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Network Evolution Towards the Optical Network

There are differences and commonalties among today's networks (telephone, data and mobile); competition and the need to save on operational costs are driving convergence.

The trends clearly indicate a preference towards integrated networks.

In the medium-to-long term, wavelength-division multiplexing (WDM) and high-density wavelength-division multiplexing (HD-WDM) will become operational and this transition will create a new networking layer; the wavelength channels will be routed by all-optical equipment, just as in the same way switches handle digital channels in today's networks.

Introduction

The rapidly changing environment and requirements for telecommunication networks, as well as insecurity about which concepts and services really will become predominant, are presenting difficult challenges both to operators and suppliers.

The challenge to the operators is how they should modify or change their current networks (Figure 1) to be able to provide their customers, at the right point in time, with competitive and business-oriented services, in a flexible way.

The challenge to the suppliers is to provide the operators with products based on a future oriented and flexible architecture in order to support their business in an optimum way.

Another key question to be answered by the operators is whether to keep different services such as narrowband, broadband, data, Internet protocol (IP) and mobile in separate overlay networks, as built today, to support single applications and services, or in an integrated one.

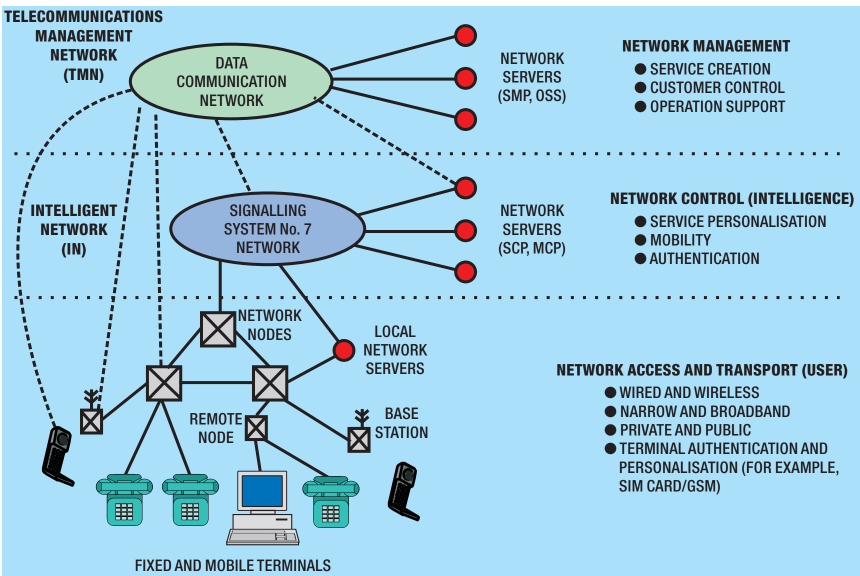
A Vision of the Current Telephone Network

It is very important to describe the two types of scenarios that can be seen now in the telecommunications market.

The high-end market segment includes about 70% of the value and the other segment about 30%. The split into two different market segments is becoming more evident as we approach the year 2000.The first is distinguished by total competition among operators leading to a vertical market approach and extreme orientation towards end customers and services. From the network perspective there will be a strong push to change the network structure towards voice and data integration.

The second segment is distinguished by only limited competition due to political influence and classical telecommunication-services such as plain-old telephone service (POTS) and TV. From the network perspective the trend is towards no change to the network structure.

Figure 1—Telecommunications network architecture



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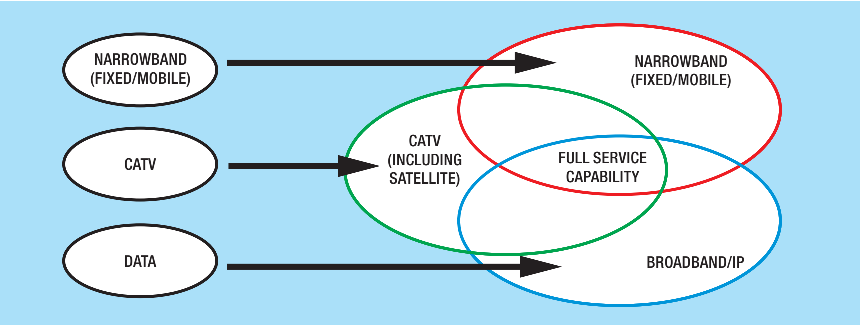


Figure 2—Network evolution. Besides the narrowband and TV broadcast networks a broadband/IP network is being established. The different networks are becoming interlinked and will have 'full service' capabilities

The evolution of the network (Figure 2) is mainly driven by the high-end market; in this market, pumped mainly by Internet and intranet growth, the sheer volume of data and mixed-media traffic has surged on both packet-and circuit-switched networks. This trend continues and will be amplified by the expansion of higher-bit-rate access options and by improved coding and applications for Internet telephony, audio, and video. Not a moment too soon, packet technology has reached the point where it surely can play a role in giving network operators—private and public—the flexibility, economy, reliability, and simplicity they require. A network operator is therefore forced to make a decision about the network architecture because the traditional one can no longer satisfy the needs—integration is the mandatory key word.

