QUESTION 16/2
Preparation of handbooks for developing countries

ITU-D STUDY GROUP 2 2nd STUDY PERIOD (1998-2002)

Handbook on new technologies and new services

FASCICLE 2
Digital networks and services

Telecommunication Development Bureau (BDT)

International Telecommunication Union

THE STUDY GROUPS OF THE ITU-D

The ITU-D Study Groups were set up in accordance with Resolution 2 of World Telecommunication Development Conference (WTDC) held in Buenos Aires, Argentina, in 1994. For the period 1998-2002, Study Group 1 is entrusted with the study of eleven Questions in the field of telecommunication development strategies and policies. Study Group 2 is entrusted with the study of seven Questions in the field of development and management of telecommunication services and networks. For this period, in order to respond as quickly as possible to the concerns of developing countries, instead of being approved during the WTDC, the output of each Question is published as and when it is ready.

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Note for the attention of the reader

This handbook has been prepared by many volunteers from different Administrations and companies. They provided examples of their products, systems, models and case studies.

The mention of specific companies or products does not imply any endorsement or recommendation by ITU.

PREFACE

1 Historical background

In today's Global Information Society (GIS) and Global Information Economy (GIE), the telecommunication sector is expected to play a major role as a leading industry in the 21st century. To meet the requirements of this new century and to close the communication gap between the industrialized and developing countries, the sharing of knowledge in telecommunication technology and services is a very important step. This was recognized by the first World Development Telecommunication Conference held in Buenos Aires, 21-29 March 1994, and also confirmed by the second World Telecommunication Development Conference held in Valletta, 23 March-1 April 1998, which established two Study Groups:

- Study Group 1: dealing with telecommunication development strategy and policies.
- Study Group 2: dealing with development and management of telecommunication services and networks.

The particular Question 2/2 in the first Study Period and Question 16/2 in the present Study Period of Study Group 2 has the objective to prepare new handbooks or revise the existing ones to spread knowledge and know-how in these fields. The handbook "New Technologies and New Services" is one way to achieve this objective.

2 Purpose of the handbook

The rapid development of telecommunications, from technological to market aspects, brings with it every day new products, equipment, systems, networks and services. It would be somewhat ambitious to attempt to produce a handbook that comprises all aspects of new technologies and new services in telecommunication matters and that fulfils, the needs of all players in the telecommunication arena.

The aim of this handbook is to provide a survey of technologies and new services taking place in the changing telecommunication environment, by presenting the general characteristics and capabilities that various networks and new services offer on the market, although not dealing with technical details that are the subject of standardization. The reviewed technologies and new services are in general compliant with the ITU Recommendations.

The handbook also touches on gender perspectives in the preparation and introduction of new services.

3 Why is the handbook necessary?

The telecommunication sector has gone through radical changes in the last decade, driven by an increasingly global and liberalized market in which the control of network capabilities has become a strategic competitive factor to satisfy increased customer requirements. The fast evolution of network intelligence is mainly driven by the convergence between telecommunications, computers and information technology developing various multimedia services. Due to that, telecommunication networks are becoming and will become increasingly complex and challenging to implement and operate. Moreover, it will be more and more important to possess the competence necessary to integrate high capacity and intelligent solutions into the existing networks to meet end-user and cost efficiency requirements.

Three of the most important requirements that have to be met by the improvement of the existing or newly planned networks are:

- *more capacity*,
- *more power,* and
- *greater efficiency.*

To summarize these driving forces, and also to provide a basis for the subject of the handbook, we can say that:

- With insufficient capacity (e.g. bandwidth, packet volume, etc.), network operators cannot satisfy the users demands, even for the universal/service access and especially for new and high quality services. However, in order to optimize the investment, more creativity and appropriate planning of the new technology applications are required.
- The opportunity of new technology applications to build up more intelligent capabilities in telecommunication equipment will give more power to network operators and service providers while increasing Intelligent Network traffic, generating new value-added services. Estimation of customers' needs is a powerful tool to win competition, but only if it is done in time.
- Development of new network management concepts, comprising operation, administration, maintenance and planning, leads to better operational efficiency and maintenance organization, thereby decreasing operational costs. An objective picture of network elements contained in, networks, services and business will improve day-to-day operations and network performance, thus fulfilling customers' expectations for higher quality of service as the target.

These reasons have been the leading concepts in developing the material contained in this handbook.

4 Who should read the handbook?

The handbook is a convenient tool for all those who are interested in telecommunications. It is specially recommended to managers, planning and technical experts of incumbent telecommunication operators as well as national regulators in the telecommunication sector, in particular from developing countries. Those managers should use this information to overview or develop concepts for long-term strategies. Technical managers and experts should extract the deployment of networks that will support the new and global services expected by the 21st century users. Regulators, especially newly established ones, should be supported to create an environment in which innovations by various players can be encouraged without applying constraints other than those needed to create productive competition. Other players will also benefit from the prepared material for improvement of their market access.

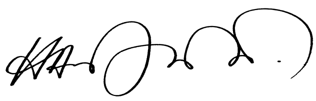
References listed in the various fascicles of the handbook should enable readers to obtain more information on the subject.

5 Homogeneity

Many people have contributed to this handbook which was edited by Ms N. Gospic assisted by Messrs B. Moore and J. Magill. The chapters and subchapters vary in scope and level of detail which is to be expected in such a handbook, reflecting the different nature of the contributions.

The handbook represents a snapshot of the development of networks and services as at the time of issue. It is therefore not a complete picture but provides guidelines and many references for further study.

It is anticipated that the handbook will be updated as the technologies evolve.



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EXECUTIVE SUMMARY

1 Introduction

Having regard to future technical and operational trends in telecommunication services, the developing countries need to know about the latest advances made by the international community in this regard, in order to pass on the benefits to their own nationals.

The developing countries must keep abreast of developments and achievements in the application of new technologies in telecommunication networks, in order to pass on the benefits of this progress to their users.

The handbook on new technologies and new services has been prepared taking into account these two statements of the Valletta Conference held in 1998.

2 Handbook structure

The complexity of telecommunication matters, and the different groups of readers, require the handbook structure to follow a certain pedagogical pattern. It is intended that the reader will be able to easily find information on a certain part of a subject. The structure is also adapted to the fast changes in telecommunications and to the fact that some subjects are still under study.

The handbook consists of four parts, which are prepared as separate fascicles:

Fascicle 1: "New technologies supporting new networks"

Fascicle 2: "Digital networks and services"

Fascicle 3: "IP-based networks and services"

Fascicle 4: "Digital radio and television networks and services"

Each chapter is self-contained (and in some cases subchapters are self-contained) in order to simplify updating of the text.

The mention of specific companies in this handbook does not imply any endorsement or recommendation by ITU.

In each fascicle there is a Chapter 1 dealing with a general review and links to other fascicles. Relevant ITU-T standards and publications are referenced in each of the chapters. Also, some of the important standards from other standardization organizations are listed. In some chapters, useful examples are annexed in order to amplify the subject matter.

A brief content of the fascicles as part of the handbook is given below. The detailed table of contents is shown at the beginning of each fascicle.

Fascicle 1 – New technologies supporting new networks

The content of this fascicle is divided into the following chapters:

1 Introduction

2 New transport media technologies
   - Optical fibre cables
   - Digital radio-relay technologies
   - Mobile communication systems
   - Satellite systems

3 Digital switching systems

4 New signalling systems and SS No. 7

5 Synchronization techniques and methods

6 Digital transmission

7 ATM Technology

Chapter 1 – Introduction and general review, discusses the need to implement new technologies in order to introduce new services and be competitive on the market with capacities and quality.

Chapter 2 – New transport media technologies, deals with main considerations when deploying optical, digital, radio, and satellite technologies.

Chapter 3 – Digital switching systems, deals with technologies for circuit and packet switching and SPC switching system organization.

Chapter 4 – New signalling systems and SS No. 7, includes necessary specifications for new digital networks.

Chapter 5 – Synchronization techniques and methods, explains implementation of synchronization in new digital networks.

Chapter 6 – Digital transmission systems, deals with PDH, SDH, WDM and xDSL techniques with reference to the most important standards and implementation examples.

Chapter 7 – ATM technology, includes ATM transport, switching and cell format, operation and maintenance and signalling and traffic management of ATM networks.

Fascicle 2 – Digital networks and services

Fascicle 2 is composed of eight chapters, annexes and test cases:

1 Introduction

2 Digital networks and services

3 Mobile digital cellular networks and services

4 Access networks

5 Network and service management

6 Planning aspects

7 Human resources aspects

8 Financial and economic aspects

Chapters 2, 3 and *4* – deal with different network technologies and structure and related services, emphasizing their main characteristics and requirements for new architectures and interworking. Chapter 2 is divided in 10 subchapters dealing with particular fixed networks, e.g. PSTN, ISDN, IN, Packet switched network, Frame relay, ATM-based networks, services and ITU-T Standards for related subjects. Development of China Telecommunications is included as Annex 2A.

Chapter 5 – deals with Service and Network Management based on the introduction of the TMN concept.

Chapter 6 – offers the guidelines for network planning with annexes as examples.

Chapter 7 – is concerned with development of human resources being capable to implement new technologies and new services, and

Chapter 8 – deals with financial and economic aspects in developing the new networks and services.

Fascicle 3 – IP-based networks and services

Fascicle 3 is composed as follows:

1 Table of contents

2 Introduction and definitions

3 Internet Protocol (IP)

4 E-commerce

5 TeleInternet services for Tel-E-Commerce

Chapter 2 – is based on dramatic grow of Internet subscribers, new services and IP-based networks. It deals with basic definitions for E-mail, WWW, Arpanet and hyperlinks.

Chapter 3 – deals with Internet Protocol-IP characteristics, IP packet structure, IP address, Voice over IP and Ipv4 and Ipv6.

Chapter 4 – explains E-commerce as a new data service realizing the vision of the Global Information Economy.

Chapter 5 – deals with new IP architecture and applications of TeleInternet services with reference to ITU publications.

Fascicle 3 is an initial introduction to the subject and further revision and expansion will be required.

Fascicle 4 – Digital radio and television networks and services

This fascicle contains five chapters:

1 Introduction

2 Digital audio broadcasting

3 Digital television broadcast services

4 Strategies for digital television broadcasting

5 Data broadcasting

Chapter 1 – deals with general introduction about radio and television networks and services.

Chapter 2 – summarizes benefit of audio digital broadcasting introducing different services and digital audio systems. It deals mainly with the terrestrial digital audio broadcasting system (T-DSB).

Chapter 3 – lists advantages of digital TV transmission, both Standard Definition Television and High Definition Television. The chapter discusses the structure of digital television system, digital satellite broadcasting, digital terrestrial broadcasting, planning aspects, different standards and networks and services.

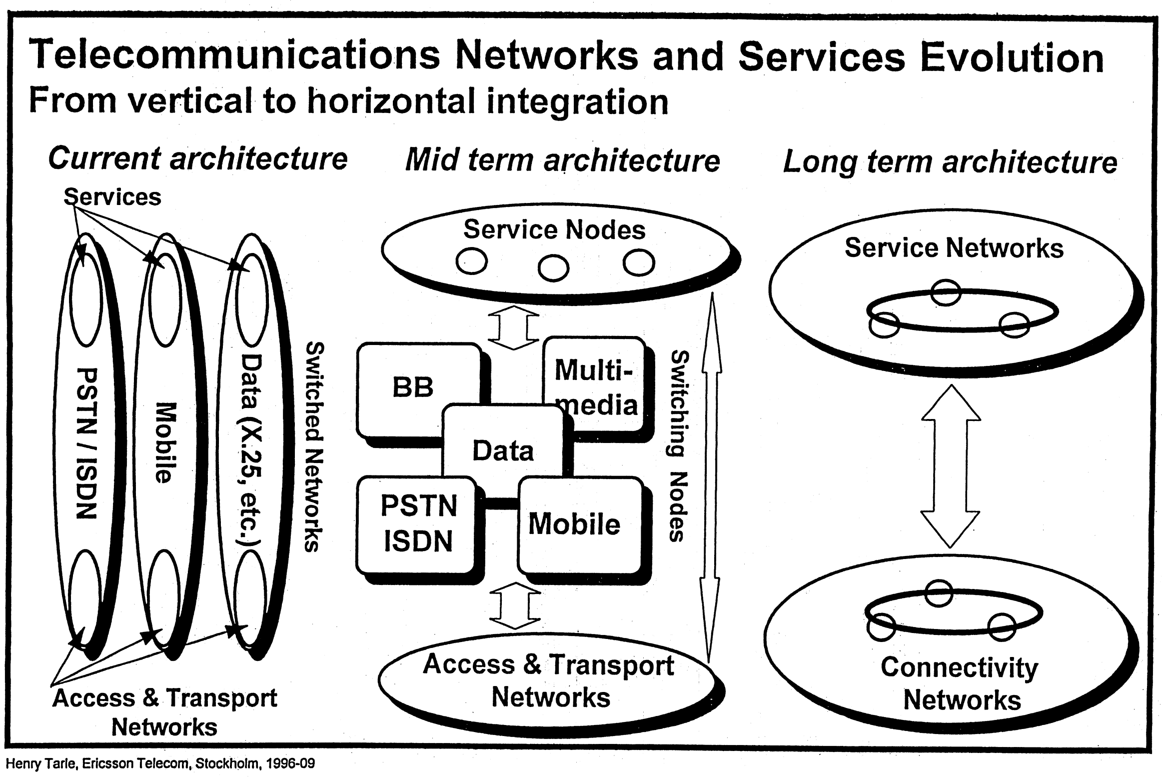
Chapter 4 – deals with strategies for digital television broadcasting emphasizing the needs in transition from analogue to digital systems. The chapter identifies planning criteria for different systems, networks and services.

Chapter 5 – "Data broadcasting" exploits a new development area for broadcasters in a competitive environment. Data broadcasting services are defined with requirements for data systems. The chapter deals in more detail with data broadcasting over terrestrial systems using broadband wireless, multichannel multipoint distribution system, ISDN, cable TV distribution and some examples for multimedia broadcasting.

How to make use of the handbook

To make a good use of the handbook, it is necessary to understand the changes in the managing of the telecommunication business. Three categories are very important for successful management of telecommunication:

FIGURE – TELECOMMUNICATION NETWORKS AND SERVICES EVOLUTION (FROM VERTICAL TO HORIZONTAL INTEGRATION)



How to read the handbook

The following charts are aimed at facilitating the reading of the handbook for different groups of readers:

FIGURE – FOR TELECOM OPERATORS AND REGULATOR MANAGERS

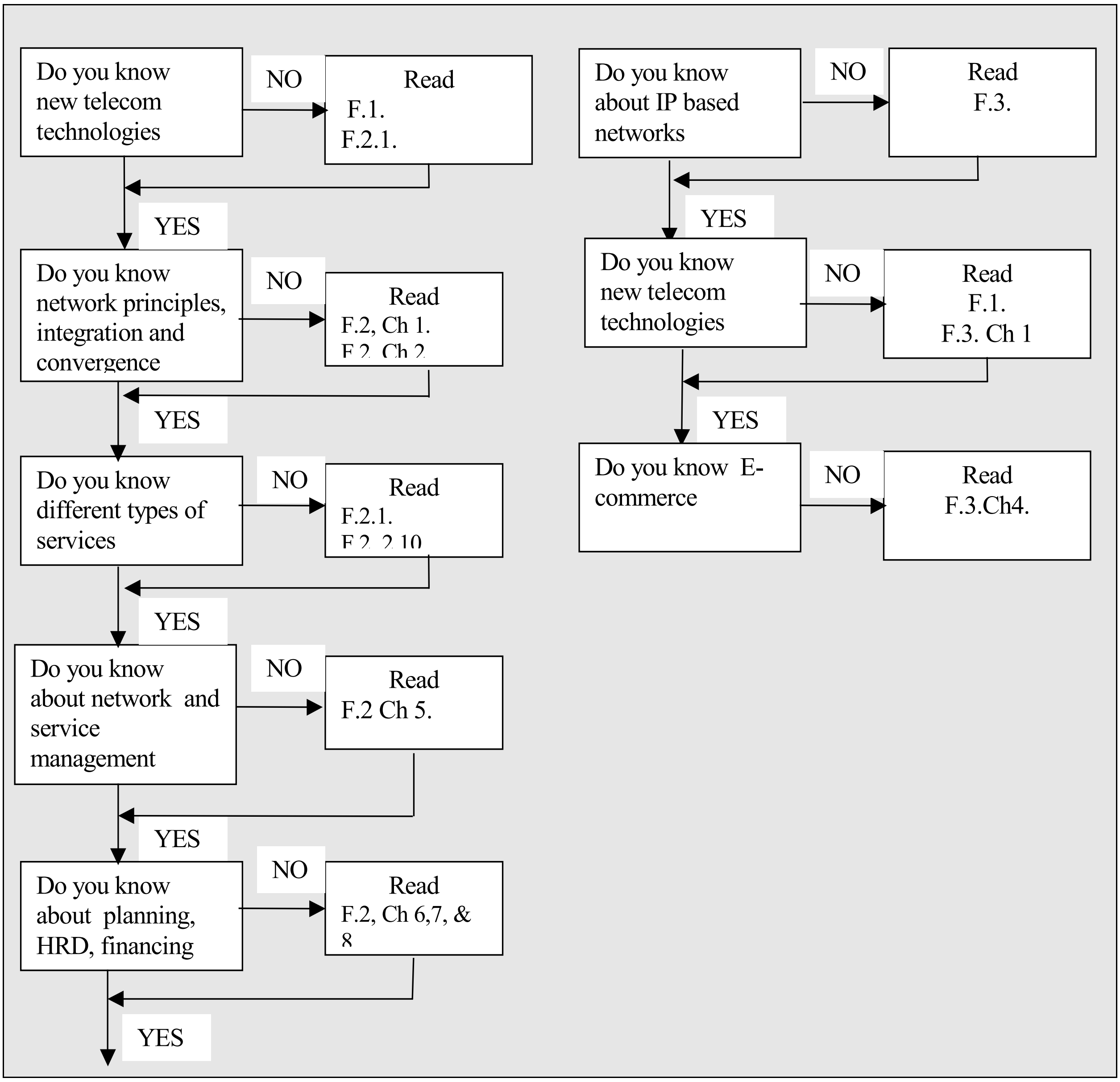


FIGURE – FOR BROADCAST MANAGERS AND OPERATOR STAFF

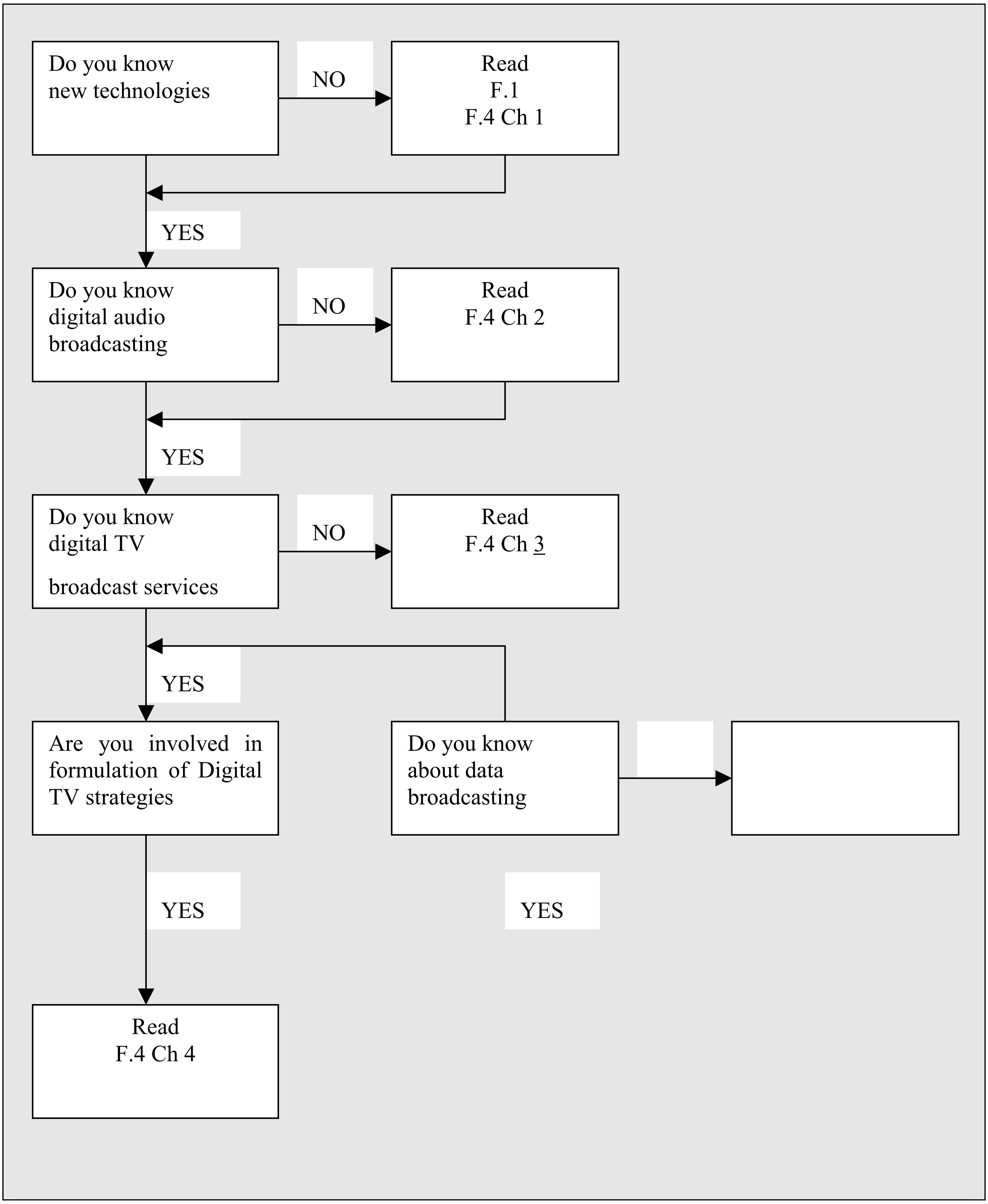
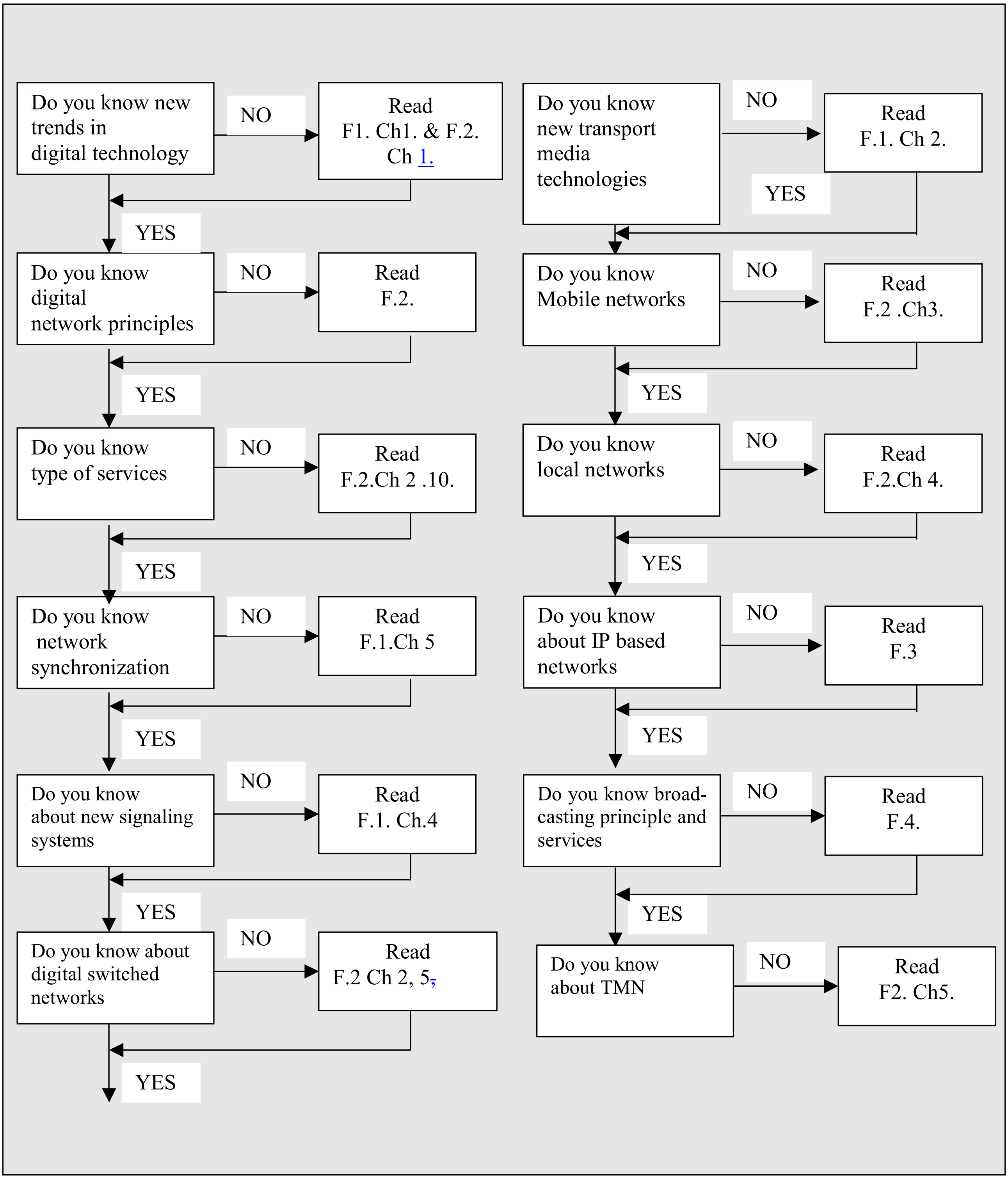


FIGURE – FOR PLANNERS AND TECHNICAL MANAGERS



FASCICLE 2

Digital networks and services

CHAPTER 1

Introduction

1.1 General

Telecommunications can be structured in different ways. One approach is to view telecommunications, from both user's and operator's viewpoints:

- Network aspect, and
- Service aspect.

Different services make different demands on the network. These demands determine which networks are suitable for specific services and also affect network planning and dimensioning. Services are characterized by the following parameters:

- Bandwidth
  - Narrowband $\leq$ 64 kbit/s
  - Wideband n × $\leq$ 64 kbit/s > 2 Mbit/s
  - Broadband > 2 Mbit/s
- Variations in bandwidth requirements:
  - Continuous bit rate
  - Variable bit rate
- Bit errors and delay
  - Voice
  - Data
  - Video

Required bandwidths for different services are illustrated in Figure 1.1.

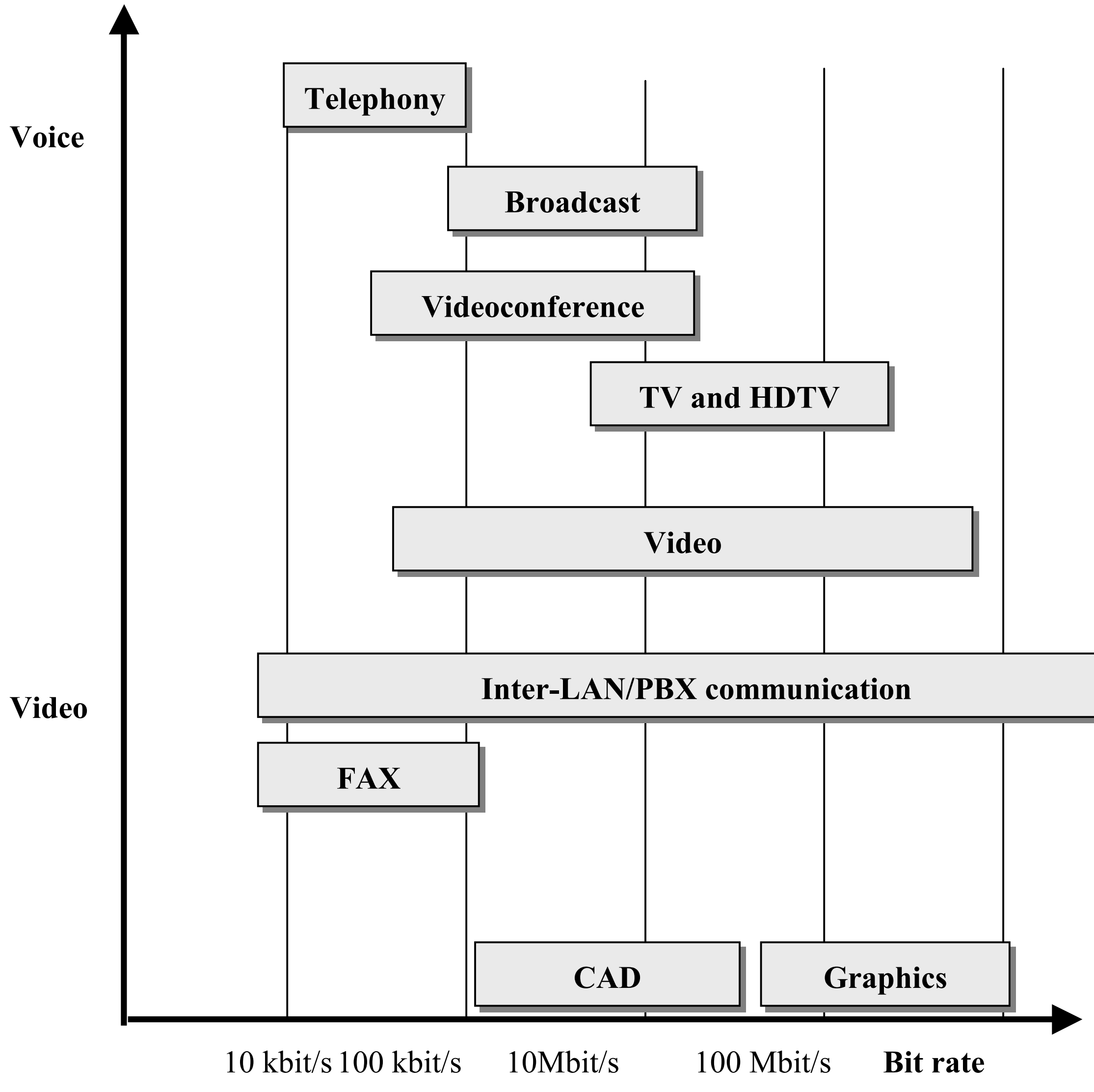
Creation of services are driven by users' requirements. These requirements can be grouped in the following ways:

- 'Always on' connectivity
- Number portability/single user address
- Service bundling (user friendly interface to an ever increasing number of network services)
- Common billing/single bill for communication services
- Universal service profile (transparently upheld across different networks)
- Common contact point of customer service and management /personalization of services.

Personalization of communications, brought about by mobile phones, coincides with the trend for more personalized services over the Internet. The emergence of vertical portals, on line communities and one-to-one marketing will take the Internet to the next stage with fully personalized content and service.

Mobile Internet service is a mechanism to extend beyond today's offerings and will deliver services to the user's pocket. The breakthrough of the Wireless Applications Protocol (WAP) in 1999/2000 is leading the way. The next step in personalizing services involves bundling voice, Internet and multimedia services over the users personal mobile device.

Figure 1.1 – Bandwidth requirements of different services



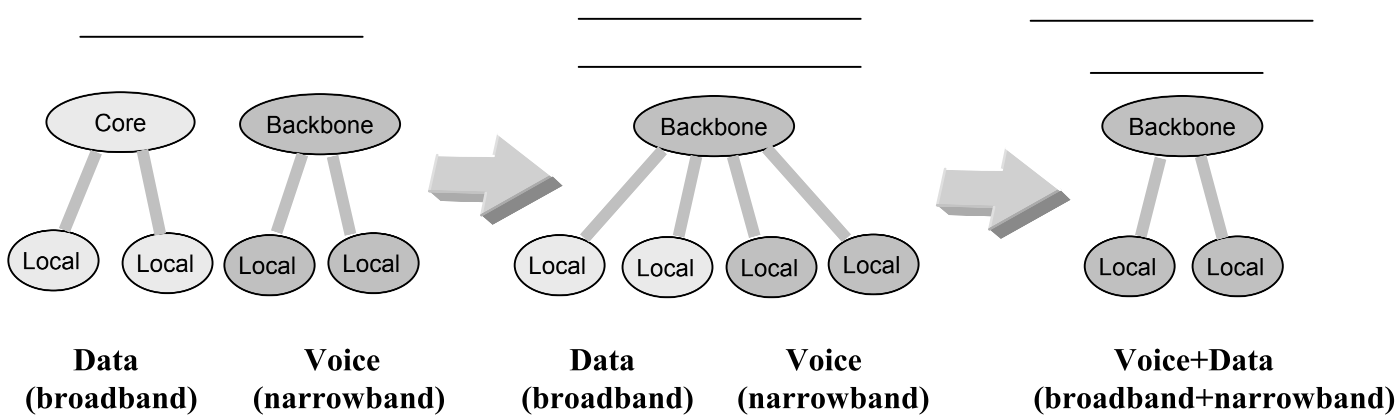
All of these trends are reflected in the development of the network. The term "convergence" is very often used and is influencing future network developments. Discussion on this issue can be summarized is following ways:

- Voice-Data Convergence
- Fixed-Mobile Convergence
- Convergence of three industrial sectors Telecommunications, Computing and Broadcasting.

