CHAPTER 6
THE EVOLUTION OF BACKBONE NETWORKS

The introduction of the optical technology in digital transmission systems has paved the way for a new typology of long-distance-communication and has allowed the capillary diffusion of TLC services worldwide.

Optical fibers still give constant technological innovation. Differently from electrical signals, optical transmission systems allow to cover very long distances – the Marconi-Ericsson systems go up to 5000 Kms – and to move large amounts of traffic in a very short time, at a transmission velocity up to 40 Gbps each channel, with good prices for the user, an absolute QoS, and a total protection of network and apparatuses.

Optical DWDM systems allow to transmit more light-paths on the same optical fiber, as we have seen in the preceding chapters, using different frequencies for the desired channels. Nowadays we can get up to 160 optical channels, each with a velocity of 10Gbps – but in the future the possible velocity is going to be 40 Gbps.

This will allow a real broadband, covering any possible distance.

Marconi-Ericsson’s optical products are involved in interesting strategies for transport networks elaborated by providers all around the world. We’re going to shortly analyze some examples to show the way the PMA32 and the more recent OMS & MHL families have been deployed to reach new interesting goals in photonics.

6.1 BACKBONE NETWORKS BASED ON “SDH over OPTICAL”

6.1.1 THE WIND-INFOSTRADA SOLUTION

Wind-Infostrada is an Italian company, involved in standard telephonic, ADSL & mobile communications. They have deployed a very large optical backbone network which covers all the Italian territory, with a total extension of 18000 Km of optical fibers.

Different typologies have been used as for the deploying of these optical fibers:

- Using the electrical lines belonging to RFI by Ferrovie Dello Stato, the Italian train society, for the capillary presence of the railway lines throughout Italy.
  The INFOSTRADA network (telephonic & internet comms) has been built like that.

- Using the ENEL (electrical society) lines as for the old network by WIND (mobile comms). OPGM (OPtical Ground Wire) is the technique which has been used to install this kind of infrastructure.

- Using cables in the soil, mostly in urban areas to let users join the network.

It is interesting to understand how many fibers have been deployed in this network, so to be able to compare the data to the solutions made possible by the PMA32.
Wind-Infostrada’s network includes 24-flows-cables as for the aerial network, 4 or 72-flows-cables in the network along the railway lines.

The Wind-Infostrada network covers national distances (Figure 6.1) but also MAN’s (Metropolitan Area Networks). 600000 Kms of fiber are the actual used in the national topology, while 230000 Kms are the ones for the MAN network.

![La Rete in fibra ottica WIND](image)

Figure 6.1 – The Italian backbone network by Wind-Infostrada

This backbone network has a ring topology and it includes:
- SDH rings on 3 levels
- SDH links (point-to-point)
- cross-connects for the grooming and for the flows distribution in the points of major presence of users.

The integration of the old 2 networks by Wind and Infostrada has been done by interfacing SDH and DWDM technologies to a superbackbone layer, superior than 10 Gbps, as shown in Figure 6.2.

Besides the existing SDH networks have been incremented up to 10 Gbps or in some case DWDM techniques have been used.
A protection has been deployed for the 100% of the network.

As the network grows, some problems are emerging:
- Multiple large rings can be difficult to be projected and to be handled.
- The expansibility of the network can be seriously limited in some cases.
- The efficiency is often low, especially because of the protection needed.
- In case of multiple faults and long times to repair the faults, serious problem could be met.

![Figure 6.2 – Integration of networks by a superbackbone network](image)

To bypass these problems and to satisfy the continuous requests for band, there is a constant migration toward a mesh network. In this kind of topology an electro-optical cross-connect can be used to a variable number of nodes. In the future these cross-connects will migrate toward all-optical apparatuses. In Figure 6.3 you can compare a mesh topology with an old ring topology. A mesh topology let the providers handle the network in an efficient, automatic and intelligent way, using control plane functionalities which have been seriously deployed by another Italian operator – Telecom Italia – as we are going to see in the next sections.

The PMA32, the OMS and the MHL3000 families can be used to satisfy these necessities – they can be used as OADM’s or Cross-connects. The OADM’s function is going to be very important in the near future as it gives the opportunity to send more and more traffic from different users on one single pair of fibers using the multimode standard and the Dense-WDM technology without adding fiber cables to the existing network. this can be very scalable, very interesting comparing the costs, and very useful in cases where no fibers can be added.

