IPLIGHT Creating an Intelligent Optical Layer

Supporting OTN Ring/Mesh Topologies

Apodis IPL4001M

Application Note

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OTN Network Topologies.
Optical networking and datacom equipment providing OTN interfaces will be deployed in access, metro and core applications. Accordingly OTN will have to evolve to support the mechanisms and processes required to properly operate these network configurations: Linear and Ring topologies at the access to the network, predominantly Ring architectures within the metro layer and Mesh connectivity characteristic of Core and Metro-Core deployments.

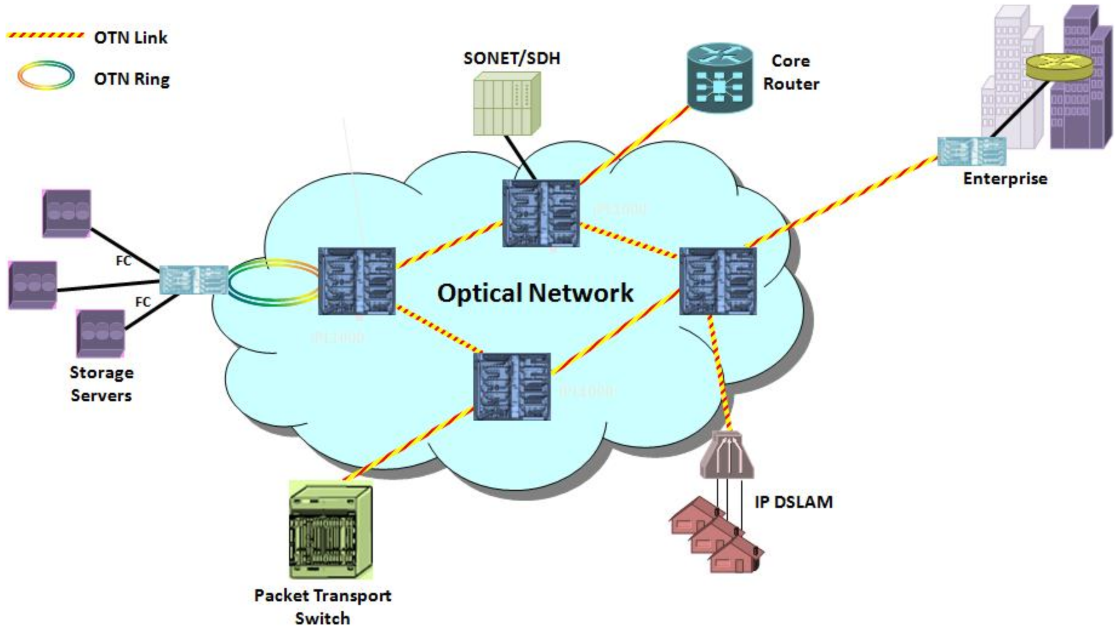


Figure 1: OTN will be deployed in Linear, Ring and Mesh configurations

OTN Evolution.
The ITU-T SG15 has recently incorporated various modifications to the ITU-T G.709 recommendations which span a wide range of applications.
In particular the ITU-T has addressed the need to provide an effective and simple way of transparently carrying the most popular sub-ODU1 (Optical Data Unit) Client Signal prevalent in modern networks: 1GE.
The new container was named ODU0, and its rate was defined as ½ the rate of an STM16 signal.
ODU0s, as any other ODU type, can be individually switched or groomed.
When transporting 1GE signals through an OTN infrastructure first they will be rate adapted to their ODU0 containers by applying a GFP-T (Generic Framing Procedure – Transparent) procedure which will allow the 1GE signals to preserve character transparency.
The resultant bit-stream is mapped into an ODU0 container with a GMP (Generic Mapping Procedure) process.
Two methods have been defined in order to carry ODU0 containers within higher speed OPU (Optical Payload Unit) signals (see **Figure 2**).
The first method multiplexes ODU0 entities into OPU1 containers drawing on an AMP (Asynchronous Mapping Procedure) process. In this type of implementation the OTN multiplexing structure becomes hierarchical since OPU1 signals which are already carrying ODU0s will be further multiplexed into higher speed OPU bearers.
An alternative method maps the ODU0 containers directly into their Higher Order (HO) OPU bearer.