Voice-Data Convergence

An evolution that will most probably impose itself is the integration of the voice and the data networks. On the one hand, voice will be increasingly transported aver data links (e.g. ATM, IP). On the other hand it is obvious that maintaining two different networks is a lot more expensive than having an integrated network. A possible migration scenario is given in Figure 1.2.

Figure 1.2 – A scenario example of Voice-Data convergence



Fixed-Mobile Convergence (FMC)

FMC presents major hurdles for operators. It is a way for fixed network operators to offer customers mobile-like attributes such as location-independence in an attempt to diminish the tide of users substituting fixed line calls with mobile, and preserve call completion on the fixed network. FMC also enables mobile network operators to offer customers the type of value for money, quality of service and transmission speeds they have traditionally been obtained from fixed networks. On the other hand, new services must complement the emerging data services. To meet this requirement mobile operators are seeking to enhance their bandwidth capabilities, but also fixed network operators are seeking ways to increase the use of the capacity and intelligence. This reason for FMC raises other questions such as: Who leads the Convergence?, Who develops it?, Who manages it?, How to regulate it? These questions require long term strategies from both fixed and mobile operators and regulators.

The first step in FMC services can be illustrated in Figure 1.3.

The FMC benefit for users are:

– Billing services that combine fixed and mobile network call charges into a single invoice, perhaps covering multiple handsets and fixed lines.

– Integrated messaging services

– Multi-standard handset

– Common customer service centres

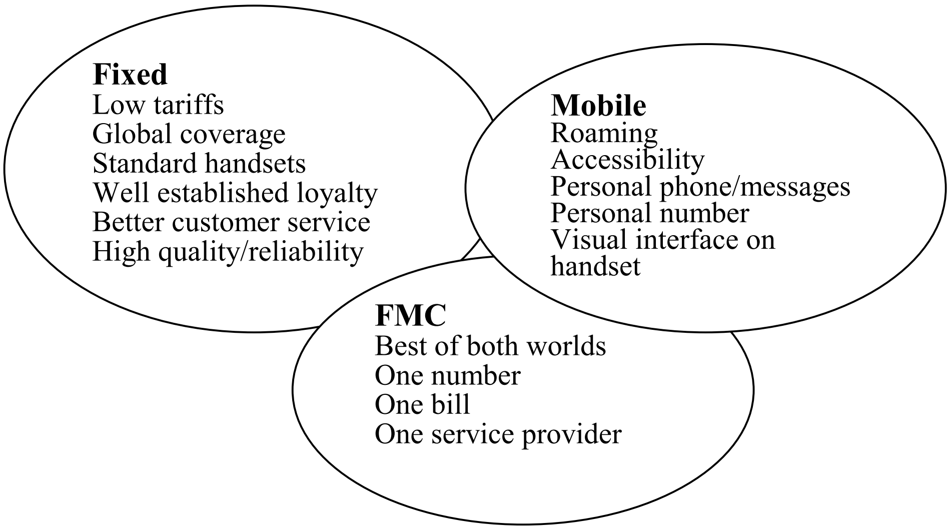
– Single numbers

– Mobile virtual private networks

– Tariff and discounting packages

The disadvantage of the FMC for operators is that management of FMC services is very complex, involving new billing platforms and customer care systems.

Figure 1.3 – FMC Service structure



Convergence of Telecommunications, Computing and Broadcasting

There is a general belief that three different technologies and industry sectors, telecommunications, computing and broadcasting, will converge into a single industry sector. This might be called the “infocommunication” industry, based on a common set of core technologies. The products and services of this industry will constitute the “information infrastructures” of networked economies and societies of the future, on an increasingly global scale. How precisely this will happen and what organizational strategies are appropriate is far from clear. However, in order to plan further development it is very important to address this issue.

To imagine how the telecommunication environment is likely to evolve in the next five to ten years ITU, in its Strategic plan, proposed the following model (Figure 1.4) as a basis for discussion:

Table 1.4 – The vertical and horizontal dimensions of infocommunication industries (The examples are illustrative, not exhaustive)

Horizontal strata	Vertical segments		
	Telecomms	**Computing**	**Broadcasting**
Terminals	Telephone Fax Telex	Dumb terminals Personal computers Network computers	Radio receivers Television sets Audio/video
Applications	Telemarketing Audiotex Value-added services	Database access E-mail Simulations (games)	Recorders Entertainment Information Education
Services	Voice Data Text	Electronic Data Processing Process automation Productivity tools	Radio Television Teletext
Network components	Local access Switching Transmission	Servers Routers LANs, MANs, WANs	Over-the-air Cable Satellite
Facilities and devices	Wires, cables, frequencies, antennas, satellites, signal generators, processors, receivers		

With this model in mind, the following scenarios are offered for consideration:

- *Network integration* scenario; the different facilities that were used in the past by the telecommunications, computing and broadcasting industries would be absorbed by high-capacity networks capable of providing all information and communication services on an integrated basis, in wired and wireless environments (B-ISDN, UMTS, UPT, IMT-2000).
- Second scenario, *vertical enrichment*; encapsulates some of the main developments that have taken place in the past ten years and primarily results in product and service enrichment within the traditional vertical market segments – as well as in the creation of new vertical segments.
- In the third scenario, *the competitive matrix* the horizontal dimensions of the "infocommunication" industry begin to become as important as its vertical dimensions. Boundaries between the vertical industry sectors (both traditional and new) would begin to dissolve, and competition would take place not only in provision of services (not only on the basis of competing infrastructures) but on the combination of the two (Internet, information service providers, capacity warehouses).
- Under the fourth scenario, *horizontal integration;* the vertical industry structures that have characterized the communication sector in the past and still dominate the industry today emerge broadly reoriented to horizontal strata.

Which scenario is going to be implement will depend on overall telecomms policy within a country.

1.2 Towards a new communications architecture

To achieve a new networking strategy for a converged communications marketplace, operators need to draw on truly open systems that invite competition on horizontal layers. In moving to this open-ended environment, it is necessary to acknowledge four requirements:

- There is no clearly defined border between past and future network technologies. Transformation must be based on viable migration strategies that safeguard business continuity.

- End-user experience ultimately determines operator success. In a highly competitive market, users will expect and demand very high quality services.
- De facto standards – whether formal industry standards or proprietary standards – can serve the market need for open interfaces to integrate complete solutions. However, formal industry standards that are widely shared and available give operators more flexibility in a multi-vendor market as well as more possibilities to leverage their own brands towards end-users.
- There is a world of difference between operating a network optimized to deliver bits of data and guaranteeing services end-to-end across different networks. This can only be addressed with large-scale end-to-end systems integration services and network management solutions that cater for a truly open multi-vendor environment.

1.3 Future communications architecture

Next-generation networks will be based on a three-layered model. This is not to say that all networks will look the same, since migration paths will vary. Generally speaking, however, future network architectures will be build on the following broad layers:

- *Content and User Applications*

The Content layer includes user applications and not, as before, applications built into the telecommunications network. Applications can reside on the Internet or on dedicated servers but are off-network from a communications perspective. Between the network and applications are middleware and open Application Programming Interfaces (APIs).

- *Communications Control & Applications*

The Communications Control and Applications layer includes all the functionality for control, intelligence and mobility management – everything that is needed to set up connections and sessions, etc.

- *Connectivity*

The Connectivity layer includes all the functionality for access, transport and backbone. It is, in effect, the "bit pipe" for carrying communications and information.

This three-pronged view is useful in understanding the logical division of tasks within a network. The layers hold for all networks – fixed, mobile, broadband, etc. This functional view can also be viewed from a business and investment perspective. As each layer has a very distinct and unique task to fulfil, it contributes to the operator's business case in different ways.

1.3.1 Content and User Applications

The content and user applications layer performs information-centric services that users pay for based on some underlying service principle, such as access/minutes of use or throughput. Services may involve e-commerce or any on-line activity but typically resides on off-network servers.

Although operators may develop some user applications themselves, they must first and foremost secure a flexible and future-proof applications environment to deploy new services with a high degree of personalization. Partners, independent software vendors and different industries can then develop and market specific user applications.

In fact, the bulk of investments will come from these players, as can be witnessed by the innovation currently being driven by Wireless Application Protocol (WAP). There are also substantial developments in Applications Service Provisioning (ASP) whereby applications software is downloaded by the user over the Internet whenever needed at a certain fee. Such services can be provided by an operator and/or Internet Service Provider (ISP), or independent player with full responsibility for quality-of-service, upgrades, etc.

High quality voice services will continue to be an important part of many applications and is thus a strong focus area of technology development. Speech recognition, advanced intelligent agents and more intuitive user interfaces will turn the human voice into an essential component of any service. Thus all conversational applications – from voice calls to information-centric applications – will rely on time-sensitive, real-time voice. The operator's ability to deliver this will cut straight through to the user experience.

Equipment in the user applications layer will consist of open server platforms with the required middleware – communications and application enablers.

1.3.2 Communications Control and Applications

The Communications Control and Applications layer incorporates all the functionality to provide seamless and high-quality services across different public and private networks. The functionality of this layer safeguards operator profitability. This layer comprises the system logic for such systems as GSM, fixed telephony networks and data/IP networks, as well as future systems like General Packet Radio Service (GPRS), third generation of Wideband Code Division Multiple Access-WCDMA and other multimedia networks.

Ultimately, this layer will be a set of servers with different service capabilities, providing the flexibility to keep current business profitable while allowing new and innovative business to develop. A key differentiator among operators will be the ability to maintain differentiated network services across diverse networks.

This layer is the real profit generator for next-generation networks. The business model requires operators to retain this core competence in-house.

1.3.3 Connectivity

The Connectivity layer is first and foremost a very large bit pipe – a transport mechanism that is independent of whether the transported information is voice, data or multimedia. This layer can and will be built on both IP and ATM equipment, and operator success will primarily be based on cost leadership.

Connectivity architecture includes both the backbone transport network as well as the access networks – fixed telephony, CATV, mobile communications and enterprise access, etc.

The backbone architecture incorporates core and edge equipment. The core equipment transports aggregated traffic streams between service nodes on the edge of the backbone network. Edge equipment provides the bit pipe with the intelligence to guarantee appropriate quality of service and collects all customer and traffic-specific data for accounting and billing purposes.

1.4 Structure of Fascicle 2

This Fascicle is composed of an Introduction and 8 Chapters.

Chapter 2 deals with digital networks and services and is divided in ten subchapters.

- Subchapter 1 explains the basic structure of *Public Switched telephone Network-PSTN* with three level structure of the Access, Local and Transit Networks.

- Subchapter 2, *Integrated Service Digital Network – ISDN* deals with ISDN interface specifications, ISDN services and reference configurations with a short description of functional blocks.

- *Intelligent Networks* are explained in Subchapter 3 with considerations on the introduction of IN services in the general network and the future role of IN. The Tables of IN functions and Capability sets are included.

- Subchapter 4, *Packet switched Network,* includes X.25 Basic structure, packet transmission principles and X.25 Layers.

- *Frame Relay* as a solution for increased bandwidth and less delay in data transmission is explained in Subchapter 5. It includes general definitions, frame formats and operation of the data link layer.

- *ATM-based networks are explained in Subchapter 6.*

- Subchapter 7 covers *Interworking between networks* and offers basic principles for interworking between different networks and example of interworking cases.

- *New services* are listed in Subchapter 8 with emphasis on N-ISDN services, Broadband services and Multimedia services and suitable examples.

- In Subchapter 9 *Future trends* in service development are explained with emphasis on IN services.

- Subchapters 10 and 11 lists important *ITU standards* for all networks covered in Chapter 2.

Annexed to Chapter 2 is a case study on China telecommunication development.

Chapter 3 deals with evolution of mobile networks from first generation to the IMT-2000.

In this chapter the Fixed Mobile Convergence phenomena is also discussed.

Chapter 4, *Access Networks* has two Subchapters. The first one studies the functional architecture of access networks and includes possible implementation scenarios and the ITU standards. The second is dealing with Wireless Access and corresponding technical solutions.

Chapter 5, *Network and Service Management,* defines driving forces for a new approach to management issues, TMN architectures and includes implementation examples and evolution of management tools.

Chapter 6 deals with *Planning aspects* and discusses separately radio and non-radio aspects. The Chapter also elaborates development plans and definition of short, medium and long term development scenarios. The relevant ITU publications are listed.

Chapter 7 discusses the need to develop human resources to support introduction of new technologies.

Chapter 8, *Financial and Economic Aspects,* deals with methods of economic analysis, policy considerations, and tariff problems.

References listed in chapters should enable readers to get more information on the subject.

Each chapter is self contained (and in some cases subchapters are self contained) in order to simplify updating of the text.

1.5 List of abbreviations

API	Application Programming Interface
ASP	Application Service Provisioning
ATM	Asynchronous Transfer Mode
CAD	Computer Added Design
FMC	Fixed Mobile Convergence
GPRS	General packet Radio Service
HDTV	High Definition Television
IMT-2000	International Mobile Telecommunications
IN	Intelligent Network
IP	Internet Protocol
ISDN	Integrated Service Digital Network
ISP	Internet Service Provider
LAN	Local Area Network
MAN	Metropolitan Area Network
N-ISDN	Narrow Band ISDN
TMN	Telecommunication Management Network
UMTS	Universal Mobile Telecommunication Services
UPT	Universal Personal Telecommunications
WAN	Wide Area Network
WAP	Wireless Application Protocol
WCDMA	Wideband Code Division Multiple Access

CHAPTER 2

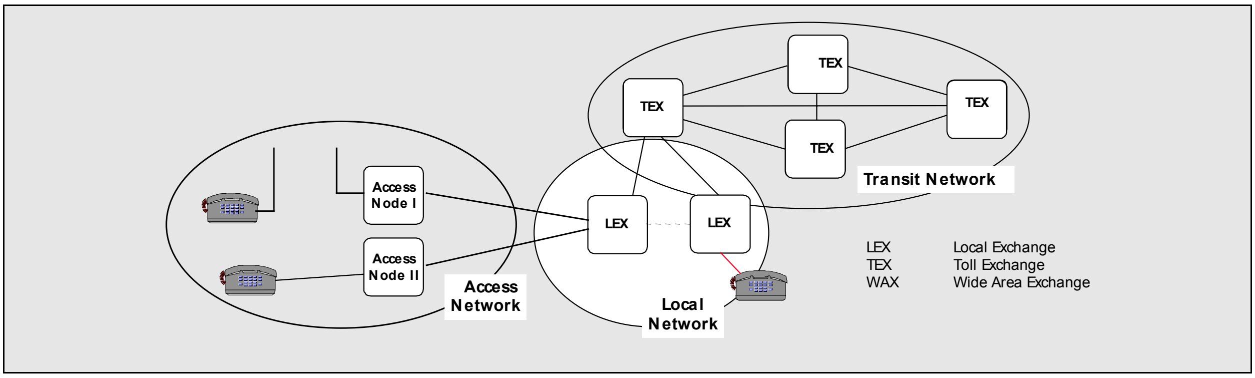
2 Digital networks and services

2.1 Public Switched Telephone Network (PSTN)

The Public Switched Telephone Network (PSTN) is the basis of today's telecommunications. It provides the users a transport medium for signals in the frequency range of 300 Hz up to 3.4 kHz where the signals are encoded with a technique called Pulse Code Modulation (PCM). This technique encodes samples of the signal, taken at regular intervals, into a digital code. This scheme has been well standardized, so that the sampling rate is 8 kHz and the sampling value is encoded in 8 bits. Each conversation therefore results in a continuous bit stream of 64 kbit/s which is multiplexed in the network into higher data rate carriers. Although the basic building block of the digital hierarchy is 64 kbit/s standards have diverged, so different data rates for the multiplexed signals exist.

In general, the PSTN is a circuit switched network. This means that an end-to-end circuit is established and maintained between the communicating entities for the duration of a 'call'. This assures minimum delay and constant quality of service throughout the duration of the call.

Figure 2.1.1 – General Structure of PSTN



In general, the PSTN is structured as depicted in Figure 2.1.1. The access network has to provide the physical communication link between the communication endpoint and the local exchange. In the local exchange (LEX) all users related functions are located. The switches of the toll exchange level (TEX) are introduced to have the possibility for structuring and optimizing the network according to traffic measurements and user behaviour.

The objective of a switching network design is primarily to minimize the cost of ownership for the network. The main principles applied to decrease the cost of ownership are:

– small number of switching systems and exchange sites;

– elimination of small trunk groups between the exchanges, and the

– introduction of centralized network element management.

This network design becomes possible because of the application of:

– large digital host exchanges in combination with;

– advanced access network technologies providing remote subscriber line access, and

– cost-effective transmission technologies.

2.1.1 Access Networks

Different solutions exist to connect users to a local exchange. Users can either be connected directly (via copper cables) to a local exchange. This solution can be taken into account if the distance between user location and exchange is in a range of up to 14 km (depending on the cable physics).

Or, for other type of access or remote locations access network nodes can be deployed. These access network nodes typically concentrate the traffic from the remote location towards the host on transmission links. Access network nodes can be connected to the hosts through channel banks (feeding of the analogue interfaces of the switch by the access network node) or through system specific multiplexing interfaces.

Some switches and access networks also support system independent ETSI V5.1 and V5.2 interfaces based on 2 Mbit/s transmission links.

In the case of system independent access networks a correlation between the subscriber line management of the host and the access network has to be implemented. This is not necessary if the access node is a remote part of the host.

To support different topology choices or physical access media, access network equipment is available for radio, copper, coax and fibre infrastructures.

2.1.2 Local Exchange Level

A local network based on today's technology typically serves between 80 000 …120 000 lines. Because of the capacity limitations of the digital switching systems existing some years ago, this required at least three switching systems per local network. These may be multiple combined local/transit switching systems at regional exchange sites and/or further local exchange sites. The exchange sites of a local network may be meshed when justified by the traffic volume.

For the provisioning of widely deployed IN services in the network the SSP function should be integrated in each local exchange.

Basic functions of the local exchange are:

– Conversion of analogue to digital signals and vice versa;

– Feeding of access lines;

– Collecting of call data records;

– Line measurements;

– Routing.

Additional functions of the exchange are:

– Provisioning of Services (e.g. centrex, call forwarding, advice of charge) and others.

2.1.3 Toll Exchange Level

Depending on the size of the network, the toll exchange level can be split into two parts as shown in Figure 2.1.2.

The highest hierarchical level of the network is the wide area network. In the wide area each exchange site is dedicated to a particular regional network. This means that the wide area exchange collects the inter-regional (or international) traffic originating from its regional network and routes it towards the destination wide area exchange. For incoming transit traffic destined to its regional network, the wide area exchange distributes the traffic to the appropriate destination regional exchanges.

The wide area network is a fully meshed transit network. Dynamic Non-Hierarchical Routing (DNHR) can be applied in order to achieve a robust high-performance backbone.

Each wide area exchange consists of two switching systems for safety and capacity.

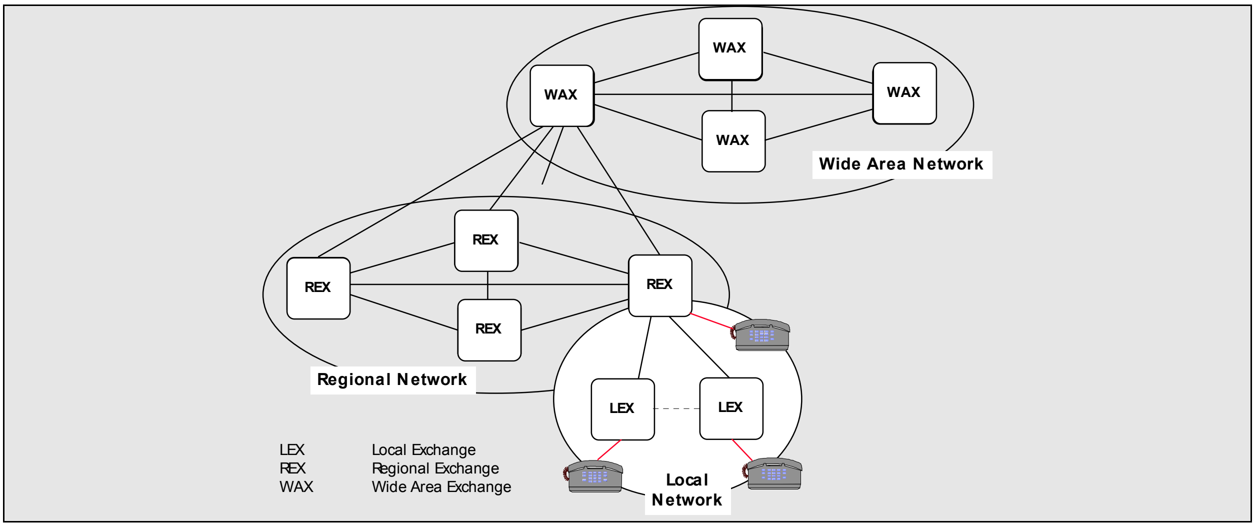
The exchanges of the regional network are dual homed, i.e. connected to both switching systems of their wide area exchange.

Each regional network is dedicated to a wide area exchange site. The inter-regional (or international) traffic originating and terminating in a region is collected and distributed over a (partial) star network topology.

The regional network carries the intra-regional traffic. For this purpose the regional exchanges within each region are partially meshed depending on the actual traffic volume between the exchange sites. Eventually the regional networks can apply the same DNHR routing as the wide area network. This enables a single network planning process to be applied for all transit sub networks.

In medium and small networks the regional network can be dropped. In this case the wide area network is responsible for the provisioning of functions described for the regional network.

Figure 2.1.2 – Structuring of Transit Network



2.1.4 Signalling

For signalling purposes in the network the Common Channel Signalling No. 7 protocol is used.

The No. 7 network needs to consider the following different signalling types:

a) Circuit-related link-by-link TUP (Telephone User Part) signalling for call control;

b) End-to-end signalling for non-circuit related services (e.g. call completion to busy subscriber) between exchanges;

c) End-to-end-INAP (Intelligent Network Application Part) signalling to/from central servers;

d) Signalling to/from other networks.

These signalling types differ with respect to their traffic characteristic (volume, source and destination, delay constraints) and routing and management requirements.

The No. 7 network basically consists of two levels.

The intra-network circuit-related link-by-link TUP signalling traffic (type a)) is handled by a No. 7 network level strongly related to the switching network structure. This means that signalling can be mostly associated with the trunk groups between the exchanges (associated mode). Only in cases when the signalling traffic s do not justify a direct link (although the user traffic justifies a direct trunk group) the quasi-associated mode (signalling via another exchange) is applied. The quasi-associated mode is also applied for alternate routes, i.e. these routes are used when the associated links are overloaded or faulty.

The second level of the No. 7 network is the backbone consisting of stand-alone No. 7 nodes in No. 7 terminology referred to as Signalling Transfer Points (STP) or Signalling Relay Points (SRP). These No. 7 nodes handle the traffic types b), c) and d). The STP/SRPs represent packet switches which merely route signalling messages but do not include application functions.

The STP/SRPs allow for a central management of the No. 7 traffic types implying stronger requirements with respect to routing and monitoring. The SPR function of the No. 7 nodes support routing based on global title translation. This is applied e.g. in order to address the SCPs serving a particular group of IN service customers. The SPR/STP are central sites for signalling interconnection from where the signalling links to other networks emerge. Therefore these sites host additional No. 7 equipment allowing a close monitoring of the interconnection signalling. By this measure the operator can protect his own network e.g. from potential fault propagation originating from other networks.

2.2 Integrated services digital network (ISDN)

ISDN (Integrated Services Digital Network) refers to both a set of digital transmission standards and a network infrastructure that allows digital transmission over existing telephone wiring, as provided by public network service providers. ITU-T defines ISDN as "a network, evolved from the telephony network, that provides end-to-end digital connectivity to support a wide range of services, including voice and non-voice, to which users have a limited set of multiple user interfaces."

The demand for ISDN first has emerged in the mid-1970s when international telecommunications usage began to push existing analogue networks to their limits. Advanced applications involving voice, data, and image transmission have required higher speeds, better performance, integrated management and flexibility. The vision of a single network handling all of users' communications needs – an integrated suite of services using digital transmission techniques – has resulted in the standards that have become ISDN.

In 1984 a set of ITU-T standards that specified the details of what an ISDN network is and how it works were published. The standards have since evolved and been adopted as a global standard by most ISDN providers. The result is a universally consistent service that is well defined, broadly accepted and efficient.

ISDN consists of a user-network interface and a means for digitally transporting user data and signalling information across multiple providers' networks. At the user premises, the service connects to a network line terminator (known as an NT-1). The digital signal travels from the NT-1 through an ISDN Terminal Adapter to the end user's device. Some or all of these components can be packaged together.

Two types of ISDN have been defined: Narrowband ISDN (N-ISDN or simply ISDN) which is the subject of this section, and Broadband ISDN (B-ISDN) which provides very high speed transmission using Asynchronous Transfer Mode (ATM) technology. B-ISDN is still relatively rare, since a native ATM service has not yet been developed and ATM services remain relatively expensive.

ISDN provides standard access to all network services allowing voice, data, fax, video and graphics to share the same line with the error-free performance associated with digital technology. The user-to-network interface is mainly of direct concern to the end user, and can be provided as Basic Rate or Primary Rate.

An ISDN access line conforming to the Basic Rate Interface (BRI) consists of three separate channels: two B channels, which carry data transparently, and one D channel, which carries signalling information such as call set-up, control and caller ID across the network. The D channel can be used to transmit packet-switched user data and to access public data networks. BRI lines are typically used to connect small key systems and individual terminal devices (such as PCs, videoconferencing units and fax machines). A BRI is also referred to as a 2B+D connection.

A Primary Rate Interface (PRI) uses higher speed physical lines. In North America, this is based on a T-1 (1.544 Mbit/s). In Europe, PRI is based upon an E-1 (2.048 Mbit/s). A PRI line is consisted of twenty-three transparent B channels (T-1), or in case of E-1, thirty channels plus one 64 Kbit/s D channel. A PRI line does not usually terminate at an end users' terminal equipment; rather it serves as a trunk between customer-based switching equipment (a PBX) and an ISDN termination at the central office. A PRI connection is also referred to as a 23 B+D (in the U.S.) or as 30 B+D connection (in Europe).

The ISDN interface specifications are summarized in the following Table 2.2.1.

Table 2.2.1 – ISDN interface specifications

	Basic Rate Interface	**Primary Rate Interface**
Line speed	144 Kbit/s	1 544 Mbit/s/2 048Mbit/s
Physical Layer Standard	ITU-T I.430	ITU-T I.431
Configuration	2B+D	23B + D (North America) 30B + D (Europe)
Bearer Channels (B)	64 Kbit/s	64 Kbit/s
Signalling Channel (D)	16 Kbit/s	64 Kbit/s
Signalling Method	Layer 3 messages based on ITU-T Q.930 to 932	

For reserved mode connections H channels can be used. Circuit switched mode H channel connections are not directly supported by ISDN connection types. They are realized in the 64 kbit/s ISDN by multiple B channels, the terminal systems are responsible for the synchronization of the individual time slots.

The following H channel types have been standardized:

– H0 at 384 kbit/s

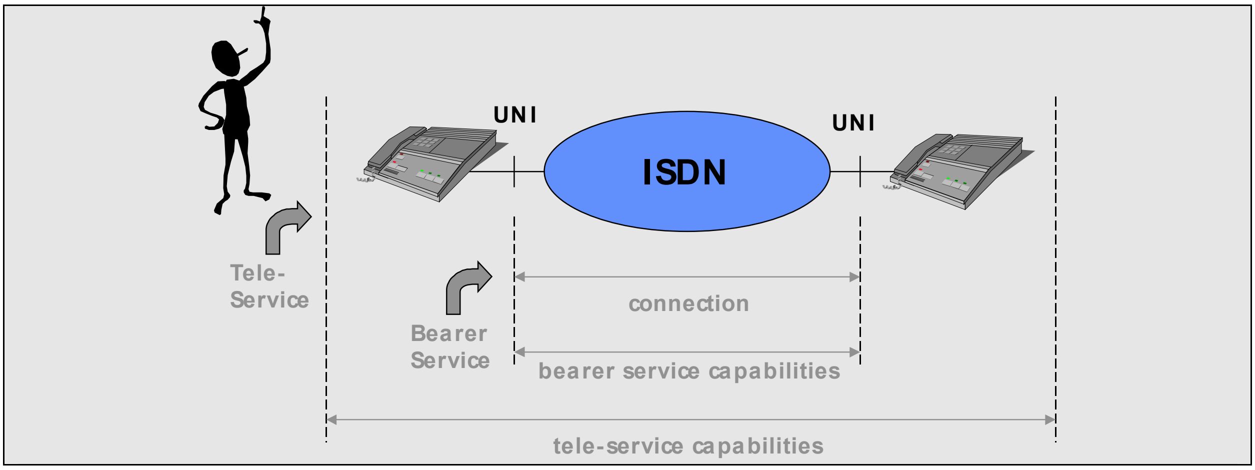
– H11 at 1 536 kbit/s (North America and Japan)

– H12 at 1 920 kbit/s (Europe)

As ISDN evolves, other H channels providing higher capabilities may be available. H21(34 Mbit/s), H22(45 Mbit/s) and H4(140 Mbit/s) channels have been proposed to be used, in circuit or fast packet mode, for applications such as LAN interconnection, high speed data transmission, teleconferencing imaging and so on.

ISDN-based digital transmission is a cost-effective way to integrate various telecommunications services into a common, globally-accepted digital infrastructure. ISDN services can be categorized as being "bearer" services (lower layer transport facilities) or as "tele-services" (having distributed application capabilities). Bearer services allow a user to transfer information to another user without restriction on the type or format of the data. The services (tele-, bearer and supplementary services) as well as the standards defining these services are illustrated in Figure 2.2.1 are listed in Section 2.8 of this Chapter. Therefore more emphasis shall be given on the technical implementation, the interfaces and the protocols.

Figure 2.2.1 – Tele and Bearer Services



Technically ISDN is characterized by:

– digital transmission and switching of information between the network borders (UNIs);
– an integration into the existing PSTN as far as this PSTN is already digitalized (of course, interworking with analogue parts is possible);
– transport/switching of voice and data;
– 64 kbit/s channels (B-channels) which form the basis of information transfer;
– out-band signalling information to control the calls (16 or 64 kbit/s D-channel);
– access to all the services via a standardized interface, the User Network Interface.

2.2.1 ISDN Market Situation

ISDN is currently growing fast in some of the European countries, also now in the USA a strong growth is expected in the next few years. It can be expected that many of the international operating companies will base a major part of their communications on ISDN. This will be facilitated by the fact that many countries all over the world already today base their PSTN on digital switches. These can be evolved to ISDN with a relatively low additional investment. Such an evolution makes ISDN a world-wide available standard network.

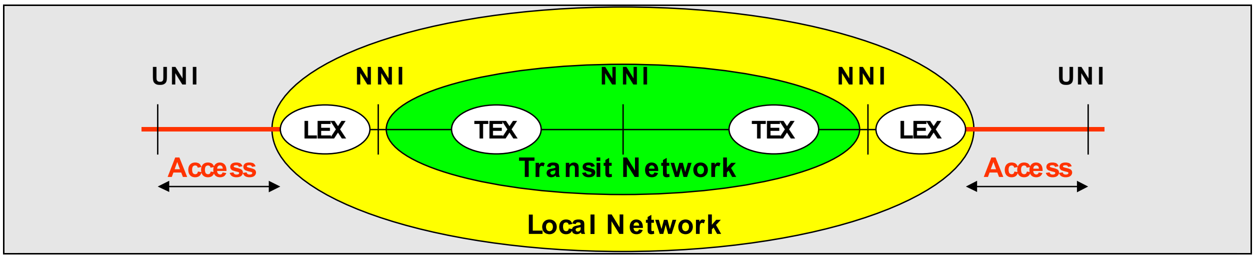
2.2.2 ISDN Services

See corresponding sections 2.8 and 2.10 of this Chapter on services and ITU Standards.

