TRANSPORT OF 10GE OVER SUBMARINE NETWORKS

L. Doyle, O. Ait Sab

laurence-patrick.doyle@alcatel-lucent.fr

Alcatel-Lucent, Centre de Villarceaux , 91625 Nozay Cedex France

Abstract: This paper deals with the transport of 10GE over submarine networks. It summarizes 10GE standardization status, describes different mapping options and discusses their impact on the submarine line design and terminal station equipment. Finally, we touch on network protection options for 10GE signals, in comparison with protection options currently used in submarine networks.

The aim is to provide a simple guide to system owners on the key issues in the transition from SDH/SONET to 10GE client traffic.

1 INTRODUCTION

Today, telecom network operators face the increasing trend of clients moving to packetized services. With the rapid development of IPTV, Video on Demand and Voice over IP (Triple play), more high-bandwidth applications are offered with broadband connections. These applications drive the growth of access rates, and lead to increasing bandwidth requirements. Ethernet (ETH) is widely used and envisioned as the right technology to transport this growing data traffic. In fact, Ethernet technology has moved from the enterprise space to carrier applications. IP routers increasingly use Gigabit Ethernet (1GE and 10GE) as the physical interfaces. The IEEE HSSG (High Speed Study Group) has started to study the specification of 100GE interfaces that will be the main interface for future core IP routers.

According to market trends, most telecommunication broadcasting services are converging on unified packet IP based communication protocols, thus more and more 10GE ports will be deployed in backbone transport networks.

However, due to its LAN heritage, many management capabilities are missing in the Ethernet protocol when compared to the rich features of SDH/SONET, for example, end-to-end monitoring, bandwidth management and protection switching capabilities. New protocols and techniques like Multi Protocol Label Switching (MPLS), GMPLS (Generalized MPLS) and Resilient Packet Ring (RPR) were developed to provide some of the lacking capabilities of the Ethernet protocol. Unfortunately, these focus mainly on issues close to the service interface (bandwidth management and QoS).

Optical transport networks, as main telecom transport backbone infrastructure, will face increasing requirements to directly transport packetized data services in an efficient way. The requirements of such core transport networks are very much more stringent than those of the LAN (for example, carrier's carrier environment and network resilience). Currently there is still no consistent solution for packet protocols which comply with the stringent requirements of transport networks, hence work in standardisation bodies is continuing on these aspects.

Today's transport core backbones were designed to transport SDH/SONET signals. With the development of Dense Wavelength Division Multiplexing (DWDM), the Optical Transport Hierarchy (OTH) had been standardized (ITU-T G.709) for Optical Transport Networks (OTN) since 2001. The OTH provides a cost efficient transport layer. Indeed, OTN supports DWDM technologies, improves many SDH/SONET concepts and precisely addresses core transport OAM tasks (Operations Administration & Maintenance). OTH will serve as a converged transport layer for new packet-based services and Time Division Multiplexing (TDM) based legacy networks.

The OTH payload rates were defined to match SDH/SONET signals from STM-16/OC-48 to STM-256/OC-768. The increasing 10GE transport requirements will lead the OTN to have a more suitable architecture for 10GE transport. 10GE physical interfaces were standardized (IEEE 802.3) in two main variants:

- 10GBASE-R (10GE LAN)
- 10GBASE-W (10GE WAN).

Even if the latter specifically was defined for long-haul applications (matching perfectly with the available payload bit rates of the underlying SDH/SONET (or OTH) transport network, market acceptance for this solution is comparably low - the higher market price applied by equipment vendors for 10GE WAN interfaces on data equipment being one of the main reasons. Therefore the requirement for transport of 10GE LAN signals is increasing. However, the bit rate of 10GE LAN signals is slightly too high for the standardised bit rates of the SDH and OTH networks.

The remainder of this paper deals with how 10GE can be transported over OTN. It summarizes 10GE standardization status, describes different mapping options and discusses especially their impact on the submarine line design and terminal station equipment. Finally, we touch on network protection options for 10GE signals, in a submarine network context.

2 STANDARDIZATION STATUS FOR 10GE TRANSPORT OVER OTN

10GE LAN has a line bit rate of 10.3125 Gb/s. A WAN Interface Sub-layer (WIS) is used to adapt 10GE LAN signals into an STM-64/OC-192 structure at a slightly lower bit rate, i.e. the 10GE WAN signal.