A Vision on the Current Mobile Network

Currently the architectures of the mobile networks (Figure 3) are still based on the same functional model. Some operators are introducing new services; for example, in Italy, a connection to the Internet can be offered to subscribers, as a special service, to provide a cheaper international telephone service, still with a reasonable quality.

Some operators are making trials with IP-backbone and others are making plans for incorporating the general packet radio service (GPRS) in their network, even if that can be considered an intermediate solution waiting for the universal mobile telecommunication system (UMTS), at least in Europe.

The third generation of mobile systems (TGMS) is based on a new air interface capable of supporting 2 Mbit/s data services but following essentially two different views:

- European Telecommunications Standards Institute (ETSI): UMTS—one new air interface as an evolution from the global system for mobile communications (GSM); and
- International Telecommunications Union (ITU): future public land mobile telecommunications system (FPLMTS)—'family' of air interfaces including:

—Europe: UMTS;
—Japan: probably a new air interface based on wideband code-division multiple access (WB-CDMA) technology; and
—USA: evolution of existing personal communications services (PCS) standards.

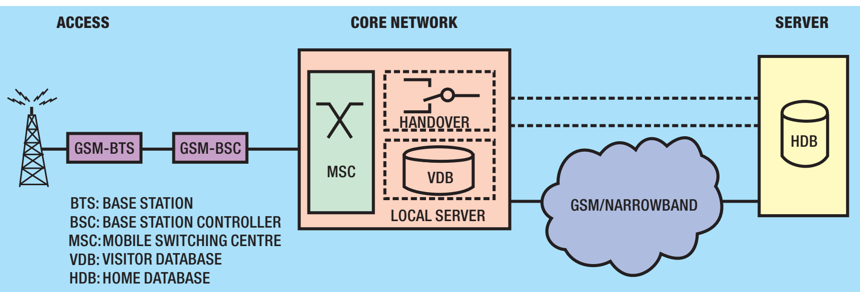
Currently FPLMTS standards activities have a more rapid time frame than UMTS activities. A failure in aligning the standards (by acceleration of the UMTS time frame) will result in a collection of incompatible FPLMTS standards rather than a single standard.

Mass explosion of UMTS will be achieved through parallel evolution in different technology domains such as information technology, transmission, terminals, service creation, mobility management, radio access and service control.

In addition to improving coverage, increasing capacity is a primary focus for mobile operators. Only UMTS offers suitable capacity for mobile voice and data and then it is a real candidate as a problem solver for the mobile network.

Another important open issue that affects operators with mobile and fixed networks is convergence. This can be obtained in three ways: convergence of services, convergence of functions (that is, billing centre, customer care centre, provisioning centre), convergence of network/architecture. It is possible to use one or more of these ways. The driver is to make savings on the network and administration, operation and maintenance by means of common use of resources. This allows lower prices to be offered to the customers.

Figure 3—Mobile communications networks architecture



A Vision on the Current Internet-Like Networks

The backbone of the Internet was originally a series of high-speed links between major supercomputer sites and educational and research institutions within the US and throughout the world. A major part of it was the NSFNet, managed by the US National Science Foundation.

In 1995, large commercial Internet service providers (ISPs), such as MCI, Sprint and UUNET, took responsibility for the Internet backbones and have considerably enhanced their capacities. Regional ISPs link into these backbones to provide lines for their subscribers, and smaller ISPs hook either directly into the national backbones or into the regional ISP.

Internet computers use the TCP/IP (transmission control protocol/Internet protocol) communications protocol. There are more than 20 million hosts on the Internet, a host being a mainframe, mini, workstation or high-end PC that is on-line via TCP/IP. The Internet is also connected to all types of computer networks worldwide through gateways that convert TCP/IP into other protocols.

