Optical Bandwidth

White Paper

The Optical Transport Network (OTN): The Next Step in Network Evolution

Introduction

The Optical Transport Network (OTN) promises to do for the transport of wavelengths what SONET did for transport of DS-1s and DS-3s. SONET was conceived and developed for the DS-1 and DS-3 world of the late 1980s and 1990s. Much has changed with the rise of Ethernet transport and the need to transport wavelengths of any variety. The potential of the OTN is to create operation, administration, and monitoring (OA&M) capability for wavelengths regardless of the traffic type being carried as well as to extend the reach of these systems through forward error correction (FEC). The OTN also promises to add protection switching capabilities at the optical layer with 50 ms or less switching times, which would greatly enhance Ethernet transport.

This goal of this White Paper is to express in simple terms some of the beneficial features of the OTN and how they might be used in transport networks. Three fundamental areas are addressed: performance monitoring, forward error correction, and protection switching.

OTN Overview

The Optical Transport Network is based on a set of ITU Recommendations (standards) with ITU-T G.709 being the cornerstone. This ITU-T Recommendation defines requirements in the areas of optical transport hierarchy (OTH), functionality of the overhead in support of multi-wavelength optical networks, frame structures, bit rates, and formats for mapping client signals. This ITU Recommendation is probably most widely known for its inclusion of standard forward correction (FEC) based on Reed-Solomon coding. Some transport schemes have incorporated G.709 FEC without any of the other features of the OTN.

Figure 1 below illustrates the structure of OTN signals. The client signal is mapped into an Optical channel Payload Unit (OPU). The Optical channel Data Unit (ODU) provides end-to-end path supervision and supports tandem connection monitoring – a feature very useful for inter-domain transport. The Optical Transport Unit (OTU) adds forward error correction (FEC) and provides OA&M functions for transport between optical channel termination points where re-timing, reshaping, and regeneration (3R) functions take place.

In this regard, the OTN resembles SONET. OPU, ODU, and OTU in the OTN mirror path, line, and section, respectively, in SONET. The payload signals are different – DS-1s and DS-3s in a SONET world and wavelengths – OC-48s or GbEs, for example – in an OTN world.

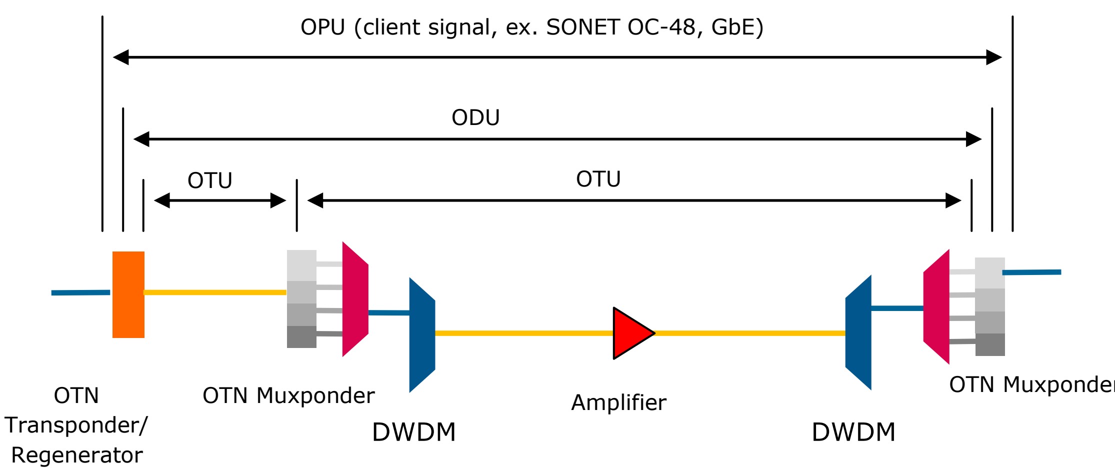

Figure 1: OTU, ODU, and OPU termination points in an OTN network.

Table 1 below shows the difference between SONET and OTN rates for the three rates standardized for OTN at present.

SONET/SDH Interface	Line Rate	G.709 OTN Interface	Line Rate
OC-48 / STM-16	2.488 Gb/s	OTU-1	2.666 Gb/s
OC-192 / STM-64	9.953 Gb/s	OTU-2	10.709 Gb/s
OC-768 / STM256	39.813 Gb/s	OTU-3	43.018 Gb/s

Table 1: Comparison of SONET and OTN Rates

OTN rates are about 7% greater than SONET rates due to the additional FEC overhead. An OTU-4 rate of approximately 100 Gb/s is under discussion in IEEE and ITU standard bodies.

Performance Monitoring

ITU-T Recommendation G.709 allows for OTN performance data to be collected for each optical signal at each OTN device. This greatly facilitates fault isolation for each wavelength transported. Figure 2 below depicts an OTN system with various add/drop and regeneration points that could provide performance data to an EMS or NMS. It is worth noting that this system could contain non-OTN network elements that would transparently pass the OTN signal but not provide OTN performance data such as the regenerator at Site 4 in the figure.

