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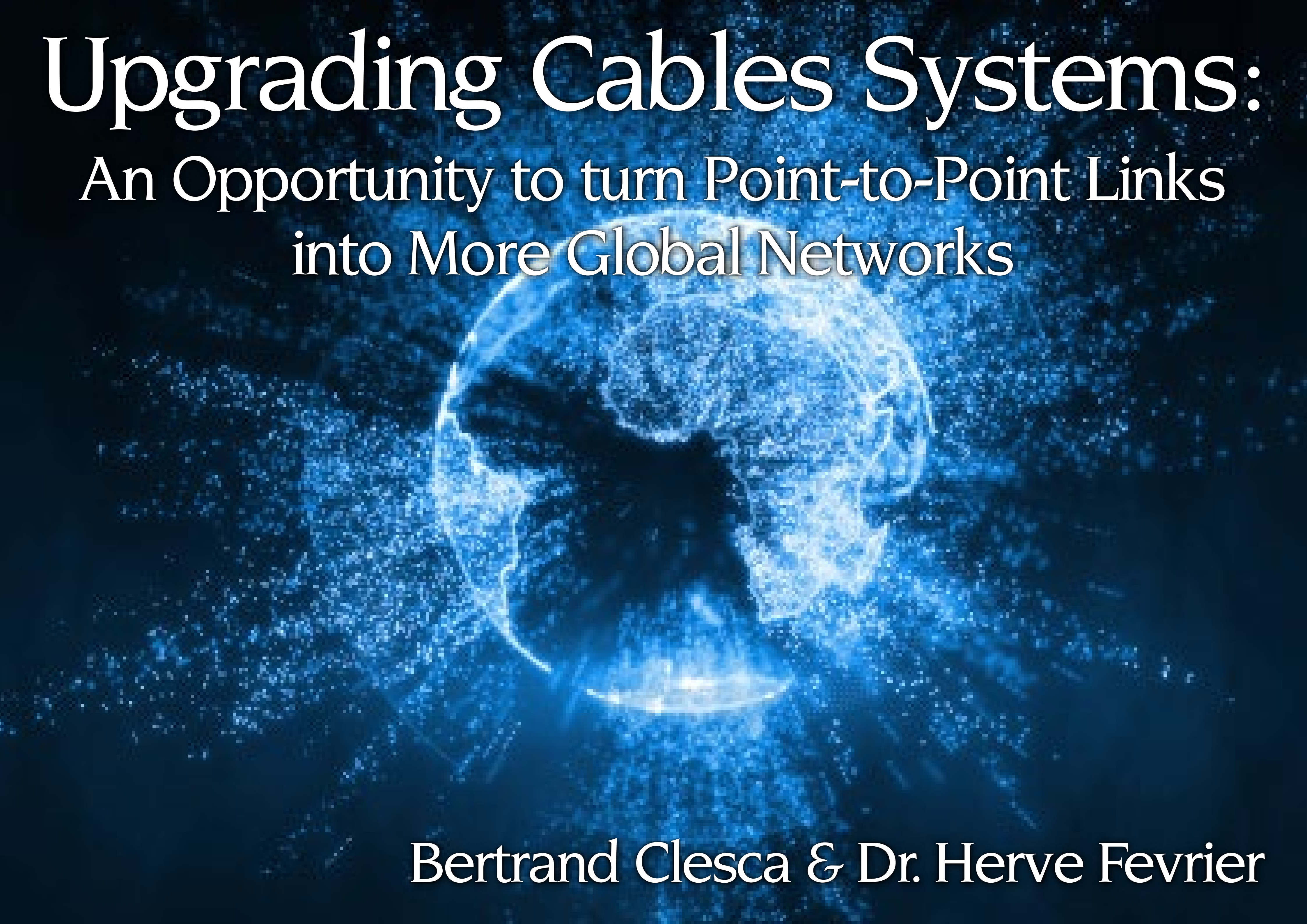
System Upgrades Edition

In This Issue:

- The Road to Upgrades
- Upgrading Cables Systems:
- An Opportunity to Turn Point-to-Point Links into More Global Networks
- Challenges & Successes: Upgrading Trans-Pacific Cables with 100 Gb/s

Upgrading Cables Systems:

An Opportunity to turn Point-to-Point Links into More Global Networks



Bertrand Clesca & Dr. Herve Fevrier

With CapEx constraints being experienced in most parts of the world and the continuous decline in capacity pricing, upgrading existing submarine optical assets to maximize their capacity and extend their lifetime has been more crucial than ever to cable operators. Because of the predominance of subsea cable systems for international connectivity, there is an persistent need to increase the transport capacity of the submarine backbone networks so that cable system operators can effectively address the skyrocketing need for bandwidth. In parallel to this need for increased capacity, there is also a need to increase the availability and resiliency of subsea cable networks.