In order to allow this direct mapping the G.709 defines within HO OPUs 1.25G Tributary Slots (TS).
As an example in case an OPU2 bearer will comprise eight 1.25G TS.
Each ODU0 will be mapped into one 1.25G TS.
Higher speed ODUs (e.g. - ODU1, ODUflex) will be assigned to 2 or more TS accordingly.
Allocation of ODUs into available TS is accomplished by decomposing LO ODU signals into an integer number of TS and then flexibly assigning each of their components into available HO OPU TS.
The mapping of Low Order (LO) ODUs into their respective HO OPU is accomplished through a GMP process.
This mechanism (1.25G TS and flexible utilization of available slots within the HO OPU bearer) allows for mixtures of different LO ODU types within the same HO OPU. It also provides a generalized forward-looking method to support Client Signals requiring arbitrary numbers of TS.
This flexible multiplexing method will allow Service Providers to effectively utilize their available DWDM capacity while offering services of varying bandwidths.

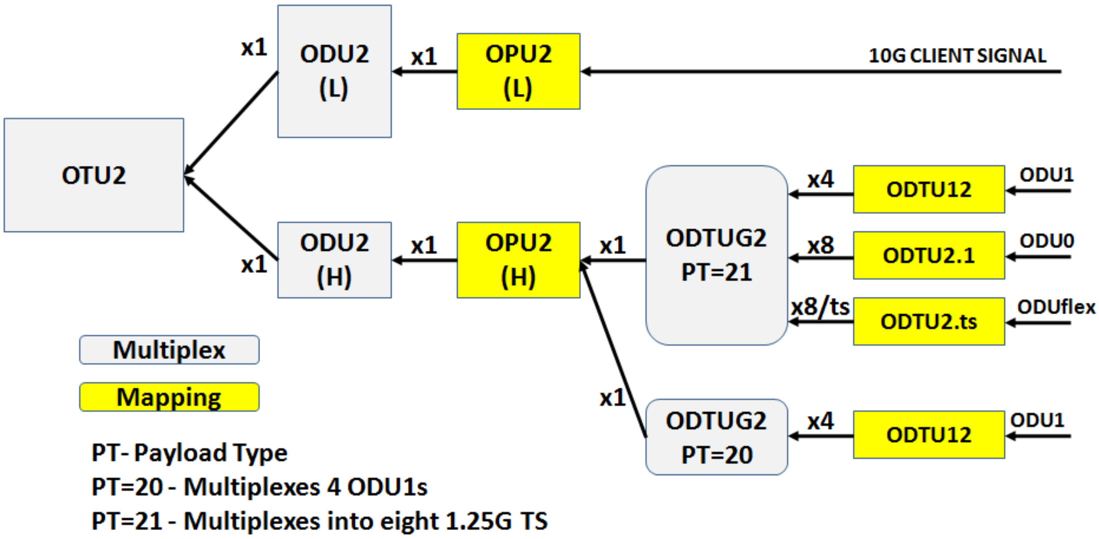


Figure 2: ODU0 signals can be transported either by 1.25G TS or by ODU1 containers

ODU TCM Area.
The basic path-level entity that is transported in between 2 OTN end points is the ODU.
The ODU frame includes a TCM (Tandem Connection Monitoring) area (**See Figure 3**). There are six TCM fields within each ODU overhead. Different Service Providers (SP) participating in
the same ODU path can use these fields to monitor their network segments irrespectively of other operators. Furthermore, the TCM areas allow the implementation of additional types of path-related protection and service related functions.