2.2.3 ISDN Reference Configuration

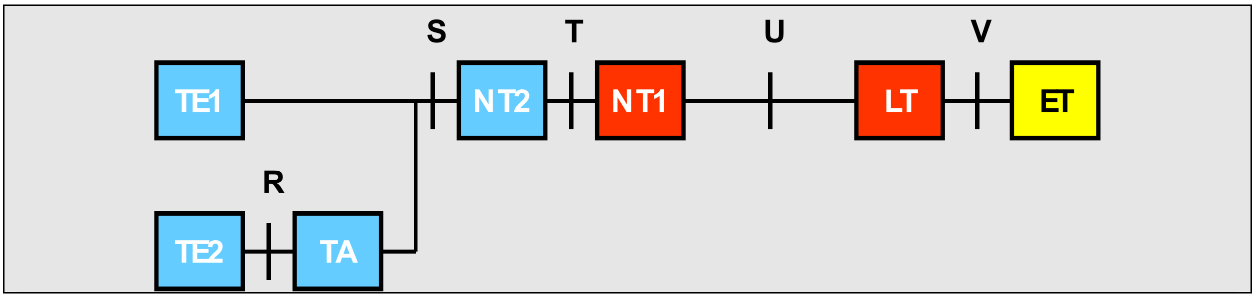
Before describing the reference configuration of the ISDN access in more detail, a survey on the network architecture is given (see Figure 2.2.2). These architectures do not differ from the PSTN structure of digital switching networks. The Local Exchange (LEX) provides an ISDN user with an ISDN Access to the network via a User Network Interface (UNI). Inside the transit network the LEX as well as the Transit Exchange (TEX) offer a Network-Node-Interface. Whether the transit network provides more than one network level is not relevant to the further considerations.

Figure 2.2.2 – ISDN Network Architecture



The ISDN reference configuration shown below structures the access as indicated in Figure 2.2.2 in functional blocks. Each of them is dedicated to a number of functions to be performed. Reference points separate the different functional blocks, Figure 2.2.3.

Figure 2.2.3 – ISDN Reference Configuration



Short description of functional blocks:

Exchange Termination (ET): The ET implements switching functions such as the termination of the signalling channel and the first processing of signalling information.

Line Termination (LT): The LT terminates the transmission line on network side. It contains all functions which are necessary to drive the transmission line (line coding, differentiation of transmission directions etc.).

Network Termination 1 (NT1): The NT1 does the transformation between the transmission interface at the U-reference point and the standardized S_0- or S_{2M}-interface (description below) on the user side. It terminates the public part of the network. Therefore it also provides supervision mechanisms to maintain the access line.

Network Termination 2 (NT2): A typical implementation of the NT2 function is an ISDN PABX. The NT2 function terminates the signalling information and transfers it towards the user respectively network side. For a simple ISDN access the NT2 function is not necessary. In that case the S_0-interface is directly provided by the NT1 at the T-reference point.

Terminal Adapter (TA): The TA performs the adaptation function between non-ISDN terminals (e.g. an analogue telephone) and the ISDN interface. For that reason the TA has to terminate / process the signalling information and to perform the coding/decoding of the user signals.

Terminal 1 (TE1): The terminal type 1 represents an ISDN terminal incorporating all necessary ISDN functions.

Terminal 2 (TE2): The terminal type 2 represents a non-ISDN terminal which can be only linked to the ISDN via a terminal adapter.

2.2.4 ISDN Interfaces

Two different types of ISDN accesses were standardized. A **Basic Access** (BA) offering two B-channels and one D16-channel to the user and a **Primary Rate Access** (PRA) providing 30 B-channels and one D64-channel.

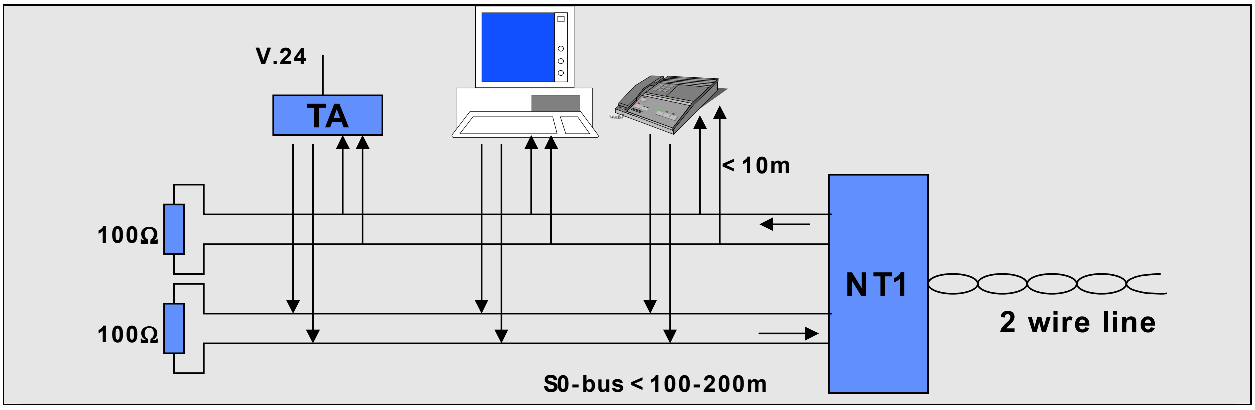
The BA offers a standardized S_0-interface and the PRA a S_{2M}-interface at the network termination towards the user. These interfaces are described in general below.

2.2.4.1 S_0-Interface

Configuration

The S_0-Interface is offered at the T-reference point via the Network Termination 1 (NT1). It is specified as a bus system implemented by two pairs of copper wire. The maximum range of a S_0-Bus is around 100 to 200 m dependent of the type of wires which are used. A connection line of a terminal to the bus shall not exceed 10 m (see Figure 2.2.4).

Figure 2.2.4 – S_0-Bus



Up to eight ISDN Terminals (TE1) or ISDN Terminal Adapters (TA) can be connected to the S_0-Bus. Two of them can be used in parallel each accessing one of the B-channels. The terminals may be ISDN telephones, Group 4 Telefaxes or Data-Equipment like a PC with ISDN Adapter-Card. Additionally, terminals may also use the data packet service offered via the D-channel.

Direct communication between terminals connected to the S_0-Bus is not possible. Such a communication can only be done via the public exchange with all its consequences (charging, both B-channels needed).

D-channel access

To guarantee fair access to the B-channels of the S_0-Bus a D-channel access procedure is defined. In order to detect collisions at the D-channel the D-bits transmitted in an S_0-frame signal (see ITU-T Rec. I.430) are mirrored at the NT1 and sent back in an E-bit to all terminals. If the D-Bit sent out by a terminal is equal to the received E-bit the terminal is allowed to continue. If not, terminal stops the access procedure and starts it again after a time out.

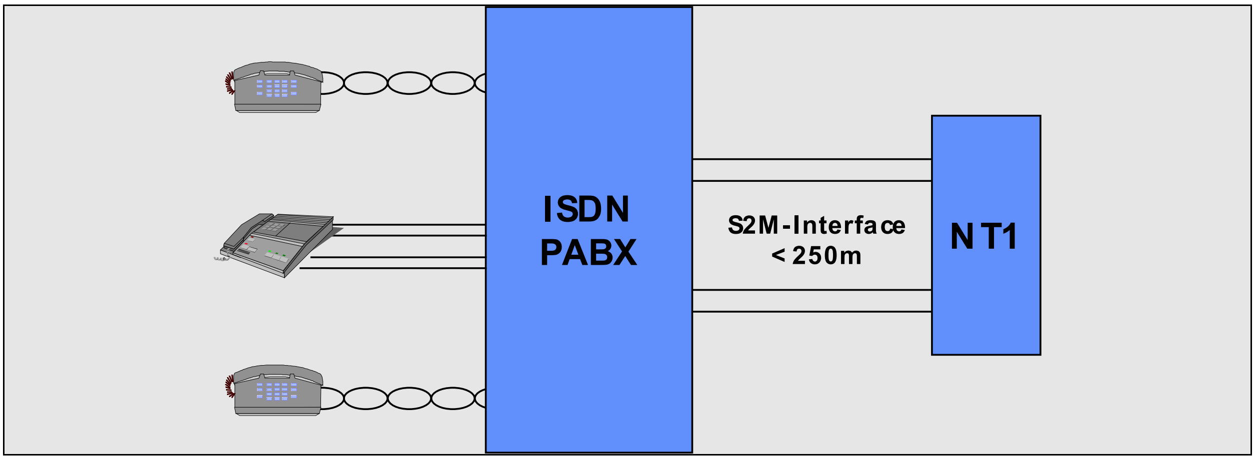
Power modes

Under normal power conditions all the telephone terminals are powered via the NT1. Data equipment and terminal adapters normally have their own power supply. In case of power failure one telephone terminal, which can run in a restricted mode, is powered from the local exchange via the NT1.

2.2.4.2 S_{2M}-Interface

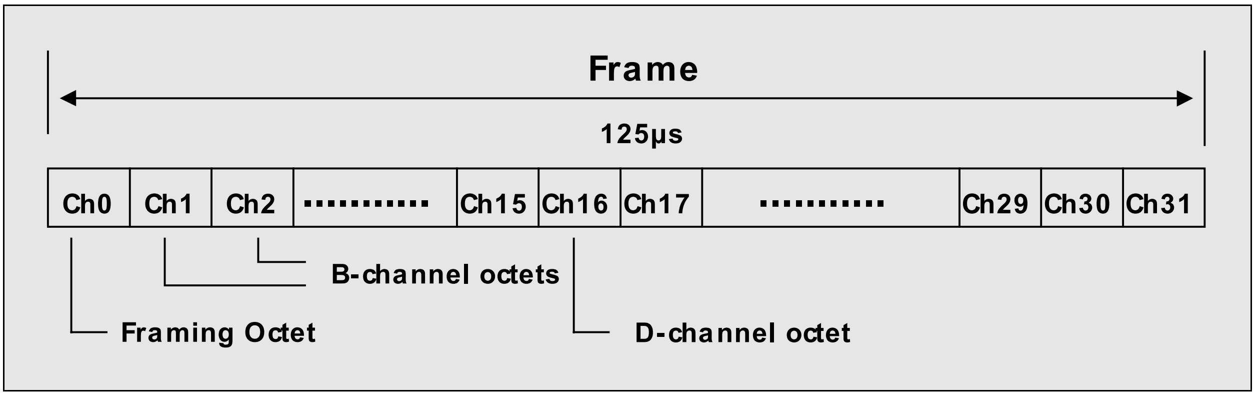
The S_{2M} Interface is a 2 Mbit/s point-to-point interface. It is used to connect ISDN PABXs or Data Equipment (e.g. routers) to the ISDN (see Figure 2.2.5.). The interface offers 30 B-channels to transport user information and one 64 kbit/s D-channel.

Figure 2.2.5 – S_{2M}-Interface



Due to the point-to-point characteristics of the interface no D-channel access mechanism is necessary. It is possible to con the 30 B-channels into bundles using only part of the 30 channels or to assign channels as incoming or outgoing channels only. 2.2.6 shows the channel structure at the S_{2M}-interface

Figure 2.2.6 – Frame Structure of the S_{2M}-Interface



2.2.5 ISDN Signalling Protocols

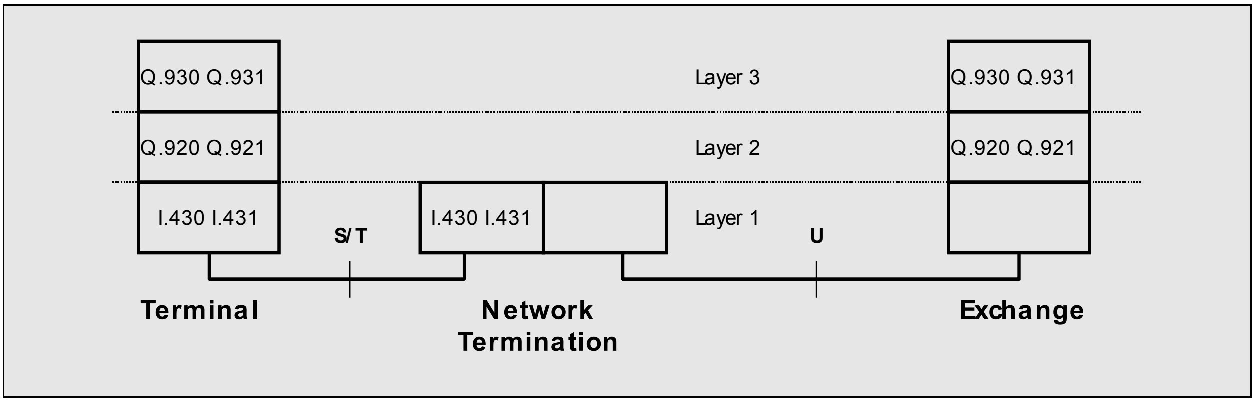
In order to set up or release a connection, or to exchange information during a call, signalling procedures between the ISDN user and the ISDN exchange and between two ISDN exchanges are necessary. In ISDN this signalling information is transported in separate signalling channels – the D-channel in the ISDN access and the SS No. 7 channel between exchanges.

The protocols describing the messages and procedures are the Digital Subscriber Signalling System No.1 (DSS1) on the ISDN access and the Signalling System No. 7 between exchanges. Both protocols are briefly described below.

2.2.5.1 Digital Subscriber Signalling System No. 1 (DSS1)

The DSS1 is based on a layered protocol structure comprising the first three layers of the OSI Layer Model, 2.2.7. Set up or release of a call is performed by an interaction between the different procedures on these three layers. The procedures on the different layers are summarized below.

Figure 2.2.7 – DSS1 Protocol Stack



Layer 1

Layer 1 supports an activated and deactivated state of the S_0-interface. Deactivation results in reduced power consumption but also means that signal synchronization is missing on the interface. A call set up needs to activate the S_0-interface first. Activation can be initialised from both sides – the user and the exchange. The deactivation is initiated by the exchange only.

Layer 2

Layer 2 offers the transport of signalling information between multiple layer 3 entities. It provides one or more data link connections on a D-channel. Signalling messages are transported in a layer 2 frame which requires frame delimiting and alignment functions in layer 2. It further offers frame sequence control, error detection and recovery as well as flow control.

Before starting the signalling procedures of layer 3 layer 2 connections have to be set up.

Layer 3

Layer 3 of DSS1 performs the ISDN Call Control functionality. On this layer messages which are exchanged between signalling entities are defined as well as the procedures for how these messages are exchanged.

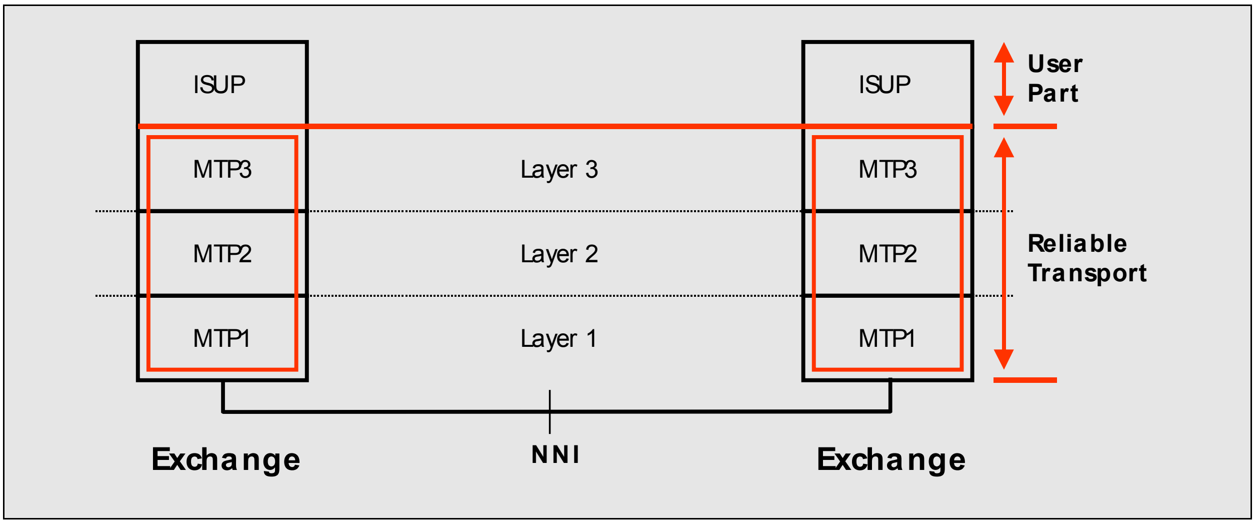
DSS1 lists a number of message types (e.g. SETUP, ALERTing, CONNect, CONNect ACKnowledge, etc.), each of them either used in the different call phases (establish, information, clearing) or to transport miscellaneous call-related or non-related additional information.

Each of these messages is structured in the same way, starting with a header indicating e.g. the message type and followed by a number of mandatory and optional information elements (e.g. dial digits).

2.2.5.2 Signalling System No. 7

Inside the network, Signalling System No. 7 is used to exchange signalling information between the signalling entities. Figure 2.2.8 shows the SS No. 7 protocol stack.

Figure 2.2.8 – SS No. 7 Protocol Structure



The Message Transfer Part (MTP) 1 and 2 provides the same functions as in layer 1 and 2 of the DSS1 stack. This results in physical transmission via a 64 kbit/s No. 7 signalling channel or sets of such channels and the provision of a reliable transport of signalling information in layer 2 across a link. For ISDN the MTP3 extends these functions to support a reliable transport between network nodes (facilitating multiple links between nodes operating in load sharing, transfer of signalling information, etc.).

For ISDN No. 7 transport network is used by the ISDN User Part (ISUP) Protocol, which is the ISDN specific protocol. The functions of ISUP can be compared to those of DSS1 layer 3 functions plus some network specific additions (e.g. adding of Echo-Cancelling function in a long distance connection, etc.).

2.3 Intelligent networks

2.3.1 Intelligent Network concepts and requirements

- *General*

Telephone customers are continually seeking higher quality and more sophisticated services as well as enhanced ease of use in both developed countries and developing countries. These trends have been helped along by requests for telephone services comparable to those available in other countries. Many countries are now introducing Intelligent Network (IN) systems to meet customer demands quickly and economically.

Meanwhile, cellular systems and digital cordless systems are being spotlighted in developing countries as Wireless Local Loop (WLL) systems for the provision of universal telephone services. Also, these systems operate under IN.

Furthermore IN is to offer traffic, charging information and so on by editing and processing administration information collected in the network, such as time-frame, user identification and location, and number of calls.

For the introduction of new services, expansion of basic telephone services, interconnection of various networks and enhancement of operation functions, IN is becoming a key issue in architecture technology.

- *Concept*

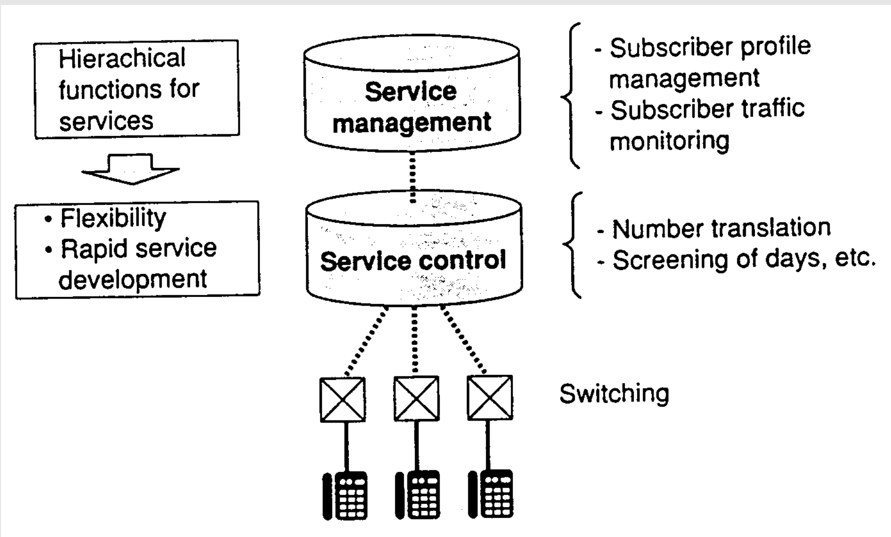
IN will make it possible to implement various advanced services quickly and easily under a multi-vendor environment and also to advance the operation for such services. IN architecture is basically composed of a service control function (SCF) and a service switching function (SSF).

The SCF can be located at a centralized node in the network separated from a switch. It analyses a customer's request, and sends appropriate instructions to the SSF. The SSF is usually located in a switch. It executes the actual call processing according to the instructions received from the SCF.

To attain efficient service development using IN architecture, it should be ensured that it is not necessary to develop an SCF or an interface between the SCF and the SSF when developing an individual service. To achieve this independence, the SCF is designed so that a service can be created by simply combining service-independent functional components (Figure 2.3.1). To ensure that the Interface between the SCF and the SSF works for every vendors' switch, it is designed based on a universal switch model.

The IN architecture thus makes it possible to implement a service by simply installing a service scenario into the SCF.

Figure 2.3.1 – Intelligent Network Concept



- *Requirements*

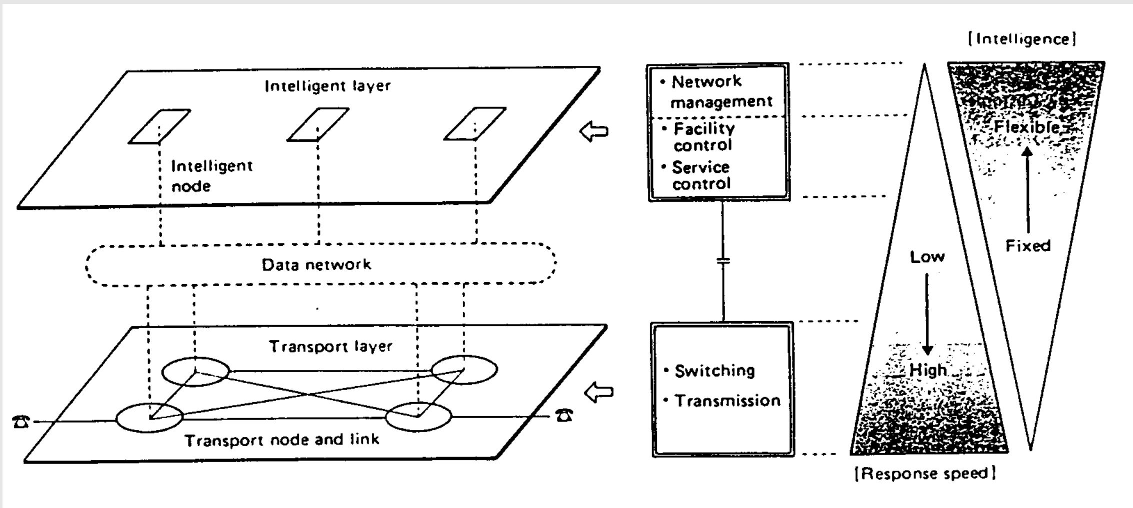
Customer expectations are now far more diverse, demanding convenience and higher quality services at a lower cost. Ultimately, the customer will want to control services himself. But at the same time, the customer will want to make requests to the network that will cause the network, in response, to alter service specifications.

The basic concept underlying the network business is to satisfy customer requirements and provide various services at lower costs. To achieve this, networks must be open to the incorporation of rapidly proliferating technical innovations. In other words, the network should be changed so that the best possible network facilities can be accommodated. To be able to offer services at competitive costs and to assure sound management of the network business, facilities and operations should be introduced at the lowest cost possible.

Demands to be able to offer services at lower operational costs and still satisfy customer requirements, underscores the need for a highly stable and reliable network.

To be able to construct telecommunications networks that will respond to these requirements effectively it is very important to define a unified network architecture concept. As shown in Figure 2.3.2, network functions can be divided into two broad layers: the Transport Layer for transport and connections, and the Intelligent Layer for service and facilities control as well as network management functions. In addition, segmented, standardized network functions must be allocated to the nodes making up each layer, that are interconnected by a standardized interface. This is a basic concept for future network construction.

Figure 2.3.2 – Network Architecture (Intelligent Layer and Transport Layer)



Advantages of IN:

From the viewpoints of customers, operators and manufactures, advantages and benefits of IN are as follows.

Customer's viewpoint

a) Customers can enjoy various kinds of services.

b) Customers can control service specifications by themselves.

c) Customers can get their service operation information.

Operator's viewpoint

a) Operators can provide various kinds of services quickly and economically.

b) Operators can accomplish service management efficiently.

c) Operators can reduce procurement costs by creating a multi-vender environment.

Manufacturer's viewpoint

A) Manufacturer's can seek to expand their market share by standardization

2.3.2 Considerations on the introduction of IN services in the network

- *Essential Technologies*

The technology required to create advanced telecommunications services can be divided into three areas: digital switching systems, the No. 7 common channel system, and intelligent nodes. These three technologies are essential to enhancement of telecommunications services.

a) Digital Switching System (Transport Layer)

Telecommunications through a public telephone network connects callers by using a switching system. Stored program control in a digital switching system is a first step in network evolution.

b) Signalling System No. 7 (Data Transport Network)

Signalling System No. 7, used to communicate information between digital switching systems, is an important technology for advanced telecommunications services. Networks have previously only been able to send dialled digits to called party switching systems when connecting a call. However, by using Signalling System No. 7, networks will be able to send more information. For instance, caller ID information can be sent to a called party switching system while the call is connected. Furthermore, Signalling System No. 7 is used to exchange information between intelligent nodes.

c) Intelligent Node (Intelligent Layer)

A third powerful component is the intelligent node. When allocating service control data at the local switching systems, it is difficult to offer network-wide services. Accordingly, service control should be managed in centralized intelligent nodes. If the software and other technologies necessary to implement these services are built into each local exchange, the call processing overhead will be too great for the switching system, and switching capacity will soon be used up. Moreover, demands to continually develop and introduce new switches embodying each new advanced technology would force an unbearably heavy burden on the R & D of common carriers. Each time service specifications are changed, it would become necessary to develop new kinds of switching systems. Accordingly, as a basic minimum, essential and common functions for service provision should be allocated to the switching system. All other advanced functions for diverse types of services will need to be implemented at the intelligent node.

As shown in Figure 2.3.1, the intelligent node has two functions, i.e. the service management function and the service control function. The processor which accommodates the service control function acts on call and communicates with the switching systems by using Signalling System No. 7. General purpose computers can be applied to the service control function and also to the management function. The service management function acts mainly as a data-base.

- Evolution of Basic Network Functions

Future services will consist of six basic functions: (a) analysing dial numbers; (b) charging; (c) connection processing; (d) transport network information; (e) interfaces for network extremities; (f) customer control. Therefore, by developing segments which are composed of these basic network functions, and by strategically allocating segmented functions to network nodes, it becomes possible to rapidly provide flexible telecommunications services. Features for development as part of each function will be as follows:

a) Dial number analysing: changing a special number (logical number)

b) Charging: devising a special charging system different from the existing system.

c) Connection processing: offering special connections different from existing ones, such as advanced call transfer, multiple connection, wide area line hunting, call screening, etc.

d) Transport network information: transporting such information within the Transport Layer or between the Transport and Intelligent Layers as caller ID, or busy signal notification.

e) Interfaces for network extremities: a high-level interface to connect with customers, processing nodes, and other carriers.

f) Customer control: network management information; changing or indicating service specification by customer. Soon, service definition by customer will be available.

2.3.3 IN functions and capability sets

IN-based information handling services comprise two main functional areas.

The IN service call handling functionality involves real-time processing of transient data, i.e. those data items that are only valid for the duration of the respective call. These functions are supported by the communications network in cooperation with SCPs (Service Control Points) which are interrogated during the call for the information to perform the service application.

The IN service management functionality deals with semi-permanent data, i.e. those data items defining the service applications with its parameters and features. The management of the related functions and objects is seen to be embedded into the Telecommunication Management Network (TMN) service management layer, while the individual call handling will be the task of the managed network.

A common set of application functions and application service components will be created to support IN service management and TMN in a consistent way. This allows services to be created by all user groups of TMN/IN (including customers) according to their respective needs and depending on their respective access rights granted by the TMN/IN operator.

Typical examples for services to be supported by extensive usage of the 'Intelligence in the Network' are:

– free-phone options of the service 800 type;

– transaction options of the service 900 type;

– alternate billing features;

– individual emergency calls;

– universal roaming subscribers (URS);

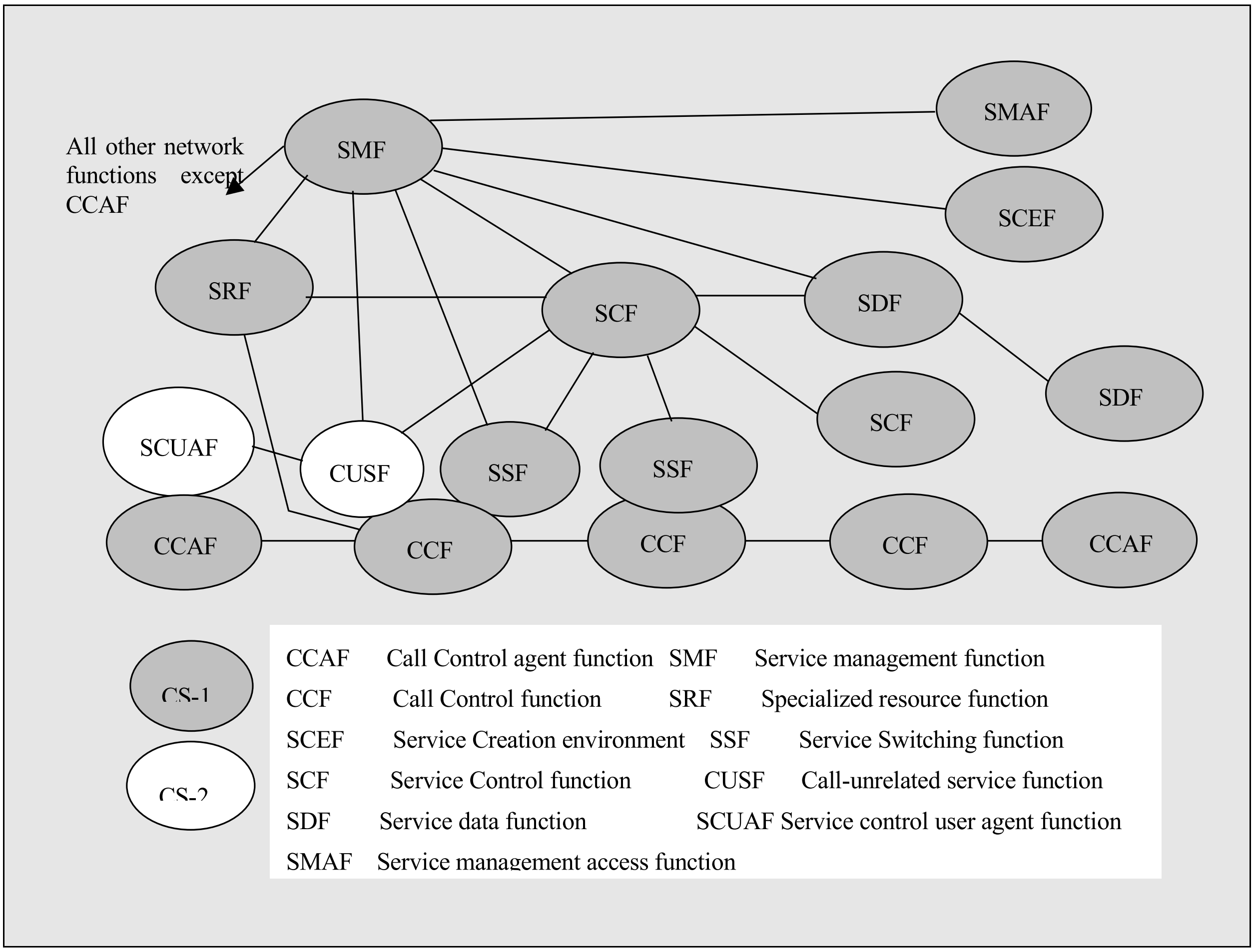
– credit card verification;

– virtual private networks;

– wide area CENTREX.

Especially these sophisticated services rely on underlying service components and functionalities in the telecommunication network itself as well as in the TMN.

Figure 2.3.3 – IN functions and functional relationships



Intelligent Network Capability Set 1 (IN CS-1) (see Table 2.3.1) is the first standardized stage of the intelligent network (IN) as an architectural concept for the creation and provision of telecommunications services.