In 2001, Xtera introduced the concept of upgrading an existing system and went on to pioneer the upgrade market, later followed by other equipment vendors. In the past decade, upgrading a subsea cable system corresponded to upgrading the transmission equipment in the Cable Landing Stations (CLS) to enable higher capacity inside the cable at a lower unitary cost. In the last few years, subsea cable system upgrades have introduced more variety, including the opportunity to change the architecture of the submarine network itself. This allows the evolution of a system from a simple point-to-point configuration to a more complex one.

This article explores the different upgrade approaches that have already been applied in the field and can be considered in the future.

Different Upgrade Approaches Inside the Cable Landing Stations

Dry upgrades consist of replacing the old Submarine Line Terminal Equipment (SLTE) inside the cable landing station with a new one. The Power Feeding Equipment (PFE) can also be upgraded in order to benefit from more reliable and more compact equipment.

Where only the SLTE and the PFE are involved, the benefits of upgrading existing subsea cable infrastructures are presently well known and accepted by the community. When compared to new builds, upgrades offer a lower cost because no CapEx is required for laying new subsea cables, a shorter lead time that is mostly driven by the supply of the new Submarine Line Terminal Equipment (SLTE) to be connected to the cable, and no permitting issues making the availability date for the new capacity more predictable.

Historically, this has not always been the case. Initially, the original suppliers of the existing systems happily supported the notion that connecting an SLTE from another vendor would not work – or at least was not a good idea technically, or it could impact the system warranty, or it could even cause some intellectual property concerns for the cable operator. Currently, the situation is quite different – with subsea cable system operators assessing upgrade possibilities not only before the end of the warranty period but sometimes even before the RFS date of the system! In fact, it seems like the only existing reason why customers do not purchase the wet plant completely separate from the dry equipment is that they have not found a way (yet) for the wet plant supplier to guarantee performance and system capacity.

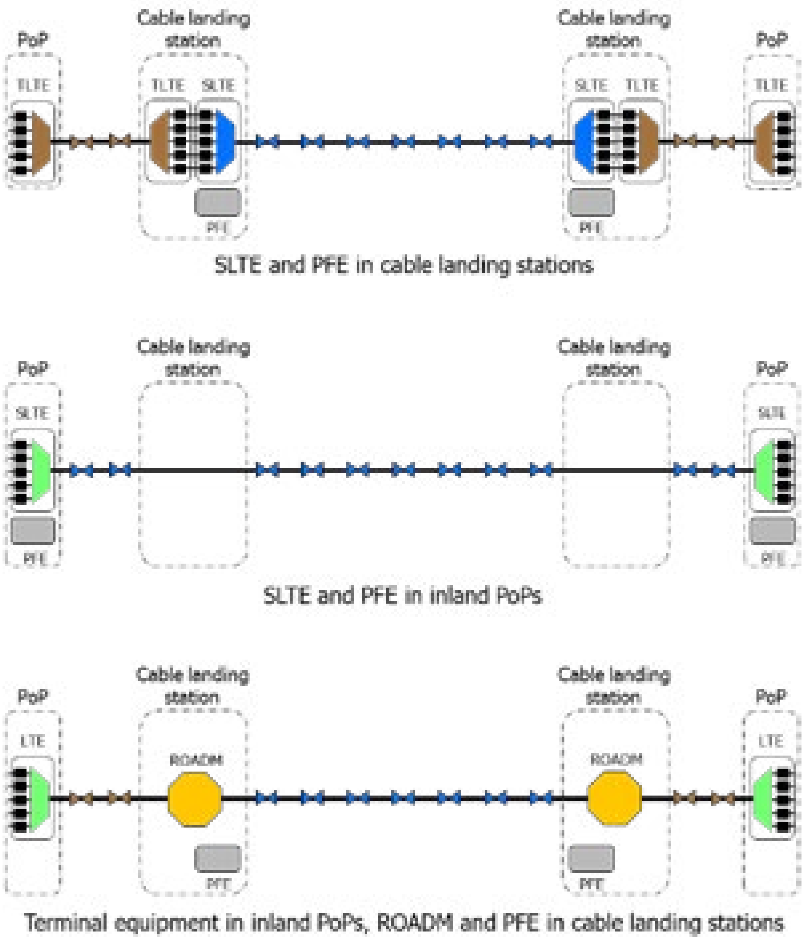
Xtera has been working on the upgrade of submarine cable systems since 2001 and carried out its first commercial upgrade project in Q1 2006. The major benefits for cable operators from this relatively recently created upgrade market are more competition, more advanced technology at the terminal level and lower incremental price for new capacity. Upgrading SLTE in the cable landing stations typically requires a procurement and installation cycle of less than 8 months, compared with an average of 3 years for building a brand new long-haul cable system (depending on the size).

