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# *Making the most of the Wired World*

### – *Installing and operating high capacity networks*

*The telecommunications business has grown rapidly over the last ten years. So much so that it has placed enormous demands on the basic transmission systems that get signals from A to B. Several companies have risen to the challenge and stated that they will 'wire the world'. But there is a lot more to this than simply putting lots of fibre in the ground. This paper examines some of the practical issues in building a reliable transport network and in keeping it going. It also assesses the impact that a wired world will have on those who supply it and those who use it.*

**The wired world**

One of the very obvious legacies of the industrial revolution is the railway network. In just about every country in the world, there is an extensive collection of main lines that serve the big cities and branch lines to connect the smaller outposts. The current information revolution is going much the same way, only this time it is optical fibre that is being installed to serve future generations.

Across Europe alone, there are at least 20 main players building high capacity fibre-optic networks. Most of these connect the financial centres of Europe and extend transatlantic capacity. But the strategy of these main players will allow a lot more than faster inter-bank transactions. Typically, the fibre networks that are being installed are designed as rings, broken at key locations known as points of presence (or PoPs). The potential of optical transmission technology combined with the flexibility of the ring topology promises to be a major enabler of the information economy.

As a supplier of high capacity networks, it is important to understand the design and operational issues that concern network providers. And as a consumer, you should understand both what is on offer (because it no longer conforms to the established 'price=bandwidth x distance' formula) and the potential for new services when bandwidth is virtually limitless.

**Technology to the rescue**

It is the exploitation of Wavelength Division Multiplexing or WDM that has fuelled the explosion in transmission capacity. With WDM, the light within an optic fibre is split up into a number of discrete wavelengths, or "colours". Each of these colours can readily carry a considerable payload – 2.4 Gbit/sec – and systems with 16 colours are now in common use. An extension to the bandwidth of a basic colour from 2.4 Gbit/sec to 10 Gbit/sec is already available, 40 Gbit/sec has been demonstrated and 80 Gbit/sec equipment is only a few years off. In addition, fibres carrying 64 and more wavelengths are likely to be available in the same timescales.

All these advances depend on developments in fibre terminating and repeater equipment: they do *not* require any upgrade or replacement of the fibre infrastructure that has been put in the ground. Hence, upgrading links from one capacity level to the next can be achieved simply by reconfiguring or upgrading terminal equipment and repeaters.

The raw capacity carried on the fibre highway needs to be structured in some way so that it can carry useful traffic and be routed where it needs to go. This is where the Synchronous Digital Hierarchy (SDH) comes into play. SDH, and its equivalent SONET in the US, is a multiplexing transmission carrier system in which lower bit rate channels are interleaved into a higher level, fixed-length, frame structures and transmitted in a "hierarchy" of successive levels. The levels commonly deployed are STM-1 at 155Mbit/s, STM-4 at 622Mbit/s and STM-64 at 2.4Gbit/s.

The table overleaf relates the SDH and SONET signal names to the capacity available and traffic that can be carried.

| SDH Signal | SONET signal | Bit Rate | Capacity – bearer circuits | Capacity – Voice (Mmins/month) |
|---|---|---|---|---|
| STM-0 | STS-1/OC1 | 51.48Mbps | 630 ISDN channels | 5 |
| STM-1 | STS-3/OC3 | 155Mbps | 63E1 or 3E3 | 15 |
| STM-4 | STS-12/OC12 | 622Mbps | 252E1 or 4E4 | 60 |
| STM-16 | STS-48/OC48 | 2.488Gbps | 1008E1 or 16E4 | 240 |
| STM-64 | STS-192/OC192 | 9.95Gbps | 4032E1 or 64E4 | 960 |

It is clear that the capacity available in a single fibre is huge. Even with today's technology, one fibre can have 16 colours, each carrying 2.4Gbps, which equates to over 16,000 standard 2Mbps (E1) circuits, enough to carry 4,000 Mmins of voice traffic per month. Put another way, this is enough capacity to download the entire movie "Gladiator" in a fraction of a second.

