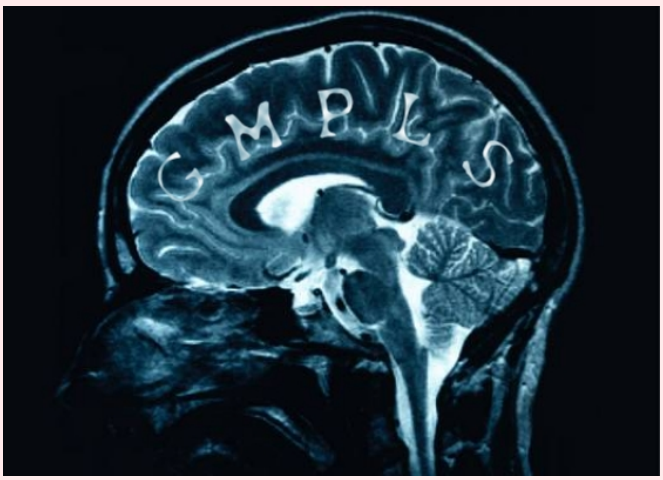
Embedded Software Intelligence in the Digital Optical Network

Reduce OpEx and increase service velocity

Overview

Software intelligence is an integral part of a modern optical transmission network. In the past however, that intelligence has tended to be proprietary in nature, limited in scope, and has been developed without any overall goal of coordination between different software functions.



By embracing and expanding the scope of embedded software intelligence (ESI), service providers can lower operational costs, and can deploy new services more rapidly and efficiently.

There are two key requirements that service providers should consider when deploying or extending ESI. First, this intelligence must be based on agreed standards, and not on proprietary protocols. Second, as we will demonstrate in this paper, the real value of embedded network intelligence is best realised within a Digital Optical Network architecture.

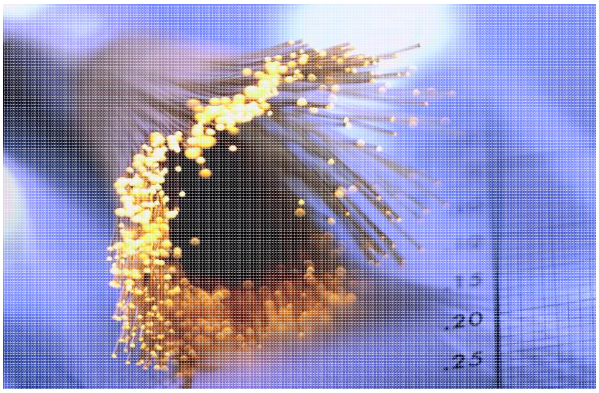
Infinera offers a mature, ESI implementation, based on ASON/GMPLS standards, that forms the control and management plane for a Digital Optical Network. Our implementation is not an “all or nothing” choice. This paper will explain how Infinera’s customers have been able to migrate to this new architecture at their own pace, and with consideration to their own operational requirements.

Note on terminology: ESI refers to an intelligent optical control plane designed to comply with an ITU ASON architecture, and based on GMPLS protocols.

infinera

Software intelligence in today's all-optical networks

Software intelligence is already well established within modern optical transmission networks. Its role is to remove the need for manual intervention at the lowest levels of network operation, thus reducing operational costs and decreasing the reaction time for critical events such as link failures.



For example:

