Mario Pagani

The Evolution of the Optical Transport Network

Traffic density growth, hunger for bandwidth and fibre congestion are just some of the main issues addressed by telecommunications operators in pursuing one of the greatest challenges they have: the development of future-proof multi-service platforms.

Telecommunications manufacturers are currently fully committed to identifying advanced and reliable network solutions to support operators in paving the path towards the network of the future.

The optical transport network is one of the cornerstones for the new network architectures and all-optical networking is its natural evolution.

Even if the basis for this future network environment is already a reality in terms of the availability of hardware and software product, a few hurdles are still present in this telecommunications race.

Technological constraints, definition of standards, network management, performance monitoring at the optical level, network protection and survivability are the most important barriers to be overcome.

Nevertheless, reliable outlooks by manufacturers give us a glimpse of consistent solutions, offering stability to operators' network enhancement plans.

The Current Environment

In recent years transport networks have been subject worldwide to profound renewal, passing from a pure plesiochronous digital hierarchy (PDH) configuration, achieved through a series of point-to-point connections, to synchronous network configurations. These solutions have been based either on US standards, that is, SONET (synchronous optical network), or on European Telecommunications Standards Institute (ETSI) standards, namely synchronous digital hierarchy (SDH).

These synchronous hierarchy networks were, at first, devoted only to leased lines applications and initially very simple network management was employed, mainly for fault monitoring and for performance checking. Recently, SONET and SDH networks, constituting the grounds for the future optical networking evolution, have become increasingly fully managed, extending the management features to centralising the network control, routing the information and generating new services.

Today, additional demand for network bandwidth is being generated by the need to provide new broadband services and improved quality of service. Telecommunications operators have to face a new challenge, since parts of their optical transmission networks are beginning to show signs of saturation. Overcoming fibre congestion problems has been one of the main factors driving the deployment of wavelength-division multiplexing (WDM) systems in the recent past. The adoption of this technique allows, as a first step, the transmission capacity of backbones and metropolitan rings to be increased by re-using the existing cables. Transmission systems based upon the consolidated technique of WDM are now a commercial reality. A large number of point-to-point systems have already been widely deployed in the US since 1996 and in the European market since 1997.

A real optical layer is increasingly taking shape, over the SDH/SONET and services layers, effectively structuring the transport network of the future (see Figure 1). A sensible design is to construct an architecture in which this optical layer is independent of the needs of the services/technologies it supports Internet protocol (IP), video, asynchronous transfer mode (ATM), SDH, SONET, PDH, etc.), thereby providing maximum flexibility.

Network Evolution

Considering the services to be delivered to customers as the source of requirements on which transmission network evolution is to be based, three main factors are driving the services market:

- Internet data traffic growth,
- the shift of some voice traffic from fixed to mobile, and
- video channels.

In terms of subscribers, the Internet (IP) boom is characterised by a compounded annual growth rate (CAGR) of more than 60%, compared with 35% for mobile and only 7% for fixed telephony.

To effectively follow the traffic evolution, the potentiality (already available or attainable by expandability) of the equipment supporting the transmission network is an essential condition, in satisfying the hunger for bandwidth, which is continuously increasing. The bandwidth need is already appearing at local operator level (see the case of local exchange carriers (LECs) and competitive LECs in the US) and is expected to become increasingly vital in the near future.

A much discussed question is the actual opportunity to maintain a layered transmission network, as shown in Figure 1, or to eliminate

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one or more layers (various alternatives are shown in Figure 2).

In particular, direct IP transport over the WDM or optical layer is still being studied in order to solve problems such as performance monitoring and restoration at the optical level.

