XTERA

# Pushing the boundaries

The advent of 100G coherent technology is revolutionising what can be achieved over long-haul fibre networks.

**MOST LONG-HAUL OPTICAL NETWORKS** today operate at 10G transmission speeds. This is leaving network operators with the challenge of managing and supporting increased traffic levels on their infrastructure, driven by such factors as mobile data, high-bandwidth applications, increasing number of connected devices and the advent of high line rate IP routers.

The answer to which many of these operators are starting to turn to give them the capacity and performance they need is 100G coherent technology. Coherent technology represents a fundamental change in how optical networks operate, and delivers on the high-capacity networking needs of today and tomorrow. Importantly, it offers a way for operators to increase the capacity of existing optical long-haul transmission infrastructure.

Developments in optical transmission technology have seen the introduction of these coherent technologies and the development of 100G interface cards for long-haul applications. These innovations deliver the dividend of capacity that can be scaled while keeping capital expenditure to a minimum and operations at a simple and sustainable level.

By using 100G coherent technology on either terrestrial or submarine systems, operators can reduce the cost of each bit of information transported while leveraging existing fibre investments. Existing systems can carry up to 10 times the amount of traffic they do today while operational costs can be controlled and new service areas explored.

## WHAT'S POSSIBLE TODAY?

Huge advances in what is possible over existing terrestrial fibre infrastructure have been made in the past two years, changing the whole optical networking game.

The first phase in coherent detection was a crucial enabler for the very first generation of 100G products. The first 100G interface cards for optical transport in Wavelength Division Multiplexing (WDM) systems were made available in 2010. This initial phase was based on a sophisticated modulation format, advanced compared with traditional binary optical power modulation. Detection was achieved by the mixing of the optical transmitted signal with a reference optical signal delivered by a local optical oscillator.

The industry stands now at the dawn of second generation 100G. Leading the field here is Xtera Communications with its soft-decision Forward Error Correction (FEC) technology. Soft-decision FEC relaxes the optical signal-to-noise ratio requirement at the output end of the link and enables longer reach. The second half of 2011 saw the deployment, in the field, of this second generation of 100G interface cards. This is bringing about a new level of performance, efficiency and cost effectiveness for a whole new generation of 100G terrestrial networks.

With WDM 100G optical networking resulting into a huge amount of transmitted capacity, the ratio of terminal equipment

**Hervé Février,** COO of Xtera

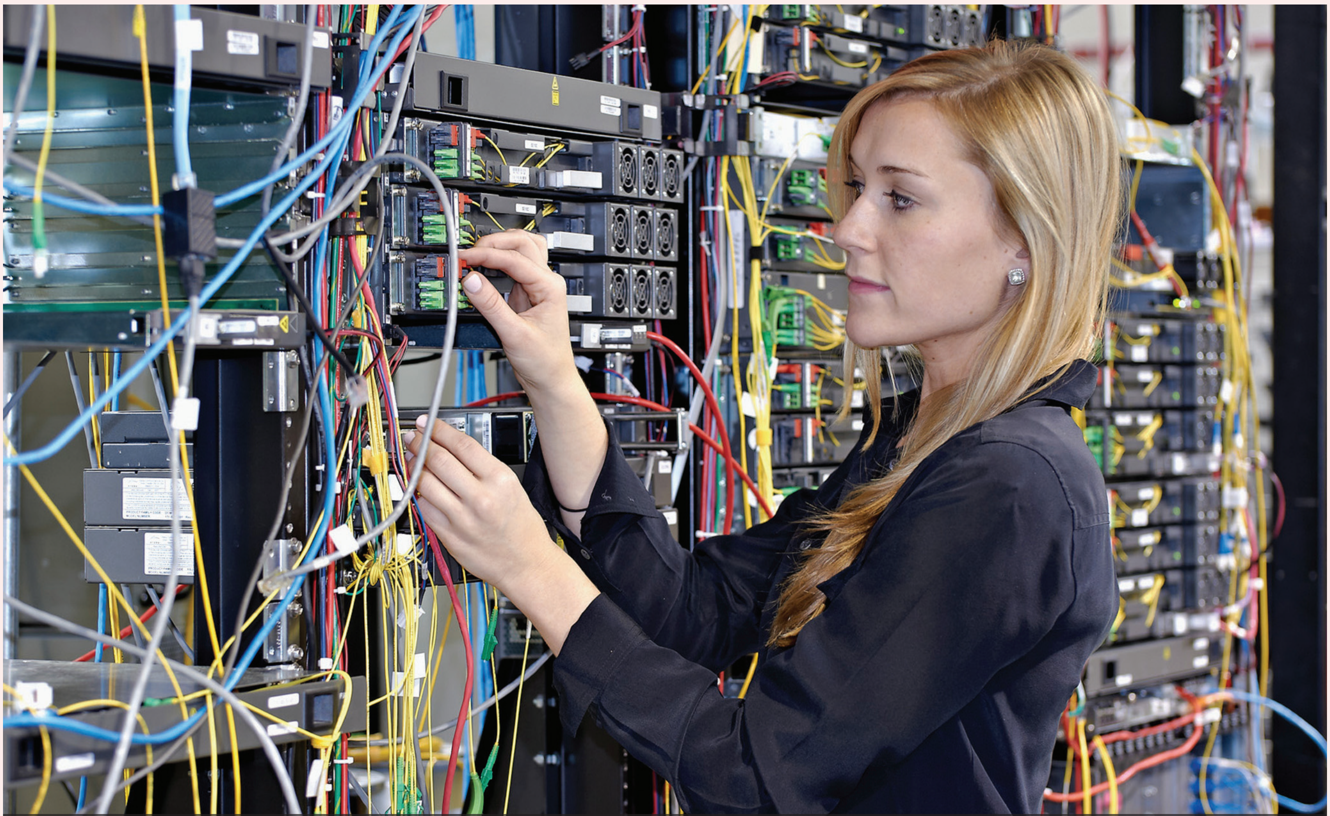
cost to line equipment cost increases drastically. Consequently investing more in higher-end line equipment, whose cost is shared between all the waves, can bring real value to the network in terms of reach and capacity. It can also reduce the relative cost of interface cards by relaxing their technical requirements and/or limiting their number required throughout the network, for example by the elimination of regeneration sites.