The IEEE had standardized 10GE WAN interface for the transport over the TDM networks at the standardised STM-64/OC-192 bit rate. However, current market realities driven by price have resulted in the prevalence of the 10GE LAN signal.

G.709 currently defines payload bitrates of 2 488 320 kbit/s (via ODU1), 238/237 × 9 953 280 kbit/s (via ODU2), and 238/236 × 39 813 120 kbit/s (via ODU3). A tributary mapping structure is defined so that lower rate signals can be multiplexed into higher rate signals. An Optical Channel Transport Unit (OTUk) frame structure is shown in Figure 1.

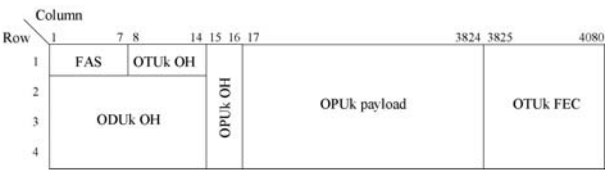

Figure 1: OTUk Frame Structure

The 10GE LAN bit rate of 10.3125 Gb/s does not fit into the standard 9.95 Gb/s OPU2 payload.

ITU-T defined also a Generic Framing Procedure (GFP G.7041) to encapsulate variable length payload of various client signals for subsequent transport over SDH and OTN networks. The frame-by-frame mapping of Ethernet MAC frames into GFP-F frames is described in ITU-T recommendation G.7041/§7.1. The format of Ethernet MAC frames itself is defined in IEEE 802.3, Section 1, paragraph 3.1. There is a one-to-one mapping between a higher-layer PDU and a GFP PDU. Specifically, the boundaries of the GFP PDU are aligned with boundaries of the framed higher layer PDUs. This relationship between Ethernet MAC frames and GFP-F frames is illustrated in figure 2.

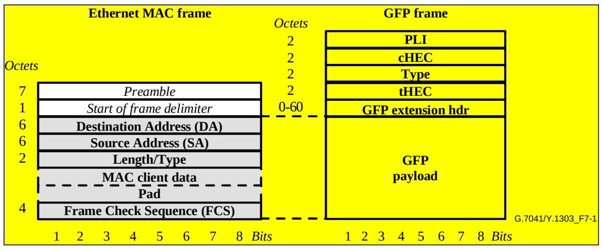

Figure 2. : GFP-F Mapping (G.7041) for Ethernet Signals

The Ethernet MAC octets from Destination Address through Frame Check Sequence, inclusive, are placed in the GFP Payload Information field. The Ethernet MAC octets from the preamble and SFD fields are discarded.

Ethernet Inter Frame Gaps (IFGs) are deleted before the Ethernet MAC frame is processed by the GFP source adaptation process and restored after the GFP frame is processed by the GFP sink adaptation process. IFGs are restored by ensuring that sufficient octets containing an idle pattern of 00 hex are present between consecutive Ethernet MAC frames to meet the minimum receiver IFG requirements.

As seen from the above, the preamble, SFD, and IFG octets of the Ethernet MAC frame are not transported across an GFP-F link, but, discarded at the ingress and generated newly at the egress. They can’t be used in this case to transport any useful (e.g. OAM) information.

3 OPTIONS FOR TRANSPORT OF 10GE LAN OVER OTN

ITU-T standardized 10GE LAN transport using frame transparent GFP (Generic Framing Procedure; ITU-T Rec. G.7041) described briefly above. The GFP-F mapping for Ethernet MAC frames decodes the 64B/66B encoding and strips off the preamble, the SFD and the IFG before mapping the remaining MAC frames into a standard OTH entity (OPU2). This solution is fully compliant with the existing OTH standards (G.872, G.709, G.798,…) and specifically the bit rates defined therein.

However, this mapping technique does not fully answer some operator requirements for a “fully transparent transmission” of 10GE LAN signals.

3.1 Market Requirements

Several companies are pushing to standardize "fully transparent" 10GE LAN transport over an OTN.

- Some carriers require end-to-end performance monitoring based on Physical Coding Sub-layer (PCS). The BER monitoring functionality of PCS enables the operators to monitor their networks. Thus there is a need to realize the transparent transport of the PCS layer entity, which is 10GE LANPHY with a bit rate of 10.3125 Gbit/s.

- There are requirements for network services. For example, some applications use the Inter Frame Gap (IFG), Preamble, and Start Frame of Delimiter (SFD) to carry OAM information used to operate and administer the networks.

