10G LAN PHY over G.709 OTN: A Service Provider Prospective

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Abstract: This paper provides a current assessment of transporting 10G LAN PHY over G.709 OTN payload in a multi-vendor environment. It highlights current available mapping schemes, a carrier view of OAM and automatic protection switching requirements.

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1. Introduction

There is a growing Local Area Network (LAN) customer demand for full 10G Ethernet rate services, with expectations of lower cost (compared to the traditional SONET-based services) and Synchronous Optical Networking (SONET)-like reliability. Traditional Point-to-Point Protocol/High Level Data Link Control (PPP/HDLC) over SONET concatenation and Ethernet over Frame mapped Generic Framing Procedure (GFP-F)/SONET virtual concatenation has bandwidth limitations for transporting full 10G Ethernet. This creates an urgent need for new, improved solutions that match SONET capabilities for transporting 10G Ethernet signals. As the technology has evolved, a new optical transport technique has been developed. This technology is G.709 Optical Transport Network (OTN)-based, which carries 10G Ethernet client traffic. The new infrastructure overcomes the bandwidth limitation inherent in SONET and enables it to carry the full 10G Ethernet line rate for transport of Media Access Control (MAC) data with GFP-F support or Physical Coding Sublayer (PCS) layers. The driving force behind this transition is the need to improve operational efficiency and to deploy more cost-effective optical transport, especially compared to the existing SONET-based infrastructure. The G.709 OTN commonly carries OC192 frames. This allows use of the existing infrastructure, often without requiring major changes. The G.709 OTN payload has been used as an underlying technology for carrying the OC192 frame in the field. Furthermore, there have been advances in OTN technologies and 10G LAN Physical Layer Entity (PHY) mapping schemes that have created a new generation of equipment that features a high degree of functional integration and is capable of providing SONET-like functionalities.

This paper evaluates and presents the 10G LAN PHY OTN payload adaptation schemes. Pairwise interoperability tests show that there are no major adaptation implementation issues. This is due in part because all involved vendors have firmware that is programmable to match the G.709 Payload Structure Identifier/Payload Type (PSI/PT) and GFP-F overhead. Also, all vendors must agree on GFP-F Frame Check Sequence (FCS) “on” or “off” selection. Without this many pairwise tests would fail. From a carrier perspective, these standards should be formalized.

Today, no vendor has fully incorporated operations, administration, maintenance (OAM), and automatic protection switching (APS) functionalities into their products. This paper also addresses the requirements in this area of development.

2. Background

The original Ethernet standard aimed for the 10Mbps shared media application which requires a well-defined fixed pattern Preamble (8 bytes) and Start Frame Delimiter (SFD) (1 byte) for receiver clock synchronization and Ethernet MAC layer frame recovery as shown in Figure 1a. As Ethernet extended to one gigabit per second in metro and wide area applications, traditional shared media architecture migrated to point-to-point SONET-based as shown in Figures 1b.

SONET concatenation containers are referenced as: STS-3c (155 Mbps), STS-12c (622 Mbps), STS48c (2448 Mbps) and STS-192c (9792 Mbps). As this hierarchy implies, bandwidth management at the physical layer is fixed.
with the selected SONET concatenation (Figure 1b). Virtual concatenation (Vcat) improves bandwidth utilization by creating variable bandwidth virtual pipes in a SONET stream (Figure 1b). The advantage of a SONET-based network for transporting IP or Ethernet traffic is its capability to carry partial or full Ethernet rate. However, it requires an inter-working protocol, such as frame-mapped Generic Frame Procedure (GFP-F) or PPP/HDLC, to encapsulate IP or Ethernet traffic into a SONET payload and recover the transmitted data at the receiving end.

