THE OPPORTUNITIES AND TECHNOLOGICAL CHALLENGES OF REGIONAL SYSTEM DESIGN

BY TONY FRISCH

This article looks at how system design choices can affect the cost, resilience and flexibility that can be achieved in regional systems, which typically connect a number of locations and often involve relatively modest distances. This produces both opportunities and challenges that are different from those found in long-span systems.

CAPACITY

Extra capacity is usually of interest and can be achieved in a number of ways. Increasing the number of fibres gives the possibility of selling a complete "dark" pair, but requires more amplifiers per repeater. By contrast, extra fibres are generally the best solution in a repeaterless system, except where expensive, ultra-low loss fibre is needed. Keeping the same number of fibres and using 8/16QAM in place of QPSK increases the capacity by 50/100 percent, but requires the Optical Signal to Noise Ratio (OSNR) to be improved by around 4/8 dB. This increases the number of repeaters, as OSNR is improved by moving the repeaters closer together, thus improving the input signal.

Increasing the amplifier bandwidth with a C+L or a hybrid EDFA/Raman architecture can roughly double the capacity, but again, the repeater spacing will be reduced and the amplifiers will probably cost somewhat more than conventional ones. The cost of a typical regional system is dominated by cable and marine costs, so increasing the capacity per fibre pair with 8/16QAM or higher bandwidth amplifiers is often very cost-effective despite the need for a few more repeaters. Adding extra fibre pairs is generally less cost-effective because it also adds extra amplifiers. As an example, Xtera recently looked at a short link where the per fibre capacity could be taken from 21T to 42T by increasing the repeater bandwidth to 63 nm and adding just two repeaters. This was significantly more economical than doubling the number of fibre pairs.

XTERA'S INNOVATIVE WIDEBAND REPEATER

With or Without Repeaters?

At first sight, a repeaterless system might seem the lowest cost solution, since the cable is less expensive and it removes cost elements such as repeaters, Power Feed Equipment (PFE) and ground systems. For short spans this is true, but as the distances become greater, it becomes necessary to use lower loss fibre and possibly to include Remote Optically-Pumped Amplifiers (ROPAs), which add expense.

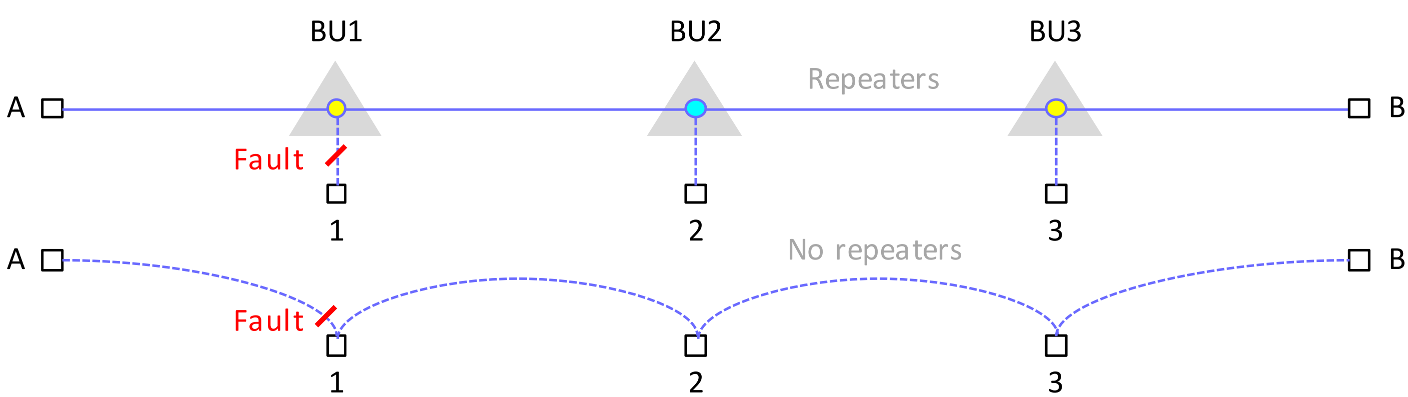
It's also important to consider resilience to faults, as can be seen by comparing a system with repeaters and Branching Units (BUs) with a repeaterless festoon.