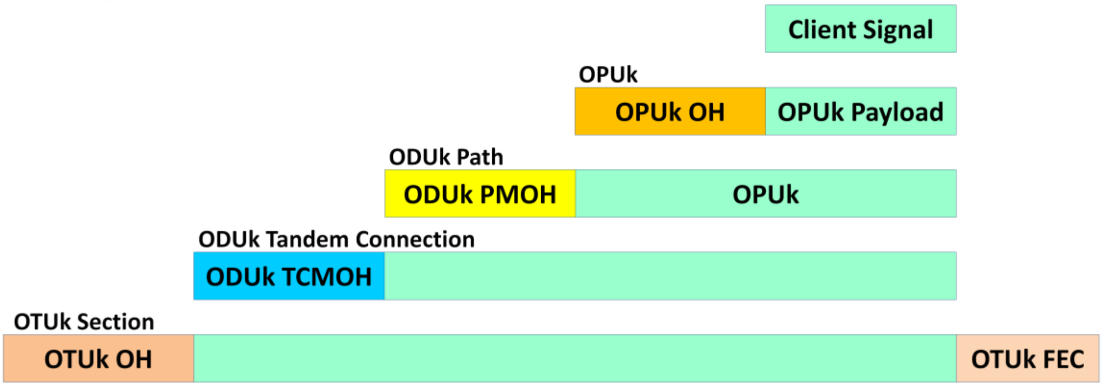


Figure 3: An ODU Tandem Connection Overhead area is appended to each ODU path

The following simplified illustration (see **Figure 4**) demonstrates how the TCM area allows 3 different SPs (Yellow, Turquoise and Orange) to independently monitor and test their path related performance within their respective network segments. In the general case the different network segments may actually overlap with each other.
Yellow SP offers service in between end points A1 and A2, Turquoise between B1 and B2 while Orange participates in the segment C1-C2. Each SP enjoys a dedicated TCM area (in the example colored Yellow, Turquoise and Orange accordingly) in order to monitor and supervise its own performance relating to the same end-to-end ODU path.

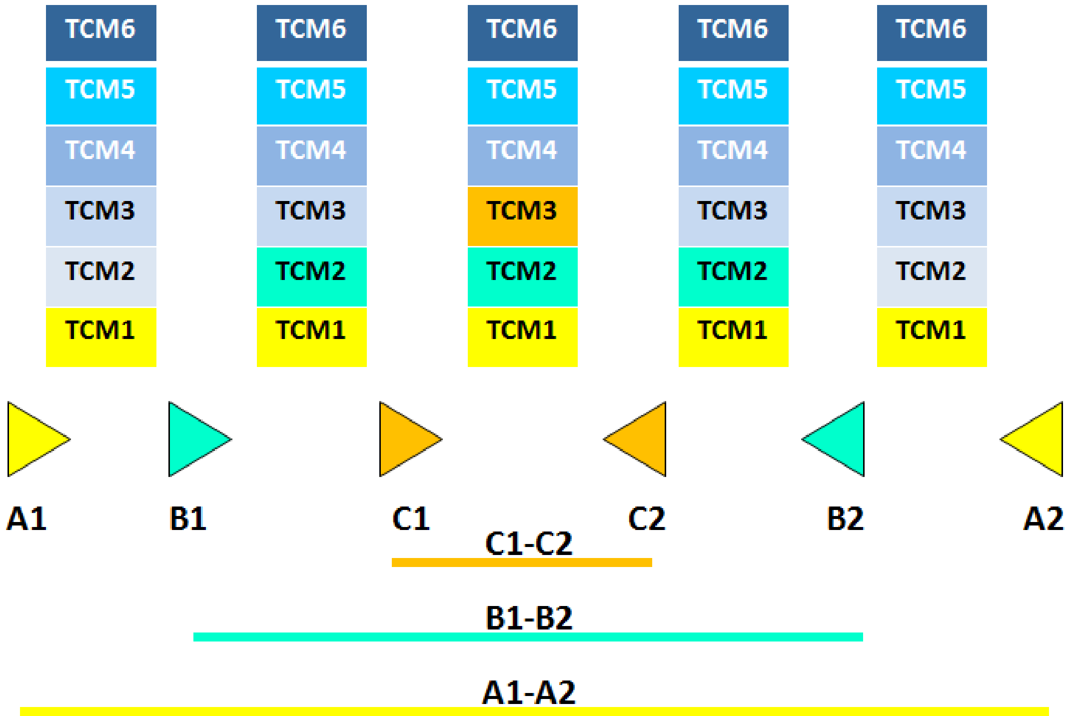


Figure 4: TCM allows different Service Providers to supervise their own network segments

TCM Overheads can be leveraged to support different types of applications.
A few examples:

- Monitor the quality of the transport service being offered by each individual SP as it reflects on the ODU paths traversing its network.

- Implement segment related path-level Automatic Protection Switching mechanisms.
- Support path-level Round-Trip Delay measurements. Round trip delay is important for certain Service Level Agreements (SLA) and for storage applications (SAN).

Apodis IPL4001M.

The Apodis IPL4001M (see **Figure 5**) is a 40G OTN processor that incorporates an ODU0-based architecture for mapping, switching, grooming and multiplexing of OTN traffic.

