THE 10GIGABIT ETHERNET IMPACT ON SUBMARINE NETWORKS

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Abstract: Over the last decade there has been an inexorable shift from voice to data in transport networks. Despite this SDH/SONET transport has remained the standard of choice for Submarine Systems despite the fact that well over 50% of all traffic is data by nature. This is typically attributed to a combination of Quality of Service (QoS) concerns, strong performance monitoring (PM) requirements and inertia. In this paper we describe the 10Gigabit Ethernet (GE) impacts and subsequent development and first application results of a 'configurable' SDH/SONET/10GE Transponder.

1 INTRODUCTION

We have recently seen the emergence of IP (Internet Protocol) as the protocol of choice for a variety of "Triple Play" applications, with video for example being quite demanding in bandwidth usage terms with a large predicted market growth. The rise of these converged services in recent years, has resulted in the rapid introduction of LAN/WAN technology to access and metro networks. This has lead to the large scale deployment of 'IP centric networks' utilising 10 Gigabit Ethernet (10GE) technology, in the operators access, metro and most recently core transport networks. In this paper we consider the likely impact on Submarine Networks.

Submarine links have become optical pipes in recent years. Routing and protection have principally been carried out in the electrical domain using SDH/SONET standardised equipment. This shift has subjugated the Submarine Line Terminal Equipment to essentially a transponder with an appropriate client interface. However, as transmission capacities grow and system designs have become ever more complex the challenge of designing suitable transponders should not be underestimated [1] [2].

We believe that the optical pipe concept can be equally applied to the submarine segment of IP Centric Networks i.e. where routing and QoS are governed by third party equipment and the SLTE provides the appropriate optical pipe and interface to the terrestrial network. Furthermore, we introduce the concept of a 'configurable' SDH/SONET/10GE Transponder. Such product ubiquity will give operators the flexibility to use the same product for both SDH/SONET and LAN/WAN applications and migration from one to the other as traffic mixes change.

Details will be shared, of a recent field trial carried out on a large network, wherein two large and remote IP networks were joined together using an optical pipe comprising 'configurable' transponders.. We will also provide some performance data and consider the impact as submarine links are blended into larger networks, along with the practicalities of interoperability and testing. Finally we will look at performance, at management issues and whether these changes, impact important Quality of Service and concomitant Service Level Agreement concepts.

2 BACKGROUND

The wholesale use of Internet Protocol has resulted in massive adoption of IP for data, video and even voice based services. This in turn has lead to migration to router based solutions penetrating the telecommunication networks from the edge towards the core thus avoiding the need for expensive SDH/SONET boxes in these parts of the network. IP has been fundamentally associated with best effort transmission. Quality of Service (QoS) however is enshrined in SDH/SONET and this along with heavy Service Level Agreement (SLA) penalties in long haul transport has prevented wholesale penetration of IP into today's long haul networks. However the differentiating features of SDH/SONET are being eroded daily.

Firstly there are many pure IP service providers who do not need to impose such swingeing SLA's (Service Level Agreements) on their carriers carrier. Secondly there is a vast initiative in the technical and standards domain to sort out these outstanding issues.

With the recent release of the IEEE802.3ae [3] 10GE specification, the Ethernet evolution in transmission speed and distance continued. The differences in the 10GE specification over previous Ethernet specifications demonstrated the potential to merge data communications and telecommunications into a 'global network' with attendant benefits in terms of cost, flexibility and scalability.

One characteristic of the evolution of IP has been the massive contribution of "self interest" groups (OIF, IETF) that have driven firstly ad hoc standards and then pushed these through the seemingly more ponderous ITU. The most recent such group to come to the fore is the MEF (Metro Ethernet Forum) and this group is tackling a number of technical standards issues that have some relevance to broader transport issues. Although the focus tends to be on metro and access and it is only lately that 'Carrier Class Ethernet' has been flagged as a priority with work from the MEF on recommendations for carrier class service and complimentary standards from the ITU (e.g. G.8110/8112/8121) on T-MPLS (Transport Multiprotocol Label Switching), a technology which should bolster the carrier class aspirations of packet networks. However even with the emergence of these ‘end to end’ protocols [4], specific recommendations for the submarine link are still not in evidence.