![Figure 6.3 – Mesh (left) and ring (right) topologies in the Italian backbone solutions](image)
6.1.2 THE ALBACOM SOLUTION

The possibility to have an own long distance network, in a capillary way, over the whole territory is a very strategic subject for a TLC operator.
Costs can be dramatically reduced when no debts are to be considered for renting the circuits.
The Albacom transport network was born in 1998, when ENI (together with the Italian BNL, British Telecom and the Italian Mediaset) got the right to use the infrastructure being part of the existing main backbone of distribution of gas from Algeria.
In the following years many other investments have been done.

In January 2001 Albacom acquires the 60% of Basictel, having the exclusivity of using the electrical railway network for optical fiber deployment. 6300 Kms of fibers throughout Italy today (Figure 6.4). A big affair considering the reduced times and costs for creating a complete backbone without efforts.

Today Albacom, as Wind-Infostrada, uses a simple SDH over optical technology with a mesh network resulting from the interconnection of existing networks through a superbackbone layer; in the future DWDM all optical infrastructures can be implemented to give users IP services directly over the optical DWDM layer.

Figure 6.4 – The Albacom backbone network
6.2 MARCONI-ERICSSON’s OMS/MHL3000 IN THE TELECOM ITALIA’s BACKBONE

6.2.1 TELECOM ITALIA’s EVOLUTION STRATEGY (Since 2003)

Telecom Italia, the first Italian telephone company, has recently been involved in the IST LION (Layers Internetworking in Optical Networks) project - 50% financed by the EU – and it is the first society accepting the challenge.

The IST LION Consortium involves Deutsche Telekom, NTT & the Polish TPSA, manufactures as Cisco, Siemens, Tellium and Agilent, some universities as IMEC (Gent-Belgium), AGH (Krakow-Poland), UPC (Barcelona-Spain) and NTUA (Athens-Greece).

The project is about research and implementation on solutions for intelligent optical networks. During the three years-project an “IP/MPLS over ASON/Optical” network demonstrator has been developed.

The resulting strategy should be then deployed to make the Italian backbone networks evolve towards a more complex and intelligent optical transport network.

The main objective can be resumed as “Only 2 layers, but many services”, and graphically explained in Figure 6.5.

Figure 6.5 – The 2 layers of Telecom Italia’s latest strategies

The IP & MPLS protocols constitute an Optical Packet Backbone (OPB), while the underlying architecture is the Optical Transport Network (OTN), and its paradigm is the so-called ASON (Automatic Switched Optical Network) – based on the DWDM technology.

Figure 6.6 shows how deep the evolution is from the existing situation to the desired architecture that Telecom Italia is going to develop.

The OTN should replace the existing SDH and DWDM with a single layer, which should be able to carry Transmission, Multiplexing, Protection and Bandwidth Provisioning – things we have already analyzed during the testing of the PMA32.

Let's just underline that Bandwidth Provisioning is a service which is not deeply implemented by the PMA32, but we can have this feature with the OMS products by Marconi.
The real innovation about the ASON (Automatic Switched Optical Network) standard was the implementation of the signaling system called RSVP-TE (ReSerVation Protocol – Traffic Engineering), which allows the creation and elimination of optical connections when required by providers or users.

OTN (Optical Transport Network) is a brand new prototype of transmission interfaces with adaptation, administration and maintenance functions. The testbed created by this project has demonstrated for the first time in the world the possibility of a real provisioning of soft-permanent connections in a multi-domain and multivendor optical network.

The main results obtained by the project mentioned above have confirmed the technical-economical convenience of intelligent optical networks, even for the reduction of costs.

The advantages offered by an ASON architecture are the following ones:

- **Fast Restoration**
  which means more efficiency and more reduced restoration-time in a mesh-topology

- **Differentiation of services according to quality**
  which means offering different priorities to different services, so creating differentiated prices too.

- **Bandwidth on Demand (BonD) service**
  which means activation and deactivation of service in some seconds with time-based costs.

- **Optical Virtual Private Network (OVPN) service**
  which allow clients to have a private virtual network on which they can autonomously do operations of traffic-flows configuration.

A distributed architecture is needed to provide such services; a distributed network provides communication between apparatuses at the borders of the network directly with client’s apparatuses, supporting a larger traffic as there could be multiple accesses to the
network, expansion of the network, interoperability among apparatuses from different
operators and among different technologies.

The ASON control plane, overlying the OTN plane, and some protocols (OSPF-TE, RSVP/RSVP-TE/LMP) for the communication between nodes - in order to
activate/deactivate connections in a distributed fashion - are the main building block of this
kind of intelligent network. The distributed model used by the routers to build their own
maps of the network collecting the information they need has been described in the last
chapter, and was one of the subjects analyzed in the Broadnets 2007 Invited Paper.
In the ASON networks there can be many physical paths available between a client and
the border-node of the network, same thing among adjacent nodes. The information about
the different paths can be combined to constitute a single path named TE (Traffic-
Engineering) Link.