Intelligent Network Capability Set 2 (IN CS-2) is the second standardized stage of the Intelligent Network (IN) as an architectural concept for the creation and provision of services, including telecommunication services, service management services and service creation services, shown in Table 2.3.2, 2.3.3 and 2.3.4.

The implementation of the IN architecture will facilitate the rapid introduction of new services. Its architecture can be applied to various types of telecommunications networks, which include: public switched telecommunications network (PSTN), public switched packet data network (PSPDN), mobile, and integrated services digital networks (N- and B-ISDN).

Table 2.3.1 – Target set of CS-1 services

Abbreviated dialling (ABD) Account card calling (ACC), Automatic alternative billing (AAB), Call distribution (CD), Call forwarding (CF), Call rerouting distribution (CRD), Completion of call to busy subscriber (CCBS), Conference calling (CON), Credit card calling (CCC), Destination call routing (DCR), Follow-me diversion (FMD), Freephone (FPH), Malicious call identification (MCI), Mass calling (MAS), Originating call screening (OCS), Premium rate (PRM), Security screening (SEC), Selective call forward on busy/don't answer (SCF), Split charging (SPL), Televoting (VOT), Terminating call screening (TCS), Universal access number (UAN), Universal personal telecommunications (UPT), User-defined routing (UDR), Virtual private network (VPN)

Table 2.3.2 – Target set of CS-2 telecommunication services

Telecommunication services	Internetwork Freephone (IFPH), Internetwork Premium rate (IPRM), Internetwork Mass calling (IMAS), Internetwork televoting (IVOT), Global Virtual Network Service (GVNS), Completion of Call to Busy Subscriber (CCBS), Conference calling (CONF), Call Hold (HOLD), Call Transfer (CT), Call Waiting (CW), Hot line (HOT), Multimedia (MMD), Terminating Key Code Screening (TKCS), Message Store and Forward (MSF), International Telecommunication Charge Card (ITCC), Mobility services (UPT)

Table 2.3.3 – Target set of CS-2 service management services

Service customization	Telecommunications Service Customization (TSC), Service Control Customization (SCC), Service Monitoring Customization (SMC)
Service control	Subscriber Service Activation/Deactivation (SSAD), Subscriber Monitoring Activation/Deactivation (SMAD), Subscriber Profile Management (SPM), Subscriber Service Limiter (SSL), Subscriber Service Invocation (SSI)
Service monitoring	Subscriber Service Report (SSR), Billing Report (BR), Subscriber Service Status Report (SSSR), Subscriber Traffic Monitoring (STM), Subscriber service Management Usage Report (SMPUR)
Other management	Subscriber Service Testing (SST), SMP Usage Report (SUR), Subscriber Security Control (SSC)

Table 2.3.4 – Target set of CS-2 service creation services

Service specification	Feature interaction detection, Cross-service feature interaction detection, Feature interaction rule/guidelines generation, Service and SIB cataloguing Created service resource utilization
Service deployment	SMP-created service data and SLP update, Service distribution, SIB distribution, Data rule distribution, Feature interaction rule distribution, Creation interface selection, Creation initiation, Editing, Combining, Data population rule generation, SMP service creation
Multiple SMP support	Network tailoring, Network element capability specification, Network element function/capability assignment
Service creation management	SCE access control, SCE usage scope, SCE recovery, SCE release management, SCE capability expansion, SCE conversion, Cross-SCE service maintenance, SCE-to-SCE system consistency, SCE service/modular/system transference, Conversion of created services, Service management interaction
Service verification	SCE testing, Created service simulation, Created service live testing

2.3.4 Reference Points and Interfaces

A reference point describes the information flow between two conceptual building blocks of a reference configuration. It now seems generally agreed that the preferred method is to specify the so called 'shared conceptual scheme' i.e. the collection of objects seen on both sides of the reference point and the operations that can be performed on these objects across the reference point.

An interface is the physical implementation of a reference point. It consists of a Message or (M) component inherited from the reference point definition, i.e. objects and operation performed on them, and a Protocol or (P) component describing the protocol stack used to transfer the information across the physical medium.

The following reference points and their implementation as interfaces will be necessary for the deployment of IN services:

- The reference point between basic call and connection control, (usually resident in the local exchange), and the advanced service control, (which may reside in the local exchange or other remote device).

The former corresponds to the SSF, CCF and CCAF conceptual blocks in Figure 2.3.3 the latter to the remaining blocks. When implemented as an interface, Signalling System No. 7 is likely to be utilized for information transport ((P) component); the (M) component remains, as yet, undefined.

- The reference point between the service control block and the service management block. Here, Service Management is considered to be a part of the TMN, whereas Service Control is part of the managed network.

Consequently it is the Q3 reference point, as defined in ITU-T Rec. M.3010, which, when implemented, becomes a Q3 Interface. Also of importance, is the reference point/interface between the IN Service Management and the rest of the TMN, in particular, the Network Management layer in the sense of the BT model. Since these may belong to different areas of responsibility, implemented on machines belonging to different operators, the X Reference Point/X interface has to be chosen. It is considered to be like Q3/Q3 with additional security features.

2.3.5 IN Conceptual Model – Global Functional Plane

The Global Functional Plane is a perspective under which specifications describe the view of an "IN-Structured Network" as offered to a service designer. This service designer may also be the IN Customer. This view describes the objects that the service designer can handle (create, delete, modify, associate to other objects) in order to build or 'customize' services for a closed set of users, for instance, a group who belong to a Virtual Private Network.

The description of a service based on these objects, called "Service Independent Building Blocks" or SIBs is called SERVICE LOGIC. The distribution of these objects and their implementation over an IN structured network is hidden to the service designer.

An object oriented approach may be taken: the objects will be named, contain a closed set of variables – each variable having a closed set of values, modified by a closed set of operations, strictly associated to the object. The definition of an object may refer to previously defined objects.

Some examples of these objects are shown in Table 2.3.5.

Table 2.3.5 – IN Managed objects

OBJECT	Operations on this object (parameters are not listed):
SIBs	create, delete, authorize, assign values to attributes:
VPN	re-name (complex object) …
USER	assign name, location, assign to VPN, modify rights …
GREEN NUMBER	modify, assign serving users, …
ORIG. AREA	declare, assign serving user in a "Green number" …
ANNOUNCEMENT	modify, assign triggers, assign answers …
LOCATION REG	assign a user (= allow its mobility), check, …
ACCOUNT NUMBER	assign to user or to VPN, …
SERVICE LOGIC	create, modify, delete, simulate, verify, …

2.3.6 Future role of the IN

In the Information Technology and Internet Protocol worlds quite a few misconceptions exist on Intelligent Networks. The most common one is that IN is 'something of the old world' and that it is strictly linked to public, switched circuit and SS No. 7 controlled networks. Although this is often the case today, IN has all the elements to be more than a 'computer outside the switch with SS No. 7 on it'…

- IN spans multiple networks: Already today, the scope of Intelligent Networks is no longer limited to the fixed PSTN. With the advent of wireless networks, IN has gradually taken care of a wide range of mobile and fixed-mobile converged (FMC) services. This expansion will continue further and result in data services and fixed-mobile-data convergence. As such, the IN philosophy, (software building blocks and network elements) will be re-used to offer similar services on switched circuit and packet networks.

In the case of mobile networks, the IN 'protocol suite' of ISUP and INAP has been complemented with other protocols such as MAP, IS41 and Camel, and the expansion into the IP world will allow the IN to adopt other new protocols such as RADIUS, H.323, SIP, WAP, etc.

- IN is a toolbox for building services on any network: Independently of the network one is building services for, there are a number of common building blocks.

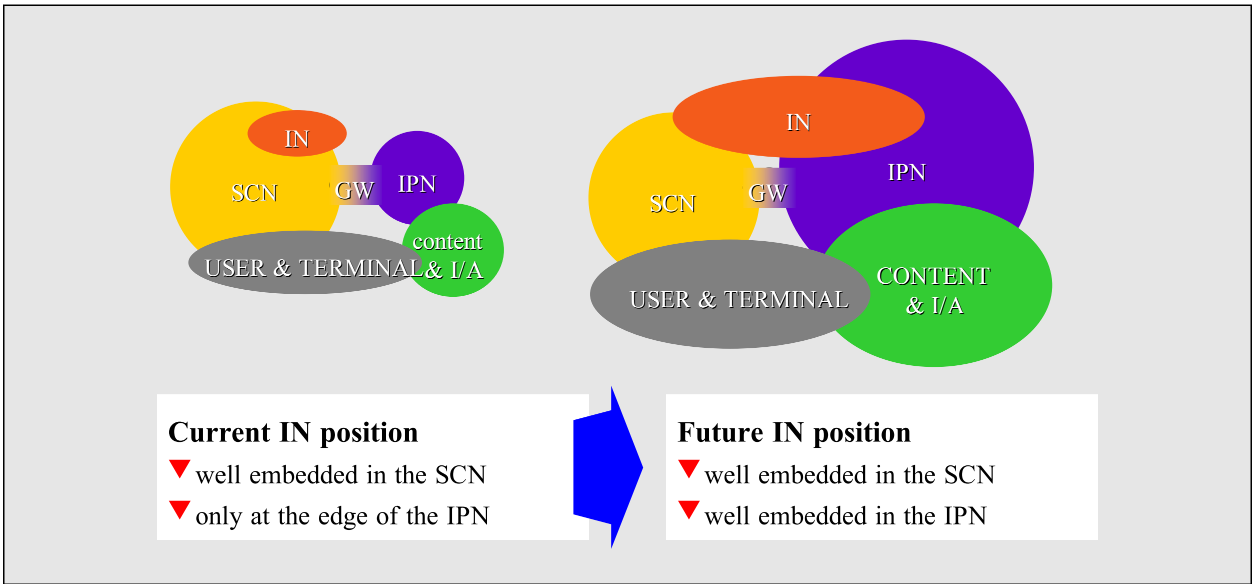
One example is the communication between the service and its user. From a functional point of view, there is no difference in implementing this communication using a Specialized Resource Point[1], generating voice and accepting DTMF (as is the case with most of today's voice services), or using a Web server (which is also to be considered as a specialized resource function) exchanging information using HTML forms or Java applets.

Other examples of IN building blocks spanning many networks are those providing connectivity (between users and services), management (network and service), charging and billing, terminal access, etc. The IN is to be considered as the toolbox for combining and integrating these building blocks into useful and revenue generating services.

- IN is an ever growing range of user oriented services: Today, a wide variety of IN services are available, generating revenue for network operators and service providers on a daily basis. With the advent of the Internet, the scope of services and applications is expanding (see Figure 2.3.4), and the IN will follow this trend.

For example, in the near future, further Intelligent Network platforms will be able to handle new applications, providing services to both the (IP) networks and the end-users.

Figure 2.3.4 – Services evolution



Together with the convergence stages there are a number of action domains in which new IN services will be developed and offered.

- Convergence services: When combining "the best of both worlds" there are opportunities to offer innovative new services, using the capabilities of both the PSTN and the Internet. As the IN is located at the most strategic position in the network (i.e. controlling the line that connects the PSTN subscriber with the Internet Access Provider), it is ideally positioned to offer a wide range of value added services, targeted at all players, ranging from Users/Subscribers ('web surfers'), to Network Operators and Internet Access and Corporate/Value Added Service Providers.

[1] The term "Specialized Resource Point" (SRP) is preferred to "Intelligent Peripheral" (IP) because of the latter's ambiguous abbreviation in an Internet context.

- Voice-over-IP services: Although today's VoIP usage is still driven by the lack of regulation of IP Telephony calls (e.g. VoIP allows users to make a long distance call for the price of a local one), market analysts agree that tomorrow's market will only be able to flourish through the presence of Value Added Services for the end-user.

As such, the availability of a powerful intelligence infrastructure with appropriate services (including both "traditional" voice services and new "convergence services" such as Click-to-Dial, Web Call Centres, etc.) is to be considered as a major asset for any operator that aims to benefit from the data wave.

– Native IP services: In the IP network, the intelligence is distributed over different components (most of them implemented at the edge of the IP network or even in the user's terminal);
– Authentication, Authorization and Accounting (AAA) servers, communicating with the Remote Access Nodes using RADIUS, TACACS, RAS, etc.;
– VoIP Gatekeepers, communicating with the Gateways using H.323, SIP, etc.;
– (LDAP based) Directory and Domain Name Servers (DNS);
– Routing tables and policy databases;
– Content and transaction servers (HTTP, FTP, etc.);
– Client applications for Dial-up (PPP), VoIP (e.g. MS Netmeeting), Internet browsing (e.g. MS Explorer, Netscape), Java applets, etc.;
– Web based provisioning and management: Personalized and dynamic service provisioning and management is a key-differentiator for operators in a liberalized telecom market. A Web interface brings full flexibility to the desk of the existing subscriber and a "billboard" to the potential subscriber.

More information on IN services can be found in the Section 2.9 of this Chapter.

2.4 Packet switched network

2.4.1 Introduction

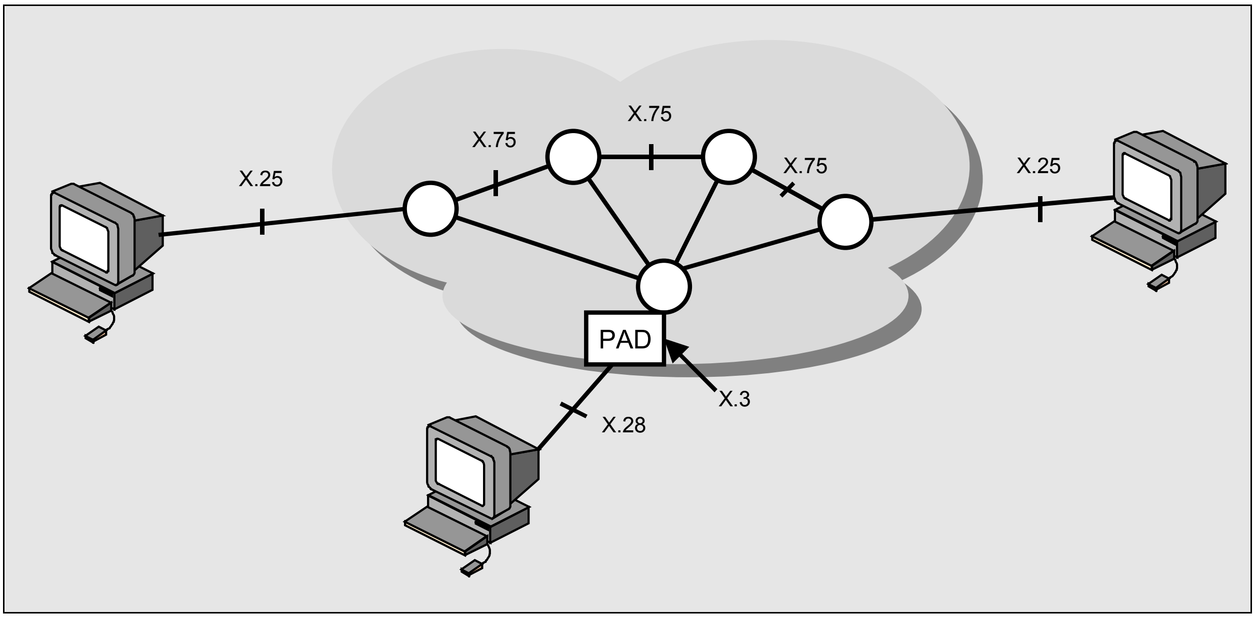
Packet Switched network technology has been utilized for a single switched communication link to access databases for multiple users simultaneously, cost-effectively and securely. Sharing network facilities with other users reduces the number of lines and modems typically needed to connect a wide area of audience with existing information resources.

Packet switching technology involves the segmentation of a data stream into packets. Packets from many users are intermixed on the same network facility. The packet network supports access through dial-up modems, ISDN and dedicated private lines. Over the last several decades, packet switching technology has evolved into a data-transport platform for statistical multiplexing of low-speed user traffic across large distances and today forms the basis of many advanced data communications networks. To begin communication, one computer calls another to request a communication session. The called computer can accept or refuse the connection. If the call is accepted, the two systems can begin full-duplex information transfer. Either side can terminate the connection at any time.

2.4.2 X.25 Basic Structure

The X.25 specification defines a point-to-point interaction between data terminal equipment (DTE) and data circuit-terminating equipment (DCE). DTEs (terminals and hosts in the user's facilities) connect to DCEs (modems, packet switches, and other ports into the PDN, generally located in the carrier's facilities), which connect to packet switching exchanges (PSEs, or simply switches) and other DCEs inside a PSN and, ultimately, to another DTE. The relationship between the entities in an X.25 network is shown in Figure 2.4.1.

Figure 2.4.1 – X.25 Model



A DTE can be a terminal that does not implement the complete X.25 functionality. A DTE is connected to a DCE through a translation device called a packet assembler/disassembler (PAD). The operation of the terminal-to-PAD interface, the services offered by the PAD, and the interaction between the PAD and the host are defined by ITU-T Recommendations X.28, X.3, and X.29, respectively.

2.4.3 Packet Transmission Principles

End-to-end communication between DTEs is accomplished through a bi-directional association called a virtual circuit. A virtual circuit (VC) characterizes an end-to-end logical link between two DTEs (Figure 2.4.2).

The switched virtual circuit technique allows for the multiplexing of several simultaneous communications on the same physical access link between the subscriber and the network.

Each of the virtual circuits are identified by a logical link number when the communication is set-up.

Virtual circuits permit communication between distinct network elements through any number of intermediate nodes without the dedication of portions of the physical medium that characterizes physical circuits. Virtual circuits can either be permanent or switched (temporary). Permanent virtual circuits are commonly called PVCs. Switched virtual circuits are commonly called SVCs. PVCs are typically used for the most-often-used data transfers, while SVCs are used for sporadic data transfers.

Once a virtual circuit is established, the DTE sends a packet to the other end of the connection by sending it to the DCE using the proper virtual circuit. The DCE looks at the virtual circuit number to determine how to route the packet through the X.25 network. The Layer 3 X.25 protocol multiplexes between all the DTEs served by the DCE on the destination side of the network and the packet delivered to the destination DTE.

The data is transmitted in blocks that are called packets (32 to 256 bytes). Each data packet is preceded by a header (3 bytes) containing the service information used, in particular, to route the packet through the network. After reception, the packets are released from their envelope and reassembled so that the initial data flow is formed once again.

Figure 2.4.2 – Virtual Circuits

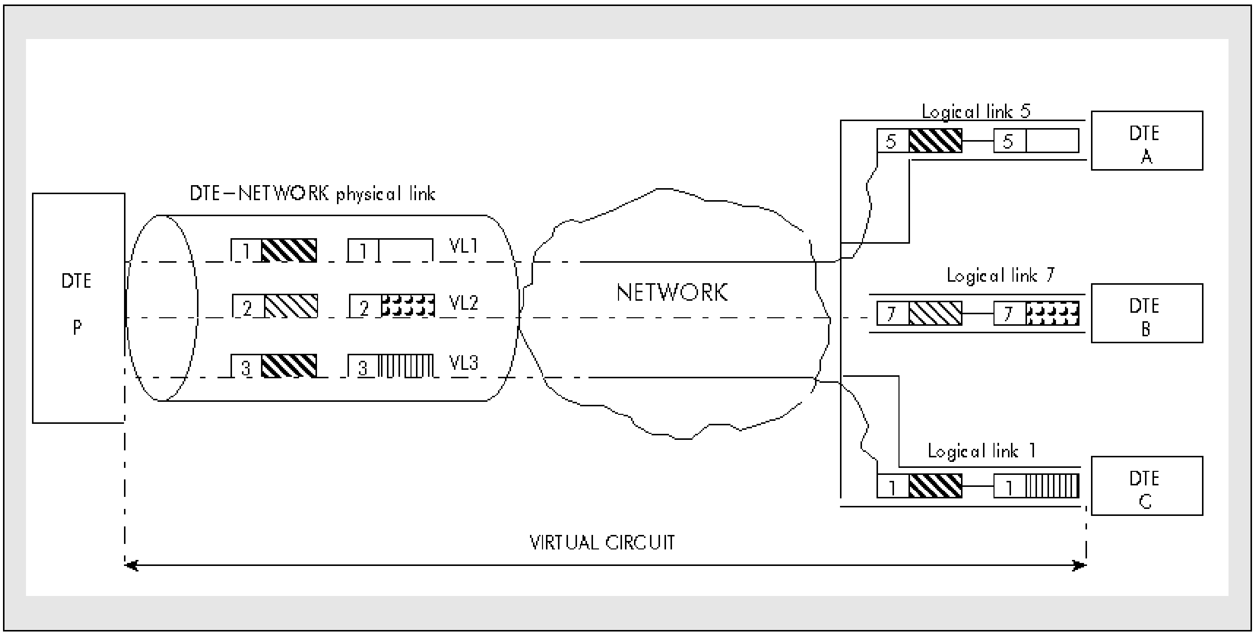
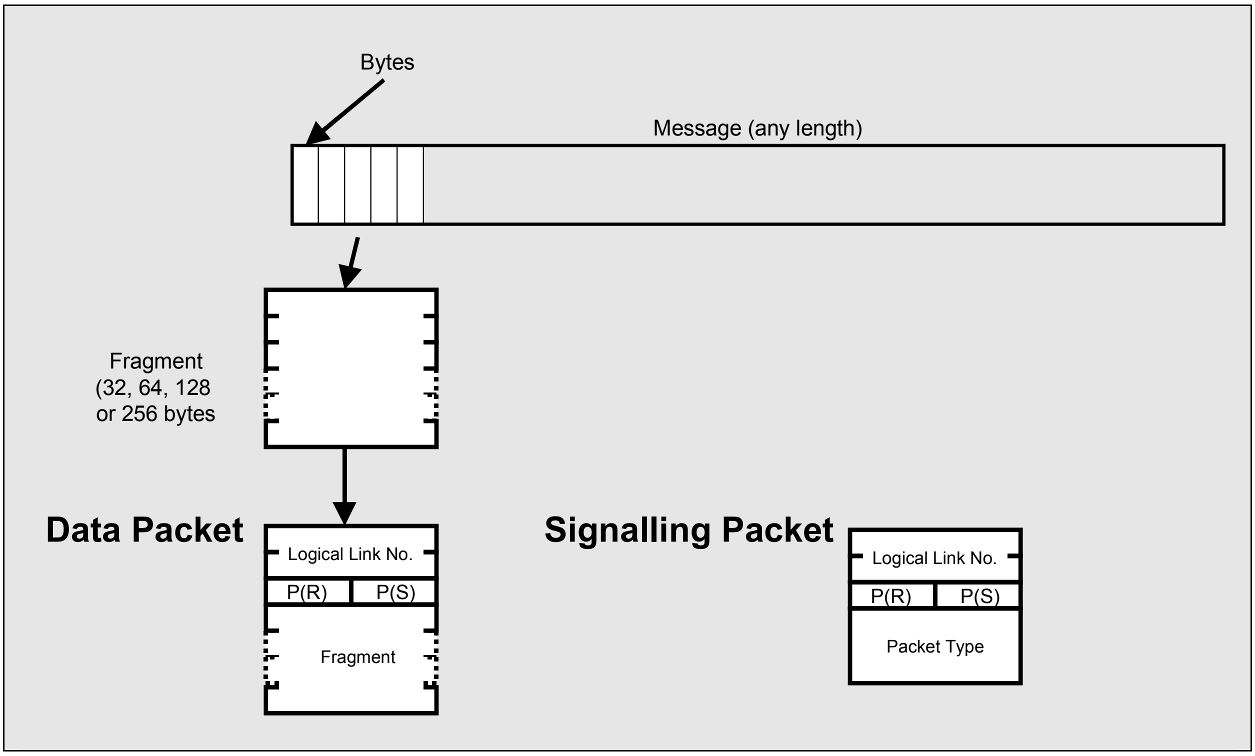


Figure 2.4.3 – Packet constitution



The frames are numbered modulo 8 (standard) or 128 (extended). Frames sent by one extremity of the link must be acknowledged by the other extremity. The procedure offers the possibility of anticipating the acknowledgements: each extremity can send a series of information frames (maximum 7 or 127 according to the case) without waiting for the acknowledgement of the first one. This device avoids dead time between frames and thus transmits at maximum speed.

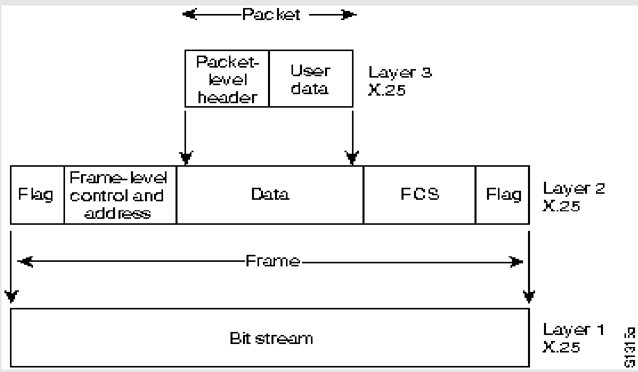
The number of frames that can be sent without reception of the acknowledgement of the first one is a parameter of the procedure and bears the name " frame window".

2.4.4 X.25 Layers

The X.25 specification maps to Layers 1 through 3 of the OSI reference model. Layer 3 X.25 describes packet formats and packet exchange procedures between peer Layer 3 entities. Layer 2 X.25 is implemented by Link Access Procedure, Balanced (LAPB). LAPB defines packet framing for the DTE/DCE link. Layer 1 X.25 defines the electrical and mechanical procedures for activating and deactivating the physical medium connecting the DTE and the DCE.

An X.25 frame is composed of a series of fields, as shown in Figure 2.4.4. Layer 3 X.25 fields make up an X.25 packet and includes a header and user data. Layer 2 X.25 (LAPB) fields include frame-level control and addressing fields, the embedded Layer 3 packet, and a frame check sequence (FCS).

Figure 2.4.4 – X.25 Frame



Layer 3

Layer 3 X.25 uses three virtual circuit operational procedures:

– Call set-up
– Data transfer
– Call clearing

The packet level handles:

– the establishment and release of the VCs,
– control of the data transfer on each VC,
– addressing between network subscribers,
– fragmentation and re-assembly of the data by 32, 64, 128 or 256 byte segments,
– flow control by packet numbering, and
– communications multiplexing on the same physical medium by numbering or logical link.

Execution of these procedures depends on the virtual circuit type being used. For PVC, Layer 3 X.25 is always in data transfer mode because the circuit has been permanently established. If SVC is used, all three procedures are used and X.121 addresses (IDN, International Data Number) have to be used in addressing fields in call set-up packets. X.121 addresses vary in length and can be up to 14 decimal digits long.

Packets are used to transfer data. Layer 3 X.25 segments and reassembles user messages if they are too long for the maximum packet size of the circuit. Each data packet is given a sequence number, so error and flow control can occur across the DTE/DCE interface.

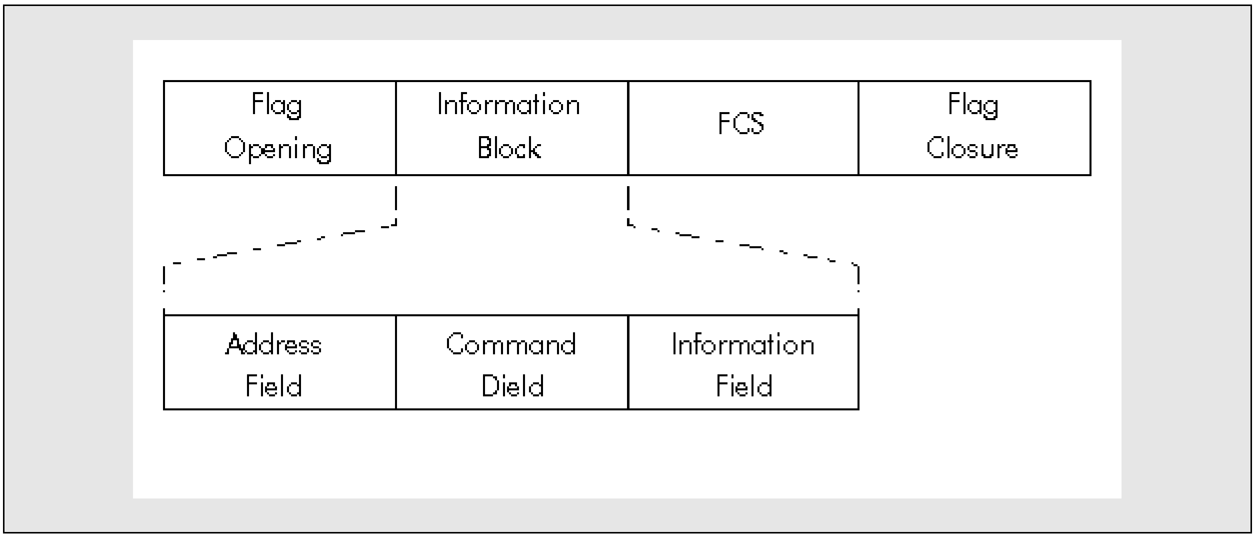
Layer 2

Frame structure is shown in 2.4.5. Layer 2 X.25 is implemented by LAPB. LAPB allows both sides (DTE and DCE) to initiate communication with the other. During information transfer, LAPB checks that the frames arrive at the receiver in the correct sequence and error-free.

As with similar link-layer protocols, LAPB uses three frame format types:

- Information (I) frame: These frames carry upper-layer information and some control information (necessary for full-duplex operation). Send and receive sequence numbers and the poll final (P/F) bit perform flow control and error recovery. The send sequence number refers to the number of the current frame. The receive sequence number records the number of the frame to be received next. In full-duplex conversation, both the sender and the receiver keep send and receive sequence numbers. The poll bit is used to force a final bit message in response; this is used for error detection and recovery.
- Supervisory (S) frames: These frames provide control information. They request and suspend transmission, report on status, and acknowledge the receipt of I frames. They do not have an information field.
- Unnumbered (U) frames: These frames, as the name suggests, are not sequenced. They are used for control purposes. For example, they can initiate a connection using standard or extended windowing (modulo 8 versus 128), disconnect the link, report a protocol error, or similar functions.

Figure 2.4.5 – Frame Structure



All the frames must start and end with a frame delimiter sequence called the flag (Figure 2.4.5). The flag is used for frame synchronization. The flag is the only frame element that can contain six consecutive 1s. If the user data should generate such a sequence, the procedure automatically inserts a 0 after the fifth 1.

Information block contains Address, Command and Information Fields. This is the sequence of bits to be delimited and protected from errors.

The FCS (Frame Check Sequence) field contains 16 bits calculated by the sender from fields A, C and I.

On reception, the recipient of the frame uses the same calculation algorithm and compares with the value of the received FCS. In this way, it can detect the transmission errors and request re transmission of the erroneous frames. The FCS:

– Is based on the Cyclic Redundancy Check (CRC) of 16 bits.
– Detects all the packets with one, two or three erroneous bits.
– Detects any error occurring every 16 bits or less.
– Detects any error occurring every 17 bits except the CRC.
– Detects all the odd numbers of the erroneous bits.
– Detects 99.998% of all other possible errors.

Layer 1

Layer 1 X.25 uses the X.21bis physical-layer protocol, which is roughly equivalent to EIA/TIA232C (formerly RS-232-C). X.21bis was derived from ITU-T Recommendations V.24 and V.28, which identify the interchange circuits and electrical characteristics (respectively) of a DTE to DCE interface. X.21*bis* supports point-to-point connections, speeds of up to 64 Kbit/s, and synchronous, full-duplex transmission over four-wire media. The maximum distance between DTE and DCE is 15 meters.

2.5 Frame relay

2.5.1 Introduction

Frame Relay network technology is designed to support users who need increased bandwidth for internetworking local area networks. Frame Relay is also designed to support users who need reduced delay for their transmissions. The technology is so named because most of the operations occur at the frame layer (layer 2) of OSI (Open System Interconnection). The basis for Frame Relay is HDLC (High Data Link Control) and HDLC-derived protocols such as LAPD (Link Access Procedure for D channel) and V.120.

Frame Relay was originally conceived as a protocol for use over ISDN interfaces. It also can be implemented on existing packet switching equipment.

Frame Relay is a system of transferring data at the data link layer level. Frame Relay is the same type of protocol as X.25. However, Frame Relay differs significantly from X.25 in its functionality and format. In particular, Frame Relay is a more streamlined protocol, facilitating higher performance and greater efficiency.

Frame Relay operates with the assumption that the network is quite reliable and fast. It also operates on the premise that end users' machines have considerable processing power as well as the software necessary to recover from occasional failures that might occur within the network itself.