So this raises the question as to how to introduce a product to the submarine space that both works and is future proof? We believe that the answer lies with the historical lessons from the evolution of SDH/SONET submarine links. Recent history shows that submarine networks have been vastly simplified. Gone are the days of complex underwater switching. By and large network and equipment protection is carried out in the electrical domain. Therefore from a management perspective, the submarine link is treated as yet another terrestrial link and we believe this principal could be extended to 10GE. A further advantage to this is that we are then largely agnostic to emerging transport standards such as MPLS (Multiprotocol Label Switching), T-MPLS and PBT (Provider Backbone Transport), providing that we can interoperate seamlessly within the ‘global’ 10GE network.

With this philosophy in mind we are then only concerned with a more limited number of technical and standards issues. To support the ‘optical pipe’ concept, the equipment must be able to scale (i.e. interoperate at the client interface with 9.95Gbps SDH-SONET/10.3Gbps LAN Phy), maintain performance standards (in line with SDH/SONET) in terms of optical transport over the submarine link and also demonstrate that the submarine portion does not cause problems (e.g. show that the submarine section is not the dominant contributor to overall network latency) with data communications. The client interface is required to be tested against ITU G.681 and IEEE8022.3a as well as the traditional interoperability testing with 3rd party terrestrial equipment. Furthermore it is wise to test the transmission performance for the 11.1 Gb/s line rate against the 10.7Gb/s required for SDH/SONET plus a strong FEC overhead.

We also looked for conformance to data network features (e.g. latency, frame loss). To do this we tested our equipment against a layer 3 test specification RFC 2544 [5]. This was run on both the submarine link and the global network (See Fig. 2). Results are recorded in Section 3 of the paper.

In terms of management, the line side monitoring is identical to the SDH/SONET methodology, in terms of providing alarms and monitors (e.g. LOS, LOF BER). The client side is very similar providing details of LOS, LOF and link status on the client receive. On the client transmit, the link will be maintained even when data is not received from upstream. Monitoring of the client and line is of course necessary in terms of fault location and performance monitoring. Protection signalling for the submarine link can be catered for similarly to the SDH/SONET methodology i.e. when critical alarms are raised (based on client or line monitoring.)This can be flagged via the SLTE EMS and can be used to trigger a protection switch at e.g. the POP or at the optical level on the SLTE

Finally and based on the above, for the submarine link only, QOS can be maintained by retaining similar optical performance levels, minimal impact to data propagation and the ability to monitor the status of the submarine link and take appropriate action as required.

3 PRODUCT DESIGN

The migration to the ‘configurable’ transponder poses a number of challenges as the product must support both the ‘standard’ Azea submarine SDH/SONET transponder and 10GE features.

Firstly the transponder will now have support for two main frequencies. The native 10GE data rate is around 10.3 Gb/s rather than the 9.95 Gb/s of SDH/SONET data, all of the transmission path components within the transponder must be capable of handling the rate uplift. This includes the line side of the transponder where, with a FEC coding algorithm applied, the line rate increases from 10.7Gb/s to 11.1Gb/s. WAN Phy is of course also an interface option but there is a bandwidth penalty over LAN Phy in the submarine link and cost/management overheads elsewhere.