- Some applications require transparency for larger 'jumbo frames' to handle large packet sizes, but these are not standardized in IEEE802.3.

- Some applications, especially those handling classified information, require security preservation and therefore request "Don't touch anything" in the transport process.

Some network operators, therefore, request solutions to transport 10GE LAN signals in a fully transparent manner, either to meet customer needs or to support internal OAM needs.

3.2 Over-clocking Solutions

A straightforward solution to transport the 10GE LAN transparently is to simply increase the OPU2 bit rate. This approach does not require a new silicon circuit and can be realized by slightly over-clocking the existing OTN mapping device. Two mapping mechanisms - with and without fixed stuffing bytes - are shown in Figures 3 and 4.

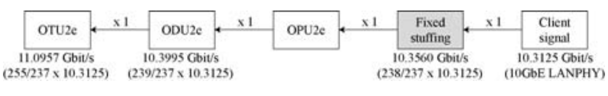

Figure 3 : Mapping with Fixed Stuffing Bytes

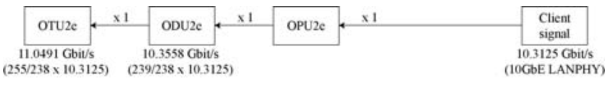

Figure 4 : Mapping without Fixed Stuffing

3.3 Other Mapping Options

Several solutions have been studied to resolve this mapping issue. One proposal is to slow down the 10GE LAN bit rate from 10.3125 Gb/s to 9.95 Gb/s.

A second alternative mapping solution decodes the 64B/66B encoding, strips off the IFG and maps the rest into the respective OTH entity (OPU2), but, in addition to the normal payload area, also uses a stuffing column and some bytes of the OPU2 overhead. This proposal complies with the original OTH bit rate, but is not completely compatible with the existing standards.

It has also proposed to use OPU1-5v to transport 10GE LAN. This solution even if very practical has the drawback of a poor bandwidth efficiency.

A rate adaptation method based on Ethernet flow control mechanisms has also been proposed. Another solution maps the Ethernet MAC frames into the OPU2 payload, processes the preamble and IFG, extracts the proprietary information and transmits it via OTU2 GCC (General Communication Channel) in the OTU2 overhead.

These solutions answer some operator requirements, but no solution complies with all of them. It seems that the over-clocking approaches are considered to be the only solution completely transparent to Preamble, SFD, IFG, and possible encrypted signals. These over-clocking solutions, however, can be used only in point to point applications (e.g. over WDM systems) as the bit rate won't fit with normal TDM hierarchy nor offer any switching or aggregation capabilities at the OTN layer.

4 10GE LAN/WAN TRANSMISSION OVER OPTICAL SUBMARINE NETWORKS

Currently deployed submarine networks are designed to transport mainly SDH/SONET signals. Owners of submarine networks have started to show interest in G.709 OTN signals. It is clear that the transport of 10GE LAN or WAN will be increasingly required in the next coming years.

4.1 Submarine Network Line Design and Performance Impact

Submarine network design has always been largely driven by performance in order to achieve a maximum capacity over a very long distance for a given investment.

The prevalence of 10GE LAN signals is due essentially to the low cost of 10GE LAN ports versus the 10GE WAN ports. But the 10GE LAN has a slightly higher bit rate than 10GE WAN (3.65%). For a metro or long haul networks this slight bit rate increase could be considered as insignificant. For a transoceanic system, this is no longer true.

In fact, the transport of 10GE LAN at an increased bit rate represents a 0.15 dB penalty on the optical power budget table compared to transport of STM-64/OC-192 signals. This extra bit rate could be more effectively used to enhance FEC performances. An extra 3.6% redundancy for UFEC would lead to 0.8 dB extra Net Coding Gain (NCG) (G975.1). This extra NCG can save many repeaters or add many additional wavelengths on long systems. The economic justification of the increasing signal bit rate to transport 10GE LAN across submarine networks cannot be readily proved.

Another issue when crossing a submarine network is the wavelength or channel spacing. A well known approach when upgrading existing submarine systems is to reduce channel spacing, e.g. from 50 Ghz down to 33 Ghz and less. Some submarine networks have been designed with a 25% OH FEC, resulting in a line bit rate of 12.45 Gb/s. A 3.65% increase in bit rate to transport 10GE LAN would lead to 12.9 Gb/s line bit rate. This will result in additional performance degradation when combined with reduced channel spacing for upgrades.