In light of the complexities and the cost of infrastructure, efforts to match Ethernet’s rates and encapsulation methods to that of SONET have not been efficient. SONET is an excellent transportation mechanism for partial 10/100/1000/10G or full 10/100/1000 full rate Ethernet services. However, full rate 10G services cannot be achieved with a SONET OC-192 payload. As technology evolves, full rate 10G Ethernet services can be transported with direct mapping of Ethernet frames into the G.709 OTN payload (Figure 1d) or with GFP-F support (Figure 1c). Without the SONET layer, the equipment and operational cost will be substantially lowered. More importantly, full rate 10G LAN services can be achieved.

The following section describes the key adaptation requirements and remaining challenges to the realization of full G.709 OTN network capabilities, with respect to OAM and APS.

3. G.709 OTN Structure Overview

In Figure 2 the generic G.709 Optical transport Unit (OTU) frame structure with OTU2 data rate of 10.7Gbps is displayed. In this case, Optical Channel Payload Unit (OPU)2 is 15168 bytes per G.709 OTN frame, excluding 64 Fixed Stuffing bytes (FSB), to provide a payload capacity of 9.95328Gbps. This is referred to as the OPU2 payload, or 15232 bytes per OTU frame. If 64 FSB is included to accommodate a payload capacity of 9.995276962Gbps, it is referred to as OPU2 + FSB. The OPU2 payload +FSB+OPU2 Overhead (OH) Reserved (RES) is defined as 15239 bytes per OTU frame if the 64 FSB and the seven (7) ODU RES bytes allocated to provide a payload capacity of 9.999870379Gbps. These payload capacities are sufficient to transport Ethernet MAC data or MAC frames without limitations.

As stated above, the maximum standard OPU2 payload capacity is less than 10Gbps. For applications that must preserve the original 10.3125 Gbps PCS data stream, the traditional 10.7Gbps OTU2 rate operates at 11.05Gbps (if the 64 FSB are included as part of the OPU2 payload) or at 11.09Gbps if the 64 FSB are preserved.

With regard to these mapping schemes, only the OPU2 payload with the 64 FSB option has been standardized. All other schemes are considered proprietary implementation.

3.1. 10G LAN PHY G.709 OTN Adaptation

As 10Mbps simplex migrates to the 10G G.709 OTN point-to-point duplex architecture, GFP-F is becoming the standard encapsulation scheme for transporting Ethernet MAC data or MAC frame over the G.709 OTN or SONET payload. These options are referred to as MAC data transparency or Standard GFP-F mapping or Semi (MAC Frame) transparency.
These two technologies utilize an eight byte overhead structure. GFP-F also provides a four byte idle frame, intended for use as a filler frame for the GFP source adaptation process in which the transport medium channel has a higher capacity than the client’s signal requirements.

With respect to legacy 10G Ethernet LAN applications, customers may use the Ethernet Preamble and Inter-Frame Gap (IFG) for carrying proprietary control or OAM messages between end clients. This is instead of MAC frame and clock recovery. In this case, the original Ethernet MAC frame and IFG must be preserved between end clients. For this application, it requires an adjustment of the G.709 OTN operating clock to 11.05 or 11.09 GHz.

Figure 2 - OTN Frame Structure

Figure 1d describes the 10G Ethernet LAN PHY stack where MAC layer data stream is 10Gbps, additionally, the 64B66B-encoded PCS layer data stream is 10.3125Gbps. This is the line speed (data rate) which is referred to as Physical Coding Sublayer “PCS” in standard and this paper.

The following sections describe the requirements for mapping the 10.3125Gbps PCS data stream into a standard 10.7Gbps G.709 OPU2 payload and expanding the OPU2 payload capacity to carry the original PCS rate of 10.3125Gbps. In this case the OTU2 line rate has to be adjusted to 11.05Gbps or 11.09Gbps.

3.1.1. Asynchronous Standard GFP-F Mapping

In Asynchronous Standard GFP-F Mapping, the 10G Ethernet client and the G.709 OTN clocks operate asynchronously. This option is defined as MAC frame transparency, since it only delivers MAC data frames to the designated remote client. With this option, Ethernet adaptation is required to extract the 10GbE frame from the incoming 10.3125Gbps PCS data stream. This option also only maps the MAC data frame into the G.709 OTN payload. The OTN payload also includes the 64 FSB, as defined in the standard OTN specification.