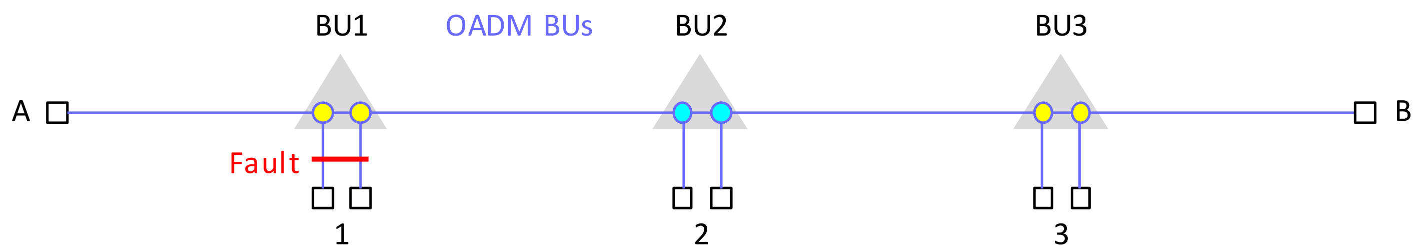
In the repeaterless festoon, one can see that there are three sites requiring two landings, which adds very significantly to the marine installation costs. The solution with repeaters and BUs has only single landings, and PFE and ground costs can be reduced by putting the BUs close enough to the shore to have no repeaters in the branches. Hence, the cost comparison is not as obvious as it might seem and will depend on the difficulty of the marine installation, e.g. burial, etc.

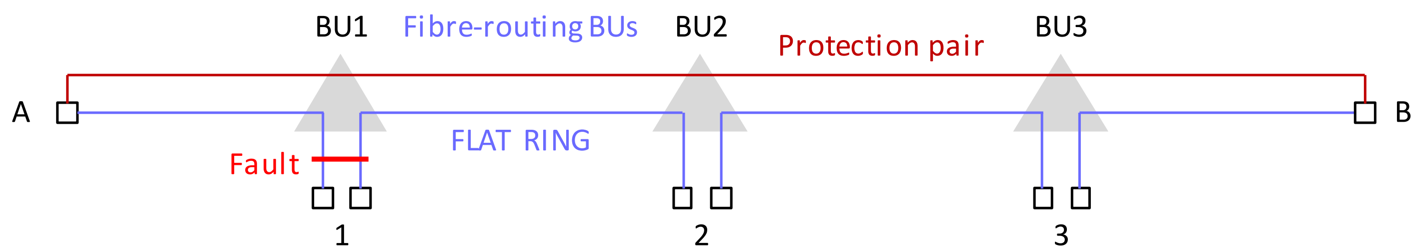
In the repeaterless festoon, all the traffic from Site A must pass through Site 1, so a cable fault in either of its landing cables, or a problem in the station, will lose all this traffic. The BU solution can avoid this, either by using Optical Add/Drop Multiplexing (OADM) BUs, or with a second fibre creating a flat ring. The ring is probably the more costly solution, as it requires extra amplifiers in each repeater.

While the OADM BU provides protection against branch cuts, its downside is that the traffic drop is fixed and traffic demands are hard to forecast. A reconfigurable OADM (ROADM) BU is the obvious solution, but compared with a simple fixed OADM BU, it comes at higher cost and it will have higher optical losses, which may require an extra repeater to be added.