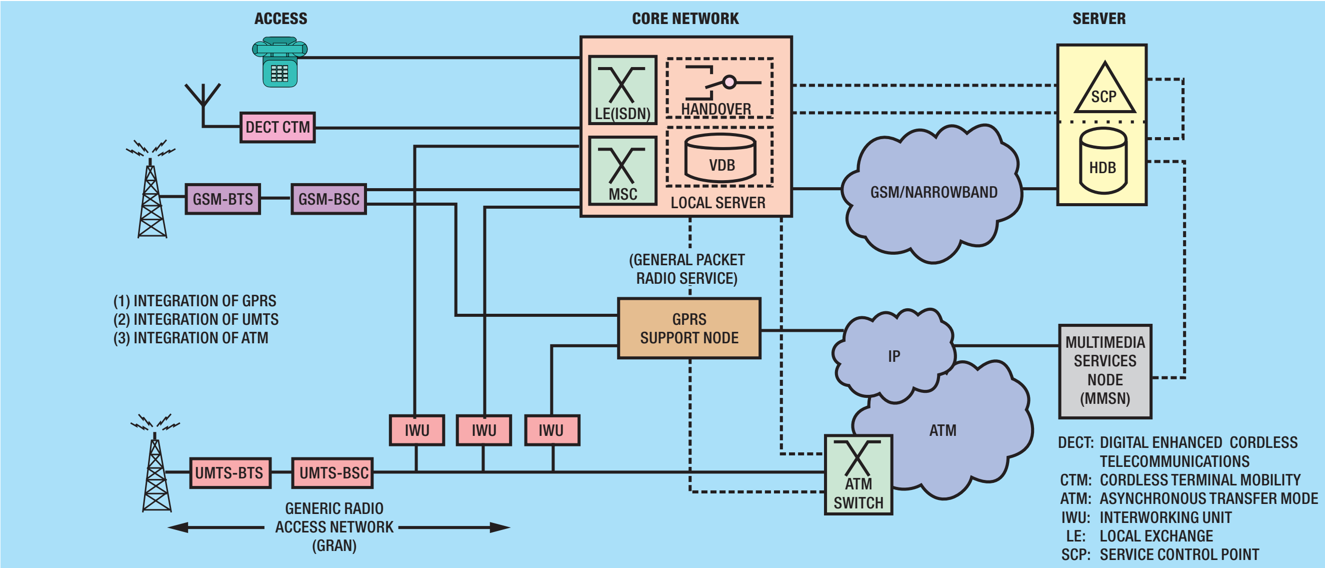


Figure 4—Convergence of communications networks

Ironically, some of the original academic and scientific users of the Internet are developing their own networks once again. The Internet is so jammed these days that they no longer enjoy the quick access they were used to.

The Internet is also used by some telco operators in order to provide cheaper international and oversea connections for international and overseas telephone traffic. Based on that experience some new operators are planning to deploy networks that can connect USA and Europe using Internet-like architecture. This means the use of a backbone, based on routers (or better Gigarouters) for the switching network and normally using optical fibre for transmission, supporting voice and data over IP.

This kind of network normally uses voice gateway for voice coding/decoding and a call agent to manage the call. The call agent normally converts the protocol from the ISDN user part (ISUP) to the media gateway control protocol (MGCP) to control the voice gateway.

These networks are based on connectionless (packet) switches while traditional networks are based on connection-oriented switches. The packets are routed in the network along several 'hops' starting from the origin to the destination; the path used for the call can change depending on the availability of the routers and links.

Such a network is well suited for carrying voice and data traffic. This means that it is suitable to support the merging of voice and data traffic—the latter is increasing rapidly worldwide while the former is increasing at a constant rate of only around a few percentage points per annum.

Steps Towards Integrating the Various Networks

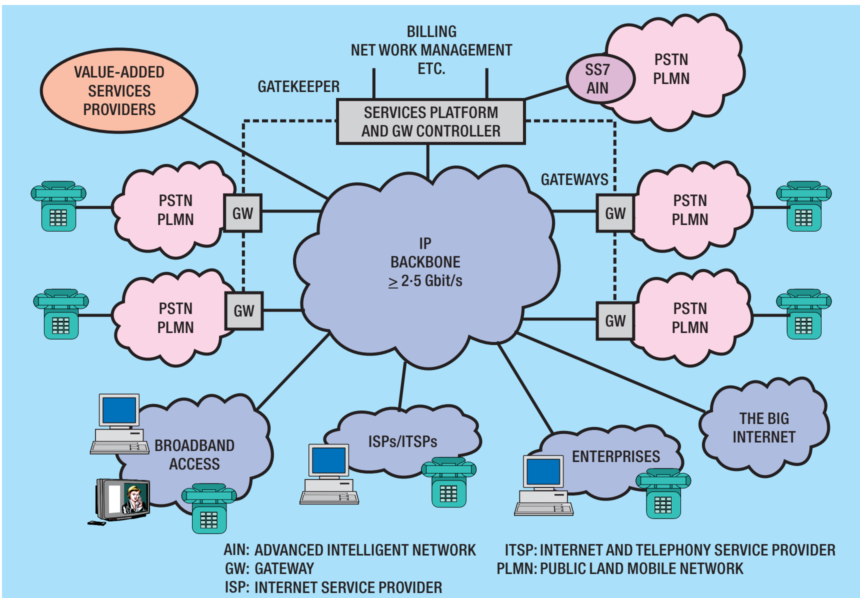
Following the theme of integration, mobile and fixed networks will converge, then data and voice networks will merge and ultimately they will collapse all into one (probably the IP network) (Figure 4).