The End terminal at the OTN hand-off to the 10GbE client extracts the MAC data frame from the ODU payload and inserts the Preamble and Start Frame Delimiter. It also inserts at least one IDLE or more if needed. This is done to recreate the standard Ethernet frame format and to convert it into a PCS format before sending it to the 10G Ethernet client.

3.1.2. Asynchronous Semi-Transparent GFP-F mapping

In Asynchronous Semi-Transparent GFP-F mapping, the 10G Ethernet client and the G.709 OTN clocks operate asynchronously. This option is referred to as “Semi-Bit transparency.” The original end terminal takes the client PCS, recovers the Ethernet frame and IDLE, drops the IDLE, and maps to GFP-F and G.709 OTN payloads. It then transmits across the network to the remote end terminal and adds a new IDLE frame(s), rebuilds the PCS and
transmits to the client. In this case, the OTN payload also includes the 64 stuffing bytes and the seven (7) ODU RES bytes as detailed in the standard OTN specification.

### 3.1.3. Overclocking OTN to 11.05Gbps

This mode maps the incoming 10G PCS data stream into the OPU payload directly, including the 64 FSB. This option provides Ethernet Bit transparency between 10GbE clients.

### 3.1.4. Overclocking OTN to 11.09Gbps

This mode maps the incoming 10G PCS data stream into the OPU payload directly without utilizing the 64 FSB. This option provides Ethernet Bit transparency between 10GbE clients.

### 3.1.5. Mapping Schemes Comparison and Summary

Table 1 displays the attributes of various 10G LAN-PHY mapping options. It is also a brief summary and comparison of the four mapping schemes. In this example, we selected the Standard GFP-F option as reference and recommendation for future deployment. This rationale is primarily due to Standard GFP-F’s standard-approved architecture and its ability to maintain the OTU and Ethernet clock tolerance of +/- 20 and +/- 100 ppm, respectively.

<table>
<thead>
<tr>
<th>LAN PHY Mapping</th>
<th>Standard GFP</th>
<th>Semi Transparent GFP</th>
<th>Overclocking 11.05Gbps</th>
<th>Overclocking 11.09Gbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.799 Bitrate Compliant</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>ODU Clock Tolerance</td>
<td>±20 ppm</td>
<td>±20 ppm</td>
<td>±100 ppm</td>
<td>±100 ppm</td>
</tr>
<tr>
<td>1G Ethernet Client Clock Tolerance</td>
<td>±100 ppm</td>
<td>±100 ppm</td>
<td>±100 ppm</td>
<td>±100 ppm</td>
</tr>
<tr>
<td>Jitter/Wander per G.8251</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Multiplex to 40Gbps per G.799</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Transport Full Rate Payload</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Transport Full Rate Preamble and Payload</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Transport FG</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Transport Ordered Sets</td>
<td>Only LR and RF</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Full Bit Transparency</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Supports proprietary usage of MAC and PCS layers</td>
<td>No</td>
<td>Preamble and ordered sets</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### Table 1 – 10G LAN-PHY Mapping Schemes Comparison

### 4. Lab Test Results and Findings

We invited several equipment vendors for interoperability testing. The participants were categorized based on the four mapping schemes described above (Table 1).

Test results indicate that most vendors support software selectable with any of the four mapping schemes. During testing, major issues did not arise at the Ethernet and G.709 OTN adaptation layers. However, issues occurred with the value of the G.709 OTN Payload Structure Identifier/Payload Type (PSI/PT) and GFP-F header fields and GFP-F FCS enable/disable. These issues were resolved with vendor firmware upgrades.

None of the vendors has implemented Tandem Connection Monitoring, or Automatic Protection Switching/Protection Communication channel functionality. None of the vendors with GFP-F option implemented Ethernet Ordered set transparency.