Frame relay does not perform error correction. Rather, it performs a simple CRC check at each FRX node. If the packet is found to have errors it is discarded. Frame relay does not guarantee the delivery of packets, but it does guarantee that if the packet reaches its destination, it is error free.

Frame relay is an example of a connection-oriented protocol. It differs from connectionless protocols in that all packets for a particular virtual connection follow the same path through the network. By sending the packets over the same path, arriving packets are always in the correct order.

Frame Relay uses many of the concepts of X.25, such as statistical time division multiplexing, including the concept of the virtual circuit.

Frame relay supports two types of circuits:

- Switched Virtual Circuits (SVCs)
- Permanent Virtual Circuits (PVCs)

SVCs are analogous to X.25 connections and it is defined in the frame relay standards.

PVCs are logical connections that exist on a physical circuit between two ports of a node. Each PVC has its own unique identifier, called a Data Link Connection Identifier (DLCI).

2.5.2 Definition

The Frame Relay service provides the bi-directional transfer of SDU (Service Data Units) from one S or T reference point to another with the order preserved. The SDUs are routed through the network by appropriate layer 2 PDU (Packet Data Units) on the basis of an attached label, a logical identifier with local significance.

The user network interface structure at the S or T reference point allows for the establishment of multiple virtual calls and/or permanent virtual circuits to many destinations. This service is generally available on the following ISDN access arrangements: point-to-multipoint (passive bus) and point-to-point (NT2).

2.5.3 General description

The Frame Relay service has the following characteristics (see Figure 2.5.1):

– All Control-plane procedures, if needed, are performed in a logically separate manner using protocol procedures that are integrated across all ISDN telecommunications.

– The User-plane procedures at layer 1 are based on Recommendation I.430/I.431. Layers 2 procedures are based on the core functions of Recommendation Q.922. These layer 2 core functions allow for the statistical multiplexing of user information flows immediately above layer 1 functions. This bearer service provides the bi-directional transfer of service data units (frames) from one S or T reference point to another with the order preserved.

This bearer service:

– Preserves the order of SDUs transmitted at one S or T reference point when they are delivered at the other end

– Detects transmission, format and operational errors (e.g. frames with unknown label)

– Transports frames transparently, and only the label and frame check sequence (FCS) may be modified by the network

– Does not acknowledge frames (within the network).

The functions above are based on the core functions of Recommendation Q.922. They provide service quality that is characterized by the value of the following parameters:

– throughput

– access rate

– committed information rate

– committed burst size

– transit delay

– residual error rate

– delivered errored frames

– delivered duplicated frames

– delivered out-of-sequence frames

– lost frames

– misdelivered frames

The core functions of Recommendation Q.922 are:

– frame delimiting, alignment and transparency

– frame multiplexing/demultiplexing using the address field

– inspection of the frame to ensure that it consists of an integer number of octets prior to zero bit insertion or following zero bit extraction

– inspection of the frame to ensure that it is neither too long nor too short

– detection of transmission errors

– congestion control functions

Figure 2.5.1 – Protocol structure of Frame Relay

Control plane	User plane	
Q.933		Network layer
Q.922 or Q.921	Q.922 Core (Frame Relay)	Data link layer
DS0, n*DS0, DS1, E1, DS3		Physical layer

2.5.4 Applications

The Frame Relay service described in this document aims to support a wide range of data applications and rates from very low to high (typically 2 Mbit/s). A typical application of Frame Relay may be interconnection between local area networks (LANs).

2.5.5 Frame format

Figure 2.5.2 shows the standard frame structure of Frame Relay with a default two-octet address based upon ITU-T Recommendation Q.922. There are also three- and four-octet address formats. The frame relay used by frame relay services is a derivative of the ISDN Link Access Protocol D-channel (LAP-D) framing structure. Frame Relay uses the beginning and ending flag, the frame check sequence field (FCS), and the information field.

Figure 2.5.2 – The Frame Relay frame format

Octet 1	2	0 ~ 8188	2	1
F	Address Field	User Data (Information)	FCS	F

MSB 8 | 7 6 5 4 3 2 1 LSB

(upper) DLCI			C/R	EA0
(lower) DLCI	FEC N	BEC N	DE	EA1

C/R: Command / Response field bit

FECN: Forward Explicit Congestion Notification bit

BECN: Backward Explicit Congestion Notification bit

DE: Discard Eligibility indicator bit

DC: DLCI or DL-core Control Indicator bit

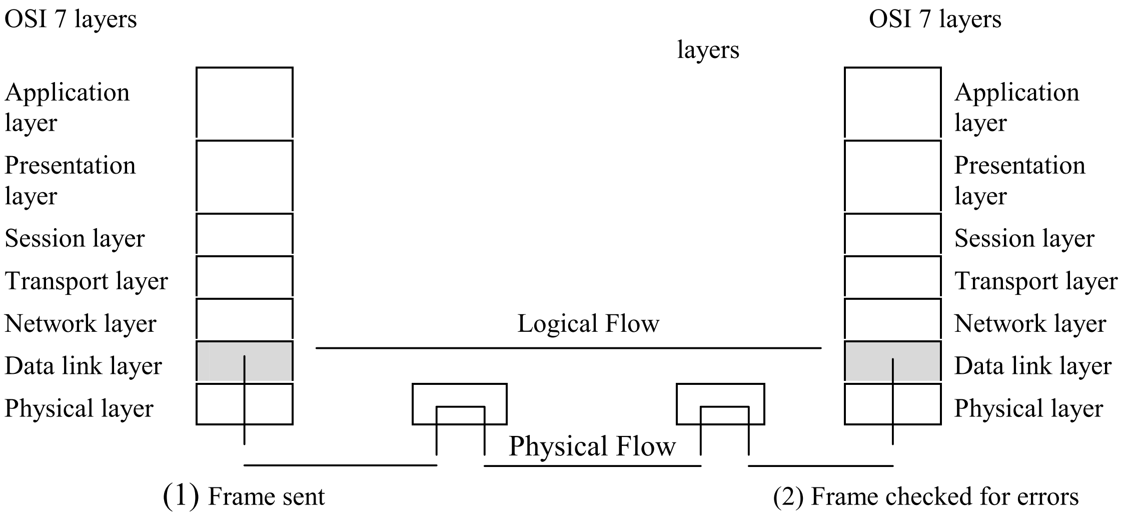
EA: Address Extension bit

2.5.6 Operations of the data link layer with Frame Relay

2.5.6.1 Operation on one link

Frame Relay continues to do an error check on the data at each node in the network as well as any routers that use the Frame Relay software. The conventional cyclic redundancy check (CRC) operation is employed against the frame check sequence (FCS) field. However, if this check reveals that the frame was distorted during transmission across the communication channel, the frame is not only discarded but also no negative acknowledgement (NAK) is returned to the sender. Figure 2.5.3 shows these operations.

Figure 2.5.3 – The Frame Relay approach



2.5.6.2 Operation on more than one link

Figure 2.5.3 also shows how each intermediate node in a Frame Relay network relays the frame. The operation proceeds on a node-to-node basis, and each node is required to perform the FCS check. It also has the option of managing congestion through the use of the Frame Relay congestion notification bits. Moreover, it may discard traffic because of congestion problems and a bad FCS check, or for that matter any reason that the network so chooses. Of course, in discarding user frames, the network runs the risk of not meeting the user's quality of service (QOS) requirement.

It is a good idea to pause once again and reflect on the rationale for implementing these stripped-down operations. First, errors are unusual in modern communications channels (especially optical fibre). Therefore, it is not efficient to do error recovery within the network. Second, end-user stations usually perform end-to-end error detection and retransmission operations anyway. Therefore, the elimination of error recovery at the data link layer removes a redundant operation.

2.5.7 Bandwidth on demand

A Frame Relay network allows a user to obtain different levels of transmission capacity in a dynamic fashion (if the network chooses to implement this concept). This concept is called bandwidth on demand. The user is given an access line to the Frame Relay network. The user can send traffic to the network at the access rate, but is only charged for that portion of the line that is used over a period of time.

2.5.8 Traffic shedding

The Frame Relay network is allowed to discard user traffic if the user is violating its contract with the network by sending excessive traffic. The user is also allowed to tag traffic which the network can shed selectively, in the event that congestion occurs.

2.5.9 Congestion notification

The network may notify users that the network is experiencing congestion problems, and/or a user is creating excessive traffic in the network. This notification can be used by the user device to decrease its rate of transmission to the network.

2.6 ATM-based networks

The integration of telecommunication and information processing, as well as recent progress in the field of audio and video presentation on computer workstations, is opening up new horizons for marketing and distribution applications. Multimedia product information consisting of still and moving images, sound and voice sequences, charts, and text, can help customers obtain information on services. In addition to product presentation, networked multimedia provides an innovative opportunity to hold small video-conferences regardless of distance. High performance broadband networks are required to provide a high-quality connection; interest here is focused on ATM-based networks, with their capacity for flexible use of bandwidths.

2.6.1 ATM network elements

The common phrase is that the ATM makes B-ISDN a reality, whilst giving no precise explanation of it. It should be noted that B-ISDN was an extension of the ISDN (involving integrated broadband services such as high-speed-data). So, B-ISDN functions as a communication network. Broadband services produced problems with switching and service time distribution, which ATM can support. The ATM related functions are implemented in the elements of the B-ISDN Reference Configuration, Figure 2.6.1.

The **Broadband Network Termination 1 (B-NT1)** performs mainly low layer functions such as:

– Line transmission termination;
– Transmission interface handling; and
– Maintenance functions.

The Broadband Network Termination 2 (B-NT2) performs:

– Adaptation functions for different media and different protocols in addition to cell delineation;
– Buffering of ATM cells;
– Multiplexing/demultiplexing;
– Signalling protocol handling;
– Resource allocation and usage parameter control;,
– Interface handling;
– Switching of internal connections.

The **Broadband Terminal Equipment** 1 (B-TE1) connects user terminals and handles the termination of all end-to-end protocols.

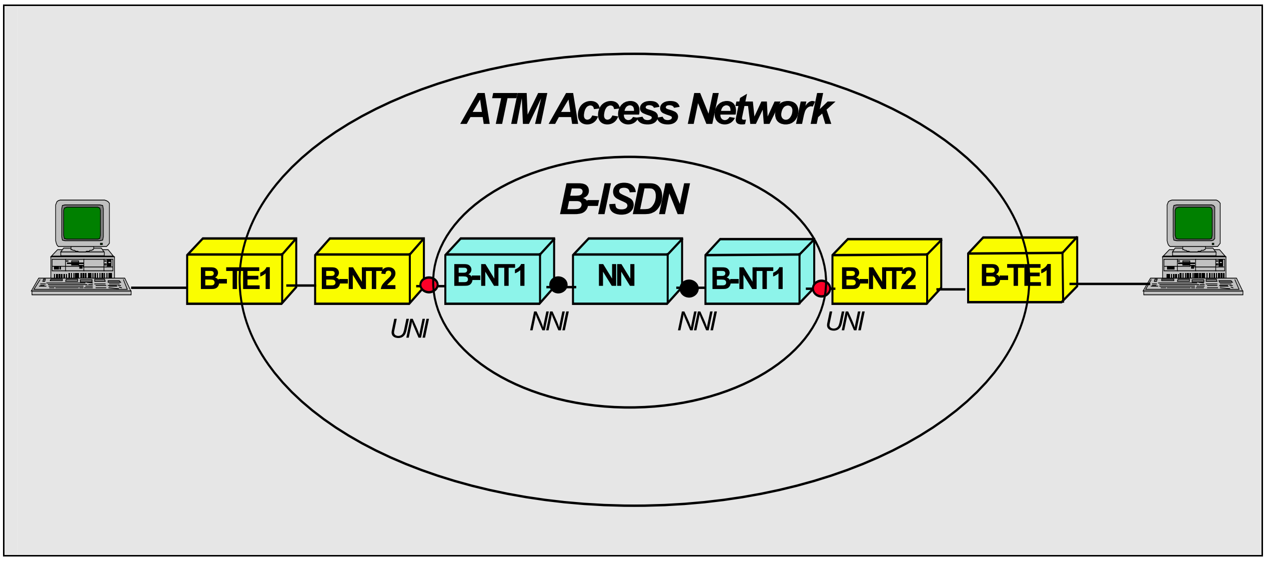
These units are separated by Network Node Interface (NNI) and User Network Interface (UNI).

Interface represents the shared boundary between two entities across which they communicate. ITU-T specified two main types of interfaces:

- **User-Network Interface (UNI)** – connects ATM end-systems (e.g. hosts, routers) to an ATM switch. A cell header at UNI contains a generic flow control field (GFC) providing flow control for the traffic originated at user equipment.
- **Network-Node Interface (NNI) –** may be defined as an interface connecting two ATM switches. It is any physical or logical link across which two ATM switches exchange the NNI protocol. The NNI (also known as network-network interface) cells have no GFC field.

The GFC field is rarely used (it is not even defined in the ATM Forum UNI specification). So there is no difference between the UNI and NNI cells with the exception of the first four bits.

Figure 2.6.1 – B-ISDN Reference Configuration



ATM will play a central role in the evolution of current and future broadband networks. It comprises a very complex technology; there is an opinion that it is the most complex ever developed by the networking industry. High performance ATM switches with point-to point ATM links or interfaces, followed by very sophisticated software, are the main components of an ATM network.

Different types and applications of ATM networks are possible:

The *public Broadband ISDN* (B-ISDN) consisting of ATM switching nodes and ATM remote units was the original idea for the application of ATM. Services considered were mainly based on video (e.g. videotelephony) and the whole set of supplementary services developed for narrowband ISDN was adapted also for Broadband ISDN. This kind of network was not deployed because the trend moved towards data applications with a dominance of IP.

Nevertheless *public ATM-based networks* consisting of ATM switching nodes (where paths are adjusted by user signalling) and ATM cross connects (where paths are adjusted by management) are in use for the interconnection of other networks, e.g. data networks based on ATM, Frame Relay or IP, or even between narrowband switches.

The third category is *private ATM based networks* used as replacement for other technologies such as FDDI in campus networks. It consists of specialized ATM switching nodes that are adapted to the needs of the data world, especially the transport of IP datagrams.

Figure 2.6.2 shows an example configuration with three ATM-based networks: the private ATM-based network, the public ATM network which might be used for B-ISDN but also as access network for the interconnection of other networks and finally a public ATM transit network to interconnect other ATM networks, both as part of a B-ISDN and as part of an ATM interconnection network.

Outgoing cells are received asynchronously from the ATM layer. Header error control sequence generation and verification generates and checks the header error control code to ensure valid data.

The cells are then packed in the SDH (SONET) frame format. Idle cells must be inserted into the frame when no "real cells" are available (cell rate decoupling). After adaptation to the physical media (optical fibre), the SDH frames are sent asynchronously.

In the opposite direction incoming SDH frames are received. The ATM cells are identified and extracted (cell delineation) from the frames and passed upwards into the ATM-layer.

In B-ISDN, the use of ATM allows for a multiplicity of service types/characteristics and for the logical separation of signalling from user information streams. A user may have multiple signalling entities connected to the network call control management via separate ATM virtual channel connections. The following sections identify the signalling capabilities needed in B-ISDN and the requirements for establishing signalling communication paths.

ATM Forum Interfaces

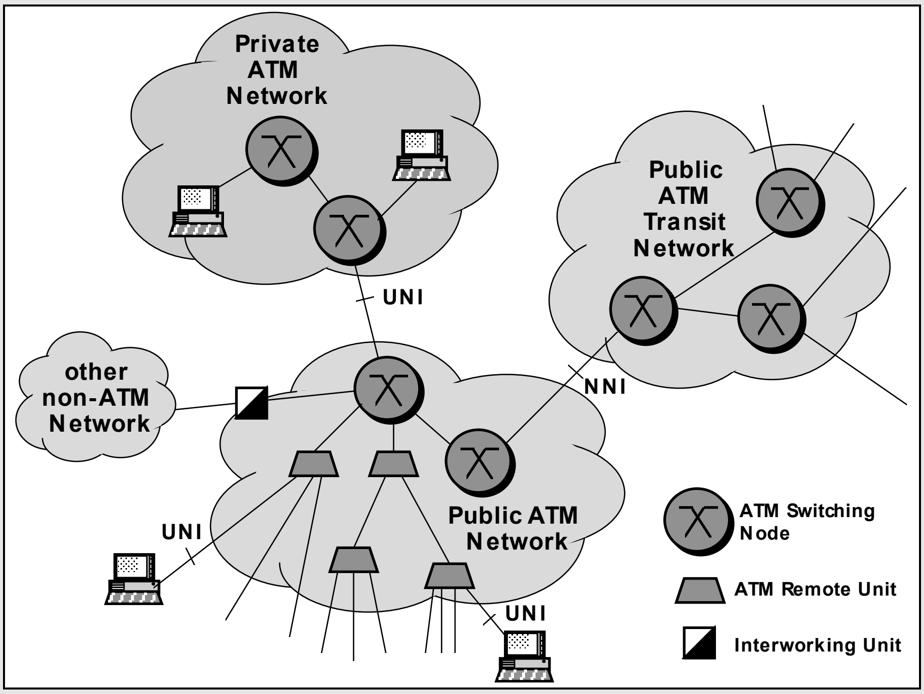
Connection between a private ATM switch and a public ATM switch is a UNI. According to the ATM Forum it is known as a **Public UNI** (it doesn't exchange the NNI information).

The User-Network Interface defines different aspect of transmission and adaptation to different *physical media*, concerning the adopted bit rates and other electro/optic characteristics for interfaces and signals. Interfaces are mainly classified according to these specifications, mainly. The ATM Forum defines specifications for **UNI** interfaces such as: ATM physical medium dependent interface for 155 Mbit/s on twisted pair cable; DS1 physical interface, UTOPIA (*Universal Test & Operations PHY Interface for ATM*); E1 (E3) Public UNI, etc.

However, there is common classification of interfaces according to its purpose, accepted by the ATM Forum, too. Some of the interfaces are listed below:

Private network-to-node interface (P-NNI) – specifies the protocol by which ATM switches communicate within a private ATM network including multi-protocol switched private networks.

Figure 2.6.2 – ATM Network



Broadband ISDN inter-carrier interface (B-ICI) – defines inter-switch communications in public networks (af-bici-0068.000).

LAN emulation user network interface (LUNI) – which enables existing LANs to communicate with similar LANs and with ATM attached stations over ATM.

Frame user network interface (FUNI) – defines a frame-based interface for ATM services.

Home user network interface (Home UNI) and **Access network interface (ANI)** – are aimed at residential broadband application.

2.6.2 ATM network operation

ATM networks are basically connection oriented. Virtual circuits have to be set up prior to any data transfer. There are two types of virtual circuits: virtual paths identified by virtual path identifiers (VPI) and virtual channels identified by combinations of VPI and VCI (Virtual Channel Identifier).

Virtual paths represent bundles of virtual channels, and all of them are switched transparently across the ATM network based on their common VPI.

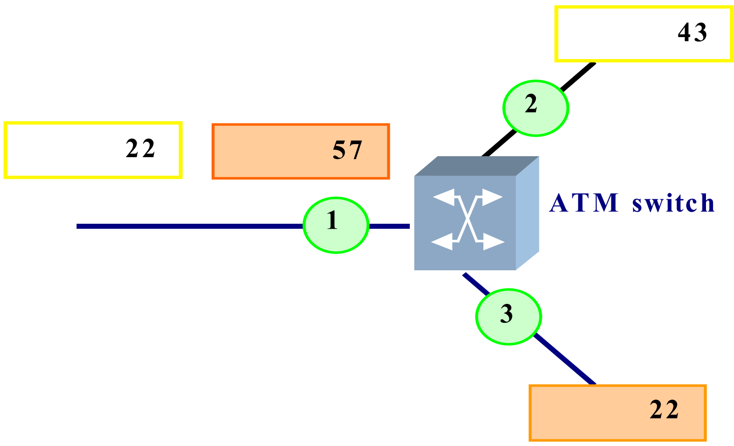
The basic operation of an ATM switch is rather simple: it receives cells across a link on a known VCI or VPI, looks up the connection value in a local translation table to determine the outgoing port (or ports) of the connection and the new VPI/VCI value of the connection on that link and finally retransmits the cell on that outgoing link.

Local translation tables are set up prior to transmittal of data by external mechanism. The mechanism determines two main types of the ATM connections:

- ***Permanent virtual connections (PVC)*** – an external mechanism sets up a set of switches between the source and the destination ATM system; they are programmed with the appropriate VPI/VCI values. PVC thus needs some manual operation (not desirable, usually).
- ***Switched virtual connections (SVC)*** – it is a connection that is set up automatically by a signalling protocol. It doesn't require any of the manual interaction needed for the set up of PVC. So, it is expected that SVC will be widely used especially for higher layer protocols over ATM.

Figure 2.6.3 – ATM switch operation

Input		Output	
Port	**VPI/VCI**	**Port**	**VPI/VCI**
1	**22**	**2**	**43**
2	**43**	**1**	**22**
1	**57**	**3**	**22**
3	**22**	**1**	**57**



An ATM end-system that desires to set up a connection through ATM network initialises signalling. This means that it sends cells on a virtual channel with VPI = 0 and VCI = 5 (this virtual channel is reserved for signalling traffic only).

After initialisation signalling is routed through the network, from switch to switch. The signalling request are passed between the signalling or call control processes associated with the switches (usually, call control capability is integrated into switches). Connection identifiers are set up in that process until the destination end system is reached. The end system can accept or confirm the connection request. Conversely it can reject it, clearing the connection. As the connection is set up along the path of the connection request, data flows along the same path.

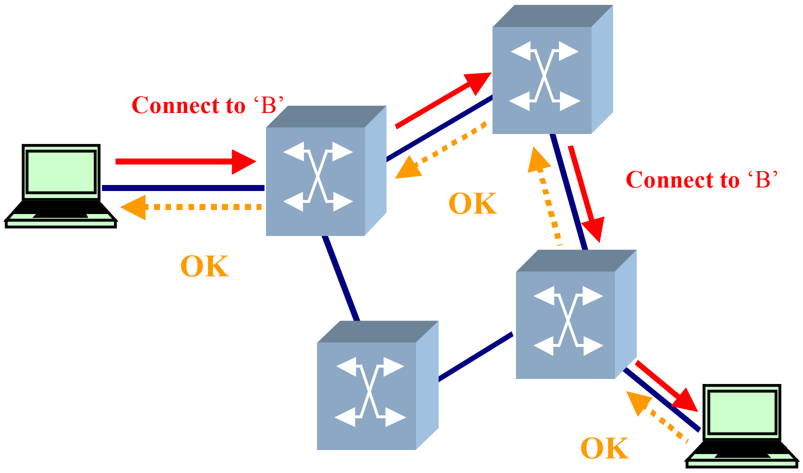
Connection identifiers (VPI/VCI values) are allocated in each direction of a connection. Traffic parameters in each direction can be different, however. For instance, the bandwidth in one direction could be zero.

Different types of ATM connections can be set up, either as permanent or switched virtual channels, Figure 2.6.5. Two main types are:

Point-to-point configuration (at the UNI) – connects two ATM end-systems which can be unidirectional or bi-directional.

Point-to-multipoint configuration (at the UNI) – a configuration with more than one terminal equipment supported by a single network termination at a user-network interface. Such connections can be unidirectional or bi-directional.

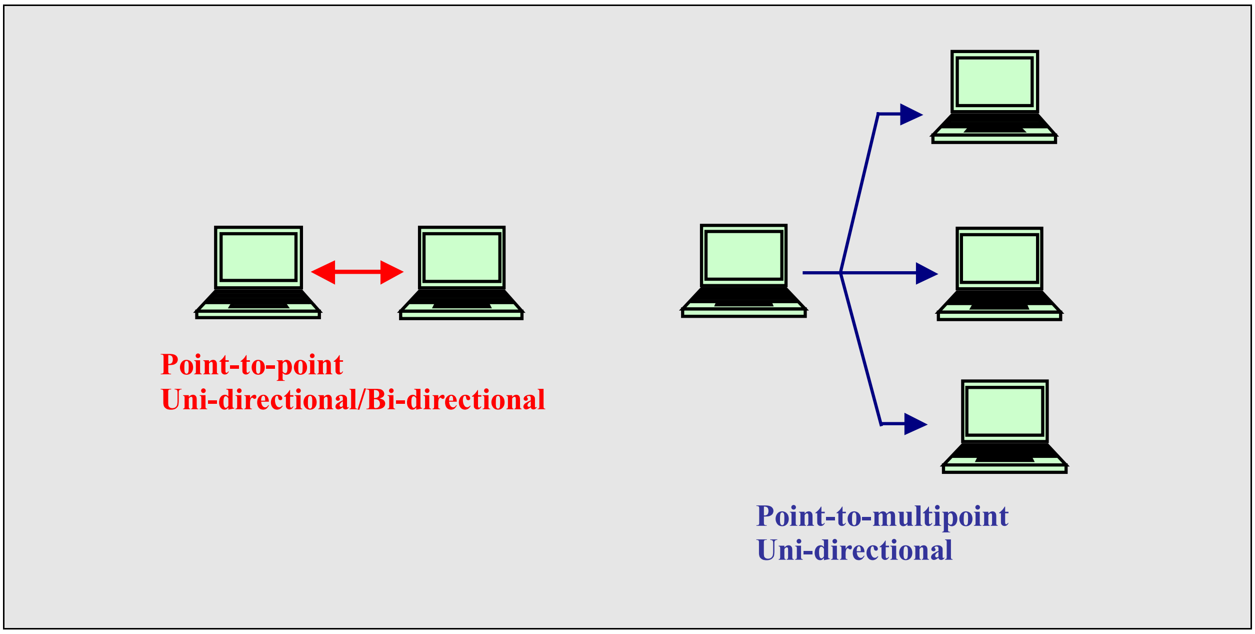
Figure 2.6.4 – Connection set-up through ATM signalling



- Signalling request
- Connection routed – set up path
- Connection accepted/rejected
- Data flow – along same path
- Connection tear-down

For a single termination – the source end-system is known as *root node*. Multiple destinations end-systems are known as *leaves*. Within the network a cell replication is performed. It is usually done by ATM switches, or rarely by end systems.

Figure 2.6.5 – Types of ATM connections



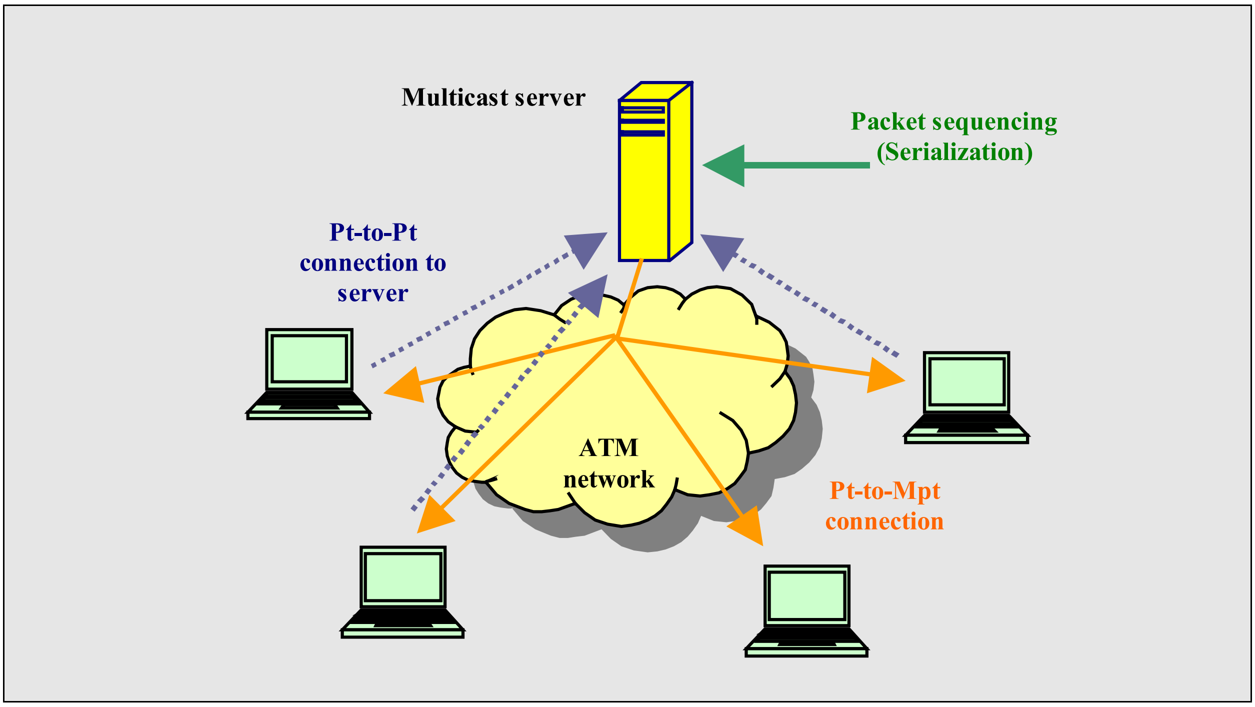
Point-to-multipoint connections are unidirectional, meaning that the root is allowed to transmit data to the leaves, and not leaves to the root or to each other.

These two types of ATM connections have no analogy with:

- ***multicasting*** capability as unidirectional communication from a single source access point to a limited number (more than one) of specified destination access points (I.140), or
- ***broadcasting*** capability as unidirectional communication from a single source access point to an unlimited number (more than one) of specified destination access points (I.140)

These are common in most of the shared medium technologies (such as Ethernet or Token Ring, for instance). In these technologies multicasting enables multiple end-systems to both receive data from the multiple systems, and to transmit data to these multiple systems. The analogy to such (LAN) multicast communications in ATM would be bi-directional multipoint-to-multipoint connection. This cannot be supported by the AAL5 (ATM adaptation layer). Namely, the AAL5 has no provision within the cell format for interleaving cells from different AAL5 packets on a single connection. In order to enable destination reassembly process, cells must be received in sequence, with no interleaving. So, ATM AAL5 point-to-multipoint connections can be only unidirectional. It should be noted that AAL5 is the most common adaptation layer intended for multimedia applications, and that AAL3/4, being more complex, supports interleaving of cells from different packets.

Figure 2.6.6 – Multicast server operation



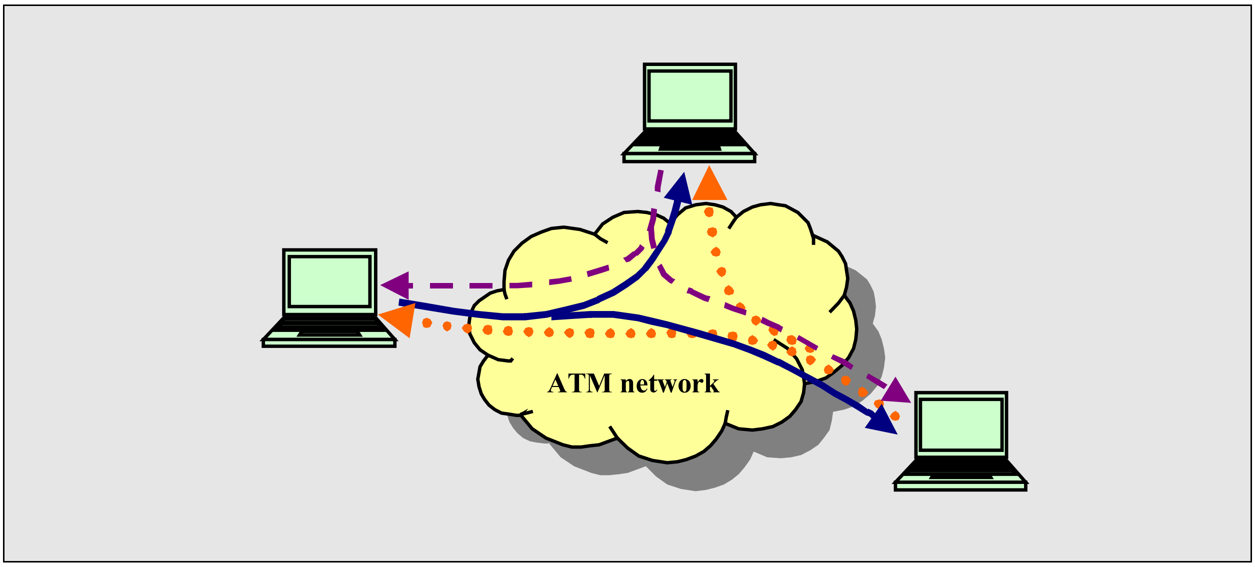
In order to accept different traffic sequences obtained from LANs which rely upon existence of a low level multicast/broadcast capability, ATM requires some form of multicast capability. Three methods have been proposed as solutions:

1 ***Virtual-path-multicasting*** – Is a mechanism in which a multipoint-to-multipoint virtual path links all nodes in the multicast group, and each node is given a unique VCI value within the VP. A protocol for uniquely allocating the VCI values to nodes will likely be very complex (does not exist yet).