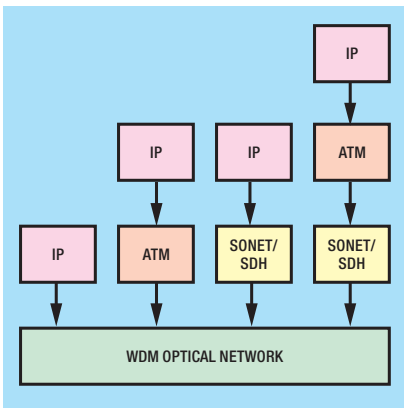
To achieve this, optical add-drop multiplexers (OADMs) and optical cross-connects (OXCs) are needed, together with the appropriate network management. However, it still takes several years to get fully industrialised products extensively employed in the transport networks. In contrast, at the network periphery, where IP and voice coexist, the electrical layer will inevitably be required, with grooming and forwarding features for both IP and ATM, to assure, for example, all the functionalities of the SDH and SONET layer. Furthermore, another trend to incorporate WDM in routers has the very significant disadvantage of a lack of flexibility. On this subject, history teaches that the insertion of PDH in the switching exchange was a dismal failure.

Telecommunications manufacturers are continuously subject to a frenetic activity devoted to designing increasingly sophisticated network solutions, capable of adapting dynamically to the different traffic configurations required by enhanced as well as completely new services.

The future transport networks will have to possess the capability not only to allow the transit of these new services, in the most transparent way, at local, national or intercontinental level, but also to easily and economically manage them.

With this objective, a smart solution is to incorporate, besides the canonical transmission features, some key functionalities, such as IP or ATM, in the transport equipment,