6.2.2 TELECOM ITALIA’s PHOENIX ARCHITECTURE

Figure 6.7 shows the actual PHOENIX optical backbone network by TELECOM ITALIA,
which is the main Italian transmission network, based on ASON & DWDM link
interconnection (OTN).

Figure 6.7 – The PHOENIX backbone network
Phoenix is an ASON network based on high capacity cross-connects ODXC’s (80 Gbps, 320 Gbps and 960 Gbps) - as shown in Figure 6.8 - equipped with electrical switching matrix and both optical and electrical interfaces among them through DWDM systems. Fast restoration, centralized routing with distributed signaling (semi-distributed control plane) and a network able to transport 155 Mbitps to 10 Gbps streams.

The ODCX’s used in the Phoenix architecture are the key-element to create a mesh topology which connects different optical rings or other topologies to one another. The DWDM apparatuses involved in the many parts of the infrastructure are OADM’s from Alcatel, Marconi-Ericsson or Siemens. As we can see in Figure 6.9, the OMS and MHL3000 families have been deployed.
Figure 6.10 shows the management chain in the Telecom Italia architecture. There is a centralized routing based on an ASTN Manager, and a distributed signaling letting the nodes in the network use a topology discovery system.

The management chain

Figure 6.10 – The management chain in the Phoenix architecture

Figure 6.11 – Activation of a new working path in Phoenix

Events sequence:
1) SG-SDH send the activation request of the working path
2) ASTN-M calculates the protection path
3) ASTN-M starts the signaling of the working path towards to ingress node (F)
4) The egress node (D) starts the acknowledge process
5) The working path is activated
Figure 6.11 shows how we can have an activation of a new working path in this ASON architecture: a node sends a request for a new path; the ASTN manager calculates the protection path and starts the signaling of the working path; acknowledgments are sent back from the nodes; the working path is activated; the ASTN manager starts signaling the protection path; acknowledgments through the protection path; the protection path is activated with no traffic sent on it.

The phoenix network performs every day successfully both in case of planned maintenance and in case of faults. Moreover it operates continuous optimizations (cost reduction) of the protection paths.

Protection actions estimated during 2005: more than 17000, among which only 5000 caused by faults, and up to 10000 which were optimization actions of the protection paths.

31 are the nodes in the Phoenix architecture, 68 connection pipes carry 240 links at 2.5 Gbps, and more than 60 links at 10 Gbps.

The new release in acceptance test (November 2006) introduced a new software architecture in both equipment and management system. It is called Phoenix 2.
It includes faster on the fly rerouting, new procedures for alignment control, and automatic deletion of unused resources.
With this new release Telecom Italia is going to evolve towards a fully distributed architecture, which is more manageable to obtain an even more dynamical and intelligent network.

### 6.3 THE GigaPop PROJECT WITH PMA32s by Marconi IN PISA

The 3 Smartphotonix PMA32’s by Marconi-Ericsson tested in the preceding chapters of this book have been included in a scientific collaboration project for a metropolitan area network in Pisa.
The project involved Marconi Communications, the CNIT, University of Pisa, Scuola Superiore Sant’Anna, Scuola Normale Superiore, CNR, Province of Pisa and Commune of Pisa.

The planned infrastructure is to be considered as a VESPER (Very High Speed Photonic Experimental Ring) – that is to say an innovative testbed for photonic technologies.

The system is able to handle 32 optical accesses at a velocity up to 10 Gbps with DWDM technique.
A GigaPop is a point of aggregation in the network where local, national and international ISP’s (Internet Service Providers) and private user networks get in contact.
The objective of the project is to implement a “Diffserv over MPLS” trial on a DWDM transport network with a GMPLS control layer.

Figure 6.12 shows the structure of this metropolitan area network.
The PMA32’s should be deployed at the Engineering faculty, at the CNIT structure and at the CNR structure.

Juniper routers, Fast Ethernet, ATM & Gigabit Ethernet modules are the other building blocks of this project. The infrastructure, created by the activity we have just concluded, is
to be enriched with a control plane with Diffserv & GMPLS strategies in order to give the town of Pisa a MAN with intelligent networks’ features. So we will be able to offer the same characteristics we have seen for the Phoenix network by Telecom Italia to a local area network.

Figure 6.12 – GigaPop logical structure

6.4 MARCONI-ERICSSON’s PMA32 IN EUROPEAN BACKBONES

Since the advent of the PMA32, Marconi, which was not yet part of the Marconi-Ericsson group, was contacted by operators all around the world to deploy its brand new photonic network components. We just give some examples here of contracts that Marconi had from companies from different countries.