An alternative could be to consider designing the system for a higher capacity and using a fixed OADM. For example, imagine that the system requirements were for







100 x 100G with 10-30 percent drop. This could be achieved with 100 x 100G and a ROADM BU, or with 120 x 100G and a fixed 30 channel drop, of which only a part might be used. The reduced losses of the fixed OADM BU will generally make the higher capacity possible without increasing the number of repeaters, thus producing a more cost-effective and simpler system. This solution, of course, becomes more difficult with larger drop ratios.

GETTING THE TRAFFIC INLAND

In general, traffic needs to be delivered to inland centres and this is most cost-effectively achieved by bypassing the landing point — replacing terminal equipment with amplifiers — and placing the terminal equipment at the point where the traffic is to be delivered. The PFE, however, needs to remain at the landing station, as terrestrial cables cannot carry the high voltages needed to power the subsea cable.

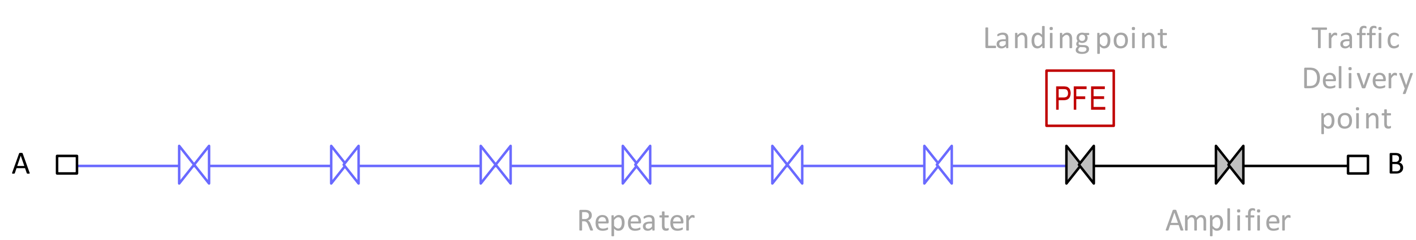
In a regional system, the amplifiers in the land section can have a significant effect on the overall noise. In the example shown, the two amplifiers in the land section would produce 25 percent of the total noise if all the spans were the same, but in reality, it could be worse. Installed terrestrial fibre often has losses of 0.23-0.25 dB/km. So, a 90 km span could be >27 dB, typically 3 dB or more worse than a submarine span, and the noise produced by an amplifier increases if it has to compensate for lower input signals. Because installed fibre usually has low effective area — typically 80 µm^2 or lower — power levels are limited by non-linear effects and one cannot offset the loss by increasing transmit power. Some improvement is possible, however, by using Raman amplification, which improves the amplifier noise figure. If this isn't enough, the optical loss between subsea amplifiers has to be reduced, which means either more repeaters or lower loss fibre, both of which add to the cost.

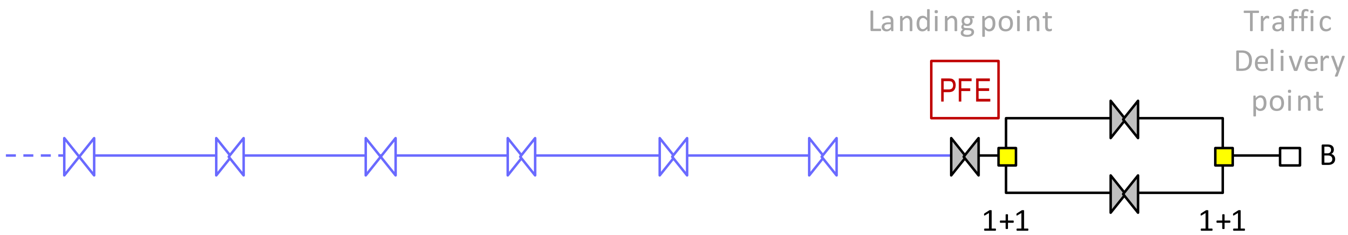
It would seem natural to use terrestrial amplifiers for the land section, but a re-packaged subsea amplifier is also worth considering for the reliability that the duplicated pumping will bring. In some cases, a larger issue may be the risk of the land cable route being damaged, in which case route diversity is required.