Figure 2—Transport alternatives



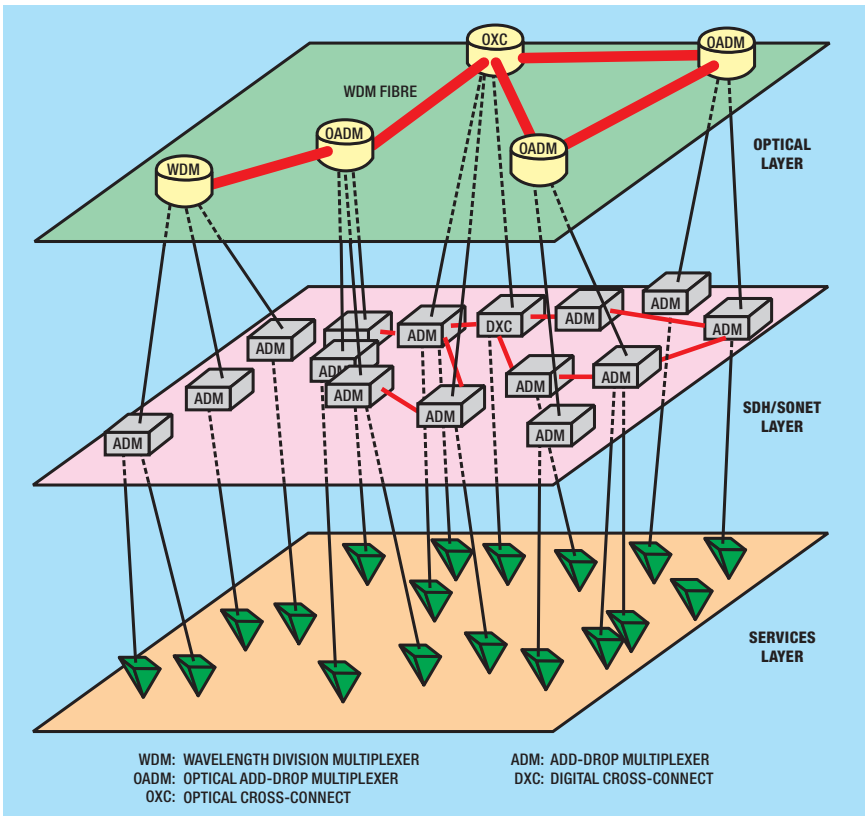


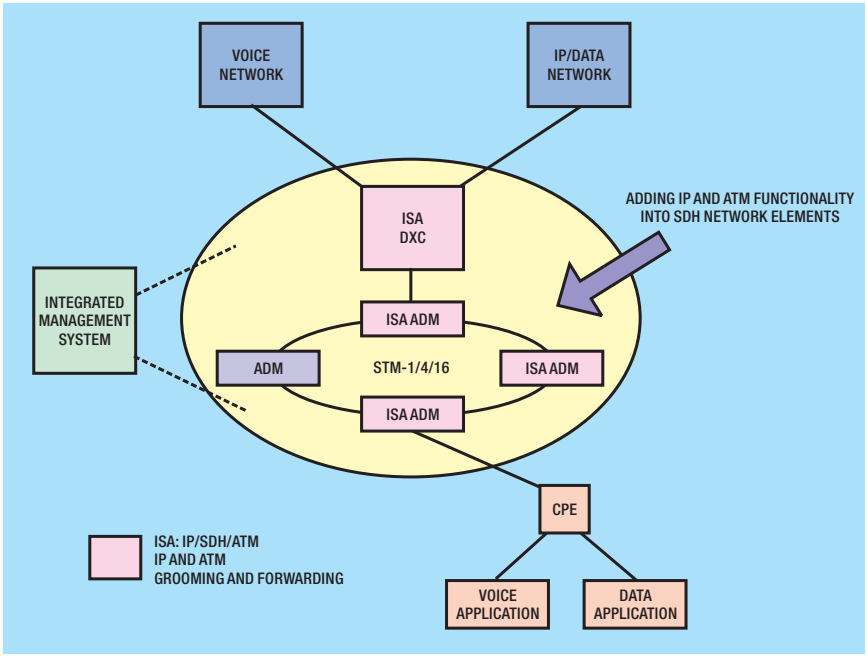
Figure 1—Network layers

enabling the transport optimisation of the new services (see Figure 3).

To meet the evolutionary transport network challenges, the new optical layer will also provide the following capabilities: high-level restoration, dynamic transport reconfiguration and optical protection. Facilitating high-level restoration by aggregating bandwidth into larger components (optical channels) creates both faster and more cost-effective restoration and the optical layer is instrumental in achieving this level of efficiency.

The related network management will have to be strictly correlated to the modularity through which network and equipment are evolving. In addition, interworking with IP service management will be required.

Figure 3—IP and ATM in transport equipment



Optical Layer Equipment

Consolidated WDM or dense WDM (DWDM) techniques, together with optical amplifiers, used in point-to-point applications, allow a total capacity per individual fibre of 400 Gbit/s and more. Cost-effective versions of DWDM are, on the other hand, employed in the metropolitan enterprise access market, where bit rate and protocol transparency, together with cost and performance optimised for short-haul applications, are necessary.

Next to these product families, the market also requires fully reconfigurable systems, opening up the prospect of efficiently performing networking functions in the optical domain, similar and complementary to those already implemented in the electrical SONET and SDH domains.

Passing from point-to-point connections to the multipoint-to-multipoint ones (into the optical layer), more sophisticated full optical equipment has to be employed such as reconfigurable OADMs and OXCs. An example of this network configuration is shown in Figure 4.

These systems provide protection, restoration and performance monitoring mechanisms performed at the optical layer level, therefore assuring the survivability of the optical network, arguably one of the most important factors in the design of optical-fibre telecommunications networks.

Technology Drive

In actual fact, to design the equipment used in the future optical networks most people are still working at the limits of technology. How these innovative technologies can be applied at the industrial level is yet to be assessed.

Essentially, for the optical transmitters, increasingly stable laser modules are required. The focus is on planar optics and optical micro machines as the technologies for the optical components to be used in future optical transmitters.

There is also an important technological impact on the receivers, even if not as critical as the case of transmitters. Narrow-band filtering and optical pre-amplification, at the optical receivers' front-end, will be used extensively.

In the case of line regenerators, investigations on the fully optical 3R (reamplifying-reshaping-retiming) regenerator are currently being carried out in research laboratories.

Another key technology, at present apparently given less attention, is the dispersion fibre compensator employed in compensating the chromatic dispersion of conventional G.652 installed fibres. Today the best compensator is almost unanimously recognised to be the dispersion compensating fibre (DCF) type. One of the driving points for this ranking is its easy integration with the erbium-doped fibre amplifiers (EDFAs).

Network Management

Extending the use of network management products already well proven for SDH and SONET to manage all optical layer products such as WDM, DWDM, OADM and OXC, etc., is the most effective choice for operators, thereby introducing an additional transmission layer on top of the 'electrical' layer.