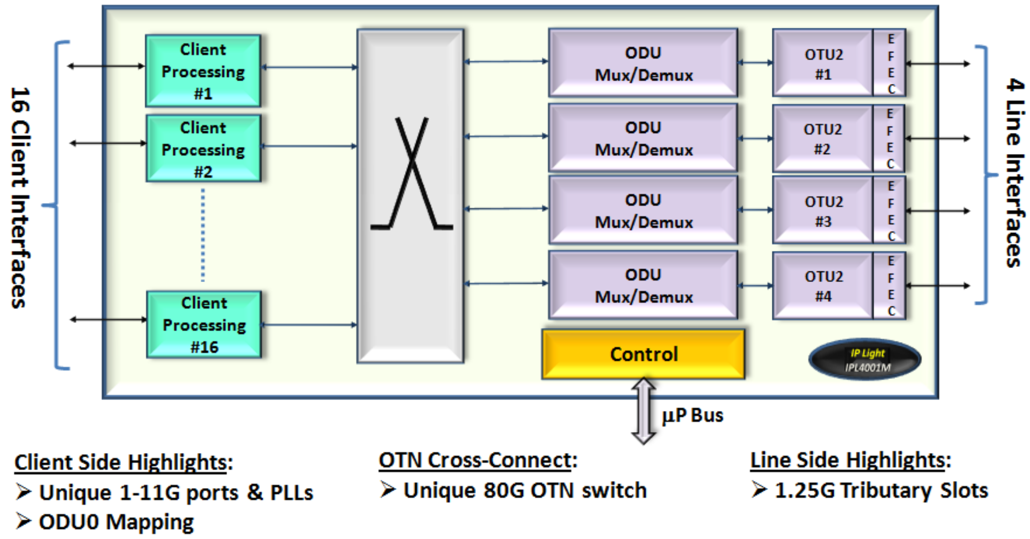


Figure 5: Apodis IPL4001M block diagram

The Apodis IPL4001M supports sixteen 1-11Gbps Client Signals and four 11Gbps Line signals. On its Client Side it offers multiple options in order to map and transport Ethernet (1GE/10GE), Storage (1GFC/10GFC), OTN (OTU1/OTU2) and SONET/SDH (OC48/STM16, OC192/STM64) Clients over OTN (see **Figure 6**).

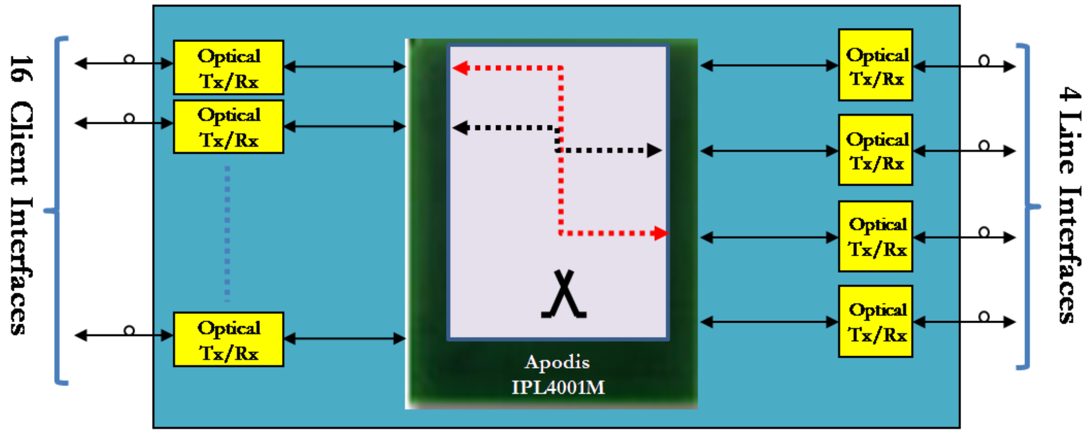
	ODU0 (x16)	ODU1 (x16)	ODU2 (x4)
GbE LAN PHY	GMP		
GbE LAN PHY		2xGFP-F	8xGFP-F
1GFC	GMP		
10GbE LAN PHY			GFP-F (G.Sup43 6.2/7.3)
10GbE LAN PHY			Bit Transparent ODU2e/ODU1e
10GFC			GFP-T to ODU2e/ODU1e
10GFC			Bit Transparent ODU2f/ODU1f
OC48/STM16/CBR2G5 WAN PHY		Bit Transparent Synchronous/Asynchronous	
OC192/STM64/CBR10G WAN PHY			Bit Transparent Synchronous/Asynchronous

Figure 6: Apodis IPL4001M provides multiple mapping options of Client Signals

In order to provide an effective solution for highly integrated optical blades the Apodis IPL4001M benefits from unique 1-11Gbps SERDES and integrated PLLs.