When the equipment in the cable landing station is upgraded, there is the possibility to either keep the original Line Monitoring Equipment (LME) or to switch to the LME equipment from the vendor supplying the new SLTE (provided of course that this vendor has the capabilities to monitor the submerged equipment from the original cable system supplier).

The older the cable system is, the more

impressive the capacity increase enabled by upgrade is. For subsea cable systems that were originally designed in the 90s with a single 2.5 or 5G channel, the capacity increase can reach, in some cases a factor, of 100! The new system design capacity is typically governed by the characteristics of the line which largely consists of the optical fiber cable and repeaters. The key characteristics that may limit the maximal system capacity include: optical attenuation (not only the original figure but also the increase due to multiple cable cuts/repairs if any) for unrepeatered systems, and the noise generated along the system as well as the fiber's chromatic dispersion map and reaction to increased optical powers (nonlinear performance) for repeatered systems.

Figure 1: Evolution to PoP-to-PoP connectivity.



Moving to the Point of Presence

Very often, the Point of Presence (PoP), which is the access point of capacity for customers such as data centers, is not located inside the cable landing station but further inland. SLTE in the cable landing station therefore imposes a physical demarcation with back-to-back connection to Terrestrial Line Terminal Equipment (TLTE) without such a demarcation need existing from connectivity or the end user's perspective. The installation of SLTE in the cable landing station leads to optical, mechanical and electrical discontinuities in the PoP-to-PoP connectivity: optical signals are terminated before being fed to the terrestrial network, the subsea cable is mechanically terminated at the beach manhole level before joints to a land cable going from the beach to the cable landing station, and the subsea cable is electrically terminated at the PFE level.

When the line capacity that can be supported by the subsea cable is increased, higher capacity needs to be offered on the terrestrial backhaul network that connects the cable landing station to the PoP. This can be achieved in different ways:

- The traditional approach is to upgrade separately the terrestrial backhaul with the deployment of higher-capacity TLTE; this approach keeps the back-to-back connection inside the cable landing station and requires a total of 6 line card interfaces for each new wavelength to be added to the subsea cable system (assuming one terrestrial backhaul at each end of the system);
- A more disruptive approach has been attempted on some occasions with the subsea cable (and its associated repeaters) traveling on land directly to the PoP; this tactic raises several technical challenges (like the temperature control of the repeaters that are designed to operate at the sea bottom with a narrow and low temperature range) and operational issues (the subsea cable supports high voltage for remotely power feeding the repeaters all along the path and is therefore very sensitive to any physical aggressions);
- A third approach has become more popular in recent years: it consists of terminating the electrical system with PFE still in the cable landing station

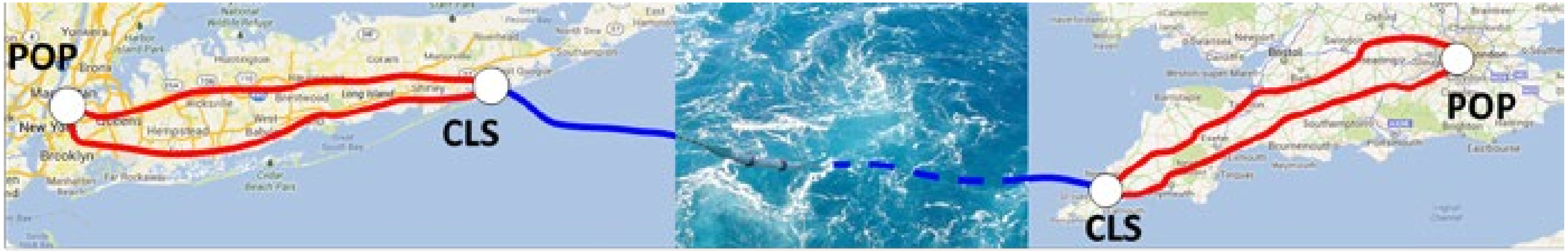


Figure 2: Terrestrial backhaul networks with protection routes.

and bypassing the wavelengths in the optical domain to reach the PoP with no more optical-electrical-optical conversion inside the cable landing station; the optical bypass is enabled by simple Optical Distribution Frames (ODFs), or Fixed or Reconfigurable Optical Add Drop Multiplexers (FOADMs or ROADMs).