2 ***Multicast server*** – In this mechanism, Figure 2.6.6, all nodes desiring to transmit onto a multicast group set up a point-to-point connection with an external device known as multicast server. The multicast server is connected to all nodes wishing to receive multicast packets through a point-to-multipoint connection. This mechanism is rather complicated: the multicast server receives packet across the point-to-point connections, then retransmits them across the point-to-multipoint connection, after ensuring that packets are serialized.

3 ***Overlaid point-to-multipoint connections*** – In this mechanism, Figure 2.6.7, all nodes in the multicast group establish a point-to-multipoint connection with each other node in the group, enabling that all nodes transmit to and receive from all other nodes.

Figure 2.6.7 – Multicast through overlaid point-to-multipoint connections



In the last mechanism each node requires N connections for each group, where N is the total number of transmitting nodes. The multicast server mechanism requires only two connections per node in a multicasting group, but it requires a registration process for telling nodes what the other nodes are in the group. The multicast server is more scalable in terms of connection resources, but introduces a centralized processor that may be a potential bottleneck.

There is no ideal solution for multicast in the ATM technology. Inter-networking protocols for ATM are very complex.

2.6.3 ATM routing

ATM is primarily connection oriented[2] so connection requests need to be routed from the requesting node through the network and to the destination node. The same way that packets are routed within a packet-switched network. The NNI protocols have the same function as routing protocols in current routing networks.

[2] **Connection oriented:** An information transfer mode in which a connection is established between end users before information is transferred.

Connectionless: An information transfer mode in which blocks of data to be transferred are individually addressed and routed to their destination. Compare with connection oriented.

Figure 2.6.8 – UNI and NNI signalling

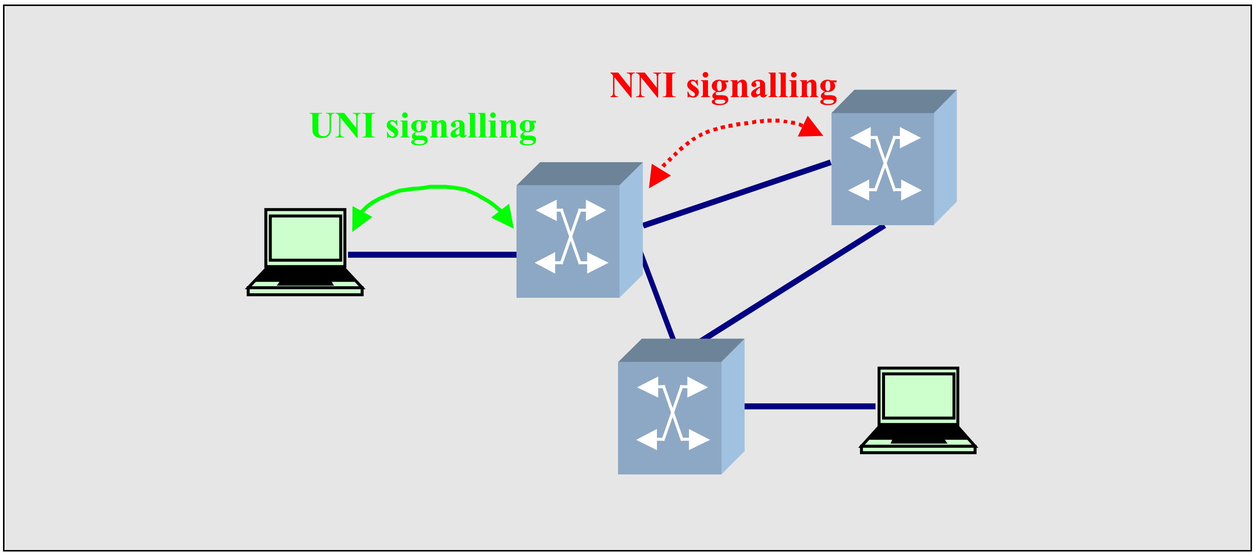
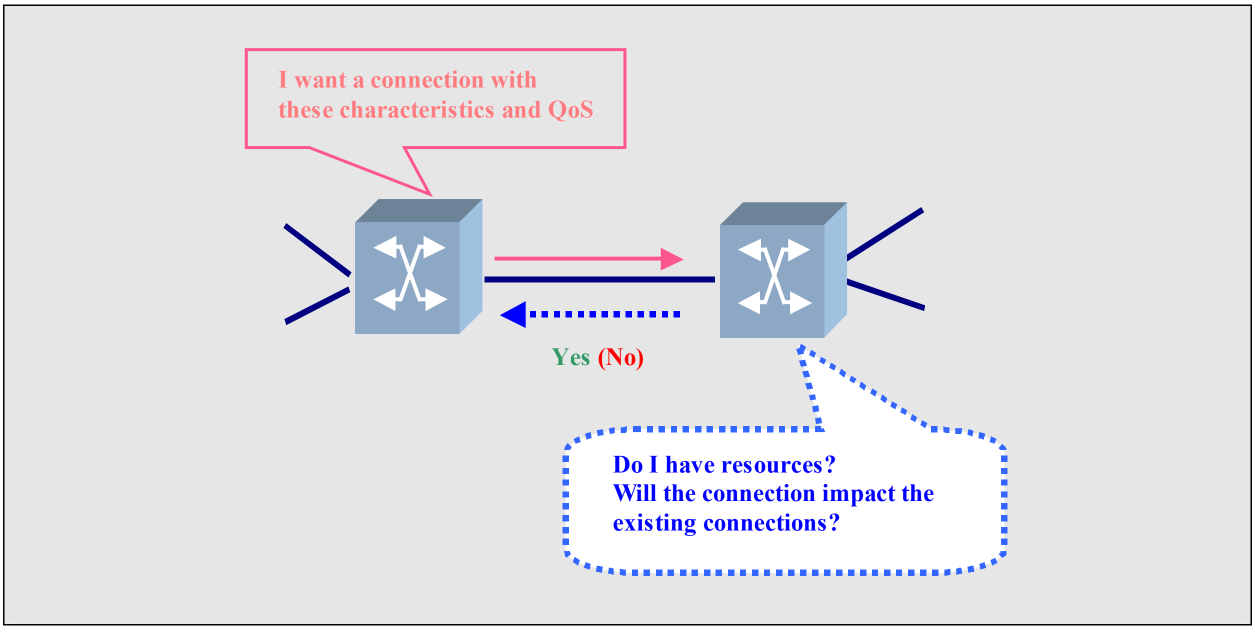


Figure 2.6.9 – Connection admission control



NNI protocols consist of two components:

- NNI signalling protocol – used to relay ATM connection requests within the networks between the source and destination UNI. The UNI signalling requests are mapped into NNI signalling at the source (ingress) switch, and remapped back into UNI signalling at the destination (egress) switch.
- Virtual circuit routing protocol – used to route signalling requests through the network. This is the route on which the ATM connection is set up, and along which the data will flow.

The NNI protocol is much more complex than any existing routing protocols for two reasons:

– it has to allow greater scalability than in existing routing networks, and

– it has to support high quality of service QoS.

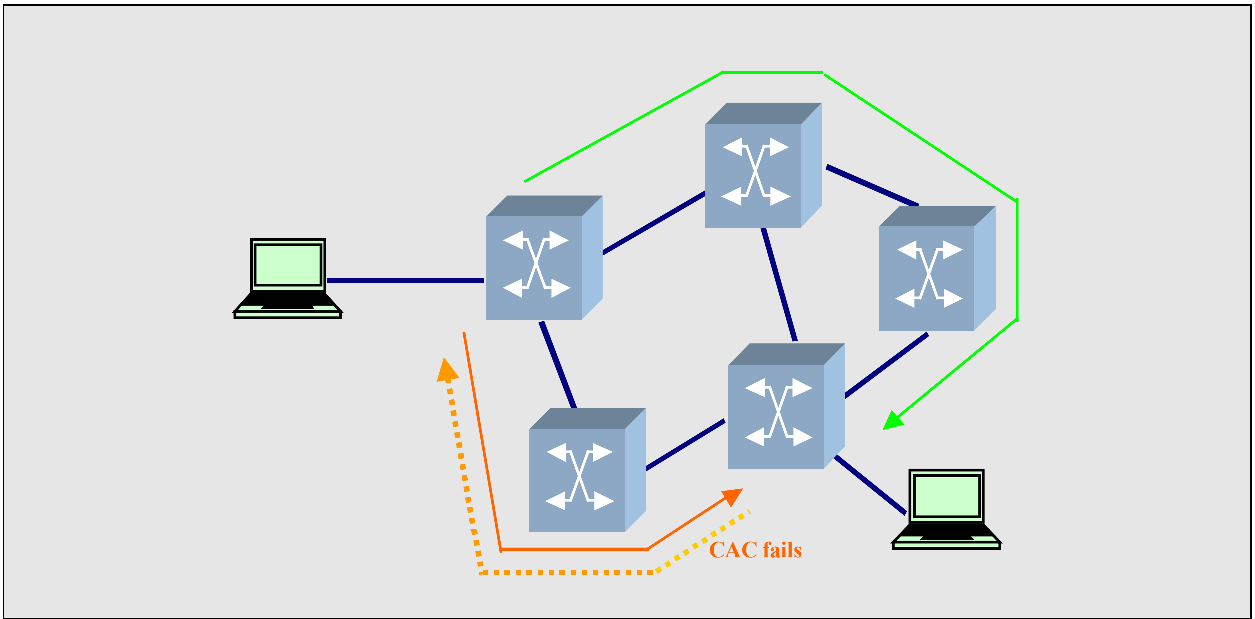
Guaranteed QoS is the great advantage of the ATM and one of the main attributes for introducing such, very complex and rather expensive, technology in communication networks. In the request for the connection set up, a certain QoS is also specified. Depending on the ATM service and QoS capabilities requested, a particular mix of QoS elements are specified (such as cell loss ratio, cell delay, cell delay variation). According to this, ATM switches implement a connection admission control procedure, Figure 2.6.9.

Connection admission control (CAC) – Is the set of actions taken by the network at the call set up phase (or during call re-negotiation phase), within the control part of network nodes, in order to establish whether a virtual channel/virtual path (VC/VP) connection can be accepted or rejected (or a request for re-allocation can be accommodated). Routing is a part of CAC actions (ETSI, TR 101 287).

The switch accepts the connection only if violation of current guarantees are not reported. CAC is a local switch function, and is dependent on the architecture of the switch and local decisions on the strictness of QoS guarantees.

The virtual circuit (VC) routing protocol must ensure that a connection request is routed along a path that leads to the destination and has a high probability of meeting the QoS requested in the connection set up – that is, of traversing switches whose local CAC will not reject the call.

Figure 2.6.10 – Operation of crankback



The protocol uses a topology state routing protocol in which nodes flood QoS and reachability information so that all nodes obtain knowledge about reachability within the network and the available traffic resources within the network.

Each node in the path still performs its own CAC on the routed request because its own state may have changed since it last advertised its state, and thus changed from the information used in the connection admission control. So, there is a possibility that connection request may fail at some intermediate node. In large networks with many levels of hierarchy, in which information cannot be accurately aggregated, this is more likely to happen. The PNNI protocol (ATM Forum) supports, for instance, the notion of crankback (Figure 2.6.10). In this procedure, a connection which is blocked along a selected path is rolled back to an intermediate node, earlier in the path. The intermediate node attempts to discover another path to the final destination using the newer, more accurate network state.

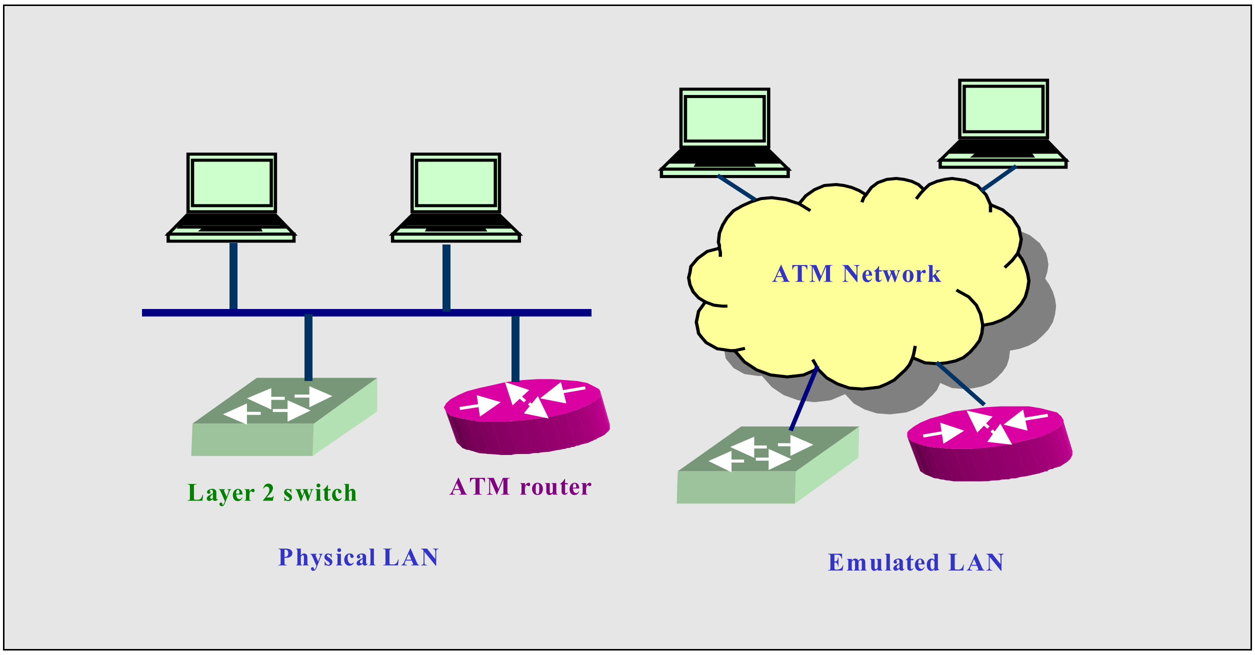
2.6.4 LAN emulation

Given the vast installed base of LANs and WANs and the network and link layer protocols operating in these networks, a key to ATM success will be the ability to allow for interoperability between these technologies and ATM. Only few users will tolerate the presence of islands of ATM without connectivity to the remainder of the enterprise network. The key to such connectivity is the use of the same network layer protocols (for instance, IP) on the both existing networks and on the ATM.

There are, however, two fundamentally different ways of running network layer protocols across an ATM network. In one method, known as native mode operation, address resolution mechanisms are used to map network layer addresses directly into ATM addresses, and the network layer packets are then carried across the ATM network. The alternate method of carrying network layer packets across an ATM network is known as LAN emulation (LANE) method.

As the name suggests, the LANE protocol defines a service interface for higher layer (that is, network layer) protocols, which is identical to that of existing LANs, and data sent across the ATM network are encapsulates in the appropriate packet format. No attempt is made to emulate the actual media access control protocol of the specific LAN concerned.

Figure 2.6.11 – Physical and emulated LAN

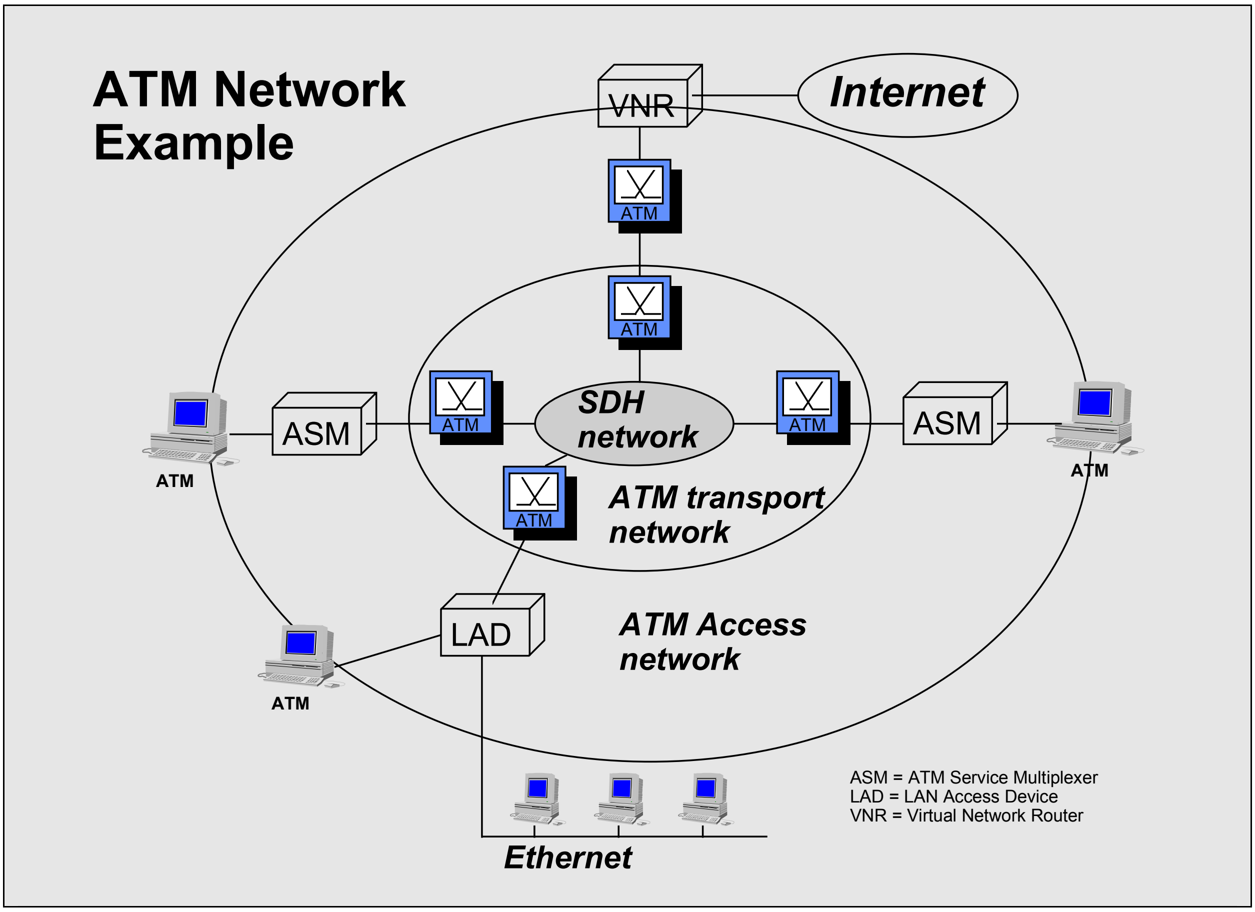


In other words, the LANE protocols make an ATM network look and behave like an Ethernet or Token Ring LAN – although one operating much faster that a real such network.

2.6.5 ATM Network examples

The network illustrated in Figure 2.6.12 consists of access and transport parts. ATM signals are generated in ATM terminals at the Customer Premises Equipment and are connected to ATM Service Multiplexers or LAN Access Devices. ATM Service Multiplexers permit the connection of various service interfaces onto a single ATM interface. LAN Access Devices are used to connect existing legacy systems, e.g. Ethernet or Token Ring, to a single ATM interface. Internet can be connected across a Virtual Network Router.

Figure 2.6.12 – An ATM network example



Besides the integration (adaptation) of services like speech and video, the integration (adaptation) of data protocols like IP (Internet Protocol) gains more importance. Here not only the packaging of the data packets into cells has to be performed, but also the subjects of addressing and routing have to be clarified. The ATM-Forum and the Internet Engineering Task Force IETF are the driving forces in the field of “IP over ATM”, resulting in a new service GFR (ATM Forum, May 1999). The ITU-T has also issued a Recommendation Y.1310 on IP over ATM.

The primary role of traffic control and congestion control parameters and procedures is to protect the network and the user in order to achieve network performance objectives. An additional role is to optimize the use of network resources.

In B-ISDN, congestion is defined as a state of network elements (e.g. switches, concentrators, cross-connects and transmission links) in which the network is not able to meet the negotiated network performance objectives for the already established connections and/or for the new connection requests.

In general, congestion can be caused by:

– unpredictable statistical fluctuations of traffic flows;

– fault conditions within the network.

Congestion is to be distinguished from the state where buffer overflow is causing cell losses, but still meets the negotiated quality of service. The uncertainties of broadband traffic patterns and the complexity of traffic control and congestion control suggest a step-wise approach for defining traffic parameters and network traffic control and congestion control mechanisms. It may be appropriate to consider additional sets of such capabilities, for which additional traffic control mechanisms will be used to achieve increased network efficiency.

Since ATM connections are unidirectional, two ATM connections are associated for the two directions of a communication and identified by the same VPI/VCI at a given interface. It should be noted that traffic control procedures that apply to a unidirectional connection (forward direction) may imply cell flows on the associated connection in the other direction (backward direction). Also, traffic control procedures may use cell flows on the forward direction to control the backward direction.

QoS requirements refer to QoS classes requested from the user. QoS commitments are referred to where the network actually commits to meet QoS objectives, assuming the user generated cell flow conforms to a traffic contract. QoS indications pertain when there is no such traffic contract between the user and the network, e.g. in cases where traffic engineering rules are used to operate the network and do not allow for commitments to the user.

Nowadays, the most attractive projects are based on satellite transmission, whether they use the ATM technique or Internet protocols. These networks play a very important role in the deployment of global networks [3], as being complementary to the future fixed or terrestrial mobile ones. The ATM Forum is working on specifications for a satellite transmission very intensively. Besides, much attention is paid to the ATM service categories available to the TCP/IP traffic [4]. There are many different networking scenarios, as well as experimental notifications [3]-[5] of the assumption that the global network should be based on interconnection of the ATM and the Internet. We shall point out, Figure 2.6.13, a possible architecture [3] based on the satellite networks connected to fixed ATM network. The satellite system used may be geostationary (GEO) or probably medium/low Earth orbits (MEO/LEO) controlled from the network control station. The network control station is responsible for routing and call management (usually one per satellite). Its interconnection to other parts of terrestrial network is obtained through the signalling system No. 7, the SS7. Ignoring the main architectural/technical problems from now on, we shall concentrate on the possible types of traffic.

In the environment described, traffic is bursty and its modelling is possible only in some constrained conditions, or for some specific applications. The main network characteristic is that almost every parameter varies (e.g. the number of users, network topology, rates, the required bandwidth). The basic assumption of the previous telephone network, the Poisson one, in data networks failed to be acceptable. On the contrary, in order to track and control traffic parameters, new complex routines have to be established. These need enormous computation power, high computing speed and real time control.

2.6.5.1 ATM traffic characteristics

The traffic measurement in the presence of data gave surprising results. Burst of packets and high variations in their rates have been observed [6]. The traffic behaviour was unknown until that moment. The authors gave an ‘intuitive interpretation' that *'traffic spikes* (*causing actual losses*) *ride on longer-term ripples, that in turn ride on still longer term swells'*. That was a very descriptive explanation of fractal-like traffic.

Mathematics contributed to the success of teletraffic theory in voice networks. Researchers hoped that it could do the same with the data traffic. However, the relevant mathematics for old telephony was of limited variability in time (the traffic processes are independent or temporal correlations decay exponentially fast) and in space (due to independence between the users, the traffic related quantities decay exponentially fast). There are many inferences of spatial variability in the data traffic causing the heavy tail distribution with infinite variance. Besides, high temporal variability in traffic patterns points out the long-range dependency in data. It was shown [10] that SS7 traffic exhibits the long-range dependent property, while holding times should be modelled by heavy tail distribution (which is in disagreement with the exponential decaying in the Poisson model). Further, there exists a very important problem of the network-wide traffic synchronization as a consequence of the periodicity in the machine generated IP traffic (i.e. in the routing messages) [11]. We can conclude that data traffic statistical descriptors lead to the fractal modelling of the teletraffic.

It was noticed that traffic bursts occur on many different time scales. Garrett was the first one who noticed that the ATM traffic of VBR type is generically fractal. He digitized and compressed the *Star Wars* movie [11]. The traces taken from the motion JPEG (*Joint Photographic Expert Group*) version of that movie is shown to be fractal [11]. Further research [17] approved that traces described have multifractal property, too. All these facts are in a sharp contrast with common traffic models used in engineering theory and practice.

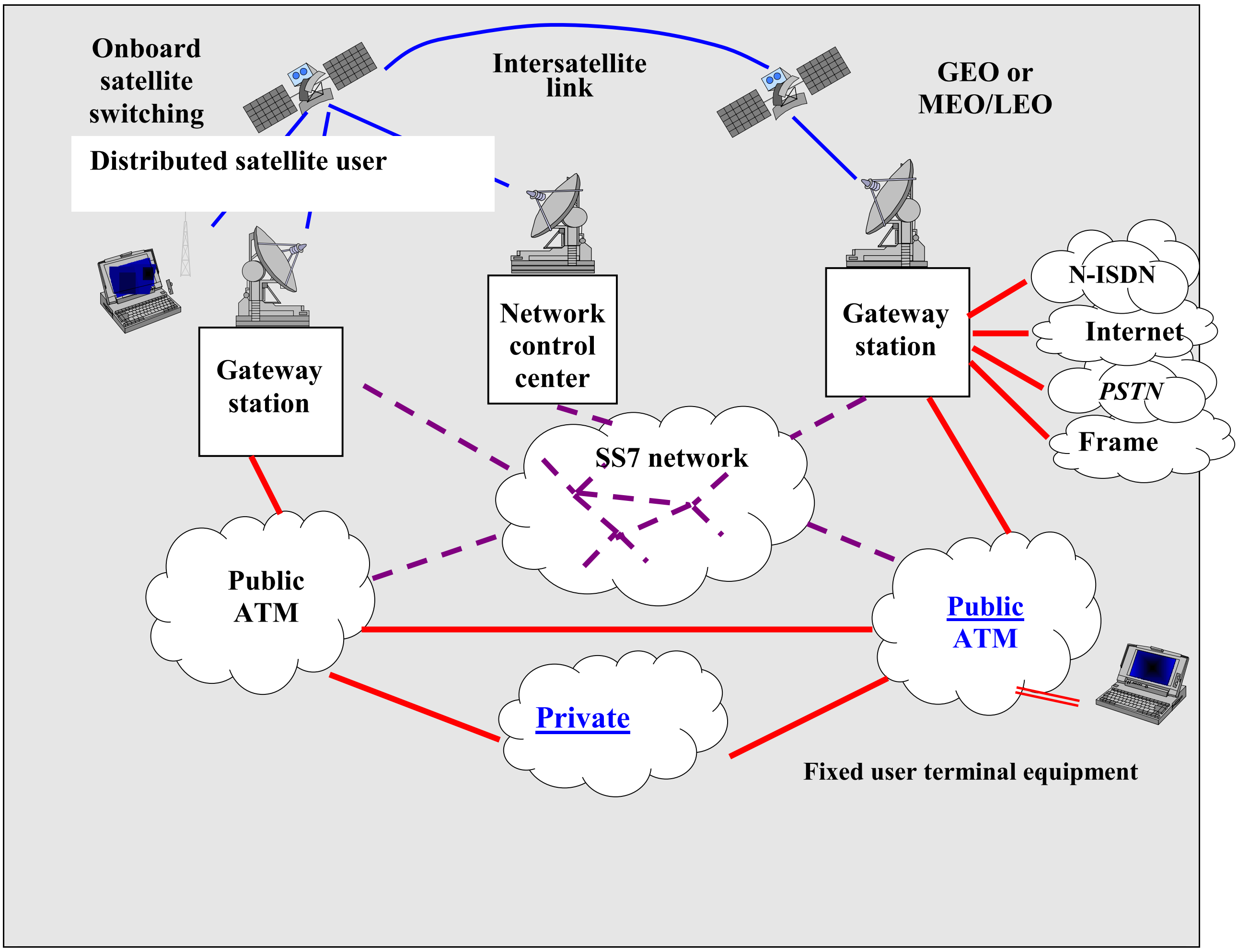
2.6.5.2 Neural Network Control at the ATM Node

Achieving high utilization, while maintaining the QoS, is the objective of an efficient ATM traffic management strategy. Designing such a strategy using programming techniques is a difficult task. In such large and complex telecommunication networks, the traffic changes in an unpredictable fashion having short-term and long-term variations, and the number of nodes and links are so large that the traditional network control may not be effective due to the high degree of complexity.

The neural network (NN) based traffic characterization and prediction is an inherent property of NNs. Thus, NNs used in admission control perform the classification of acceptable and unacceptable traffic types and NNs used in congestion control need first to predict the rate of arrival so that they suggest optimum control actions. For these purposes the feed-forward NNs with backpropagation learning algorithm are commonly used.

Admission control implies that each new call makes a request for a connection. The request includes the QoS required by the call. If the QoS can be obtained without altering those of the existing calls, then the new one is admitted, otherwise is rejected. Thus an estimate of the QoS is required based on monitoring traffic patterns and buffer status (i.e., number of cells waiting in the buffers for service). The latter parameter is important in determining the cell loss ratio (CLR), cell delay and the delay variations. Training a NN to learn a QoS parameter such as the CLR is a difficult task, because this parameter depends on the traffic generation rate, even if the number of connections is kept constant [21]. Hence, the NN should be trained to learn the average of those values. However, due to the exponential wide range of the CLR (from 10E0 to 10E-12), it is difficult to derive their average value accurately. In [22], a method called *relative target* was proposed to solve this problem.

Figure 2.6.13 – Global ATM network, according to [3]-[4]

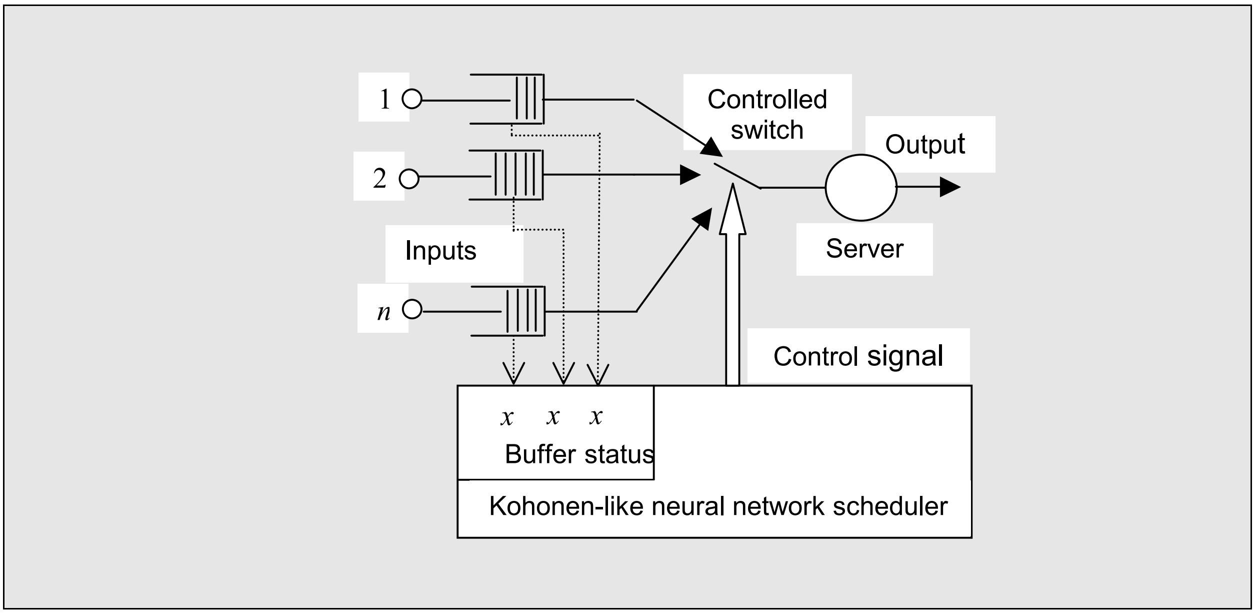


In some cases, it is desirable to have on-line or real-time training capabilities in the NN. In [22] the virtual output method is proposed to estimate very small CLP from virtual cell loss data. By using that method an accurate estimation of the cell loss rate (CLR) was obtained for a real buffer size of 100 cells and a different number of connections ranging from 20 to 40 voice sources.