At its core the Apodis IPL4001M switches and grooms the traffic traversing it at the relevant

OTN granularities: ODU0, ODU1 and ODU2 (see **Figure 7**).



Apodis IPL4001M OTN Switching Fabric Characteristics:

- **80Gx80G**
- **OTN Granularities: ODU0/ODU1/ODU2**
- **Fully available, non-blocking**
- **Supports broadcast, multicast**

Figure 7: Apodis IPL4001M provides non-blocking connectivity at the OTN level

Once traffic is being presented to its appropriate Line Side interface it is multiplexed into OTU2 bearers.
The Apodis IPL4001M can support both single-step (ODTU02) and hierarchically multiplexed (ODU0→ODU1) signals within OTU2 bearers.

Built-In Processing of OTN overheads.

Built-in processing of all the overheads of the OTN signals terminating or transiting across the Apodis IPL4001M is being provided (see **Figure 8**). The Apodis IPL4001M also provides real-time Read/Write access to all OTN GCC channels.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Frame Alignment Overhead							OTUk Overhead							OPUk Overhead	
Reserved		PM& TCM	TCM ACT	TCM6			TCM5			TCM4			FTFL		
TCM3			TCM2			TCM1			PM			Experimental			
GCC1		GCC2		APS/PCC				Reserved						PSI	

Figure 8: Apodis IPL4001M provides simultaneous built-in processing of all OTN overheads

Users can process the entire OTN overhead information, focus on a fraction of the information or trigger processor interrupts based on signal events.
Additional external Read/Write access to the OTN overhead information is provided as well. Information retrieval is carried out without impairing the ongoing processing of alarms and collection of performance monitoring data.

TCM Support within the Apodis IPL4001M:

Processing of the TCMOH area and 6-level TCMs on all pass-through or terminated ODUs (**See Figure 9**) is being provided by the Apodis IPL4001M.

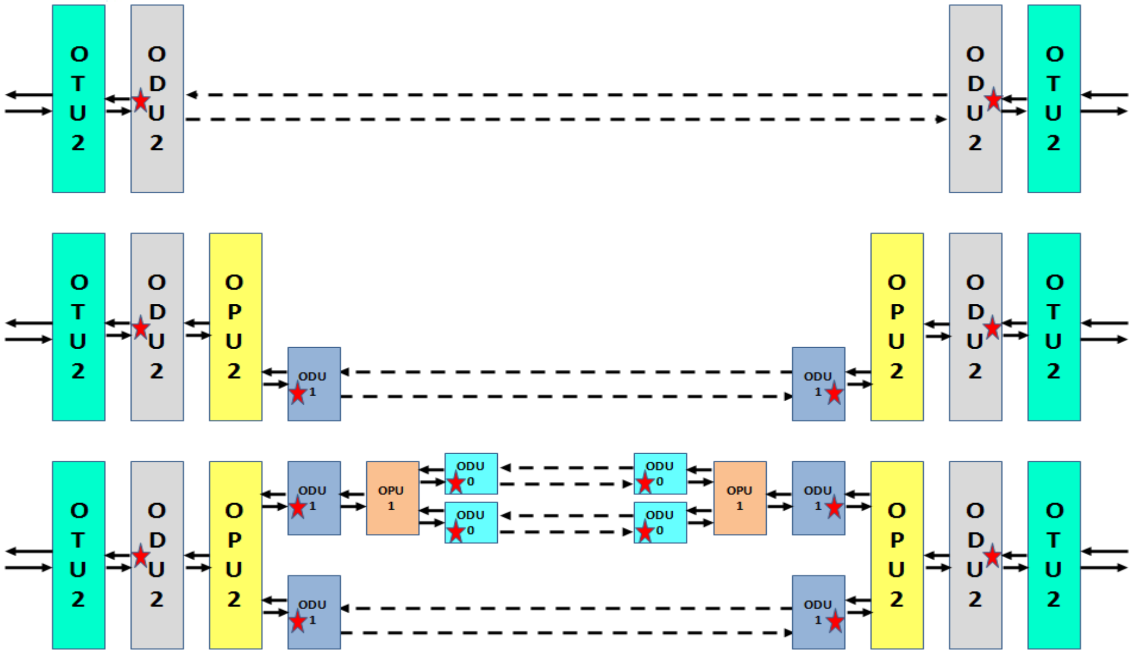


Figure 9: TCM processing instances within Apodis IPL4001M

- **Red stars indicate the places where TCM processing is implemented.**
- **Fragmented lines indicate links across the internal switching fabric.**
- **Full arrows indicate signals flows.**