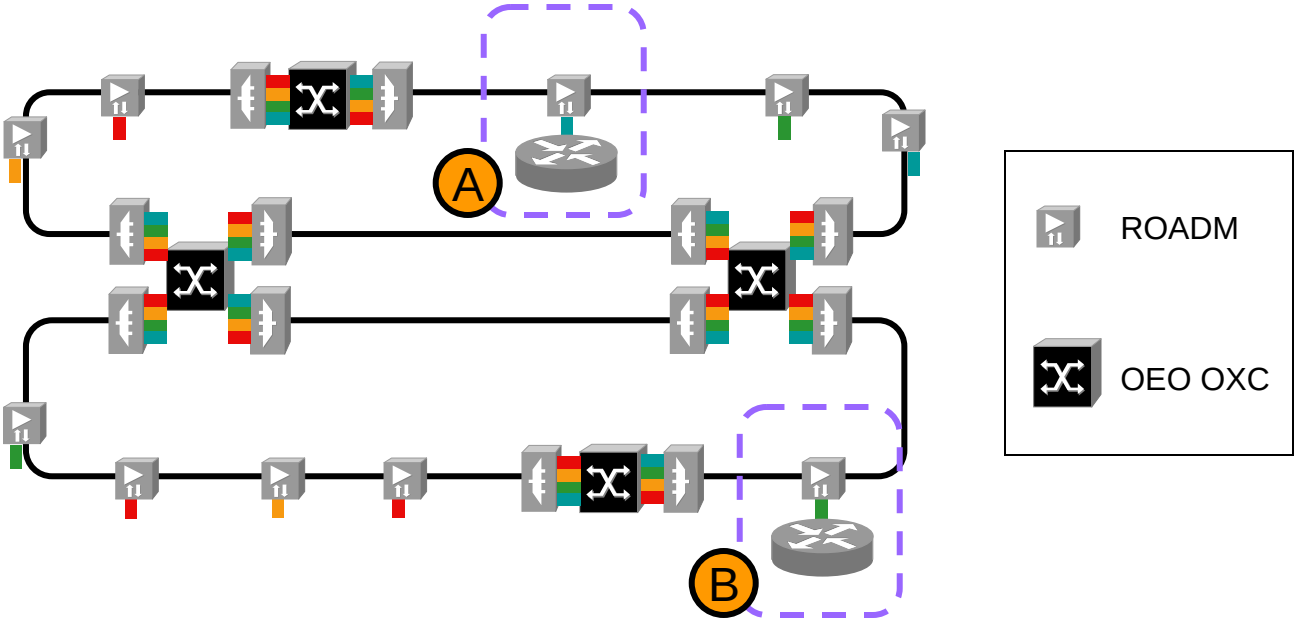
- Software may already exist within your network to automatically perform inventory management on components or subsystems within a communications shelf.
- Software may already exist within your network to automatically manage power levels of all-optical line components between 3R regenerators (also known as optical span management).
- If you have SONET or SDH networks then there may be software running on the network elements that will allows services to be protected against link failure, or the failure of a switching unit.

Historically, however, this software tends to have been developed without any overall coordination of the various software functions. It tends to be based on proprietary protocols, and is usually limited in scope.

To make matters worse, the analog nature of all-optical networks is a real barrier to the efficient functionality of software intelligence. For example, if you cannot see digital information for most of the service path, then how can you monitor vital, but inherently digital parameters such as bit error rate? And if devices can't see bit error rates, how are they supposed to automatically initiate protection switching?

Extending the scope of ESI in all-optical network has not been a priority for most manufacturers because the complexity introduced in an all-analog system makes the task of software automation all but impossible. For example , just a few of the parameters that restoration software in an all-optical system would need to consider includes: optical losses on each wavelength; the number of channels in use and the impact that this will have on in-line amplifer performance; dispersion characteristics of the fiber in a given span; and the optical capabilities of a given transponder. Creating a stable routing protocols that has to take these, and many other metrics into consideration is simply impractical.

Given these limitations it's extremely difficult to implement ESI effectively in an all-optical network because a large part of what ESI does is concerned with involves the routing and signalling of connections. In an all-optical network the network elements are often unable to flexibly route connections, or are prevented from routing connections for reasons such as wavelength blocking.