### 5. The Future of G.709 OTN
Figure 3 describes the typical multi-vendor 10G LAN PHY G.709 OTN network, which consists of the basic G.709 OTN layers, Ethernet client signal and Ordered set paths, protection options, trail protection or subnetwork protection (SNC). Figure 3 shows two customer terminals (vendors A and I) and six vendors/carriers (vendors/carriers B through H). From the service providers’ point of view, this is one end-to-end network with OAM monitoring and client protection architecture. To facilitate end-to-end G.709 OTN performance monitoring capabilities, it is important to select only one of the four mapping schemes. Otherwise, performance monitoring will be interrupted at the conversion point. A singular mapping scheme also detects incoming optical signal conditions and inserts appropriate OTN alarms. Subsequently, the system is able to address incoming alarms or pass the alarm onto the downstream node “as received.” Therefore, it is important to have a set of hand-off requirements to all vendors/carriers prior to the equipment installation or end-to-end path provisioning. The End Terminal vendors A and I can pass the Ethernet Ordered Set information from the OTN or 10G Ethernet Client as received onto 10G Ethernet Client or OTN, respectively. While operating under the GFP-F mode, these terminals are able to encapsulate the Ethernet Ordered Set to the predefined GFP-F payload with the appropriate GFP-F header set up.

![Figure 3 - OTN Architecture Block Diagram](image)

5.1. Ethernet Order Set Support

Figure 4 shows a typical network model that handles Ethernet and G.709 OTN OAM signals. End terminals (vendors A and I) support Local Fault (LF) detection from the incoming 10G Ethernet client and inserts Remote Faults (RF) to the 10GbE Clients (as defined in IEEE Standard 802.3-2005). LF is viewed as Loss-of-Signal (LOS), Loss-of-block-sync and High-bit-error rate at the Local 10GbE Client interface with no OTN faults. If an OTN fault is detected, the system issues ODU-AIS (as defined in G.709 Standard). Subsequently, LF and ODU-BDI are issued at the Remote 10GbE Client Interface to downstream Remote 10GbE Client and upstream OTN network, respectively.

5.1.1. Ethernet Ordered Set (LF, RF) Support w/o OTN Faults for GFP Options

Figure 5 illustrates the Ethernet ordered set (LF, RF) support without OTN faults for the GFP option. The local 10GbE client interface detects LF from the incoming signal and injects the OPU-AIS per G.709 standard toward the OTN network. Support and mapping of Ethernet Ordered Set other then LF into GFP Client Management Frame (GFP CMF (LF)) is optional. In the event that the option to provide support and mapping to an Ethernet Ordered Set (other than LF into GFP) is exercised, requirements that define this action are necessary.

Upon receipt of OPU-AIS at remote OTN Interface, LF will be injected and sent to the remote 10GbE Client. Upon receipt of GFP CMF(LF), the remote 10GbE Client Interface will decode GFP CMF(LF) frame and inject LF into the downstream 10GbE Client. Upon detection of RF at Local 10GbE Client Interface with GFP-F option, the system will map RF into the GFP Client Management Frame. The mapping will be sent to the remote 10GbE Client.
Interface. Upon receipt of GFP CMF from OTN, RF, the system injects the GFP CMF and sends it to the remote 10GbE Client.

![Image](image1.png)

**Figure 4** - shows a typical network model for handling Ethernet and G.709 OTN OAM signals

5.1.2. **Ethernet Ordered Set (LF, RF) Support w/o OTN Faults for GFP Options**

Figure 6 illustrates support Ethernet ordered set (LF, RF) support without OTN faults for the GFP option. Upon detection of LF at Local PCS / OTN mapping, the Local OTN Interface injects OPU-AIS per G.709 standard toward the OTN network. Upon receipt OPU-AIS at Remote OTN Interface, the End Terminal injects LF and sends it to Remote 10GbE Client.