The OTN allows for the performance monitoring of BER prior to and after the insertion of forward error correction (FEC). It extends several SONET performance monitoring concepts, such as BIP-8 and trace messaging, to the optical layer. It also has overhead to facilitate tandem connection path monitoring which will be extremely useful for optical signals that are transported across several different carrier domains. Carriers will be able to isolate faults to a particular connection and thereby reduce the length of time to repair an outage as a result of the better diagnostics. Up to six (6) tandem connections are supported in the OTN overhead.

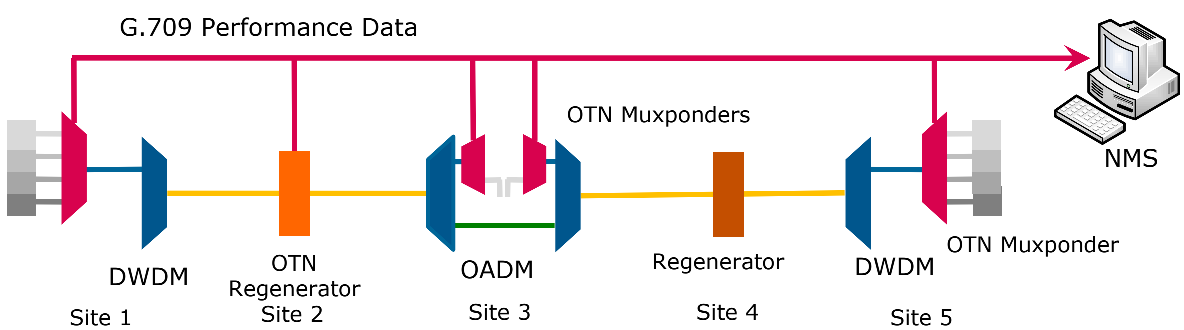

Figure 2: Illustration of Collection of OTN Performance Data

Forward Error Correction

ITU-T Recommendation G.709 defines standard forward error correction (FEC) referred to as GFEC while ITU-T G.975 provides several non-standard FEC schemes. GFEC allows an additional gain of 6 dB while non-standard SuperFEC will allow enhanced coding gain and a few more dB of reach. The 6.0 dB gain of Standard FEC allows an additional reach of 25 to 30 km at 1550 nm as illustrated in Figure 3 below.

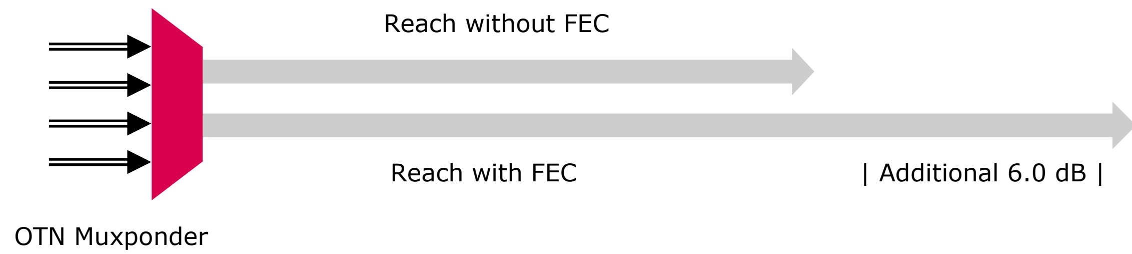

Figure 3: Additional 6 dB gain with Standard FEC

GFEC will be a useful tool to extend the reach of a transport system by 6 dB. This additional reach may allow a carrier to place a 10 Gb/s system on a fiber span that was engineered for only 2.5 Gb/s thus avoiding costly re-engineering of add/drop and regenerator locations.

Protection Switching

ITU-T G.709 builds into the Optical Channel Data Unit (ODU) frame structure – which contains the optical payload unit (OPU) - overhead for an Automatic Protection Switching coordination channel. One of the practical implications of this is the ability to add overhead or "wrap" an Ethernet signal such as GbE or 10 GbE and derive protection switching as a result of the overhead in the ODU. This is something that has been sorely lacking in Ethernet transport and has caused many carriers to go to the extra expense of transporting Ethernet over SONET in order to be assured of a robust protection mechanism.

Economics and Reality

One of the main issues in implementing an optical transport network will be how many of the OTN's capabilities carriers will realistically be able to implement. The OTN offers a rich set of features which will need to be implemented in another operation support system (OSS). This will be in addition to the OSS that supports SONET, Ethernet, DWDM, and IP. There will be a cost burden on both carriers and vendors to build additional OA&M features into OTN equipment and the operational support systems to monitor and manage this equipment.

Conclusions

For the near term, forward error correction (FEC) and the ability to extract performance monitoring data, particularly on signals such as GbE that have not had this performance monitoring data available, will be the most useful features of the OTN. Protection switching will also be an attractive feature and could prove extremely useful for, again, signals such as GbE that lack a robust protection switching capability such as SONET.