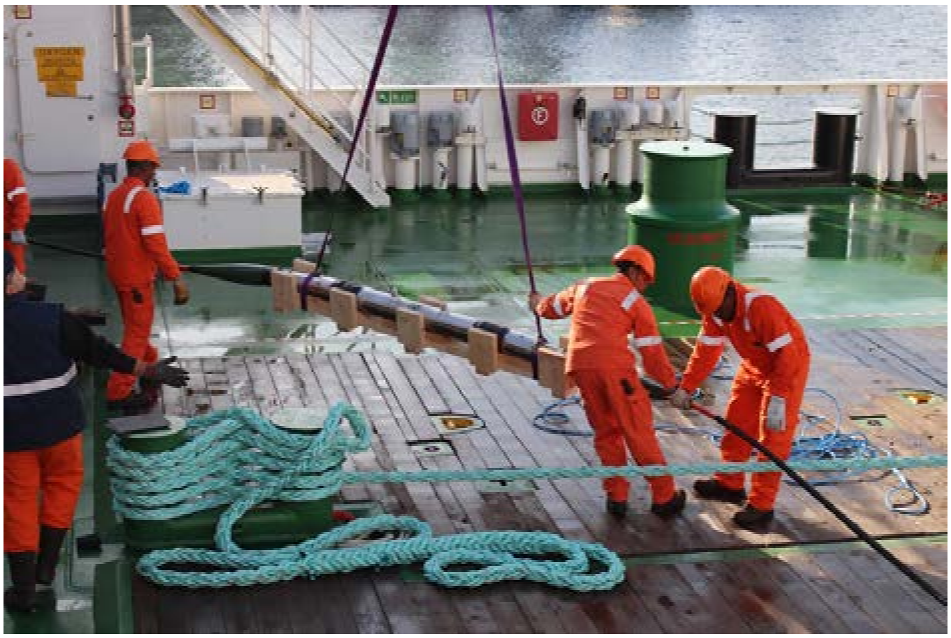
In this case, there is no need for a complex protection mechanism, and Xtera has supplied a simple 1+1 protection switch that simply selects whichever route is available for a number of applications.

Another requirement could be to deliver the traffic from one fibre pair to several different sites, which can be achieved by an ROADM or fixed wavelength splitter/combiner at the landing point.

In this scenario, the specialised Line Monitoring Equipment (LME) that handles the repeaters must be sited at the landing point because the LME requires access to the full spectrum, not just a part of it. It's worth noting that because all the



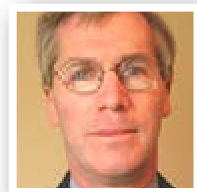




submarine-specific units are at the landing point, this configuration could be "open" to other suppliers' terminals at B, C and D, providing that the "ROADM" is able to handle issues such as the failure or disconnection of the other suppliers' terminals.

SUMMARY

Regional system design can benefit from the modest spans in these networks, which make the cost of capacity low. It's possible to bypass the landing station and put terminal equipment inland, but this may be more challenging than with a longer system because the number of amplifiers on land is a larger fraction of the total. These extended systems can connect to multiple traffic delivery points and, with appropriate equipment design, can be "open" to the use of other suppliers' terminals.



Tony joined Xtera in 2004 initially managing Marketing and Proposals for terminal equipment and upgrades and then responsible for products such as Repeaters and Branching Units, and now serves as CTO.

Tony started work at BT's Research labs investigating cable problems and then moved to Alcatel Australia, becoming involved in testing and commissioning submarine systems. A move to Bell Labs gave him experience in terminal design and troubleshooting, after which he went back to Alcatel France, where he worked in Alcatel Submarine Networks' Technical Sales before moving to head Product Marketing.