From the network point of view, the trends clearly indicate:

- A big interest in an integrated network; this new concept and related technology brings new opportunities and ways to gain benefits and enables a complete range of services to be offered to the customers.
- Orientation towards networks based on asynchronous transfer mode (ATM), especially at the backbone level; this will come primarily from demands of the edge data networks including IP. The deployment of the ATM infrastructure will force narrowband/broadband integration and penetration of ATM in the local/access networks.
- A solution using ATM at the edge and IP inside the backbone; that could provide a reasonable compromise (integrating narrowband and broadband traffic) or an intermediate step before the full IP network can be realised (Figure 5).

At any rate, the convergence process of the telephone networks

Figure 5—Network architecture for next-generation telcos



(including both fixed and mobile ones) has to take into account one of the methods mentioned above for integrating voice and data traffic; as a consequence data networks and telephone networks will be integrated, at the same time.

Steps Towards the Optical Network

Customers are demanding more services and options and are carrying more and different types of data traffic. To provide full end-to-end connectivity, a new paradigm was necessary to meet all the needs for high capacity and various forms of traffic.

Optical networks provide the required bandwidth and flexibility to enable end-to-end wavelength services. Optical network began with wavelength division multiplexing (WDM), which arose to provide additional capacity on existing fibres. The optical network will be based on wavelengths as its basic building blocks rather than using a defined bit-rate and frame structure. The components of the optical network will be defined according to how the wavelengths are transmitted, groomed or implemented in the network.

Viewing the network from a layered approach, the optical network requires the addition of an *optical layer*. The steps needed for the complete optical network are dependent on the following basic components (Figure 6):

- wavelength division multiplexing (WDM, dense WDM (DWDM), and high-density WDM (HD-WDM)),
- optical add-drop multiplexer (OADM), and
- optical cross-connect (OXC).

Experience has shown that the public carrier market is an evolutionary, not a revolutionary, environment. Optical networking technology must be closely integrated with the rest of the network, but it is here that much work remains to be done. It is clear therefore that the emergence of the all-optical network and all its benefits is not going to occur overnight.

The definition of a standard will become increasingly important and essential as operators seek to interface their optical systems and evolve to more complex optical network architectures. Basic standards exists for WDM point-to-point links, but there is much work to be done in the areas of optical networking and vendor interoperability. The standard bodies are addressing many of the issues, but it is uncertain whether they can keep pace with rapidly changing market developments.

WDM and optical components will form the foundation of broadband networking in the next decade. Interesting times lie ahead in the optical transmission arena.

WDM: A New Technology on the Scene

Wavelength-division multiplexing is a technique for transmitting traffic over fibre in multiple channels. Traditional optical fibre transmission uses light of a single wavelength (that is, color); in contrast, WDM combines multiple wavelengths of light into a single multiplexed signal for transmission along the fibre.

Each channel utilises the full capacity of the fibre being used; WDM then creates a virtual fibre for carrying traffic over; for example, four WDM wavelength channels boosts the capacity by four times.

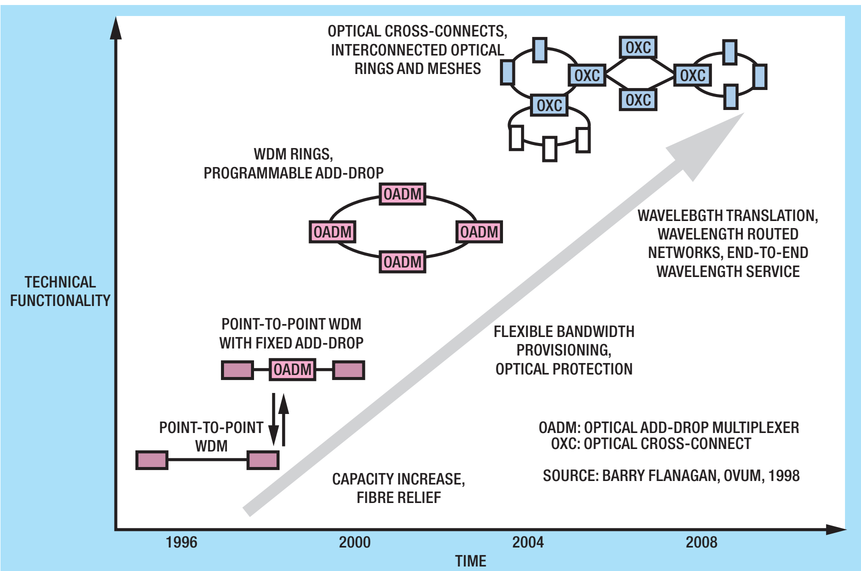
WDM is now being used worldwide to boost dramatically the capacity of installed optical fibre cables.