Apodis IPL4001M also supports TCM-based measurements of round-trip path delays. Round-trip latency (see **Figure 10**) is being measured by the delay incurred between the start of transmission and the detection of a test signal.

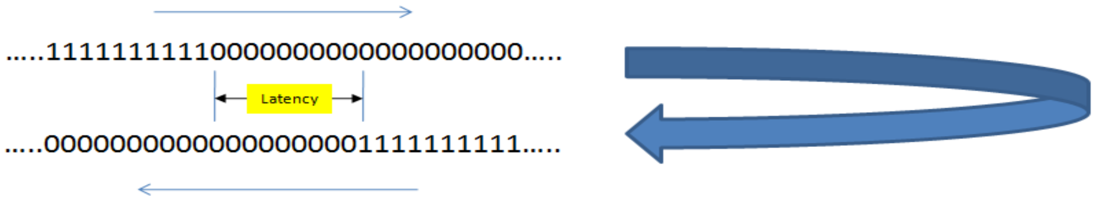


Figure 10: Round-trip link latency is measured by looping around a test signal

The test is conducted within a TCMk area. Accordingly, the SP to whom the specific TCMk was allocated can measure its performance within its own relevant network segment.

Timing.

In order to support different network applications and protection mechanisms Network Elements (NEs) have to implement a variety of timing options on their interfaces.

A few examples (see **Figure 11**):

- Loop Timing: Synchronize the Tx side of an interface to its Rx (see **Orange** below).
- Synchronize a Client or Line Signal to the clock recovered from a Client Signal transported by OTN (see **Green** below).
- Synchronize Line or Client Side interfaces to a reference clock (see **Red** below).

Apodis IPL4001M has been equipped with Serializer/De-Serializer (SERDES) that incorporate sophisticated Phase Locked Loops (PLLs) and integrated synthesizers.

- The SERDES operate in the range of 1-11Gbps thus supporting Any Port/Any Service system architectures.

- The integrated PLLs clean OTN induced jitter and preserve the original timing characteristics of Client Signals without requiring external components. This capability greatly simplifies board-level designs.
- The integrated synthesizers operate off a single reference clock with all additional required timing signals generated internally.

Apodis IPL4001M provides integrated support of the varied timing options required by different applications and network topologies.

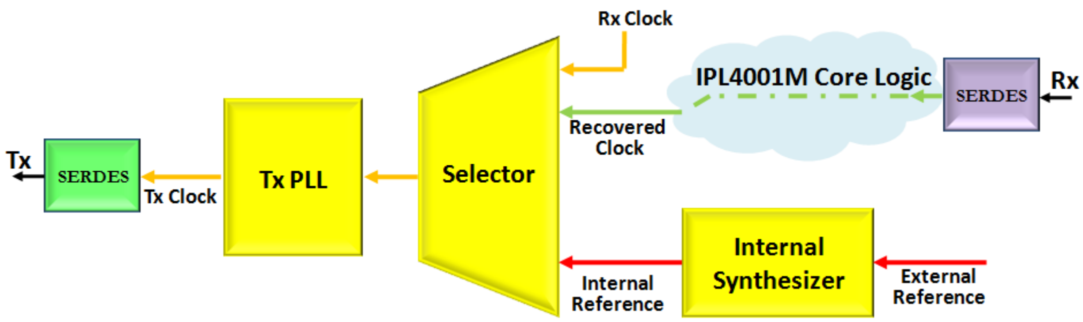


Figure 11: Apodis IPL4001M supports on its interfaces different timing options

11G Interfaces:

Each of Apodis IPL4001M's eight 11G interfaces can be configured to operate either as a serial XFI signal or as a parallel interface.

10GE and 10GFC signals can be accepted by Apodis IPL4001M either serially or through 4-lane XAUI parallel interfaces.

OTU2 signals (Client or Network Side) can be accepted by Apodis IPL4001M either as serial XFI signals or through 2 or 4 lane XBI2 parallel interfaces.