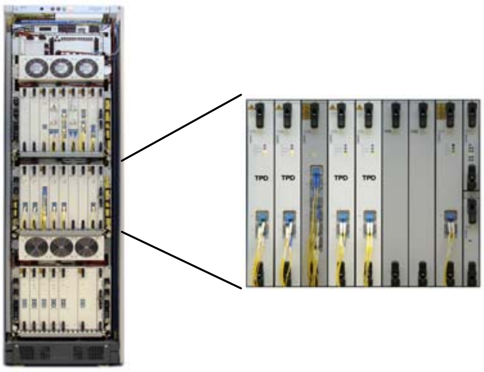
This presents challenges to the Phase Lock Loop (PLL) operation. With FEC (Forward Error Correction) applied, there are now two frequency domains within the transponder, where the data transfer across the interface is controlled by a PLL. The challenge here is twofold. First, these loops are typically very narrowband, focusing on a small capture range around the operating frequency in order to achieve good jitter performance. Second, the required frequency tracking range for 10GE traffic is significantly greater than that of SDH/SONET traffic (+/-100ppm rather than +/-20ppm), so in order to offer a fully compliant 10GE interface it is necessary to improve the capture range of the PLL without degrading the overall performance.

Finally we have to consider 10GE frame monitoring. Blind connection between two 10GE networks on the submarine pipe could give insufficient performance information at the network management layer. This in turn can significantly hamper any network diagnostic activities. As with SDH/SONET data, some top level frame/packet recognition and major alarm monitoring of the 10GE data is required. The Transponder therefore applies established techniques, using a combination of physical interface and data content monitoring to provide suitable network management information. A summary of the monitors and alarms provided is detailed in Figure 1. One added benefit of this approach is that it provides a performance reporting structure which is very similar to that of SDH/SONET submarine links, thereby simplifying the interface.

Client Alarms	Line Alarms
Loss of Signal (LOS)	Loss of signal
Loss of Frame/Data (LOF)	Loss of Frame
Frequency out of limits	Frequency out of limits
Local Fault Detection	AIS
Remote Fault Detection	Line Rx BER

Figure 1 : 10GE required alarm summary

Having SDH/SONET/10GE as a configurable feature, allows operators to use one or the other or a mixture of both, as part of the Azea Submarine Line Terminal Equipment (SLTE). From a management perspective the SLTE is capable of handling and monitoring either SDH/SONET, or 10GE client data and can be switched between formats remotely. An example of this pack is shown in Figure 2.



(a) SLTE (b) Subrack

Figure 2 : SLTE incorporating SDH/SONET and 10GE configured Transponders.

4 FIELD TESTING

Since developing the product we have had the opportunity to test the product on a representative network and to that end a trial was conducted on a 10GE network incorporating a transatlantic link. The network chosen included a Generation 3 submarine link, originally designed for a total of 16 channels of SDH/SONET data at 10Gb/s, with a channel spacing of 100GHz and a link span of approximately 6000km. The submarine system is connected into a Pan European and Pan US 10 Gig E terrestrial networks. This is illustrated in Figure 3. It is also worth noting that today the IP Networks are connected through SDH/SONET pipes, which is not logical.

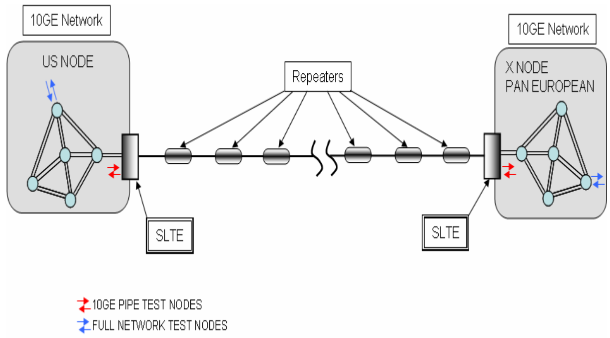
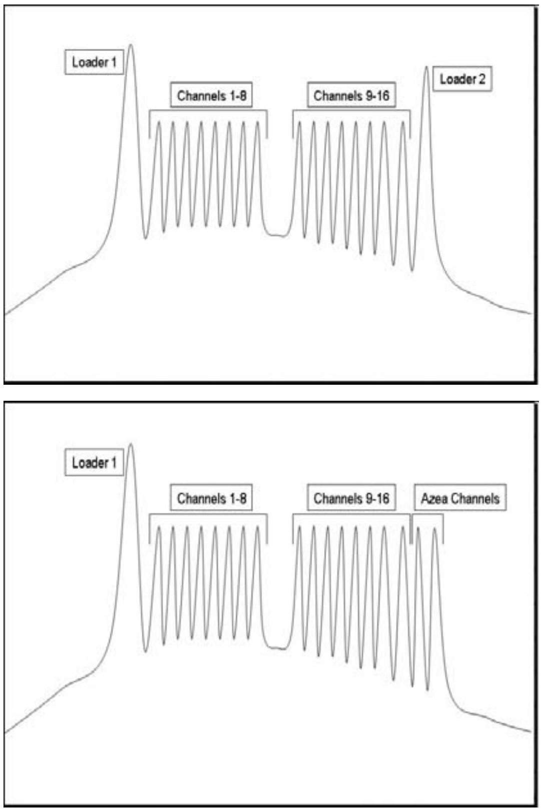


