SUBSEA OPTICAL SYSTEMS
A DEEP DIVE

It's difficult to overstate the criticality of subsea optical systems to the functioning of the planet's global telecommunications ecosystem, writes **John Williamson.** One estimate by Pioneer Consulting is that submarine cable fibre systems support 99% of international telecommunications traffic. Market research and consultancy TeleGeography calculates in early 2021 there were approximately 426 submarine cables in service around the world, extending over 1.3 million km. Subsea communications is also a giant business in and of itself. According to a report available from research publishing house StrategyR, the 2020 global market for submarine optical fibre systems was valued at US$14.1 billion, and this could reach US$32.7 billion by 2027.

Notwithstanding the scale of present activity, there's intense and intensifying pressure to greatly expand the operations and performance windows of subsea optical systems, both by upgrading extant cables and planning and installing new, better-efficient plant. Several factors are at work.

A major one, says Geoff Bennett, Infinera's director of solutions & technology, is the circumstance that hyperscale Internet Content Providers (ICPs) are continuing to massively grow their share of international capacity. This is at a time when conventional Communication Service Providers (CSPs) are also exhibiting healthy subsea growth. In addition, he cites the major trend towards direct routes, and instances Ellalink linking Portugal and Brazil, with onward connections at both ends to Spain and the rest of Latin America. "Previously traffic would follow twice the distance – Europe to USA to Brazil," he observes. "EllaLink's route will halve the latency for applications like financial trading and gaming.

UPPING THE GAME

Since it's not realistic or economically viable to recover and replace wet plant, the practical way of increasing the capacity of an existing cable system is to deploy new terminal equipment - the Submarine Line Terminal Equipment (SLTE) that handles optical-to-electrical-to-optical conversion - at each end. And here, explains Bertrand Clesca, director of client solutions at Pioneer Consulting, coherent transmission has come to the fore. "Developed by Nortel about 12 years ago, optical coherent technology has offered a ten-fold increase in the capacity per fibre pair in the last decade," he reports.

Second generation coherent systems are further expanding subsea fibre capabilities. "We have a whole presentation on the toolkit of features that a modern transponder can use to maximise either the fibre capacity or the wavelength data rate," states Bennett. "But two of the biggest contributors are Nyquist subcarriers and Probabilistic Constellation Shaping (PCS)."

Olivier Courtois, director, submarine product management, strategy and marketing, Alcatel Submarine Networks, reflects that all major vendors have today some kind of PCS-based solution in their catalogues, and PCS has been adopted in virtually all new cable deployments and upgrades over the last couple of years. "Classic modulation schemes like, for example, BPSK/QPSK are by now confined to legacy systems."

Virginie Hollebecque, vice president and managing director for Western Europe and Middle East at Ciena, also lists PCS, along with soft-decision Forward Error Correction (FEC), nonlinear mitigation techniques, selectable baud, and machine learning–based link monitor metrics that are accessible via open APIs, as some of the technologies that allow operators to massively increase the total information-carrying capacity of existing (and new) submarine cable networks. At the same time, she observes, with some of these technologies, costs are reduced by requiring fewer modems.

Meantime, according to Luca Luchesini, Nokia senior director, subsea business development, there's advances in component technology. He describes the continuous improvement of optical hardware via more sophisticated DSPs and integrated silicon photonics that have almost reached Shannon limit capabilities, and says that most vendors are moving to 7nm technology from previous 16nm and 28nm chipsets. "We can say that these systems allowed on average an additional 10 to 20% gain in terms of overall performance, that is, capacity for the same reach or reach for the same capacity."

He adds that there's a race on to reach 5nm solutions but that gains here may be not so much in total capacity made available, but in performance and operability such as

less power consumption, more operational flexibility, and density.

On a system level what can be achieved with advanced solutions is indicated by the MAREA transatlantic cable system. Entering service in April 2018, it was designed with a goal of 20Tbps per fibre pair but the transponders maxed out at 18Tbps. Applying the fourth and sixth generations of Infinera's Infinite Capacity Engine (ICE) resulted first in 26.2Tbps 'hero' capacity and 24Tbps 'commercial' capacity, and then 30Tbps hero and 28Tbps commercial. Hero is maximum error-free transmission capacity, commercial is deployable capacity, including margin to account for link degradation.