In a global context, all of the international telephony traffic leaving the UK during 1997 would fit on one fibre using current technology. With 64 wavelengths on a fibre, each carrying 80Gbps, there would be enough capacity (over 5Tbps) to carry virtually all of the world's telephony traffic!

Of course, there is some inefficiency along the way. For instance, in the second line in the table, the 155Mbps potential translates into three E3 circuits, each carrying 34Mbps; fitting one established transmission format into another can have significant overheads. Whether SDH/Sonet persists as the layer between the information layer (voice and, increasingly packet data) and the optical layer is not clear – the cost and resilience of alternatives will settle that debate. And then, there is the question of getting the links to start and finish where they are actually needed, making sure that links are always available and so on. Hence, for all the raw capacity on offer, there is still some design work to be done!

| Link configuration | Mean time between failure (MTBF) | Mean time to repair (MTTR) | Availability |
|---|---|---|---|
| Point to point link | 8khrs | 4hrs | 99.95% |
| Point to point link | 4khrs | 8hrs | 99.8% |
| Ring | 8khrs | 4hrs | 99.9999% |
| Ring | 4khrs | 8hrs | 99.999% |

**The design angle**

As with any technology, there are choices to be made in the way that the network is built. The main one is the trade off between installation cost and the resilience of the network.

Large scale WDM/SDH systems are usually constructed as dual, counter-rotating rings. The frames that carry information are sent simultaneously both ways round the network so that they are guaranteed to arrive even if one direction fails. The two paths are physically separate thus eliminating any one single point of failure. During normal operation one of the paths is denoted as the main, and acts on the data received on it whilst discarding the same data being presented simultaneously on the alternative path. If the error ratio exceeds a preset level (say one corrupt packet in $10^{11}$) on the path programmed as main, the system automatically switches to the alternative path within a few milliseconds. Using this configuration, the mean time between failures is low. Hence, with even a moderate mean time to repair, very high availability figures can be achieved – well in excess of 99.99%. In many cases, it may be acceptable to rely on simple point to point connections. This can cut cost and may still yield acceptable availability figures.

Data is inserted into SDH system at multiplexers commonly termed Add / Drop multiplexers (ADMs) situated in designated network connection locations known as points of presence (PoPs). Once added to the system the data can be dropped at another of the PoPs or at the SDH multiplexer termed the "head-end". The head-end multiplexer is typically located at a switching site. Here the data can be cross-connected to other rings or passed to switching equipment providing controlled access to other facilities such as the Public Switched Network (PSN)

There is an ever-growing list of suppliers in the transmission marketplace. Some, such as Lucent, Marconi, Nortel Networks, Alcatel and Fujitsu offer a full range, from optical drivers through to the boxes used to recover the tributary that contains one customer's network connection. Others, such as Corning OCA, Ditech, DiCon, Sumitomo Ciena and Bosch provide specialist (and often very innovative) components of the overall picture.

**The operational view**

There is no such thing as a 'typical' network. In most cases, there is a need to offer reliable service, and since rings (whether at the fibre, wavelength or SDH level) give high availability (at least in theory!) this is the 'standard' approach. However, in practice, an end to end link inevitably entails the interconnection of a variety of networks (whether they are metropolitan, national or international), so it is almost inevitable that you will have some bottlenecks somewhere.

It is always possible to make some sort of trade-off between capacity, complexity and availability, but care should be taken that the network does not grow to be too complex (in an attempt to get better utilisation of the links) as this usually results in poorer overload performance, and makes the network. more difficult to manage.