Operators will choose the appropriate network management solution for their operational procedures. Going for combined management, the network operator enjoys the benefits of the network resource usage optimisation for traffic and protection as well as fast fault localisation and common service management throughout the layers. Going for separated management of the layers, the operator will take advantage of the rich set of network management features; for example, state-of-the-art alarm management and enhanced security mechanisms, such as network access domain (NAD) management.

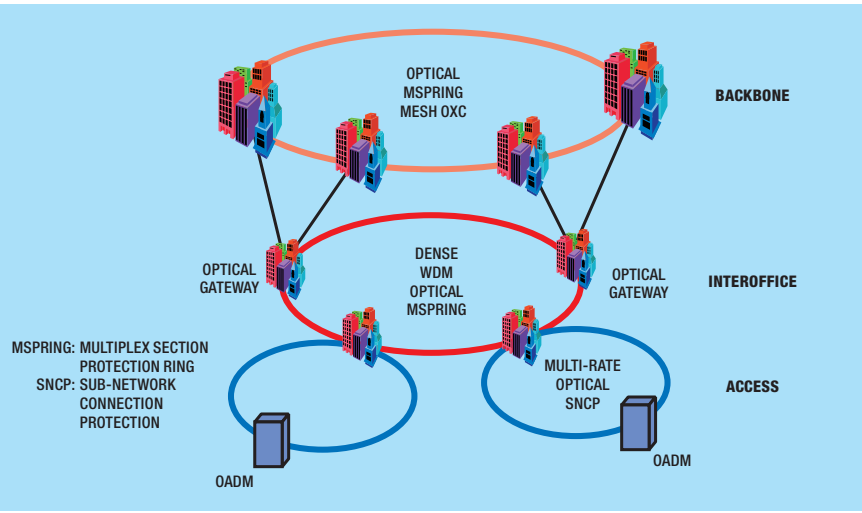
Independently of the solution chosen, all the benefits mentioned above apply in full.

One of the main issues in technology driven industries, in general, is to design systems to cope with future technology changes and shifts in applications and demands. Therefore, the transmission management system has to be suitable to manage the very first synchronous networks, as well as the most updated networking technologies such as IP and ATM, WDM, DWDM and optical networking.

A reliable network management system also needs to provide evolution of transmission services as well as continuity of management services throughout upgrade or migration procedures. This allows simple introduction of new network features by upgrading the existing network or adding new network elements without affecting previous functions and services. This protects network investments by allowing the existing infrastructure to be upgraded to exploit benefits from state-of-the-art technology.

Another important feature of the network management system is its 'openness'. The network management system must be suitable for integration into legacy systems and be able to facilitate the integration of legacy systems. To achieve this, a range of open interfaces, flexible and customisable, have to be designed, ranging from an alarm export interface to an external alarm collector up to a bi-directional service level interface including retrieval accounting data sets and quality of service data.

Figure 4—Optical network configuration



Conclusions

Here we have considered only a few aspects (however the more important

ones) impacting the evolution of the transmission network. These are the main criteria operators should use in deciding how to build up their future networks or enhance their installed base.

Technological evolution, availability of industrial products, safeguarding legacy networks investments all make up the operator business environment which will characterise the next few years.

Even if a computer data networks approach has some beneficial impact on the telecommunications world, a full IT mentality is not the key to success for telecos in pursuing their targets and in evolving or building up their networks.

Radical restructuring in upgrading the network is not the solution. Only evolution by gradual steps is the course to be followed to generate, in an aggressively competitive market environment, the required service quality, security and reliability.

Biography

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Mario Pagani was awarded a degree in Physics from the University of Milan in 1970. He joined Telettra laboratories where he was involved in the design and standardisation of 8/34/140 Mbit/s PDH multiplexers. After some experience in the sales department, he became product manager for optical-fibre digital transmission systems and subsequently responsible for the strategic plan of FIAT, Telecommunication Sector. In 1990, Telettra joined the Alcatel group and, since January 1996, he has been appointed Director, Marketing and Business Development for the Transmission Systems Division. In this position he is responsible for strategies, strategic marketing, standardisation, intellectual property and marketing communication.