In these conditions, the capital expenditure that operators invest in line equipment leads to larger savings at the interface card level, as well as operational expenditure reduction through the network's lifetime.

Compared to conventional Erbium-Doped Fiber Amplifiers (EDFAs), Raman amplification technology offers better noise performance, wider optical bandwidth and lower per channel power in the line for mitigating non-linear effects occurring during the transmission of the optical waves, effectively leading to performance, capex and opex benefits.

So what is the outer limit of what's possible today by combining the best of interface card and line equipment technologies?

Raman amplification offers the potential for capacities of 15Tbit/s, based on the multiplexing of 150 x 100G for reach



**Testing 15Tbit/s optical transmission equipment ready for deployment**

exceeding 3,000km in real network conditions, aided by soft-decision FEC. Avoiding regeneration sites, this ultra-long-reach capability is crucial not only for ultra-long-haul links but also for highly meshed network configurations.

In 2011 a 22,000km network was deployed, including the longest 100G link ever deployed in the field – a 2,500km all-optical path going through nine Reconfigurable Optical Add Drop Multiplexers (ROADMs).

In the same network, long distance between intermediate sites was demonstrated with the deployment of a 1,350km multi-span link including a 250km / 60-dB span. Such a span would normally require termination and regeneration of all the wavelengths at either end with more traditional line equipment.

And in early 2012, a 436km unrepeatered transmission of 34 x 100G was carried out, with no active elements along the cable between the two terminal sites, further demonstrating the value from Raman technology for long-distance transport.

The technology leverages the huge amount of terrestrial optical cable infrastructure already installed in the ground around the world, and the unused potential of dark fibre capacity.

Raman amplification makes possible line equipment with optical bandwidth still wider enabling capacities even larger than 15Tbit/s.

As far back as 2004, Xtera was installing in commercial networks a configuration of Raman-based line equipment with a 100-nm optical bandwidth, accommodating 240 waves, representing a straightforward solution to offer 24Tbit/s line capacity with reach exceeding 3,000km.

This approach is based on mature 100G technology at the interface level whose cost will decrease within the next several years, contrary to other options making use of complex and expensive (on a per wavelength basis) technology for the interface cards.

## BENEATH THE WAVES

A major intercontinental network will be likely to span land and sea, incorporating major submarine sections as well as terrestrial.

In order to avoid any bottleneck between the end points of any international data path, attention must also be paid to the submarine cable transmission infrastructure, connecting countries or continents across oceans and seas worldwide.

Here there are two approaches to consider. Firstly, the upgrading of an existing subsea cable system by changing the terminal equipment connected to the cable, leaving untouched the equipment laid on the seabed.

Option two is the building of a new subsea cable system where all the parameters – including submerged repeaters and fibre characteristics – can be optimised to maximise the capacity.