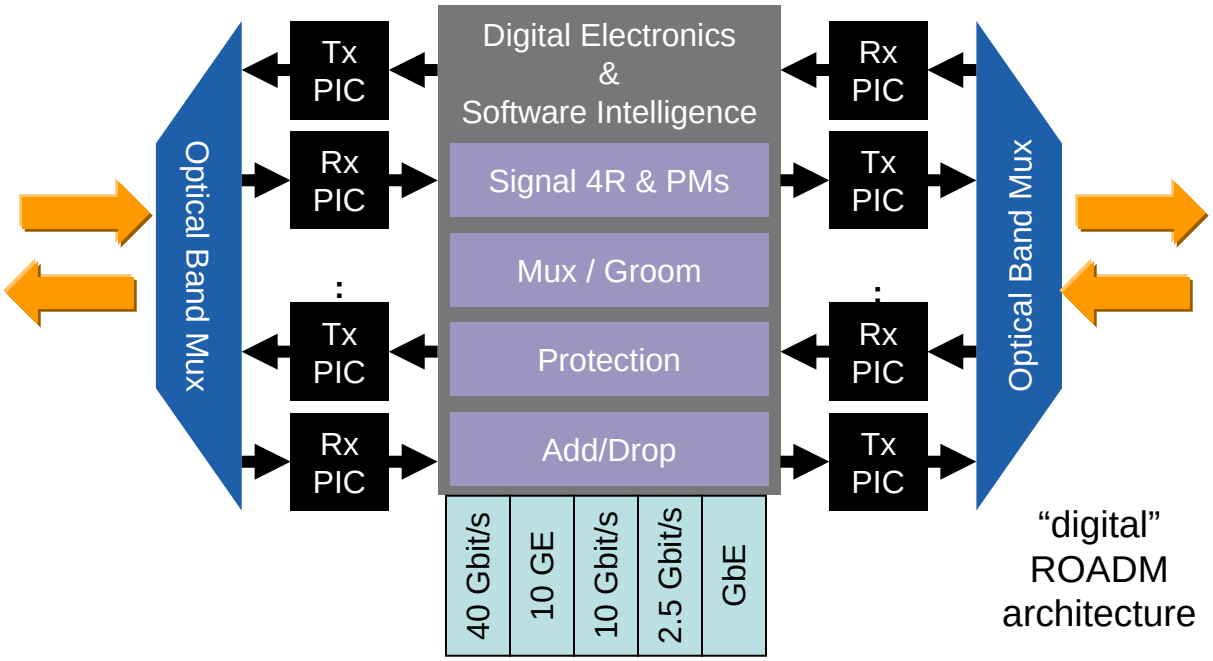
This diagram shows the way that a conventional optical network tends to implement ESI. There are broadly two kinds of device in this network:

- All-optical reconfigurable optical add-drop multiplexers (ROADM) devices that cannot take a direct part in most ESI operations because they have no visibility of the digital character of services.
- Opto-Electronic-Opto (OEO) cross-connect devices (OXC) that do have digital visibility.

Although both types of device (OXC and ROADM) may have ESI capability, it's simply not possible to bring up services dynamically on an all-optical ROADM because the appropriate transponders may not be installed, and even if they were pre-positioned, there's no guarantee that a particular wavelength could support the required service. In the past, the all-digital world of SONET/SDH could have coped with the demands of ESI, but with the advent of DWDM the costs of converting many wavelengths of SONET/SDH from optical to electrical and back to optical at each hop (known as OEO conversions) was perceived to be unacceptable.