Another approach, using adaptive self-organizing neural network [18]-[20], was successfully applied to control input buffers in ATM multiple-input-single-output node, Figure 2.6.14. The method takes into account the buffer status, x_i, $i = 1, 2,\ldots, n$, as well as the changes of the input signal (i.e., the burstiness), avoiding thus the buffer overflow. The network flexibility and adaptability is improved by applying the 'winner-take-most' algorithm. The winning input is connected to the output in an asynchronous manner through a controlled switch.

Network performance parameters such as delay, loss, and jitter are observed while carrying various combinations of calls and their relationship is learned by a NN. The NN approach estimates the traffic's entire congestive behaviour from its impact on the output queue via measurements of quantities such as mean cell delay, cell loss, and jitter.

Figure 2.6.14 – Neural network ATM scheduler [19]



Traffic policing mechanism, based on the NNs, is proven to be more effective than algorithmic ones due to the non-linear and time-varying nature of the traffic. The policing algorithm should be capable of the following: 1) detecting any non-regular traffic situation, 2) selecting the range of checked parameters (i.e., the algorithm could determine whether the user's behaviour is within an acceptable region), and 3) rapid reaction time to any violations in the traffic parameters.

All the examples described above indicate that neural networks can be applied in solving specific problems or as a part of the overall traffic control. All of them need the understanding of the traffic behaviour and they take into account specific features of the underlying network structure.

References

[1] ATM Forum Specifications,

[2] ITU-T Recommendations.

[3] A. Alles, "ATM Networking", *Engineering InterOp*, Las Vegas, March 1995.

[4] I. Mertzanis, G. Sfikas, R. Tafazolli, B. Evans, "Protocol architectures for satellite ATM broadband networks", *IEEE Comm. Magazine*, Vol. 37, No. 3, pp. 46-54, March 1999.

[5] R. Goyal, R. Jain, M. Goyal, S. Fahmy, B, Vandalore, "Traffic management for TCP/IP over satellite networks", *IEEE Comm. Magazine*, Vol. 37, No. 3, pp. 56-61, March 1999.

[6] TEN-155: Trans-European Network with access ports of 155 Mbit/s, http://www.dante.net/ten-155

[7] H. Fowl, W. Leland, "Local area network traffic characteristics with implications for broadband network congestion management", *IEEE J. on Sel. Areas in Comm.,* Vol. 9, No. 7, pp. 1139-1149, Sept. 1991.

[8] V. Paxon, S. Floyd, "Wide area traffic: the failure of Poisson modeling", *IEEE/ACM Trans. Networking*, Vol. 3, No. 3, June 1995.

[9] M. Garrett, A service Architecture for ATM: From Applications to Scheduling, *IEEE Network Magazine*, Vol. 10, No. 3, May/June1996.

[10] M. Garrett, "Contributions toward real-time services on packet switched networks", *PhD. Thesis*, Columbia Univ., NY, 1993.

[11] D. Duffy, A. McIntosh, M. Rosenstein, W. Willinger, "Statistical analysis of CCSN/SS & traffic data from working CCS subnetworks", *IEEE J. on Sel. Areas in Comm.*, Vol. 12, No. 3, pp. 544-551, April 1994.

[12] S. Floyd, V. Jacobson, "The synchronization of periodic routing messages", *IEEE/ACM Trans. on Networking*, Vol. 2, pp. 122-136, 1994.

[13] B. Ryu, "Fractal network traffic modeling: past, present and future", http://www.hrl.com/people/ryu

[14] R. Riedi, W. Willinger, "Toward an improved understanding of network traffic dynamics", to appear in *Self-similar Network traffic and performance evaluation*, J. Wiley, June 1999.

[15] A. Adas, "Traffic models in broadband networks", *IEEE Comm. Magazine,* Vol. 35, No. 7, pp. 82-89, July 1997.

[16] H. Michiel, K. Laevens, "Teltraffic engineering in a broadband era", *Proc. IEEE*, Vol. 85, No. 12, pp. 2007-2034, Dec. 1997.

[17] W. Willinger, V. Paxon, "Discussion of *Heavy tail modeling and teletraffic data*", http://www.aciri.org/vern/papers

[18] B. Reljin, I. Reljin, "Neural networks in teletraffic control: Pro et contra?", in *Proc. TELSIKS'99*, Nish (Yugoslavia), pp. 518-527, Oct. 1999.

[19] I. Reljin, "Neural networks application in high speed communication networks", in *Proc. NEUREL'97*, Belgrade (Yugoslavia), pp. 111-114, Sept. 1997.

[20] I. Reljin, "Neural network based cell scheduling in ATM node", *IEEE Communications Letters,* Vol. 2, No. 3, pp.78-81, March 1998.

[21] I. Reljin, "Neural network control in ATM node", in *Proc. etc.'98*, Timisoara (Romania), pp. 288-293, Sept. 1998.

[22] A. Hiramatsu, "ATM communications network control by neural networks", *IEEE Trans. Neural Networks*, Vol. 1, 1990.

2.7 Interworking between networks

This section defines principles and detailed arrangements for the interworking of different networks in order to provide a data transmission service. This section also specifies, in a general network context, the necessary interaction between elements of user interfaces, inter-exchange signalling systems and other network functions for the support of data transmission services, telematic services and the OSI connection-mode network service where appropriate. In addition, it defines the principle for realization of international user facilities and network utilities for data transmission services.

2.7.1 General

The rapid evolution of data transmission services has resulted in a large number of international standards in this field. The increasing complexity of the totality of these standards creates a need to rationalize common aspects in order to achieve a coherent relationship between these standards.

Data transmission services and user facilities may be provided by different types of public networks such as, PSDNs and Integrated Services Digital Networks (ISDN) (see also Recommendations I.500 and I.510). As a result, there may be a demand to interconnect these networks in order for a DTE on one network to communicate in a uniform way with a DTE on the same network, or with a DTE on another network of the same type, or with a DTE on a network of another type.

The inter-network signalling between the various types of networks can be of the type defined by Recommendations such as, X.70, X.71, X.75, or of the common channel signalling type such as, Recommendation X.61. In particular, at an inter-network signalling interface, network utilities may be exchanged between the networks involved. These network utilities may be handled by different types of network.

In addition, the reference model as a part of the scope of Recommendation X.200 (Reference Model of Open Systems Interconnection for ITU-T applications) is to enable different users to communicate with each other by encouraging the implementation of compatible communication features. The use of this reference model is expected to be encouraged in future user terminal designs

As defined by this reference model, one of the major functions of the network layer is to establish a network-connection between network-service users (within end systems). This may involve the concatenation of dissimilar networks. Therefore, the arrangements and procedures for inter-network signalling between PDNs and other public networks should provide the user with the capability to operate data transmission services, telematic services and the OSI connection-mode network service over the connections derived over either one network, or over concatenated networks.

NOTE – This does not imply that any individual public network is required to implement all the mechanisms related to the OSI connection-mode network service.

Figure 2.7.1 gives a summary of the relevant interworking Recommendations, which are grouped under three main categories:

a) general aspects of interworking;

b) description of each interworking case;

c) description of inter-network signalling interfaces.

2.7.2 Principles for interworking involving transmission capabilities only

The different categories of interworking may involve different levels of functions:

a) in some cases only the functions related to the transparent transfer of information between two DTEs through the network(s) (transmission capability) apply;

b) also, in other cases, additional functions built upon those related to the transparent transfer of information (communication capability) are also included.

2.7.2.1 Composition and decomposition of subnetworks

Consideration of the different conditions for interworking involving only transmission capabilities requires the development of appropriate concepts for the different types of networks which may be involved. In particular, the concept of subnetwork and of different types of subnetworks is intended to assist in developing an appropriate framework for studying the interworking between networks.

2.7.2.2 Principles for interworking between subnetworks

Interworking between subnetworks should be based on considerations on the functionality of the subnetworks concerned. In such interworking, it is not necessary to consider any individual intermediate system involved in a given network connection. Each network should be considered globally, in association with any appropriate interworking functions whenever it is necessary. For the purpose of interworking between two networks, the pieces of network equipment will be represented as interconnected subnetworks.

2.7.3 Categories of interworking

This subsection describes the categories of interworking that involve functions related to the transmission capability only. Two different categories of interworking between two networks are considered:

a) interworking by call control mapping;

b) interworking by port access.

2.7.3.1 Interworking by call control mapping

Possible examples of this type of interworking include interworking between CSPDNs using X.71, interworking between PSPDN and ISDN using X.75 and interworking between CSPDN and PSPDN in the case where the call control information of the CSPDN is mapped into the call control information of the PSPDN.

2.7.3.2 Interworking by port access

Possible examples of this type of interworking include interworking between PSTN and PSPDN where first a connection (switched or hot-line) through the PSTN is established to a port of the PSPDN, after which procedures are operated over this connection for establishment of a connection through the PSPDN.

2.7.4 Relationships with respect to management

Management information for the control of user calls, internal network management, or inter-network exchange of such information may be provided by the same and/or separate entities exchanging a user requested call control and user-to-user information. The network can be decomposed into two or more logical entities:

a) entities exchanging user-to-user information and, in some cases, user call control information; and/or

b) separate entities providing exchange of management information.

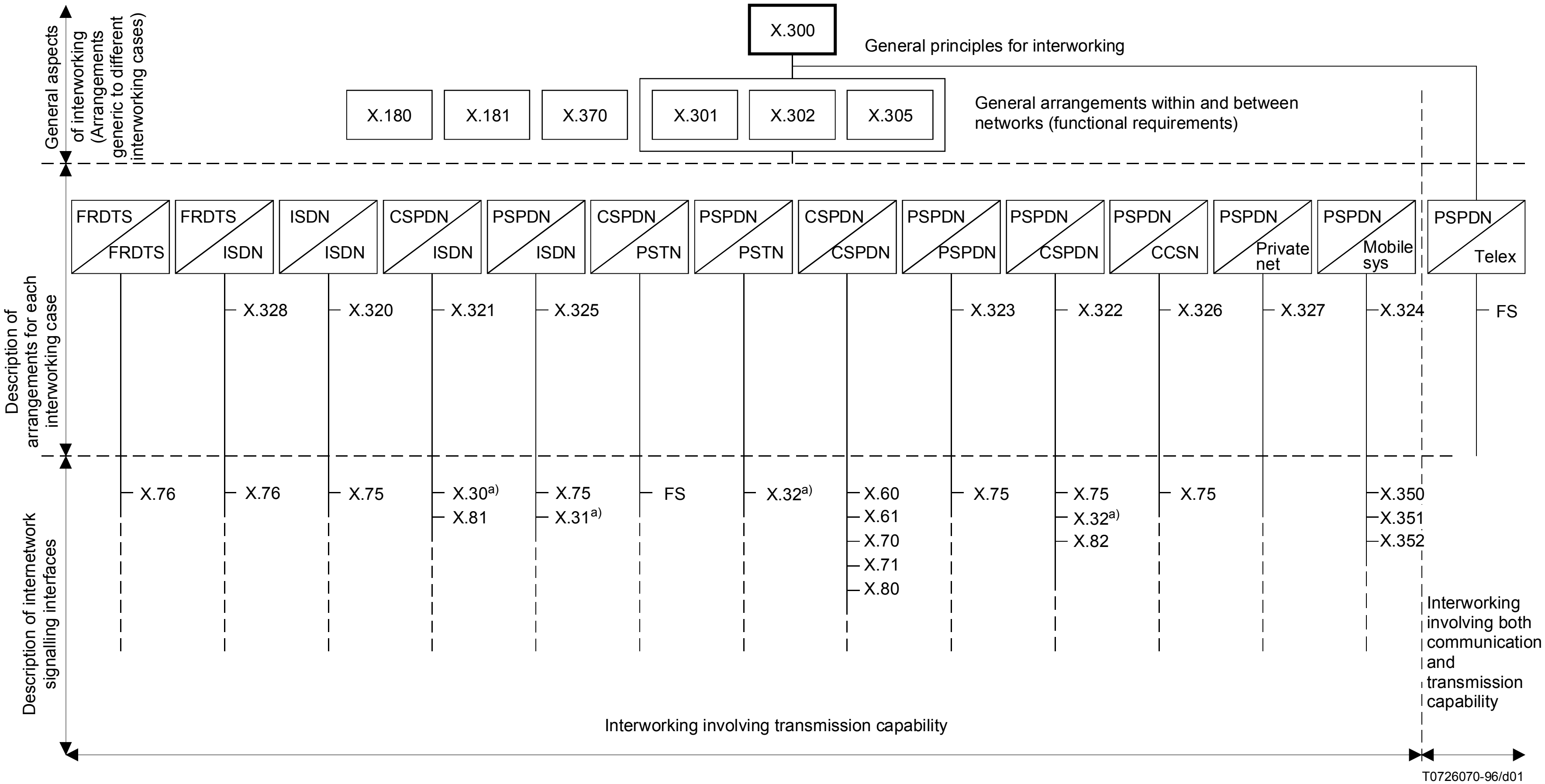
Example: PSTN with Signalling System No. 7.

The Signalling System No. 7 uses layered protocols to exchange call control and management information outside the user information flow. Detailed arrangements for exchange of management information are the subject of separate Recommendations (e.g. Recommendation X.370 and Q.700-Series Recommendations).

2.7.5 Example of Interworking Cases

2.7.5.1 ISDN – ISDN Interworking

The interworking between networks requires the physical and logical linking of networks in order to enable end to end communication. The Figure 2.7.2 illustrates the respective linking of two ISDN networks of different operators commonly referred to as interconnection.



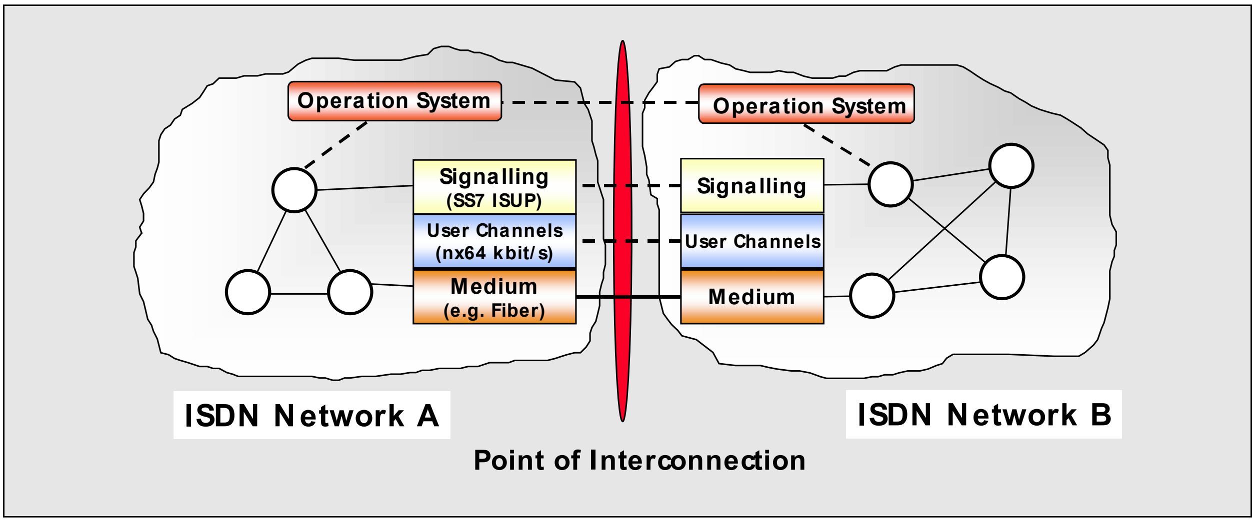
FS For further study
FRDTS Frame Relay Data Transmission Service

a) This Recommendation is considered mainly a user interface.

FIGURI 2.7.1

Framework of X-Series Recommendations in relation with interworking

Figure 2.7.2 – Physical and logical linking of ISDN networks



Besides the actual linking of the networks, ISDN switching network interconnection requires exchanges with specific interworking functions. Network operators implement these functions at selected exchange sites, commonly referred to as gateway exchanges. These are referred to as international gateways when implementing the traditional interconnection between operators in different countries. In liberalized telecommunication markets gateway exchanges also exist within the national networks for interconnection of the networks of competing operators.

The gateway exchanges of different networks are interconnected by inter-office trunk groups, consisting of n times 2 Mbit/s PCM trunks.

The specific interworking functions comprise the:

– screening of inbound and outbound traffic
(e.g. to reject unauthorized use of services and features),
– signalling interworking between external and internal protocols and
– call data recording for inter-operator accounting.

Since two networks of the same type inter-work, the interworking functions are restricted to the control plane. No interworking function is included into the user communication (different to the 2nd interworking case below).

The signalling capabilities determine the set of services that is available across the networks. While the network-internal signalling is a matter of the network operator, there is a need to agree on a signalling type and a capability set for interworking. In the ISDN – ISDN case Signalling System SS7 is applied based on the international standards. Because of the recent liberalization of many telecommunication markets the set of services supported has also become a regulatory issue. The minimum set of services according to the universal service obligations in the respective market has to be supported. Of course, this is granted by the standard SS7 ISDN User Part (ISUP). Furthermore, the ISUP supports more services and features which may be additionally agreed between ISDN network operators.

SS7 transport level interworking by means of a separate SS7 sub network ensures the interoperability of the networks, while preserving the autonomy and integrity of each of the operator networks.

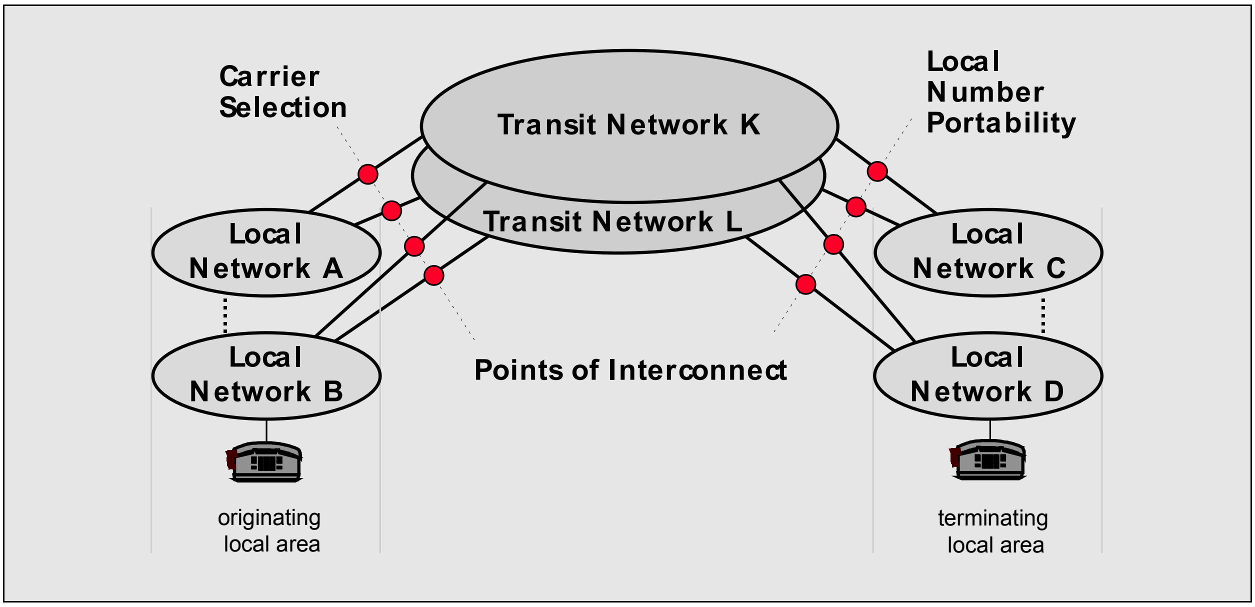
New requirements for interworking functions between ISDN networks resulting from the liberalization of the telecommunication markets are further the support of:

– carrier selection; and

– number portability.

Carrier selection divides the telecommunication market into a local and a long distance segment. Virtually the networks are decomposed into local networks and transit networks. Within the local call areas defined by numbering, local networks of different operators compete with each other. The local networks in different local call areas are interconnected by transit networks.

Figure 2.7.3 – Network interworking with carrier selection and number portability



As indicated in the Figure 2.7.3, in case of a long distance call, carrier selection determines the call routing towards and interworking at the point of interconnection in the originating local area. In the terminating local call area, number portability requires new routing methods to select the point of interconnection to and appropriately inter-work with destination local networks.

2.7.5.2 ISDN – Packet Network Interworking

Interworking between ISDN and Packet Switched Public Data Networks, PSPDN, is a means for "Support of Packet Mode Terminal Equipment by an ISDN".

This ISDN-PSPDN inter working scenario is specified by ITU in Rec. X.31, and offers access to Packet Mode Bearer Services for terminals, which are connected to an ISDN.

X.31 distinguishes between two interworking scenarios:

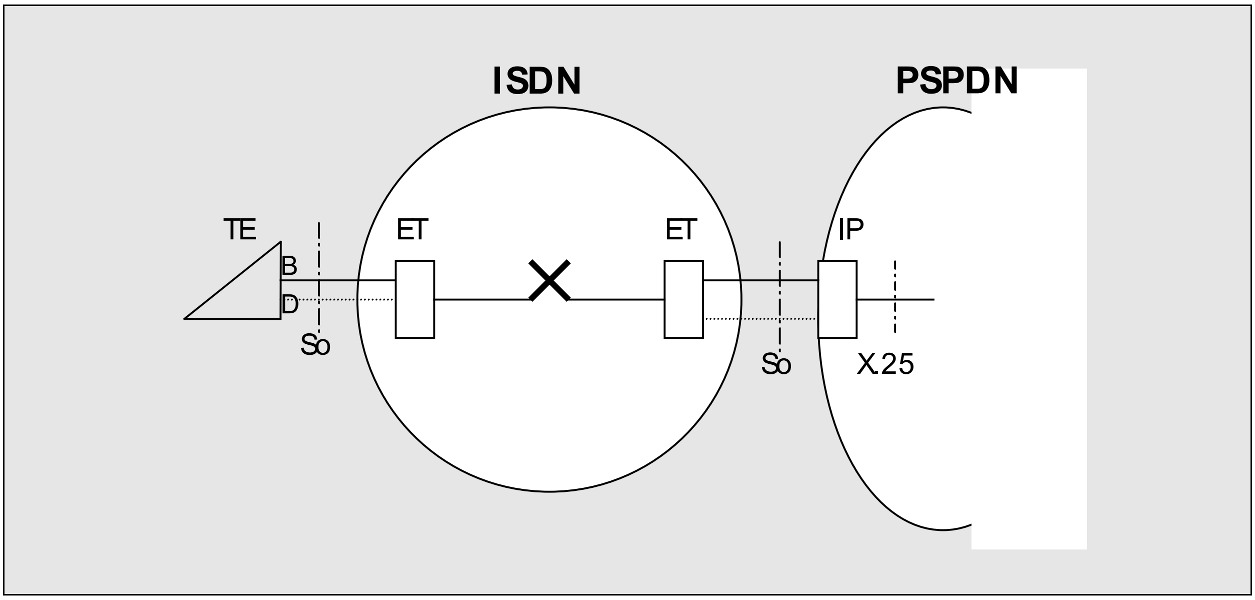
– Minimum Integration Scenario

– Maximum Integration Scenario

2.7.5.2.1 X.31 Minimum Integration Scenario (X.31 CASE A)

The reference model of this scenario is shown in Figure 2.7.4.

Figure 2.7.4 – X.31 case A



An ISDN terminal, TE, capable of X.25 Protocol or an X.25 DTE adapted to ISDN So-interface, is accessing the PSPDN via B-channel(s) terminating in an ISDN interworking Port unit, IP.

In this scenario the ISDN is just providing transparent access to an appropriate port of the X.25 packet network. The access can be non-switched or established on-demand switched via 64 kbit/sec circuits through the ISDN.

The D-channel may in this scenario only be used for signalling (to establish a dialled connection to the IP), not for any X.25 packet transfer.

2.7.5.2.2 X.31 Maximum Integration Scenario (X.31 CASE B)

The reference model of this scenario is shown in Figure 2.7.5.

An ISDN terminal, TE, capable of X.25 Protocol or an X.25 DTE adapted to ISDN So-interface, is accessing an X.25 Packet Handling Function, PH, belonging to the ISDN, via B-channel(s) and/or via D-channel. This scenario implies, that the ISDN-switch provides some additional Frame Handling function, FH, (at the Exchange Termination, ET) which terminates the D-channels also for X.25-packet traffic, and passes this traffic on, via the Digital Switching Network, DSN, to the PH.

The ISDN-PH takes the role of an interworking unit towards the PSPDN, using in the general case X.75 interface and protocol for access to the next PSPDN switch node.

2.7.5.3 European Maximum Integration Scenario

ETSI, in ETS 300 099, has gone one step further in regulation of PSPDN access and has standardized the following ISDN-PSPDN interworking scenario, shown in Figure 2.7.6:

Figure 2.7.5 – X.31 case B

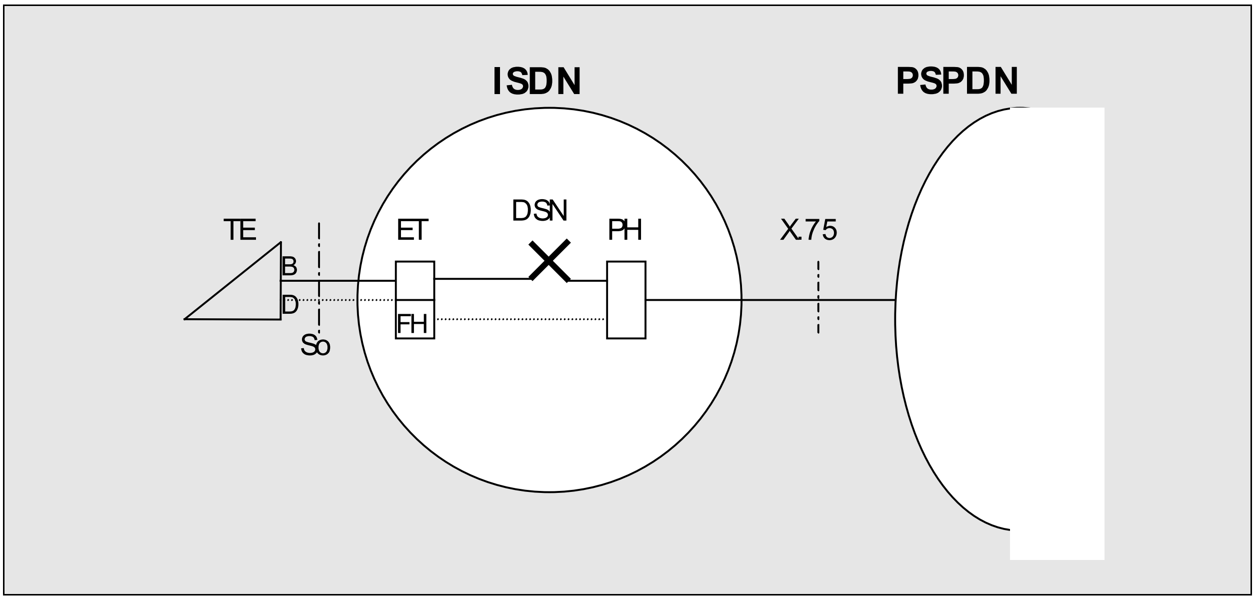
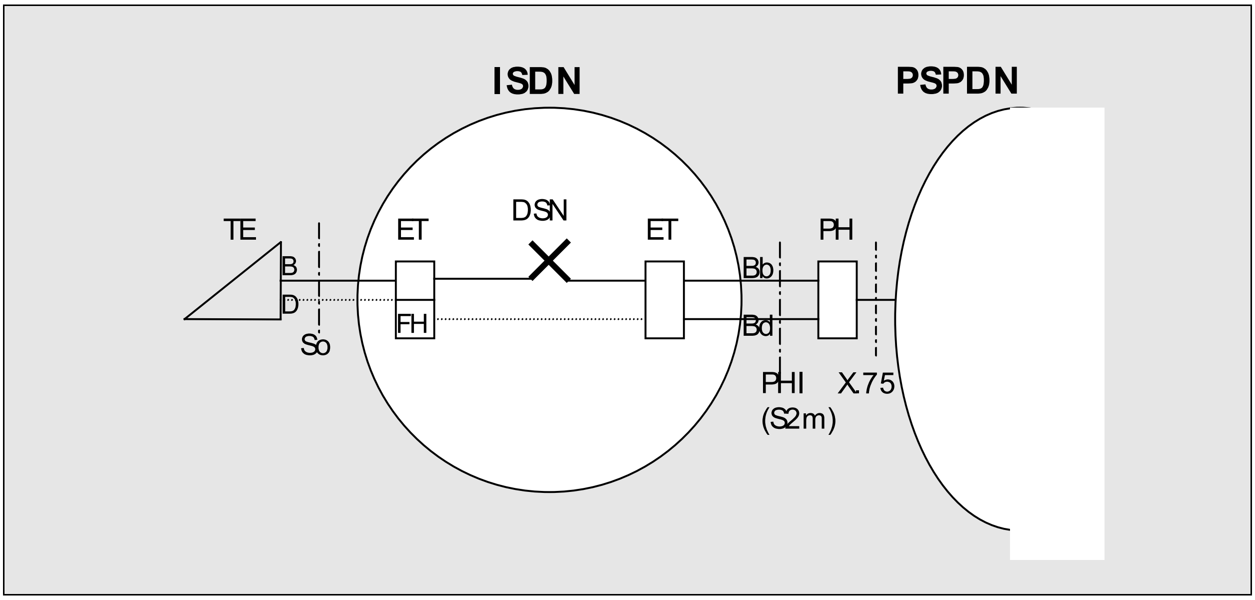


Figure 2.7.6 – Maximum integration scenario according to ETSI



In the ETSI scenario the PH-function is located outside the ISDN, often close to the PSPDN, but still logically belonging to the ISDN. The PH is accessed via a standard Packet Handler Interface, PHI, which is physically an ISDN Primary Rate Interface.

Two types of 64 kbit/sec packet traffic channels are defined at the PHI:

– Bb-channels as a transparent prolongation of the user side B-channels,
– Bd-channels, concentrating (by Layer2 LAPD multiplexing) D-channel packet traffic of many users into a 64 kbit/sec channel.

Both types of channel can be established either on-demand by signalling, or semi-permanently.

Also in this scenario the ISDN-PH takes on the role of an interworking unit using X.75 as a neutral interface towards one or several PSPDN(s). The PH-function may be provided at a few locations only per network, in this case accessed remotely (via ISDN transit exchanges) from many ISDN local exchanges with through connected Bb and Bd-channels.

A Frame Handling function is required per ISDN exchange for support of the D-channel packet traffic.

For switched connections this scenario covers both X.31 scenarios, Case A and Case B :

For Case A access only circuit mode (bearer capability) connections from the users Terminal via B-channel(s) can be established,

For Case B access, packet mode (bearer capability) connections can be established optionally via the B-channel or the D-channel.

The ETSI-scenario is introduced in many European telecommunication networks.

Generally, in scenarios including a PH function, part of this function is also number translation between the E.164 subscriber numbers in ISDN, and the X.121 numbering system in PSPDN.

2.7.6 Interworking related Recommendations

For further information, ITU-T Recommendations that are related interworking issues are described in 2.10.

2.8 Types of new services

This section is focused mainly on network related telecommunication services and service classifications as already elaborated or currently under work within ITU-T. In addition, at the end of the section, it provides a short outlook on future trends in the area of telecommunication services.

2.8.1 N-ISDN services

Services are generally defined by the communication capabilities that are made available to customers and telecommunication service providers based on a set of network capabilities that are defined by standardized protocols and functions.

A more precise classification of telecommunication services was required as work on ISDN specifications progressed. ITU-T Recommendation I.210 classifies telecommunication services in detail.

A telecommunication service is, from the static point of view, composed of

– technical attributes as seen by the customer; and
– other attributes associated with the service provision, e.g. operational and commercial attributes.

Realization of the technical attributes of a telecommunication service requires a combination of network and terminal capabilities and other service providing systems.

The capabilities required to fully support a telecommunication service include:

- network capabilities;
- terminal capabilities, when required;
- other services providing capabilities, when required;
- operational and commercial features associated with the service provision (i.e. sales or marketing aspects).

Telecommunication services are divided into two broad families, i.e. bearer services and teleservices, Table 2.8.1.

- *Bearer services*

Bearer services provide capabilities merely for the transmission of signals between user-network interfaces. Examples include circuit mode bearer services, packet mode bearer services and frame mode bearer services.

- *Teleservices*

Teleservices provide complete capabilities, including terminal equipment functions, for communication between users. Examples include telephony, telephony 7 kHz and telefax Group 4.