The life of a fibre is likely to be well in excess of 10 years, so the key factor for an operator is how to best use the fibre. Is it to be used to carry SDH (in which case Add/Drop Multiplexers or ADMs will be needed, inserting some flexibility into the network) or will there be direct optical connections to the service specific equipment (e.g. routers)? Given current trends in carrying capacity, equipment installed today will not have a shelf life much in excess of 2 or 3 years. So, care needs to be taken that the equipment can (or is likely to be able) be upgraded to carry more traffic. Even then, note should be taken that existing services (such as voice) will become commodities very quickly, and costs will become key to the successful operators in such a market. Hence, installing plenty of capacity ensures you can offer capacity quickly, but your prices are not likely to be as low as an operator installing equipment when needed to meet demand.

There are several ways in which a provider of fibre-based capacity can recover its costs. At one end of the spectrum, a provider who has installed a cable with (for example) 100 or more pairs will probably try to recoup the investment by reselling some of the fibres and by offering SDH capacity to be used as core transport by other carriers. A provider who has bought one or two fibre pairs (or even just a wavelength) may use it for providing lower-capacity links to their customers (whether voice, managed bandwidth or IP). In the end, the keys to success are ownership of the customers and having a low-cost, reliable network.

Another key factor is telehousing – every network connection must terminate somewhere, and the closer this is to the customer (and preferably many potential customers), the better. Telehousing is not only expensive (despite there being several possible locations in any large city) but the choice of the right location can be crucial in winning customers. In many telehousing locations, both space and access are difficult (or impossible) to secure, as demand has been so high. At least in Europe, we are reaching the point where there are fibre rings between the different locations in each city, and many players (some local, some world-wide) delivering circuits to them.

A final point that any operator needs to bear in mind is that billing and customer care should be kept simple. With so many players potentially between the fibre and the end service, it is important to keep the reporting and control chains as short as possible and minimise the amount of complexity seen by the end user. In some cases large organisations (such as BT) split off different businesses to effect this. Don't try to be all things to all people.

**The consumer view**

The most striking impact of high capacity fibre from the consumer's point of view is that cost dynamics are very different from those of the recent past. They are now driven by 'last mile' – the link between the user and the provider's PoP. In the past, the cost of the long distance part of the link was dominant. Now the cost of the local tails is a significant part of the total, and this does not seem to be falling at the same rate as the long-distance part, probably because there are fewer (if any) competitors. This may change as the local loop is unbundled and new entrants introduce DSL technology but the picture is not yet clear – it is another year before the UK removes the last mile monopoly and later in other countries.

Since long haul capacity providers use each other's resources, any 'network' is in fact a mix of owned and leased fibres, wavelengths and circuits. Often providers 'swap' capacity with another provider, where this is necessary to give the geographical coverage they want at an acceptable cost. As these swaps become more routine, so their availability and ease of purchase will rise. And with so many players providing capacity, all of them looking to fill their network, a 'spot market' is likely to develop and this is something that the end user could well benefit from in the short term.

**Reality bites**

The cost of long-distance links has decreased significantly over the last few years, and looks set to reduce further in the next year or two. For the bandwidth purchaser (whether buying on a 1 year lease or a 10 year IRU (Indefeasible Right of Use)) it is tricky to pick exactly the right time to buy. Buy too early and the price is high, buy later and find you have insufficient bandwidth when you need it (e.g. for reselling services to your customers. An important factor, which must be kept under tight control, is the cost of maintenance – whether of fibre, wavelength or equipment. Providers often seek to charge a percentage of the purchase price (e.g. of the 10year IRU). Care should be taken to ensure this does not very quickly become exorbitant in relation to the value of the capacity to the operator. The charges can easily make the link worthless within quite a short period of time unless they are re-negotiable or benchmarked in some way. As an example, after 3 or 4 years a rented 2.5Gbit/s wavelength will have a significantly lower value to the renter than it does today, but the ongoing charges may not have reduced at all.

**Summary**

Technology now allows huge amounts of information to be sent down a single optic fibre. Like many fundamental shifts in capability, this shifts the established 'rules of the game'. This paper has examined some of the key factors that affect both operators and consumers in a world where the cost of connecting to a specific location are driven by network cover, not distance. Emerging telegeography means that a link from London to Australia will soon be virtually local but one to Skye will be long distance!

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