However, while the basic principle of the technology is very simple, the effect WDM will have on the telecommunications industry is much more complex, extending far beyond simple capacity increases in networks. WDM is emerging as fundamental to enabling networks to cope with the telecommunication demands of the next century. The future growth of the Internet, the development of broadband networking, the creation of new high-bandwidth applications and the economics of the bandwidth market itself are all inextricably linked with this simple technology.

Outside the US, deployment has been small, although the market is now starting to take off. In Europe in particular, WDM was not a concern before 1997; network traffic levels are lower than in North America, and the network has different characteristics. Whereas North America has a large number of high-capacity long-haul routes, European backbones networks tend to consist of a number of relatively short haul (30–100 km) high-capacity links meshed together. This suggests different network economics for WDM and alternative solutions.

As traffic levels rise however, and prices come down, a host of deployments in Europe and elsewhere are emerging. BT for example, has been conducting trials on two WDM links in its national network, with plans to roll out more of the technology over the next year. It also intends to use WDM on its new pan-European network. In August, the first of a series of WDM systems went live in the network of Deutsche Telekom. Worldcom deploys WDM in its pan-European network project, Ulysses, and Hermes Europe Railtel has purchased 40-channel WDM systems for its network linking over 20 cities in Europe. These announcements and others indicate the increasing importance of WDM in carrier networks.

Figure 6—The evoltion of optical networking



The Emerging Optical Layer

In the medium-to-long term, WDM will be used to route traffic on individual wavelengths in all levels of the network, significantly increasing flexibility, leading to *optical networking*.

This transition will create an optical layer (a new networking layer) in which wavelength channels are processed and routed by all-optical equipment, just as electronic multiplexers, cross-connects and switches handle semi-permanent digital channels in the SDH/SONET (synchronous digital hierarchy/ synchronous optical network) and ATM layers of today's networks.

This will involve the deployment of optical add-drop multiplexers, enabling WDM ring architectures to be constructed. In the longer term, this will also require the deployment of optical cross-connects to reconfigure and reroute individual wavelength channels in the network.

It is evident then that the broadband networks will evolve in the next decade to include a number of different layers. There will be no solution based on a single architecture for all applications, rather a range of diverse interfaces will exist in the network between ATM, IP, SDH/SONET and WDM equipment.

The main challenge for operators and vendors is how best to integrate and interwork electronic-layer and optical-layer technologies, and ensure that both can be managed in the network effectively.

The Vision of an 'All-optical Network'

The vision of an all-optical network will provide operators with flexibility and cost savings by allowing them to simplify network architectures and achieve more efficient provision and management of bandwidth resources in the network.

The optical layer will be transparent to bit rates and protocols, potentially providing a common transport mechanism independent of the type of service carried.

Different technologies will access the optical layer via an optical interface, which will translate the output of multiplexers, routers and data switches into optical signals following the standard.

This will be particularly important for access networks where a wide range of different types of traffic and line rates are being generated.

Eventually, optical networking will enable operators to provide wavelength services—that is, the ability to resell bandwidth, rather than fibre—on different dedicated wavelengths for different customers, making more efficient use of the network capacity.

Biographies

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Claudio Chiarenza was born in 1950 and joined Italtel in 1975 after graduating from Politecnico of Milan. He began working as a hardware systems engineer and then he headed Switching Systems Integration Tests. In 1987, he became Director of the Marketing Division where he coordinated several start-ups of switching and radio products. Since 1989, he has been Director of Business Development and Planning in the Fixed Networks Area; he has been programme manager for several Italtel projects such as: Linea UT, intelligent network, ISDN and DECT network.

Eugenio Stefanotti
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Eugenio Stefanotti was born in 1944 and is currently working in Italtel, which he joined in 1964. He is now Director of Architecture and Service Innovation, in the Business Development and Planning department. He has worked on the Italian intelligent network and then on DECT trials and the development of cordless mobility services for Telecom Italia and for cordless mobility applications for other countries.