THE NETHERLANDS
Marconi in 2000 won a broadband optical networking contract with Telfort, the Dutch telecoms operator. The contract involved Marconi building and operating a managed wavelength optical network which should provide 2.5Gbit/s or 10Gbit/s optical services. The first phase, based on Marconi's PMA32 family of remotely configurable all optical add/drop multiplexers, went into service in January 2001. The network was gradually expanded throughout Holland.

HUNGARY
Magyar Telekom, (formerly known as Matáv), Hungary's incumbent telecommunications and Internet service provider, in 2005 decided to upgrade its existing SDH transport network using Marconi's OMS1664, OMS840, and SMA1/4UC multiservice optical platforms, as well as the company's network management system.
Using Marconi’s multiservice SDH products, the operator said it will achieve significant operational cost savings through network simplification.

**BOSNIA-HERZEGOVINA**

BH Telecom, the largest operator in Bosnia-Herzegovina to provide fixed, mobile, and data services, decided in 2005 to upgrade its core network by introducing Marconi’s next generation multiservice optical platform, the OMS1664. According to a press release, the upgrade would allow the operator to seamlessly support increasing levels of voice and data traffic alongside other broadband services, while substantially reducing operating costs and increasing the flexibility of its network. Marconi's ServiceOn network management system will manage the platform, with the vendor also providing installation and commissioning services.

**GERMANY**

T-Com, a unit of Deutsche Telekom, decided in 2005 to use Marconi Corporation's Multihaul 3000 platform as the first building block of Europe’s first 40G bit/sec, high-capacity optical network. The platform will be managed by Marconi’s ServiceOn Optical network management system. The new network will allow T-Com to further enhance its transport capacity in the optical network, extend distances between systems, and improve its flexibility and responsiveness in setting up new high-bandwidth services as well as lowering operating costs for these services.

**SPAIN**

Telefonica de Espana, Spain’s largest network operator, deployed in 2005 Marconi's Multihaul 3000 optical platform in two links between Madrid and Barcelona to increase the capacity of its long-distance Dense Wavelength Division Multiplexing (DWDM) network as result of the growing demand of traffic. The new Multihaul 3000 is the first DWDM system supplied to Telefonica. It is also the first DWDM system supplied and installed through Ericsson as part of the renewed agreement between the local companies of both Ericsson and Marconi in Spain. The Multihaul 3000 feature set enabled Telefonica to increase the speed, security and flexibility of its service provisioning, allowing it to meet current traffic demands as well as satisfy future requirements with limited incremental investment.

**SARDINIA (ITALY)**

Marconi announced in 2008 the deployment of MHL3000 apparatuses for Vodafone Italia, with the goal to connect Sardinia’s optical transport network to the rest of Italy. Thanks to the MHL3000 Marconi obtained a big technological success: it is the first infrastructure in the world of such a long fiber cable without optical amplifiers or amplified fiber.

### 6.5 OPTICAL WORLDWIDE BACKBONES

A first example of very large backbone was planned in 1999, when Corning Incorporated, the world’s leading supplier of optical fiber, and i-21 Future Communication, a subsidiary of Interoute TLCs, announced that the new carrier would deploy nearly eight million kilometers of advanced optical fiber in the largest European broadband network ever announced.
Interoute had stated that the network would be operational by May 2000 and would be 90% complete by year-end 2000. The network was going to offer managed bandwidth and IP-based services and to link 70 European cities with 200 points of presence across Europe. Fully operational, the network should offer one petabit per second, that is to say 1000 terabits of traffic.

Ciena’s products were selected to provide intelligent optical transport systems to the planned Interoute TLCs’ network.

The gigantic infrastructure can be viewed in Figure 6.13.

Moving from Europe to a worldwide perspective, let’s have a look at Figure 6.14. FLAG (Fiber optic Link Across the Globe) is a network connecting Great Britain to Japan through a path of about 28000 Kms with 16 points of presence in 13 countries. The project was announced in 1999 by FLAG Telecom as the world’s longest optical path under water. The infrastructure was to be managed and directly used by AT&T, BT, Cable & Wireless and other companies. Up to 2.4 Tbitps, first big example of worldwide high capacity optical
transport, totally financed by private money. The second part of this experiment was to deploy another optical network between the US and Britain (Europe). The connection of this network with the existing Europe-Asian one is in Cornwall. DWDM up to 80 channels running at 10 Gbps is the technology used for this network.

Figure 6.14 – European-Asian FLAG network by FLAG Telecom