Figure 3 : Network Diagram, showing monitoring points

On the submarine section of the network the repeater bandwidth extends from 1541nm to 1560nm with gain equalisation applied along the system length. The spectrum of the original system is shown in Figure 4(a) and shows the 16 data channels and 2 loading channels at either edge.



(a) before (b) after

Figure 4 : Channel plan (a) Initial system with dual loading channels, and (b) final system with single loader and Azea channels

Two Azea channels were added to the system at the top end of the wavelength band, in place of the high wavelength loading channel. The channel spacing for these channels was also set to 100GHz. Figure 4(b) shows the system spectrum after the addition of the pair of Azea channels.

Such configuration represents a so-called overlay upgrade, which means that additional channels are added to a system while leaving already existing traffic in operation. It has been demonstrated previously that overlay upgrades can be done with a different bit rate than the existing channels [6].

Testing was carried out in two distinct phases. Initially tests were carried out on the submarine link focusing on traditional parameters such as bit error rate measurements along with IP specific features such as latency and other RFC 2544 tests.

Test Type	RFC 2544	
Physical Alarms	Value	
LOS	No Fault	
Frequency	No Fault	
LOC	No Fault	
Ethernet Alarms	Value	
Error	No Fault	
Link	No Fault	
Fault	No Fault	
Frame Count	Tx	Rx
	812744	812744

Figure 5 : RFC 2544 Test Summary

Measurements were conducted at the client interface of the SLTE and showed full compliance with the appropriate 10GE interface standard (IEEE 802.3ae, 10GBASE-ER/EW). In order to characterise the line performance, data was collected at the line receive error correction block. We have monitored pre-FEC error statistics for both channels over a period of 3 months and compared with similar measurements from a SDH/SONET transponder over a similar period. The results show that switching the channel from SDH/SONET to 10GE has no measurable impact on the line performance. It also shows that the rate increase, and associated broadening of the transmit spectrum, has no effect on the adjacent channel.

The SLTE was then connected into the proprietary terrestrial network. Interoperability testing was successfully carried out. RFC 2544 testing was repeated from various nodes in the Pan European Network to PoPs in the US.

Throughout the network testing it was shown that the link was operational over the full allowable frequency range for 10GE traffic, and RFC2544 testing showed faultless performance, with no packet loss. A summary of these results is shown in Figure 5.

The impact of latency induced by the submarine link on the performance of the overall network was a concern but was in part allayed with the results achieved. There appeared to be no impact on this particular system but this has not been comprehensively studied and we intend to carry out further studies in the near future.

5 CONCLUSIONS

This paper has described the impact of 10GE networks on the submarine sector and the subsequent development and test of equipment with the following conclusions. To get around current deficiencies in the the standards domain and remain agnostic to future changes an optical pipe approach was adopted for the transmission of 10GE over the submarine link. This approach offers the benefits of reduced cost and complexity as well as future proofing. We have made the product configurable and therefore Operators will be able to respond to traffic mix changes in their networks much more quickly. Furthermore we have shown that links can support both types of traffic concurrently. Finally we have demonstrated this in a complex long haul network containing a transatlantic submarine link.

6 REFERENCES

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