These three approaches are depicted in Figure 1.

Moving to Interconnected Cable Systems

ROADMs obviously bring flexibility in the optical connectivity between the cable landing stations and the PoP or other Network Elements (NEs).

One example of flexible connectivity enabled by ROADMs in the cable landing stations is the switching in the optical domain from working to protect route when two physically-diverted routes are available in the backhaul network as illustrated in Figure 2.

When two long subsea legs are available, i.e. two transoceanic cables, more robust and fault-tolerant configurations can be built with the addition of short subsea legs connecting a pair of cable landing stations on each side of the ocean. In the example depicted below, ROADMs route the optical wavelengths onto the subsea or terrestrial links depending on their availability to reach the nearest PoP. Access to the traffic is offered typically only in the inland PoPs. If access to part of the traffic is also required in the cable landing stations, ROADMs can locally drop the needed wavelengths that will be terminated and connected to terminal equipment. Figure 3 illustrates a simple example where physically-diverse routes are available on both subsea and land parts of the PoP-to-PoP network, enabling multiple protection and restoration scenarios for higher global resiliency with respect to multiple faults in the network.

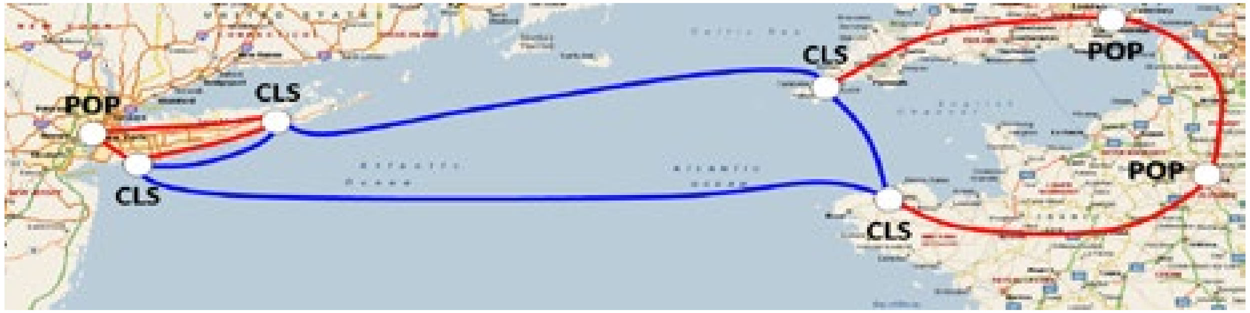
Of course, to be in a position to move the terminal equipment inland and optically bypass the wavelengths through the cable landing stations during the upgrade of existing cable systems, high-performance transmission technologies must be used in order to extend the reach from the original CLS-to-CLS distance to PoP-to-PoP distance.

Compared to 2.5, 5 or 10G technologies, 100G channel rate with PM-QPSK modulation format (PM: Polarization Multiplexing; QPSK: Quadrature Phase Shift Keying) with digital coherent detection offers the transmission performance boost that can enable new PoP-to-PoP configurations on existing cable systems. Because optical transport along an optical fiber is essentially a highly analog process with much potential degradation that can impair the optical signals, thorough simulations and tests are required on a case-by-case basis to check the actual feasibility of PoP-to-PoP configurations. With further incremental improvements to come on today's 100G technology, it is expected that more and more existing cable systems will be candidates for PoP-to-PoP configuration during their upgrade.

Moving from SIE in Cable Landing Stations to OTN Switch in PoPs

Traditionally, SONET/SDH Interconnection Equipment (SIE) was connected to SLTE inside the cable landing stations. SIE is based on standard SONET/

Figure 3: Terrestrial backhaul and subsea networks multiple protection routes for more restoration possibilities.



SDH transmission protocol and allows interconnection to terrestrial networks, system protection and grooming of capacity to optimize system usage. With the terminal equipment moving inland to PoP, the natural location of SIE is now inside of the PoP.

In parallel to this "geographical" evolution, there are also evolutions of standards and products with the advent of the Optical Transport Network (OTN) concept. OTN is designed and standardized to provide support for high-capacity optical networking using Wavelength Division Multiplexing (WDM) unlike its predecessor SONET/SDH that was standardized to support lower-capacity, single-channel signals (practically up to 10 Gbit/s, corresponding to OC-192/STM-64 standards) and lower granularity (e.g. OC-3/STM-1 at 155 Mbit/s). Electrical switch handling OTN signals presently offer more efficient and resilient utilization of the capacity resources throughout the optical network and the possibility to handle any type of service at any rate.