For future 40 Gb/s systems, the need of strong FEC will lead to an increase of the redundancy (up to 25%) or to the use of soft decision FEC decoding strategy. Transport of 4x10GE LAN would require 51.6 Gb/s instead of 49.7 Gb/s for 4x10GE WAN. The line design impact will be clearly significant and has to be taken carefully into account.

4.2 Protection Aspects

10GE Traffic: Use of Link Aggregation Group (LAG)

Several point-to-point wavelengths transporting 10GE traffic can be grouped in a single ‘conduit’ (LAG) with a given capacity. The router assigns traffic (packets) on the various LAG ports according to packet prioritisation. If one port fails, its traffic is re-distributed on to the working ports of the LAG. If more than one port fails simultaneously, their traffic is re-distributed to the remaining working ports. With such a dynamic re-distribution of packet traffic being managed entirely within the routers in a short timeframe, added wavelength protection on SLTEs or SDH/SONET protection mechanisms at STM-64/OC-192 level to achieve the committed service quality may not be necessary. Some options for such additional protection are described in [5].

10GE LAN traffic :

If N+1 wavelength protection is to be applied to 10GE LAN traffic, a specific 10GE LAN protection group needs to be created on the SLTEs, separate from protection groups for SDH/SONET signals which may be present on the same SLTE. In other words, specific added investment is needed for 10GE LAN protection which cannot be shared with protection of SDH/SONET traffic on the same SLTE, unless more sophisticated solutions are considered, such as described in the next paragraph.

A possible alternative is the development of an intelligent SLTE tributary unit, capable of recognising the format of the client traffic (SDH/SONET framed or Ethernet MAC framed), and adapting its characteristics to suit. This would resolve the need for specific SLTE protection groups in the case of protection, and in theory would provide a flexible self-configuring platform for transport of both existing SDH/SONET framed traffic and 10GE LAN traffic. However, issues such as costs, re-configuration time (especially in the case of N+1 protection), and the complexity of managing different traffic types may well outweigh the potential advantages of such a solution.

10GE WAN traffic :

Since 10GE WAN traffic has the same bit rate as STM-64/OC-192 traffic, the protection mechanisms supported by SLTEs for wavelengths at this existing SDH/SONET bit rate can be applied.

Typically at start of life, a single N+1 wavelength protection group is sufficient for all 10 Gb/s wavelengths requiring protection. Wavelengths carrying 10GE WAN traffic and SDH/SONET traffic can be freely mixed in the same protection group. Additional protection groups can be added as system capacity is increased. In addition, protection using OTH protection mechanisms is also perfectly applicable when OTH switching is available in the network nodes.

5 CONCLUSION

In response to network transformation programs being implemented in carrier networks, submarine networks will need to transport a growing amount of packetized traffic on 10GE client signals. While standards define two formats for such client signals (10GE LAN and 10GE WAN), the pricing strategy of data equipment vendors has led to the prevalence of 10 GE LAN traffic which has an incompatible bit rate with OPU2 payload of the OTN. The transport of 10 GE LAN over OTN still an open issue even at the standardization level.

The requirement for fully transparent transport of 10 GE LAN signals can be achieved only by over-clocking at 11.1 Gb/s the OTU2 bit rate. This solution is very simple to implement. However, it does not comply with ITU-T standard bit rates and thus can be used only in point-to-point applications. Some price and performance penalties can be expected on long systems. Furthermore, no switching or aggregation capabilities at the OTN layer can be supported.

For submarine networks, two standardized solutions, 10GE WAN interface and GFP-F mapping of 10GE LAN signals into OPU2, are very attractive. Existing line submarine design is not affected, and the existing SLTE protection schemes can be applied cost effectively. In addition, these signal formats are fully compatible with the OTH protection and switching mechanisms in the emerging OTN layer.

6 REFERENCES

[1] ITU-T G975.1 : Forward Error Correction for High Bit-rate DWDM Submarine Systems

[2] ITU-T G.709/Y.1331: Interfaces for Optical Transport Network (OTN)

[3] ITU-T G.7041/Y.1303: Generic Framing Procedure (GFP)

[4] IEEE 802.3 Part 3: IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements, Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications

[5] Laurie Doyle, Gert Grammel, Thibault Burdin de St. Martin : Intelligent Protection and Restoration for Submarine Networks, SubOptic 2004.