XBI2 is a fairly simple proprietary parallel protocol whose lanes operate at ½ or ¼ the rate of the original OTU2 signal.

XAUI interfaces allow the Apodis IPL4001M to interface directly with packet or fibre-channel engines.

The 2 or 4 lane XBI2 interfaces (see **Figure 12**) enable direct connections between peer XBI-2 devices (Apodis IPL4001M or other) across backplanes or within the same blade.

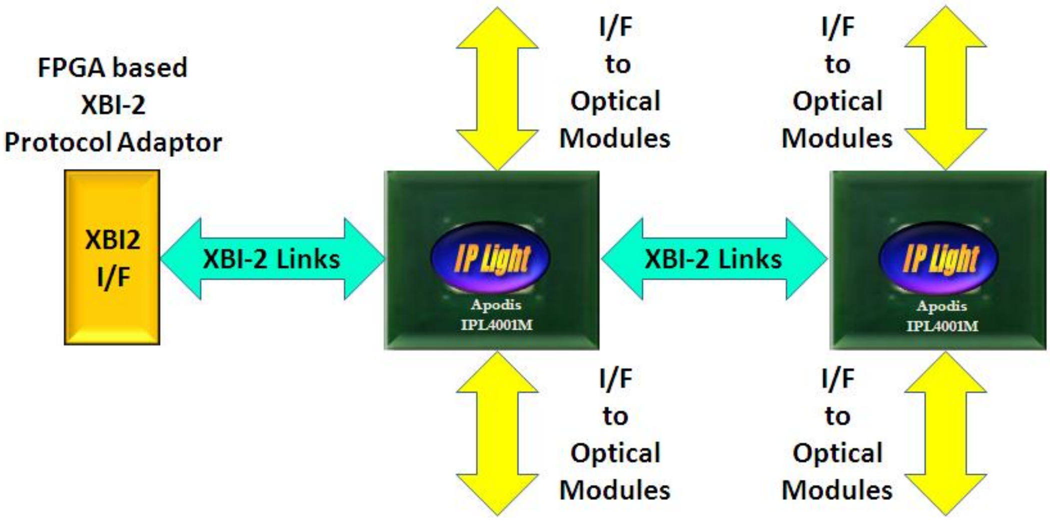


Figure 12: Direct links between XBI-2 devices

XBI-2 Highlights:
- 2 or 4 parallel lanes operation at ½ or ¼ the rate of the OTU2 signal
- Spans up to 30" between XBI-2 devices (including connectors)
- FEC for added signal integrity

Accordingly, protected architectures (see **Figure 13**) are gracefully supported.

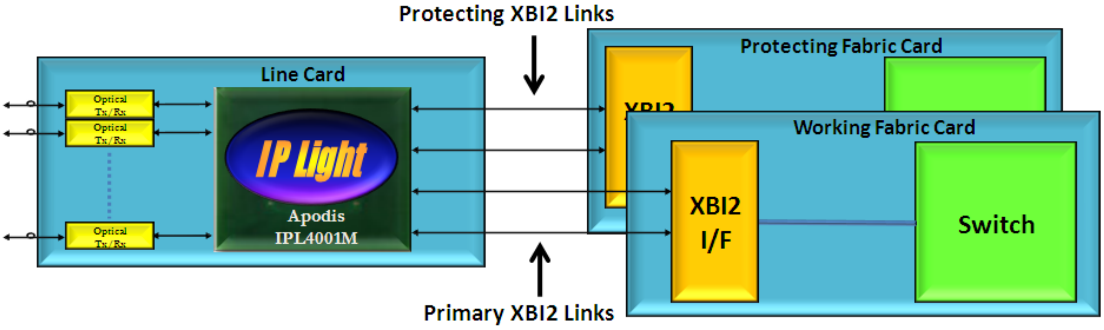


Figure 13: Integrated broadcast and XBI-2 links support protected architectures

Apodis IPL4001M in OTN Linear, Ring or Mesh Network Applications.
Thanks to its unique capabilities Apodis IPL4001M supports the requirements of different OTN network topologies (Mesh, Linear, Ring) in a highly cost effective way.
The main highlights in this context:

- Maps 1-11Gbps Client Signals into OTN according to the latest ITU-T drafts.
- Switches and grooms traffic at the various OTN granularities (ODU0/1/2).
- Supports direct and hierarchical OTU2 multiplexing options.
- Multiple timing options as required by the various network applications.
- Integrated support of protected architectures.
- Support of remote in-band control applications.
- Local access to full East/ West side information for path-level switching decisions.