OTN switching equipment is the preferred way to deliver and manage new services and enable more meshed network architectures with enhanced protection/ restoration functionalities.

Bringing together ROADMs, 100G and OTN switching technologies leads to the following implementation that enables an efficient and resilient PoP-to-PoP connectivity. This implementation minimizes the number of interface cards to be added to the network for new PoP-to-PoP capacity, allows protection/switching routing at the optical wavelength levels in the cable landing stations and offers capacity efficiency, resiliency and flexibility to handle any type of service inside the PoPs. Figure 4 symbolizes the implementations of these recent technologies in the case of a simple PoP-to-PoP connectivity.

For configurations based on different subsea routes, like the one depicted in Figure 3, or more complex configurations involving multiple cable landing stations and multiple subsea routes, the same basic equipment will be used: multi-degree ROADMs in cable landing stations, OTN switches in PoPs and 100G interface cards for the optical wavelengths supporting OTN frames and traveling throughout the network. Whatever the complexity of the network configuration and the diversity of physical routes, both terrestrial and submarine, the objective is the same: ensure end-to-end connectivity within a unified network with the smallest number of demarcation points or at least with no impact on the transmission distance. The higher the number of routes available in the network, the higher the resiliency with respect to multiple cable cuts or equipment failures. In order to enable fast and reliable protection/restoration, different options for the control plane are proposed by the equipment vendor. Meshing multiple terrestrial and subsea routes to offer resilient unified PoP-to-PoP connectivity is key for capacity consumers, especially in areas that are sensitive to earthquakes (like south east Asia) or that forms some kind of geographical bottlenecks (like Egypt).

Wet upgrades

Only dry upgrades, leaving untouched the wet plant, have been considered so far in this article. Upgrading the wet plant, however, and not just the equipment in the cable landing stations or PoPs, can be very effective in improving cable systems from capacity and connectivity perspectives.

The simplest wet plant reconfiguration is the insertion of a Remote Optically Pumped Amplifier (ROPA) into an existing unrepeatered cable system. While carefully assessing the commercial and operational consequences, more complex wet plant reconfigurations including: replacement of faulty/underspecified units, insertion of branching units, addition of spurs, or redeployment of decommissioned cable systems, can be carried out. Some of these wet upgrades will increase the cable capacity while the insertion of branching units and addition of spurs will impact the network configuration and enhance its connectivity. Wet upgrades require not only a strong experience in building and managing projects that can be more complex than the deployment of a new cable system, but also the capabilities of a full supplier for offering all the products and services that are necessary. With its innovative repeater that successfully completed two sea trials (in deep and shallow waters), Xtera can offer multiple wet upgrade options

Figure 4: Combining ROADMs, 100G and OTN switching technologies to build efficient and resilient PoP-to-PoP connectivity.

Conclusion

In conclusion, upgrading existing subsea cable systems can be achieved at different levels and applied to virtually all the cable types and generations. The advent of high-performance transmission technologies, like coherent 100G, enables relocation of the optical wavelength termination point from the cable landing stations to further inland PoPs. This offers the possibility to unify terrestrial and submarine links in order to build end-to-end, PoP-to-PoP connectivity. ROADMs and OTN switches, implemented inside cable landing stations and PoPs respectively, in addition to the associated control plane, become the crucial equipment to build a global network with high resiliency against multiple faults.

Bertrand Clesca is Head of Global Marketing for Xtera and is based in Paris, France. Bertrand has over twenty years' experience in the optical telecommunications industry, having held a number of research, engineering, marketing and Sales positions in both small and large organizations. Bertrand joined Xtera in 2004 where his responsibilities included marketing, customer interactions, and business development for both submarine and terrestrial high-capacity networks in EMEA area before moving to his current Global Marketing position. Bertrand Clesca holds an MSC in Physics and Optical Engineering from Ecole Superieure d'Optique, Orsay (France), an MSC in Telecommunications from Ecole Nationale Superieure des Telecommunications, Paris (France), and an MBA from Sciences Politiques, Paris (France).

Dr Herve Fevrier joined Xtera in 2000 and serves as the Executive Vice President and Chief Strategy Officer. He provides the strategic leadership that leads to the acquisition of new customers, development of new products, partnerships with vendors, and developers of complementary technologies. Prior to Xtera, Dr Fevrier spent more than 17 years with Alcatel in a wide variety of responsibilities including Director of the Photonic Networks research unit, Sr Director for DWDM Product Development Worldwide, VP & GM Optical Networks Alcatel USA and VP Network and Product Strategy Alcatel Optics. Dr Fevrier received his doctoral degree in Physics from the University of Paris and he holds a Physics engineering degree from the Ecole Centrale de Paris.