that are required to enable both deep water and sub sea connectivity.

The dynamic riser is one of them for versatile connectivity applications from platforms or vessels to the sea bottom. An other one is a power and communication gateway offering electrical power and telecommunication to a sub sea client. Equally important is the latched branching unit whose switching commands are optically transmitted and which can enable routing of fiber pairs and controlled distribution of high voltage DC power.

5.3 Tradeoffs

The repeatered systems appear to be the best all around solution in order to implement deep water connectivity. The unrepeatered technology has been considered as well but it does not bring the flexibility, future proofness and reach of the repeatered solution. The latter can effect a backbone of any kind with undersea branching units that will allow any hub in the field to get connected to it. The unrepeatered technology still remains the best choice for simple point to point application or last mile extension from a hub node.

As for the sub sea network, there is no way around the repeatered technology. It alone can provide the reach and power transport capability.

6 ARCHITECTURAL TRENDS

6.1 Driving forces

The next generation of networks will be driven by the services Telcos offer to the consumer market. Over 60% of the international traffic is Internet traffic and over 60 % of this Internet traffic stem from peer-to-peer applications behaviours with large household consumption, poised to reach about 1 Terabit/day in the Western world and in Asia. The traffic patterns will be driven towards symetrical behaviour and will be best served by IP content distribution networks based around 10 Gethernet interfaces [4]

6.2 Standards

The standardization efforts should aim at smoothing the move to an overall efficient IP traffic transmission. In order to improve the Ethernet affinity, the SLTE should comply with the OTN (Optical Transport Network. ITU-T G.709). The next generation of SDH/SONET equipment should also encompass GMPLS control planes.

Therefore the OTN and GMPLS are likely to be the reference standards.

6.3 Future architecture, protection and bandwidth management

The IP transport network leans towards a meshed architecture with the GMPLS control plane. Thus the submarine cables will have to better fit within this picture so that operators can transmit traffic over more than two cables over any major route [5]. The recent earthquake off Taiwan did shed more light on this requirement after the Asian traffic got shut off from the rest of the world with six cable cuts.

In addition, packet traffic and meshed networks allow for different protection scheme, avoiding transporting the same information on two separate routes. It therefore provides better bandwidth management and can free up capacity.

7 A LOOK AHEAD

7.1 Transoceanic

The most discussed topic throughout the industry is the time inception of 40 Gb/s. It is likely that the submarine adoption of 40Gb/s will be driven by the wide adoption of 10 Gb/s in the terrestrial world, forcing 40 Gb/s at the back-end of the submarine solutions. The discussion is two fold since it entails the 40 Gb/s upgradability over deployed lines and the 40 Gb/s compatibility of future solutions. It has to be borne in mind that the main 40 Gb/s hurdle is the polarization mode dispersion requirements which increase with the solution length. It is likely that 40 Gb/s upgrades can be implemented on the current wet plant generation for distances up to 5000 km while still maintaining the same overall capacity [6]. 40 Gb/s line operating solutions over 5000-6000 km could certainly be designed and manufactured from 2009-2010 but they may call for novel polarization mode dispersion compensators in the terminal equipment and a new generation of fiber. While technically feasible, this would lead to significant price increases. It is more likely that 40 Gb/s will be initially catered for over 10 Gb/s compatible wet plant with 40 Gb/s to 10 Gb/s demultiplexing/multiplexing.

As for the repeater technology, it seems like the EDFA has still quite a lot of life left in it and will remain the technology of choice through to 2010. The use of Raman pumps has been discussed on and off the past 5 years but there are practical and manufacturing difficulties that may not be overcome.

Nowadays, the Forward Error Correcting techniques have significantly narrowed the gap to 1 dB with the theoretical limit using hard decision techniques. Only a move to soft decision coding would be of practical interest with an upside potential of about 3dB.

With the advent of the RZ-DPSK modulation format and 33 GHz channel spacing, a significant improvement has been achieved. It would make sense that future developments aim at improving the spectral effiency so the R&D should concentrate on those format that can offer high resiliency to non linear effects and small bandwidth occupation.

A new generation of compact chromatic dispersion compensators are likely to come to the fore as the previous gene

It is difficult at this stage to clearly foresee the next generation of fiber, albeit 40 Gb/s will put a premium on low polarization mode dispersion. The natural step would be to increase the core effective area to increase the non linear effect threshold.

7.2 Regional

As far as the regional solution is concerned, the efforts, if any, will aim at further reducing the cost base. The 10 Gb/s line rate will suffice to cope with the traffic requirements of those systems even though upgradability to 40 Gb/s should not be an issue. This solution is already fit for purpose and will only benefit from improvement in terminal technology.

7.3 Unrepeatered

The unrepeatered next best friend is the 500 km mark. Since the name of the unrepeatered game is to shrewdly manage the optical power, the improvements should mainly stem from a new generation of fiber, providing a larger core (e.g 150-200 square microns) and lower attenuation (< 0.165 dB/km). An other improvement will come from the transmitter-receiver capability to cope with non-linear effects and low signal-to-noise ratio. As such, RZ and DPSK modulation formats are good candidates.This is the only cost effective and reliable way to enhance the reach of the unrepeatered solutions past 500 km.

7.4 Offshore

As there will be increased demands for sub sea processing and cable observatories, the R&D efforts will concentrate on sub sea nodes and sub sea gateways: more features and more agile characteritics will have to be traded off between the back bone and the local area networks. This will directly impact the nodes, their interfaces and their functions as the overall architectures mature. The architecture choices will drive the R&D efforts of the sub sea elements.

8 CONCLUSION

The current submarine solutions have been optimized for 10 Gb/s and a low upfront cost. All the latest developments have been driven by this requirement which does not show any signs of abating. From an architecture standpoint, the submarine solutions should in the future more seamlessly integrate into meshed architectures based around the OTN and GMPLS and driven by IP connectivity and Ethernet interfaces. New markets have opened up which can seize benefit of the field proven telecom submarine technology while requiring new products for sub sea processing nodes. As far as the telecom submarine technology itself is concerned, the next logical step should be to operate the lines at 40 Gb/s. This will bear a significant cost impact in the early stages while not demonstrating a sizeable capacity increase. Although technically feasible, this is the reason why it looks as though this step lies a few years down the road.

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