NEW WAVE

In recent years a new generation of Spatial Division Multiplexing (SDM) or High Fiber Count (HFC) wet plants has been introduced. The SDM approach is based on using more fibre pairs in the cable, each operated in a quasi linear regime, transmission-wise. "This design makes a more efficient use of the optical pump power available inside the repeaters," says Clesca. "And it requires less complex and less expensive line fibre, with a typical effective area ranging from 80 to 110 µm2, instead of 150 µm2 in a MAREA-like design."

Power is a central consideration for SDM. "There is a lot of modelling that says if you apply, for example, half the amp power you get more than half the capacity," reports Bennett. "So SDM is about running amps at lower power so that you can support more fibre pairs in the cable. You may have slightly less capacity per fibre pair, but you have a lot more fibre pairs, and that means more capacity per cable."

"Combining modern coherent modems with new SDM wet plants brings overall cable capacities to unprecedented levels that are well into the hundreds of Terabits per second," adds Hollebecque.

Google's Dunant 6,600km transatlantic cable, ready for service in February 2021, was reported to be the first long-haul 12-fibre pair system to use the technology. 2Africa and Equiano are among the cable systems planning to use SDM.

POWER PLAY

Another power-related subsea system issue concerns the material used in cable conductors. Clesca notes that some technical papers show that aluminium used as a conductor is less costly compared to copper. "Additionally, aluminium also allows for lower DC resistance at lower cost and reduces the cable voltage drop, which then allows for an increased number of fibre pairs," he states. "Facebook has claimed that the 2Africa cable system will make use of cables built with aluminium used as a conductor. It will be very interesting to follow the installation and the first years of operation of this cable system".

TURN ON, TUNE IN OR DROP OUT?

But when does it make sense to retire a subsea route and build a new one? Clesca makes the point that the cost of O&M along the cable lifetime is virtually independent from the number of bits transported per second and that, therefore, the higher the system capacity, the lower the O&M cost per unit of capacity. As such, he observes that cable economic life is defined as the period where annual unit cost of O&M must be lower than the annual unit price of capacity on newer cable systems on the same routes. "The key factor that dictates retirement date is competition from newer cable systems."

NEXT WAVE

What characteristics and technologies are these newer and future cable systems likely to feature?

Bennett is predicting we'll see more spectrum sharing as a means of making capacity more affordable for individual customers. "In the old days we would have shared capacity using OTN switches, but they do not scale to the kinds of capacity in a cable landing station today," he comments. "So all-optical sharing is key – that is what spectrum sharing is about."

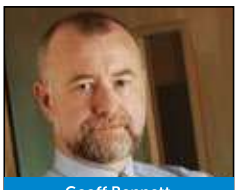
Ciena sets some store by improved operational and management capabilities. "Streaming telemetry and analytics, coupled with software control and automation, will allow operators to ensure their submarine network assets are operating in an optimal manner by continually adapting to ever-changing conditions," says Hollebecque. "Reactive capabilities allow operators to intelligently and automatically reroute traffic around inevitable faults. Proactive capabilities, like preventive maintenance, allow operators to address outages before they occur, such as rerouting traffic around a faulty transmitter that's showing signs of impending failure."

For Luchesini, the evolution of CapEx in new wet plant is of primary importance. "Many analysts point that capacity demand growth requires much more new buildouts than (are) currently planned in the next four years," he says. "If this is true, it will further drive demand for coherent, high capacity and cost-optimised systems."

Among other things, Clesca puts some emphasis on fibre innovation, and mentions smaller Outer Diameter (OD) fibre to pack more fibre cores in the existing submarine cable design and structure.

He references research to develop multi-core optical fibres to overcome the limited space that constrains an increase in the number of fibre cores in submarine cable and repeater structures. "When such multi-core fibres are ready for manufacturing and deployment, they will require the development of a new ecosystem of components and sub-systems – for example Multiple-Input Multiple-Output (MIMO) optical amplifiers," he concludes.


Bertrand Clesca, director, client solutions, Pioneer Consulting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