For the upgrade of existing subsea cable systems, the first step is to assess to what extent the terrestrial 100G coherent approach can be used. Depending on the characteristics of the cable system to be upgraded and the operator's long-term capacity requirements, terrestrial 100G coherent technology can be an appropriate solution for cable system lengths of up to 3,000km.

When it comes to older cable systems, a lower channel rate, like 40G, can prove a better approach to maximising line capacity. For the upgrade of existing subsea cable systems with cable lengths beyond 3,000km, new 100G technology needs to be developed to effectively increase the line capacity.

For new builds, the characteristics of terminal equipment, submerged repeaters and optical line fibre can be optimised so that the terrestrial 100G approach, with minor improvements, will make sense.

**WHAT'S NEXT?**

There has been exciting progress made in extending the capacity and performance of major fibre infrastructure, and further progress is yet to unfold, within the natural limits of physics.

For EDFA-based line equipment there is an upper limit on the optical bandwidth that restricts the channel count to 88, assuming 50GHz channel spacing. In this instance, the next steps for increasing line capacity beyond 8.8Tbit/s must be achieved at the terminal/interface levels.

Most equipment vendors are pursuing one of the following two paths:

- That of increasing the number of bits per symbol by developing a higher-order modulation format in order to increase the capacity supported by each optical channel. However higher-order modulation formats suffer from a reduced reach due a weaker tolerance to non-linearities.

- Building super channels by multiplexing a number of "sub-carriers" with a small channel spacing in order to maximise the usage of the limited optical bandwidth. The typical capacity gain is less than 30%, resulting in a line capacity lower than 12Tbit/s, assuming PM-QPSK modulation format for each 100G sub-carrier.

Combining higher-order modulation format and super channels, some suppliers are working on equipment to deliver 23Tbit/s line capacity by combining 400G waves in a gridless approach. This capacity is expected to be available in 2014 on the earliest with a limited reach because the 400G waves will rely on high-order modulation format that is sensitive to non-linearities. The gridless approach, where the carrier wavelengths are no longer allocated to specific spectral slots, might be applicable to a simple point-to-point link but not to meshed networks.

An additional option for future improvement is to work at the line level. For line equipment, Raman amplification is a field-proven approach for improving amplifier noise performance and increasing amplifier optical bandwidth. In future we can expect further research and progress involving new fibre types, for new builds, like new subsea cable systems, and for terrestrial networks using fibre existing in the ground.

**Xtera Communications**

Founded in 1998 in the USA, Xtera specialises in the field of optical high-capacity transmission equipment. It owns patent-protected fundamental technology in the form of Raman optical amplification, and has world-renowned optical technology expertise covering both submarine and long-haul terrestrial networks.

It deploys the most advanced 100G technology currently deployed in the field, offering the highest 'capacity times reach' metric in the industry for optical WDM transport on any fibre type.

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## 100G in the real world – two examples in action

The **Comisión Federal de Electricidad (CFE)** is a Mexican state-owned utility company. Working with Xtera it has equipped a nationwide 22,000km optical network with 100G optical wavelengths.

Uniquely, the deployment used a hybrid Raman/EDFA approach, giving it both the longest reach and highest capacity possible. The combined use of 100G coherent and hybrid Raman/EDFA amplification technologies avoided the installation of more repeaters than necessary, and costly new huts. The result is all-optical data paths up to 2,500km with no regenerators.

The Raman optical amplification technology in particular helped to maximise both capacity and reach, enabling the bridging of long spans with no need to build new sites, and making the network simpler and faster to build and operate.

A very different kind of 100G network is that which **Gulf Bridge International (GBI)** has built between the Persian Gulf and Europe, with a submarine section landing at every country in the Gulf region before taking traffic up to Europe over a mixed land/subsea route.

GBI was in fact the first subsea network to go live with 100G performance, giving it an important advantage in terms of cutting edge speeds to that it can meet wholesale capacity demands in the region into the future.

"100G has been something that has been discussed in the industry for a long time and GBI is proud to be the operator to usher in this new era of undersea cable connectivity," said Ahmed Mekky, founder and CEO of GBI.

"As capacity demands continue to grow aggressively, GBI made the decision to use the latest in technology and ensure that we are prepared to meet the demands of our customers in the long term. The emerging markets we serve have only begun to see the benefits of increased connectivity and we will see exciting growth in these markets challenging operators to keep up. GBI has built its business to meet these capacity challenges."

Xtera Communications supplied GBI's 100G networking needs for its terrestrial and submarine routes in Europe, the Mediterranean and North Africa.

"Xtera has technology that allows the company to address both our terrestrial and submarine networks requirements using the same platform at 100G," added Mekky.