5.1.3. **Support of ALL Clear (LF, RF) w/o OTN Faults for GFP Options**

**Figure 7** illustrates support of ALL Clear (LF, RF) support without OTN Faults for the GFP option. The system requires at least three injected GFP CMF (ALL Clear) message(s) toward the OTN. These messages should be injected over 30msec with a 10msec sampling rate. At the Remote 10GbE Client Interface, detection of GFP CMF (ALL Clear) and clear LF and RF fault toward 10GbE Client; when no Client Management frame (LF, RF) detected for 3 seconds, the system clears LF or RF fault to the 10GbE Client.

![Image](image2.png)

**Figure 6 – Ethernet Ordered Set (LF, RF) Support without OTN Faults for GFP Option**

**Figure 7 – Support of ALL Clear (LF, RF) without OTN Faults for GFP Option**
5.1.4. Ethernet Ordered Set (LF, RF) Support with OTN Faults for GFP Options

Figure 8 illustrates Ethernet Ordered set (LF, RF) support with OTN faults for GFP option. OTN faults include ODU-AIS, ODU-OEI, ODU-LCK, ODU-BIP8 signal fail, OPU2-PSI/PT mismatch, OTU-LOS, OTU2-LOF, OTU-FEC signal fail, LOS-P, LOF, AIS, LOM. G.709 OTN standard requires 3R Regen nodes generates ODU-AIS upon received OTN fault. Local OTN mapping (see Figure 8) injects ODU-RDI toward the OTN.

Upon receiving OTN fault at remote OTN mapping (see Figure 8), the remote client mapping injects LF toward 10GbE client. For clients that do not support LF, a user-specified option to turn transmit laser off is optional.

Upon receipt ODU-BDI and OTU-BDI local OTN mapping, Ethernet ordered set has not yet been received from Remote 10GbE client. At the Remote 10GbE Interface, where clients support RF, the system will inject RF toward 10GbE client. Otherwise, the local OTN mapping injects RF toward OTN.

5.1.5. Ethernet Ordered Set (LF, RF) Support with OTN Faults for Overclocking Options

Figure 9 illustrates Ethernet ordered set (LF, RF) support with OTN faults for Overclocking options. Upon receipt of remote PCS / OTN mapping injects LF toward the 10GbE client upon receipt ODU-AIS from OTN and local PCS/OTN mapping injects ODU-RDI toward OTN. If the client does not support LF, the system provides a user-specified option to turn the transmit laser off. If remote PCS/OTN mapping receives, ODU-BDI or OTU-BDI, and if Ordered set (RF) has not been received from Remote 10GbE client, then at Remote 10GbE Interface, the remote PCS Extraction will inject RF toward 10GbE client. If the client does not support RF, the system will provide a user-specified option to turn transmit laser off.

5.2. G.709 OTN In-Service Performance Monitoring

G.709 OTN provides in-line monitoring capabilities at Optical Transport Unit (OTU) level, Section Monitoring (SM) and at Optical Data Unit (ODU) level. The ODU also consists of six user-defined tandem connection monitoring (TCM) fields in conjunction with Fault Type and Fault Location channel (FTFL). SM and PM monitoring are extensively defined in the ITU standard and will not be further discussed. Conversely, TCM will be discussed in the following sections.

5.2.1. Tandem Connection Monitoring (TCM)

G.709 OTN fault monitoring provides Section (SM) and Path (PM) monitoring with six tandem connection monitoring levels (TCM1…6). SM and PM are sufficient to monitor for errors occurring within a network operator.
domain. However, problems arise if part of this path passes through the network of a second operator. In this scenario, it is not possible to determine who is responsible for the bit errors that occurred. This makes it challenging to resolve any problems. Subsequently, it is necessary to utilize the TCM to monitor the status of the path outside the carrier network without looking at traffic in the neighboring network.