Single Chip OTU2 Add/Drop Multiplexer:
A single Apodis IPL4001M device (see **Figure 14**) can support two OTU2 rings with full Drop/Insert capability of 40Gbps of payload traffic through sixteen 1-11Gbps Client ports.

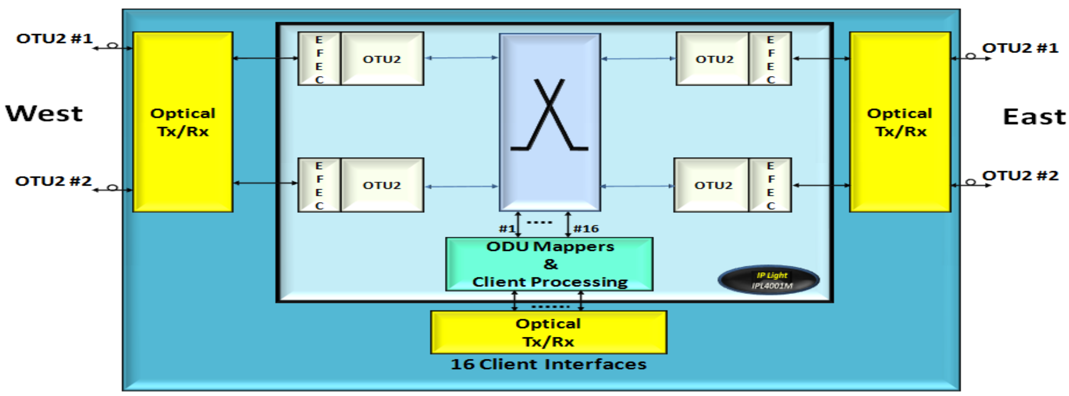


Figure 14: Single-Chip two OTU2 rings ADM with Drop/Insert of 40Gbps of Client traffic

Fully protected OTU2 ring in a centralized switching fabric system:
Two Apodis IPL4001M devices, one in each blade (see **Figure 15**) can support a fully protected architecture with Drop/Insert access to up to 20Gbps of payload traffic and redundant 10Gbps XBI2 links to centralized switching fabrics.

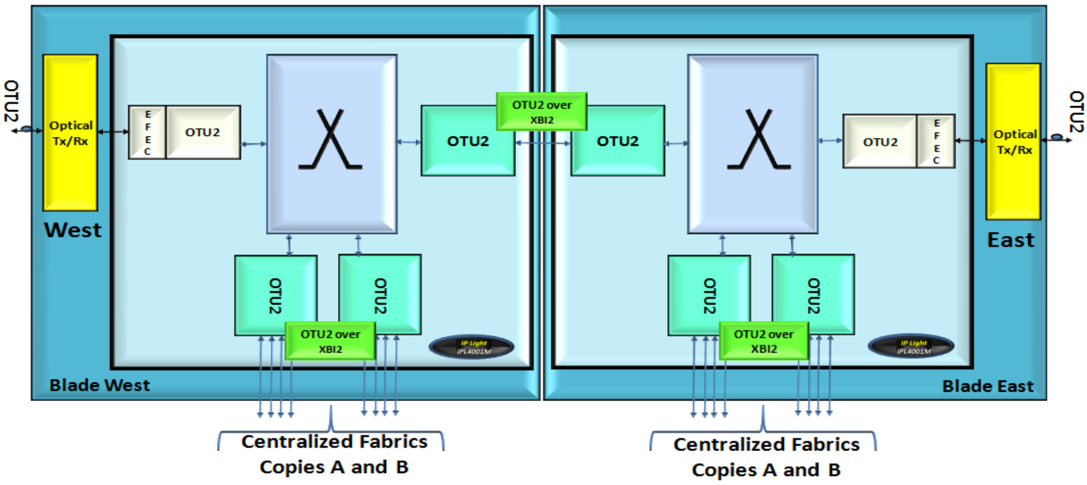


Figure 15: 2 Apodis IPL4001M devices support a fully protected configuration

About IP Light*:*

IP Light is developing a family of leading edge OTN processors designed to facilitate the introduction of new OTN capabilities into multiple types of network and service applications.

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