Digital Optical Network – the "new" optical architecture

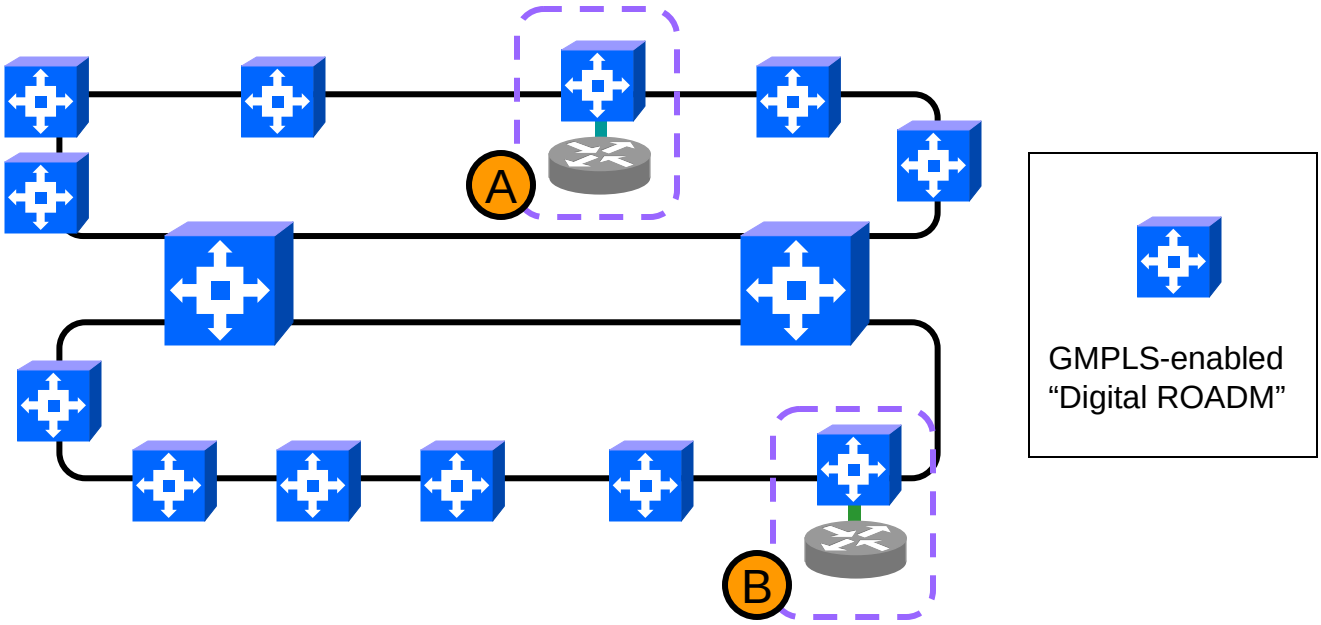
So all-optical networks are supposed to be cheaper because they avoid OEO conversions, but what DWDM manufacturers failed to consider was the dramatic loss of functionality in an all-optical architecture. At Infinera, rather than accept the limitations of all-optical we have focused on making OEO conversion a cost-effective thing to do, and thereby allow a return to digital optical networking.



This diagram shows the heart of our DTN, which we describe as the world's first *digital* ROADM. Optical devices are used for the operations at which they excel – fibre optic transmission at very high speeds and capacities. We use electrical devices for everything else because 50 years of electronic circuit integration means that electronics are the best approach for signal regeneration; switching; grooming; protection; service selection for add-drop; and performance management.

The unique advantage for Infinera is that, in addition to highly integrated electronics, we have developed the world's first photonic integrated circuit (PIC) – which essentially integrates all of the functions required by ten channels of 10Gbit/s into a single pair of chips (one for transmit and one for receive).

Using PIC technology, Infinera networks turn up wavelength capacity in 100Gbit/s increments, and this capacity is immediately available for ESI service routing and provisioning. If we replace both the all-optical ROADMs and the OEO OXCs with a GMPLS-aware "digital ROADM" then the mechanism of service routing changes completely.



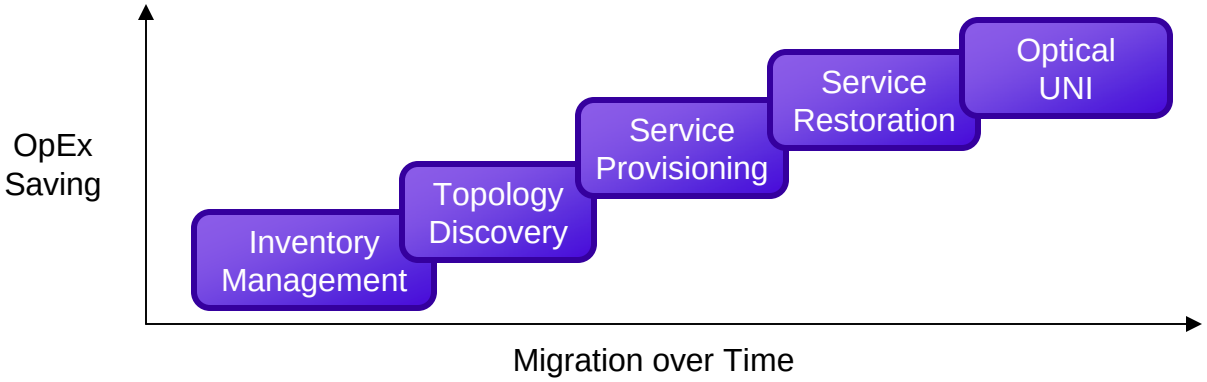
Unlike in the all-optical network, service provisioning and routing can now be automated. There are three reasons why this is now possible:

- Thanks to PIC economics, capacity is already positioned in the network waiting to be used by ESI
- Thanks to the ubiquitous presence of ESI, all devices have a complete view of the network topology

…and..