As shown in Figure 9, Operator C is carrying Operator B’s signal. However, Operator B must monitor the signal as it passes through Operator C’s network. This scenario describes a “tandem connection,” which is a layer between Section and Path monitoring. Figure 8 is an example of TCM assignments. Network operators must collaborate with other operators to ensure that their signals do not conflict. This is important to note, as there is not a commonly-held standard that specifies how the TCM levels should be assigned.

<table>
<thead>
<tr>
<th>TCM Level</th>
<th>Domain Monitoring Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UNI-UNI TCM monitoring the CDDU connection through Carrier A, B &amp; C</td>
</tr>
<tr>
<td>2</td>
<td>Monitoring the service provider network</td>
</tr>
<tr>
<td>3</td>
<td>NNI to NNI monitoring &amp; service provider internal nodes</td>
</tr>
<tr>
<td>4</td>
<td>Protection path monitoring and to initiate APS to the protection path</td>
</tr>
<tr>
<td>5</td>
<td>Reserved for Future Usage</td>
</tr>
<tr>
<td>6</td>
<td>Reserved for Future Usage</td>
</tr>
</tbody>
</table>

5.3. Automatic Protection Switching / Protection Communication Channel (APS/PCC)

10G G.709 OTN is intended to provide SONET-like network reliability and performance. Additionally, the TCM, FTFL and APS/PCC enable signal management across multiple domain (carrier) networks. The typical criteria for initiating APS are:

- Detection of failure (e.g. loss of signal (LOS), loss of framing (LOF))
- Signal failure / degraded (high BER)
- Externally initiated commands from craft or OSS (e.g. manual switches or forced switched)

In SONET, this APS signaling information is communicated in the K1 and K2 overhead bytes. These two bytes constitute the SONET APS signaling channel. G.709 OTN has also reserved overhead four bytes for the implementation of an APS/PCC signaling channel (i.e. APS/PCC). Although the G.709 OTN APS/PCC function has not been fully implemented or defined into the standard, service providers are actively evaluating the APS requirements to ensure a smooth migration.

Table 2 shows up to eight connection monitoring signals which may be present at APS/PCC field. The APS/PCC bytes in a given frame are assigned to dedicated connection monitoring levels depending on bits 6, 7, 8 of MFAS and the standard recommended monitoring method. For APS protection, the 10G Ethernet system operates in full-duplex point-to-point mode only, over fiber optic media and linear 1+1, 1:1 or 1:N APS classes for 10G LAN PHY over G.709 OTN protection is recommended as outlined in ITU-T 805 and ITU-T G.872. Figures 10 and 11 are examples of the well-defined linear APS protection schemes that allow technically-sound implementation. In these examples and in real-world applications, the optical transport network may be managed by one service provider (Carrier A) as shown in the 1+1 case (Figure 11). However, more than one service provider may operate the target optical transport network (Carriers A, B, C, D and E), as shown in the 1:1 and 1:N cases (Figures 10 and
In the single operator, multi-vendor case, the operator has full control of the network. In the multi-vendor, multi-operator case, a service level agreements (SLAs) must be in place between carriers before the network incorporates APS schemes.

Based on the agreement and network reliability requirements, Trail, Subnetwork or mixed Trail and Subnetwork can be deployed. Trail protection is the protection class used to ensure the viability of a trail across an entire operator’s network or multiple operators’ networks. Sub-network connection protection is used to protect a portion of a trail across an operator’s network or multiple operators’ networks.