- Thanks to integrated switching and grooming all devices have the ability to route services over any available timeslot or wavelength without the risk of wavelength blocking.

In the Infinera architecture all services operate over 10Gbit/s wavelengths in the network core – including "super-lambda" services such as 40Gbit/s. More importantly from an ESI perspective is the fact that IP routing operations have historically been developed around digital networks, not analog.



Service providers have tended to adopt GMPLS in a series of discrete steps, as shown in this chart. Migrating from left to right brings incremental OpEx savings, while giving the service provider time to integrate the ESI function into existing operational procedures.

Automated Inventory Management

As new nodes, or new line cards are added to the network, ESI will automatically discover them, and report them to the inventory control function within the network management system. Manual inventory management is expensive, error prone, and increases the time before a service provider can start to bill a new customer.

Automated Topology Discovery

As nodes are connected to each other, ESI in an Infinera network ensures that they will automatically discover both internal connection within the node, and connection to each other. PIC economics means that capacity becomes available in 100Gbit/s chunks. These wavelengths are constantly monitored for power levels and bit error rates thanks to the digital nature of the system.

Point and Click Service Provisioning

Now that working capacity exists between network nodes, operators can use ESI to provision services quickly and efficiently. This is a well loved feature from SONET/SDH days that was lost with the advent of the all-optical network.

Flexible Service Restoration

For protected wavelength services, service providers tend to prefer conventional SONET/SDH “50ms” protection. But most wavelengths that carry IP services are unprotected. By using the rapid restoration function that ESI provides, service providers can slash their Mean Time to Repair an unprotected wavelength from hours to seconds without resorting to dedicated protection capacity.

IP-Optical Integration via the Optical UNI

The ASON/GMPLS architecture includes the notion of the unification of the IP and optical transmission worlds. While this has not been widely adopted by service providers to date, it does represent the most logical architecture for tomorrow’s optical networks.

Where do cost savings come from?

Infinera's GMPLS implementation is used in some of the largest GMPLS-powered networks in the world. From this experience of a "full function" GMPLS implementation over a Digital Optical Network architecture we've been able to derive some significant examples of operational cost savings.

Operation/Task	All-optical network	GMPLS-powered DON
Installation, commissioning and turn-up (700km circuit)	2 weeks	3 days
10G/2.5G wavelength turn-up	1 to 3 days	<1 day
Conversion of pass-through site to add/drop	3 to 4 days	2 hours
Sub-lambda grooming efficiency	Low	High

The DON also offers a number of other operational cost savings because the network operator is able to return to digital operations. These include the fact that the Infinera DTN can offer digital loopback for error checking and diagnostics, and this leads to much more rapid fault isolation. Our implementation of ITU-T G.709 allows pre-and post-Forward Error Check (FEC) bit error rates to be monitored at every switching point in the network.

This table also shows a vital feature of the GMPLS-powered DON – the ability to deliver services much more rapidly than a conventional, all-optical network. In today's highly competitive business environment, business is awarded to the first service provider to be able to deliver a given service at a given price. Prices are set by market forces, but your ability to deliver service in a given timescale depend on the efficiency of your operational procedures, and the flexibility and efficiency of your network architecture.

Conclusions

Embedded software intelligence offers a clear path to lower operational costs within a modern optical transmission network.

ESI offers five distinct, incremental stages to achieving those operational savings: automated inventory management; automated topology discovery; point and click service provisioning; flexible service restoration; and IP-Optical integration via the optical UNI.

In the Infinera implementation, the migration plan through those stages is not an “all or nothing” deal. Any of the stages can be implemented while retaining legacy protocols and procedures for the other functions.

Most of the functions of ESI reside within the digital domain, and so all-optical network architectures can be a significant barrier to achieving the true operational cost savings that should be possible when migrating to an ESI-enabled network.

Infinera’s PIC technology allows us to build cost-effective Digital Optical Networks. These in turn allow the full potential of ESI and its associated cost savings to be fully realised by our customers.