<table>
<thead>
<tr>
<th>Monitoring Methods*</th>
<th>NPAS IOI (bit)</th>
<th>APS/PCC Request/Initiate</th>
<th>APS/PCC Protection Type</th>
<th>APS Protection Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNCR for Path Monitoring</td>
<td>0,0,0</td>
<td>1. Lockout of Protection</td>
<td>1. No APS/PCC chained</td>
<td></td>
</tr>
<tr>
<td>SNCC and SNCR for TMG</td>
<td>0,0,1</td>
<td>2. Forced Switch</td>
<td>2. 1+1 (Permanent Bridge)</td>
<td></td>
</tr>
<tr>
<td>SNCC and SNCR for TCM</td>
<td>0,0,0</td>
<td>3. Signal Fail</td>
<td>3. Protecting / Merging switching</td>
<td></td>
</tr>
<tr>
<td>SNCC and SNCR for TMM</td>
<td>0,0,1</td>
<td>4. Signal Degraded</td>
<td>4. Non-recoverable / Reversion / Operation</td>
<td></td>
</tr>
<tr>
<td>SNCC and SNCR for TMX</td>
<td>1,0,0</td>
<td>5. Web-to-Remote</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SNCC and SNCR for TMW</td>
<td>1,0,1</td>
<td>6. Do Not Respond</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SNCR for Subroute Monitoring</td>
<td>1,1,1</td>
<td>7. Restore</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>8. Reserved</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:

* Monitoring Methods: Subnetwork Connection (SNCR) and Full, for protection are required by the following conditions:
  - SNCR = Section Victor connection function or adaptation function at the trail end;
  - SNCC = Section Victor connection function at the trail end of the protection group.

** APS/PCC are assigned to Monitoring Methods in a given frame depending on bit 6,7,8 of NPAS.

Protection Classes:

1. Path/Trail Protection – adding switches and selectors at both ends of the trailpath and an additional trail between these bridges and selectors.
2. Subnetwork Connection Protection – connection protection within the subnetwork connections protected adding bridges and selectors at both ends of each node and an additional trail between these bridges and selectors.

Table 2 – G.709/Y.1331 – Multiframe to allow separate APS/PCC for each monitoring level

Figure 8 – Example of 1+1 and 1:1 APS Schemes

Figure 9 – Example of 1:N APS Scheme

6. Challenges for Future 10G LAN PHY over G.709 OTN Deployment

Service providers and equipment vendors are facing technical challenges in meeting the multi level connection monitoring and APS/PCC processes for G.709 OTN when compared with the familiar single level SONET k1, k2 bytes. G.709 OTN has 8 levels, namely Section to Path and six tandem connection monitoring. This increases the complexity for implementing the fault isolation processes since it may be required to analyze and pass on up to eight incoming connection monitoring signals. Another major challenge to service providers is to enhance the protection communication signaling and APS verification and decision processes. This includes the APS algorithm and may also involve with service level agreements (SLAs) between carriers if the network passes through other carrier(s).
As the industry moves forward with full 10G LAN PHY over G.709 rate deployment, additional work is needed in terms of the industry standards and vendors/service provider cooperation to address these challenges.

7. Summary and Conclusions

This paper presented the use of G.709 OTN techniques for transporting a 10G Ethernet signal to improve the operational efficiency of next generation 10G LAN applications. Test results and field deployment issues and requirements in a multi-vendor / multi-carrier environment were discussed. All four mapping schemes have been tested and no critical issues were identified at the adaptation layers.

It is possible to begin cost effectively managing 10G OTN networks as a single domain, multi-vendor, multi-carrier networks with respect fault isolation and protection. This can be accomplished using the existing fiber and optical amplifier infrastructure that is currently used to support OC-192 SONET-based deployment.

Ethernet Ordered set (LF, RF), TCM and APS have yet to be implemented. Vendors, carriers and standards bodies have to collaborate in a timely manner to incorporate these features for field deployment. Otherwise, this technique will be no more than another enterprise customer deployment. For new deployment, GFP-F is recommended as it is an approved standard. Other mapping schemes should be deployed for Enterprise customers or legacy deployment.

For future consideration, we must explore operating clock tolerance issues as the differences between Ethernet and G.709 OTN are +/- 100 part per million (ppm) and +/- 20 ppm, respectively. Ethernet and G.709 OT operating clock synchronization should be evaluated. Also, OTU2 (10G) to OTU3 (40G) has not been discussed and this will affect the mapping schemes selection.

Finally, these new features will enhance the 10G Ethernet services to its potential as a single domain multi-vendor / multi-carrier OTN.

7. Acknowledgements

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8. References


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