- *Supplementary Services*

Supplementary services modify or supplement a basic telecommunication service, i.e. a bearer service or teleservice. Examples include number identification, forwarding, conference calling and advice of charge.

Table 2.8.1 – Classification of telecommunication services

Telecommunication service			
Bearer service		Teleservice	
Basic bearer service	Basic bearer service + supplementary services	Basic teleservice	Basic teleservice + supplementary services

Meanwhile a large number of individual ISDN services have been described in detail by ITU-T (about 60) following a three stage modelling method. The method represents a top down approach covering service descriptions, information flows and protocol definitions. These services are sometimes also called fully standardized ISDN services. The individual service descriptions can be found in the ITU-T I.230-, I.240-, and I.250-series.

2.8.2 Broadband Services

As work on ATM progressed ITU-T provided a classification of Broadband Services (Rec. I.211). ATM based broadband networks, in principle, offer much more flexibility for the support of telecommunication services than the standard ISDN.

Figure 2.8.1 – Telecommunication service types

Interactive services
- – Conversational services
- – Messaging services
- – Retrieval services

Distribution services
- – Distribution services without user
- – Individual presentation control
- – Distribution services with user
- – Individual presentation control

According to the point of view of the network and not from the user point of view, the service is classified with two main service categories: interactive services and distribution services.

- **Interactive services**

Conversational services in general provide the means for bidirectional communication with real-time (no store-and-forward) end-to-end information transfer from user to user or between user and host (e.g. for data processing). The flow of the user information may be bidirectional symmetric, bidirectional asymmetric and in some specific cases (e.g. such as video surveillance), the flow of information may be unidirectional. The information is generated by the sending user or users, and is dedicated to one or more of the communication partners at the receiving site.

Messaging services: Messaging services offer user-to-user communication between individual users via storage units with store-and-forward, mailbox and/or message handling (e.g. information editing, processing and conversion) functions.

Retrieval services: The user of retrieval services can retrieve information stored in information centres provided for public use. This information will be sent to the user on his demand only. The information can be retrieved on an individual basis. Moreover, the time at which an information sequence is to start is under the control of the user.

- **Distribution services**

Distribution services without user individual presentation control: These services include broadcast services. They provide a continuous flow of information which is distributed from a central source to an unlimited number of authorized receivers connected to the network. The user can access this flow of information without the ability to determine at which instant the distribution of a string of information will be started. The user cannot control the start and order of the presentation of the broadcasted information. Depending on the point of time of the user's access, the information will not be presented from the beginning.

Distribution services with user individual presentation control: Services of this class also distribute information from a central source to a large number of users. However, the information is provided as a sequence of information entities (e.g. frames) with cyclical repetition. So, the user has the ability of individual access to the cyclical distributed information and can control start and order of presentation. Due to the cyclical repetition, the information entities selected by the user will always be presented from the beginning.

Meanwhile ITU-T has published three service descriptions for broadband data communication considering the more flexible ATM capabilities (ITU-T F.811 to F.813). These services cover wide area data transport of the booming data traffic produced in Local Area Networks – which is predominant connectionless.

2.8.3 Examples of new broadband services

Table 2.8.2 contains examples of possible services, their applications and some possible attribute values describing the main characteristics of the services.

The identification and full specification of specific services for standardization can only be completed after a through examination of the needs of users by e.g. market research. The full specification of such services should be based on the application of appropriate description methodology.

Table 2.8.2 – Service classes and their possible applications

Service classes	Type of information	Examples of broadband services	Applications	Some possible attribute values
Conversation-al services	Moving pictures (video) and sound	Broadband, video-telephony	Communication for the transfer of voice (sound), moving pictures, and video scanned still images and documents between two locations (person-to-person) – Tele-education – Tele-shopping – Tele-advertising	– Demand /reserved / permanent – Point-to-point/multipoint – Bidirectional symmetric/ bidirectional asymmetric – Value for information transfer (rate is under study)
		Broadband, video-conference	Multipoint commu-nication for the transfer of voice (sound), moving pictures, and video scanned still images and documents between two or more locations (person-to-group, group-to-group) – Tele-education – Tele-shopping – Tele-advertising	– Demand/ reserved/ permanent – Point-to-point/multipoint – Bidirectional symmetric/ bidirectional asymmetric
		Video-surveillance	– Building security – Traffic monitoring	– Demand/ reserved/ permanent – Point-to-point/multipoint – Bidirectional symmetric/ unidirectional

Service classes	Type of information	Examples of broadband services	Applications	Some possible attribute values
		Video/audio information transmission service	– TV signal transfer – Video/audio dialogue – Contribution of information	– Demand/ reserved/ permanent – Point-to-point/multipoint – Bidirectional symmetric/ bidirectional asymmetric
	Sound	Multiple sound-programme signals	– Multilingual commentary channels – Multiple programme transfers	– Demand/reserved/ permanent – Point-to-point/multipoint – Bidirectional symmetric/ bidirectional asymmetric
	Data	High speed unrestricted digital information transmission service	– High speed data transfer – LAN (local area network) interconnection – MAN (metropolitan area network) interconnection – Computer-computer interconnection – Transfer of video and other information types – Still image transfer – Multi-site interactive CAD/CAM	– Demand/ reserved/ permanent – Point-to-point/multipoint – Bidirectional symmetric/ bidirectional asymmetric – Connection oriented connectionless
		High volume file transfer service	– Data file transfer	– Demand – Point-to-point/multipoint – Bidirectional symmetric/ bidirectional asymmetric
		High speed teleaction	– Realtime control – Telemetry – Alarms	
	Document	High speed Telefax	User-to-user transfer of text, images, drawings, etc.	– Demand – Point-to-point/multipoint – Bidirectional symmetric/ bidirectional asymmetric
		High resolution image communication service	– Professional images – Medical images – Remote games and game networks	
		Document communication service	User-to-user transfer of mixed documents	– Demand – Point-to-point/multipoint – Bidirectional symmetric/ bidirectional asymmetric
Messaging services	Moving pictures (video) and sound	Video mail service	Electronic mailbox service for the transfer of moving pictures and accompanying sound	– Demand – Point-to-point/multipoint – Bidirectional symmetric/ unidirectional (for further study)
	Document	Document mail service	Electronic mailbox service for mixed documents	– Demand – Point-to-point/multipoint – Bidirectional symmetric/ unidirectional (for further study)

Service classes	Type of information	Examples of broadband services	Applications	Some possible attribute values
Retrieval services	Text, data, graphics, sound, still images, moving pictures	Broadband videotex	– Videotex including moving pictures – Remote education and training – Telesoftware – Tele-shopping – Tele-advertising – News retrieval	– Demand – Point-to-point – Bidirectional asymmetric
		Video retrieval service	– Entertainment purposes – Remote education and training	– Demand/reserved – Point-to-point/ multipoint f) – Bidirectional asymmetric
		High resolution image retrieval service	– Entertainment purposes – Remote education and training – Professional image communications – Medical image communications	– Demand/reserved – Point-to-point/ multipoint – Bidirectional asymmetric
		Document retrieval service	"Mixed documents" retrieval from information centres, archives, etc.	– Demand/reserved – Point-to-point/ multipoint – Bidirectional asymmetric
		Data retrieval service	Telesoftware	
Distribution services without user individual presentation control	Video	Existing quality TV distribution service (PAL, SECAM, NTSC)	TV programme distribution	– Demand (selection) / permanent – Broadcast Bidirectional asymmetric/ unidirectional
		Extended quality TV distribution service – Enhanced definition TV distribution service – High quality TV	TV programme distribution	– Demand (selection)/permanent – Broadcast – Bidirectional asymmetric/ unidirectional
		High definition TV distribution service	TV programme distribution	– Demand (selection)/ permanent Broadcast Bidirectional asymmetric/ unidirectional
		Pay-TV (pay-per-view, pay-per-channel)	TV programme distribution	– Demand (selection)/ permanent – Broadcast/multipoint – Bidirectional asymmetric/ unidirectional
	Text, graphics, still images	Document distribution service	– Electronic newspaper – Electronic publishing	– Demand (selection)/ permanent – Broadcast/multipoint – Bidirectional asymmetric/ unidirectional

Service classes	Type of information	Examples of broadband services	Applications	Some possible attribute values
Distribution services without user individual presentation control	Data	High speed unrestricted digital information distribution service	– Distribution of unrestricted data	– Permanent – Broadcast – Unidirectional
(continued)	Moving pictures and sound	Video information distribution service	– Distribution of video/audio signals	– Permanent – Broadcast – Unidirectional
Distribution services with user individual presentation control	Text, graphics, sound, still images	Full channel broadcast videography	– Remote education and training – Tele-advertising – News retrieval – Telesoftware	– Permanent – Broadcast – Unidirectional

2.8.4 Multimedia Services

In the early days multimedia communication was regarded as the 'killer' application for ATM based broadband networks. Meanwhile, multimedia communication with rather different service quality is intended to cover all communication networks. ATM based broadband networks are capable of offering very high service quality.

The videotelephony teleservice for ISDN was the first service defined by ITU-T (F.721) carrying multimedia information, namely voice, video and data. The respective terminal recommendation (H.320) in conjunction with a set of protocol definitions ensures compatibility for the basic end-to-end communication. However, considerable freedom was left to exploit the advantages of voice/video compression algorithms and information technology. In particular the terminal recommendation supports various coder algorithms and various information transfer rates. Thereby it offers flexibility to adapt service quality and expenses for terminal equipment and communication to the required application.

With the rapid advance of voice/video compression and information technology it became evident that multimedia communication could be supported advantageously across different networks including TCP/IP and mobile networks. Considering the different network capabilities can mean, as a consequence, different service qualities, e.g. reduced picture resolution. ITU-T framework recommendation on audiovisual/multimedia services (F.700) covers among other things this significant point.

Based on the Recommendation for narrowband visual telephone systems (H.320) a set of further multimedia terminal recommendations and interworking components for further network environments are under study within ITU-T. Examples include B-ISDN (H.321), LAN (H.322), packet mode (H.323), low bit rate multimedia communication (H.324). The intention is to take into account the state of the art compression technique and to ensure compatible end-to-end communication. Basically, it works similarly to the best available bit rate negotiation of modem communication in analogue networks.

2.9 Future trends

As a result of deregulation in many countries, future service offerings will have to face stronger competition. New players like new operators, service providers, content providers and regulation authorities significantly influence the telecommunication market. This and the growing influence of the state of the art Information Technology (IT) is expected to require more flexibility from future telecommunication service offerings. The flexibility concerns for example information transfer rates, information transfer modes, appropriate service quality and the capability to tailor higher layer communication functions easily to specific communication needs.

Services offered in addition to basic service types are called Value Added Services. Value Added Services can be offered to a user by a respective server. For the access to Value Added Services the user can make use of bearer services and teleservices. Examples include innumerable IN services, e-mail, electronic banking and tele-shopping. The ITU-T has produced several Recommendations on platforms for Value Added Services, e.g. for Message Handling Systems (F.400/X.400 series), Directory Systems (F.500 series), Intelligent Network (Q.1200 series). The recommendations take into account that the use of information technology offers considerable flexibility.

Specifications for the booming mobile telecommunication infrastructure have been elaborated, up to now, mainly outside ITU-T. The third generation mobile networks require new service concepts like multimedia service capabilities, mobile Internet access capabilities and offering the same service look and feel when roaming. This needs considerations within ITU-T for the development of IMT-2000 recommendations. Keywords of this service area include Customized Application for Mobile Enhanced new Logic (CAMEL), Virtual Home Environment (VHE) and Fixed Mobile Convergence (FMC).

Specifications for the booming Internet have been elaborated again outside ITU-T in the Internet Engineering Task Force. Internet Specifications, called Request for Comments (RFCs) seem to follow more a bottom up approach. An Internet like service is made up of respective transport/application protocols and server/client functions. A set of future telecommunication services may follow this server/client approach.

Security services like authentication, encryption, electronic signature are prerequisites for a set of significant applications like mobile service access and electronic commerce. These services are expected to increase the use of smart cards in telecommunications.

Typical new IT services are more likely to be created outside standardization bodies. This trend is expected to have an influence on the generation of new telecommunications services as convergence between telecommunication and information technology progresses. However, there is also a tendency to achieve compatible end-to-end communication based on mutually agreed standards. Nearly any telecommunication area with the promise of new revenue making services today creates quickly it's own user forum.

2.9.1 Intelligent Network Services

As most switches and networks were being digitalized in the 1980s they looked more like computers. Initially services were programmed in CHILL-like languages and had to be installed manually in any switch. It was soon recognized that it would be better to deploy and manage a new type of services, called Intelligent Network (IN) services, from one location making use of a higher level language. This prompted ITU-T to standardize the Intelligent Network Concept (Q.1200 series).

The first set of ITU-T IN recommendations, known as Capability Set 1, allows only services with limited control over the switching infrastructure. Capability Set 2, now under development, will provide greater control, thereby allowing more sophisticated services to be offered to the user. With the rapid advance of Information Technology the potential of INs is just beginning to unfold. In future, INs will play a key role in providing telecommunication services across different networks and information transfer modes such telephone networks, mobile networks and internet.

A broad range of Value Added Services can be provided using INs; these services can be grouped into a number of families, e.g.

- Number translation and routing services

These services translate the dialled number into a destination number based on various criteria such as day of week, call origin or routing to a company location closest to the caller.

- Special charging services

These services allow a charging split based on various criteria. Examples include Freephone and Premium Rate.

- Calling Card services

These services enable calls from any terminal to an account of the Calling Card service subscriber.

- Lifestyle services

These services allow calls to be handled in a way specified by the user, e.g. filtering to various conditions.

- Enterprise network services

These services offer corporate network services like Virtual Private Networks or Wide Area Centrex.

- Operator oriented services

These services allow for example various screening options or keeping the number in case of a location or service provider change.

Exploiting the capabilities of the information technology, Ins include a Service Creation Environment. Service Creation Environment uses a graphical design methodology to create new services. A new service is created by using programmable Service Independent Building Blocks (SIBs) from an extensive library. The service is then personalized in accordance with the service provider's needs by entering on-line all the data required by the SIBs.

2.9.2 Examples of new IN Services

With the introduction of the Intelligent Network (IN) the traditional telephony services has been enriched a lot, mostly to match the evolution of a market that changes continuously. Today, widely spread IN services include Calling Card services, Number Translation and Routing services (such as Freephone, Premium Rate and Universal Access Number), and Enterprise Network services (such as Virtual Private Networks and Wide Area Centrex).

One of the most recent revolutions in telecommunications is without any doubt the explosive growth of the Internet and other IP based data networks[3] and services. Voice-over-IP (VoIP) has been growing up into a mature technology, and IP telephony has become a serious business.

To maximize the potential of future multi-service networks, services will have to take into account the different philosophies of network "intelligence" applied in the switched circuit (voice) and data (IP) worlds.

- Voice switching paradigm: A lot of intelligence resides in the network since the end-user equipment, i.e. the telephone, is a fairly simple device. The network must also guarantee time critical throughput upon successful call establishment. Services have gradually migrated from the switching equipment into the Intelligent Network (IN). This has allowed enhanced call control, greater network, service and user profile manageability, and has satisfied one of the most important drivers of today's service oriented networks – faster product time to market.

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[3] The term "Internet" refers to the public access, best-effort, non-managed IP Network (the 'World Wide Web'), while the term "IP Network" will be used for all managed and non-managed private and public IP infrastructure.

- Data networking paradigm: The network primarily provides transport of data. Most intelligence required to utilize the transported data resides in applications running on hosts connected to the data network. These hosts may intrinsically be a part of the carrier's network, or reside on service provider or end user platforms. The evolution here is mainly to provide better and guaranteed Quality of Service (QoS) in terms of network and bandwidth availability, delay, reliability, efficiency, etc.

Some developments are forcing the convergence of both networking paradigms. One of them is the increased use of the switched telephony network for remote Internet access (dial-up to an Internet Service Provider). Another one is the growing application of packetized voice (VoIP) technology for providing telephone calls originating from and terminating to either the voice or the data network.

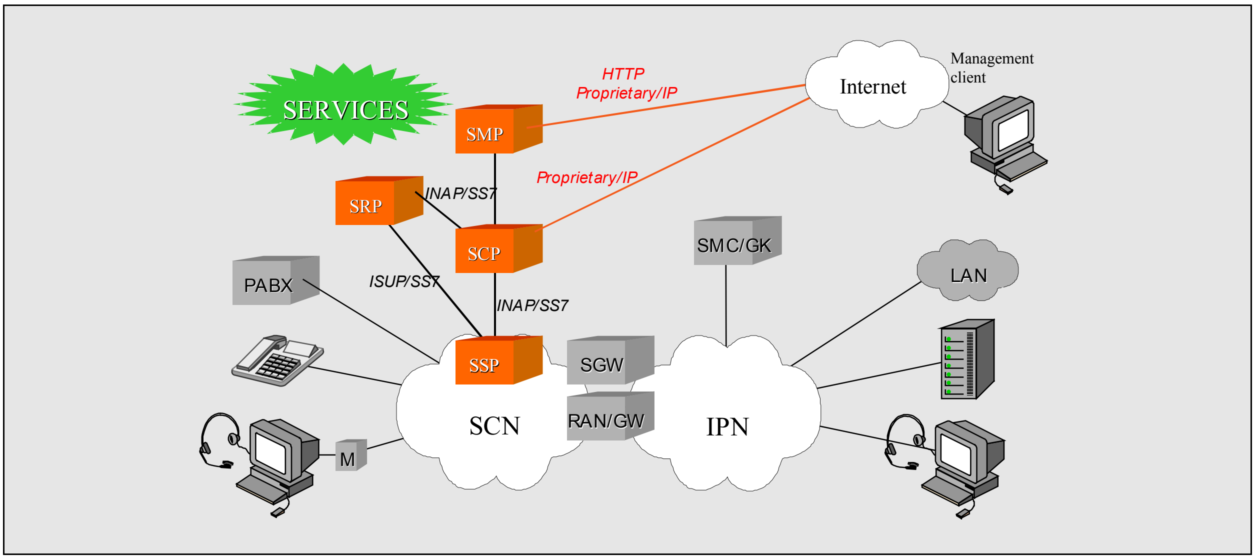
Although there is a tendency to consider the 'traditional' (fixed or mobile) Switched Circuit Network (SCN) and the 'emerging' IP Network (IPN) as two separate worlds – that are at the same time complementary (SCN for the access, Internet for the services) and competitive (VoIP). The Intelligent Network may play an important role in pasting them together, bringing enhancements for both network types.

As such, from the IN point of view, the convergence of voice and data networks will be more an evolution than a revolution.

2.9.2.1 A new role for 'classical' IN services ("reuse" step)

The majority of today's Internet subscribers are using the (analogue or digital) Switched Telephony Network to access their Internet (Telephony) Service Provider through dial-up to the ISP's Remote Access Node (RAN) or the ITSP's Voice-over-IP Gateway (VoIP GW). As the Intelligent Network is already in place in this environment, it may be used for to provide a number of services to the Internet users and service providers.

Figure 2.9.2 – Network architecture for a 'reuse' scenario



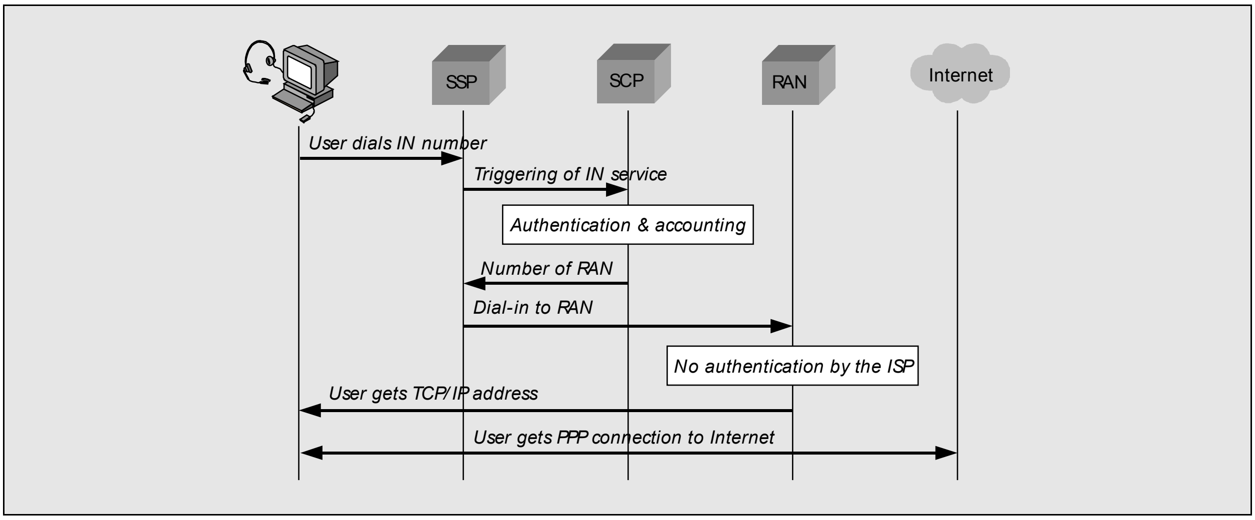
Although the network architecture to implement this scenario (Figure 2.9.2) may sound "non inventive" from an IP-centric viewpoint, the solution is easy-to-implement for established operators and a will quickly generate additional revenue and value for (switched) network operators, I(T)SPs and end-users.

2.9.2.2 Service example: a simple "Pay-per-Surf" service

In today's Internet access scenario, the role of the Network Operator is limited to the offering of a (local) connection from the end-user to the ISP. In general, an Internet user has a subscription agreement with an ISP, that allows him to access the Internet for a maximum amount of time, at a flat rate

The Pay per Surf service enables flexible routing and charging of Internet dial-up calls. Any service user can (anonymously) dial in (through an IN number) to the ISP's Internet access equipment (RAN), without need for a subscription agreement with the latter (Figure 2.9.3). The Network Operator or IN Service Provider charges the user, on a time basis, for the cost of a telephone call, increased with a premium for Internet access which is refunded to the ISP.

Figure 2.9.3 – 'Pay per Surf' service flow



2.9.2.3 Service example: "Browse & Talk" Internet Call Waiting

Telephone users with only one analogue line that are frequently connected to the Internet (>1 hour/day) are blocking their line for incoming and outgoing calls. Investment in a second line, ISDN or xDSL (where available) may be too expensive for them. IN is offering them a variety of alternative mechanisms for call set-up, call delivery, call notification and call completion (Figure 2.9.4).

As such, while a user is surfing, incoming calls may be delivered to his telephone set (with automatic disconnection from/reconnection to the ISP), a second line (fixed or mobile), his voice mailbox, etc. As Voice-over-IP is becoming a mature technology, it may be used as an alternative communication channel. As such, incoming calls may be re-routed to a VoIP Gateway, and delivered to the surfer's PC (equipped with a VoIP client, such as MS Netscape) over the Internet (Figure 2.9.4).

Figure 2.9.4 – 'Browse & Talk' client interface

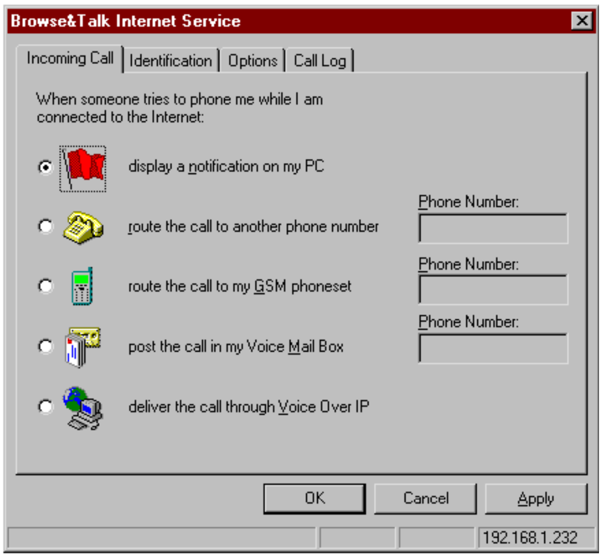
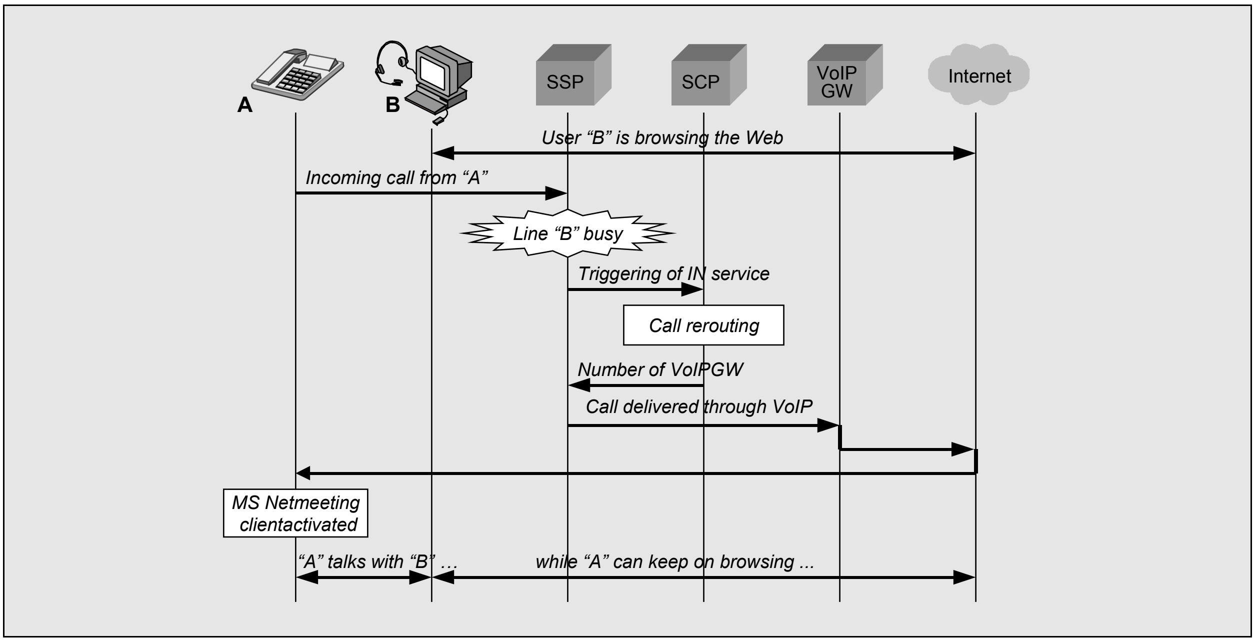


Figure 2.9.5 – 'Browse & Talk' service flow (with call delivery through VoIP)

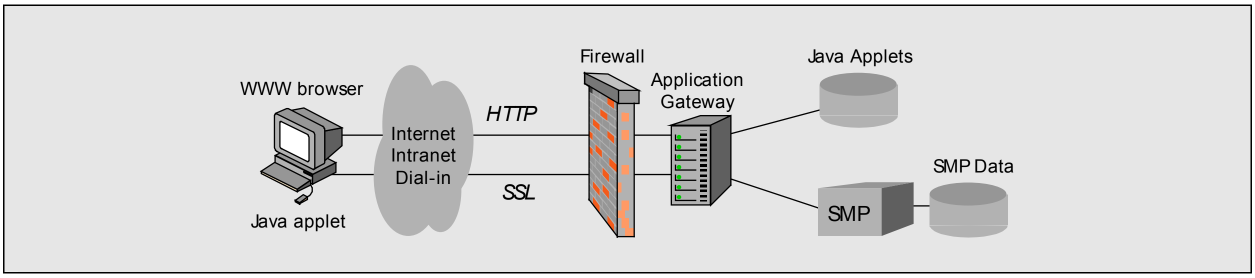


2.9.2.4 Service example: Web-based IN service management

With the pervasive availability of IN services for professional and residential subscribers, the management of these services (i.e. changing the profiles) might rapidly become an important cost factor and a bottle neck for the operator. In fact the subscriber is probably best placed and capable to manage his own service.

Already for professional services (e.g. advanced freephone service) the management, within the limitations set by the provider, can be done with minimum operator intervention. Service logic changes or service supervisions such as statistics demands, are all performed in a secured way (using state of the art cryptographic techniques) over the Internet without any software installation at the subscriber's premises.

Figure 2.9.6 – Web based service management



In Figure 2.9.6 the Web interface guides, in a user-friendly manner, the subscriber via hyperlinks and Java applets through the Service logic and data management and Service supervision management.

This service can easily be extended to "life style" services for the residential subscribers in future. Moreover, and combined with e-commerce techniques, this Web based management service can be extended to a full Web based self subscription service where a residential subscriber would be capable of choosing from a menu of e.g. life style services. He would select the services he is interested in, configuring them and paying for them in one user-friendly surfing session.

2.9.2.5 Expanding into the IP network ("interwork" step)

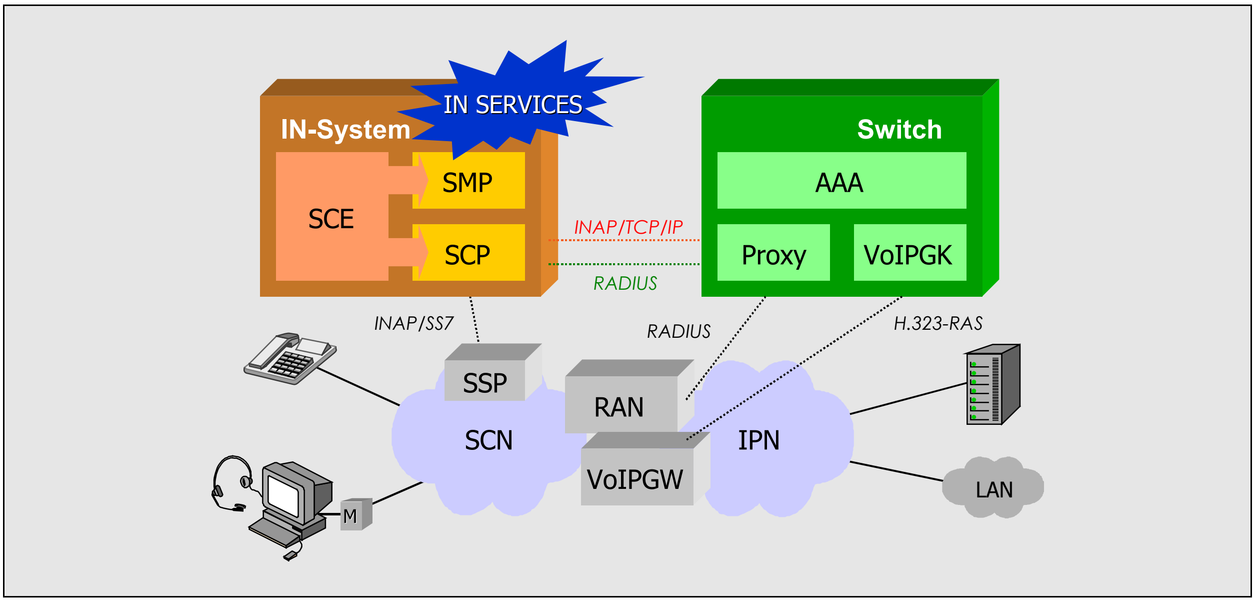
In the I(T)SP network, the intelligence is distributed over different components (most of them implemented at the edge of the IP network or even in the user's terminal), such as AAA servers, Dial-up and VoIP Gateways, VoIP Gatekeepers, Directory and Domain Name Servers, content servers, Java applets and Windows applications, etc.

Figure 2.9.7 shows how an interface between the SCP (operated by the voice network operator) and the SMC (operated by the data network operator) equipment is implemented. This allows the respective network elements to interwork in two directions:

- Where the SCP is initiating the connection with the SMC's AAA server to the latter offering an Service Data Function (SDF) to the IN;
- When the ISP server acts as client to the SCP, and may be considered as an IP 'Service Switching Point' (SSP) with respect to the SCP, and the SCP taking up the role of "Back-end Server' to the SMC's Gatekeeper function.

As an short term solution, the proposed interfaces and resulting interworking services are attractive to operators who are also providing Internet access and/or IP telephony services, because it makes optimal reuse of the existing IN platform and services through standardized interfaces between the ISP servers and the SCP.

Figure 2.9.7 IN-SMC 'interwork' scenario



As an short term solution, the proposed interfaces and resulting interworking services are attractive to operators who are also providing Internet access and/or IP telephony services, because it makes optimal reuse of the existing IN platform and services through standardized interfaces between the ISP servers and the SCP.

The following two service examples show how this interface may add value to both the network operator and the ISP.

The third example shows how the IN concepts may be reused to extend the scope of Domain Name Services (DNS) with service control features.

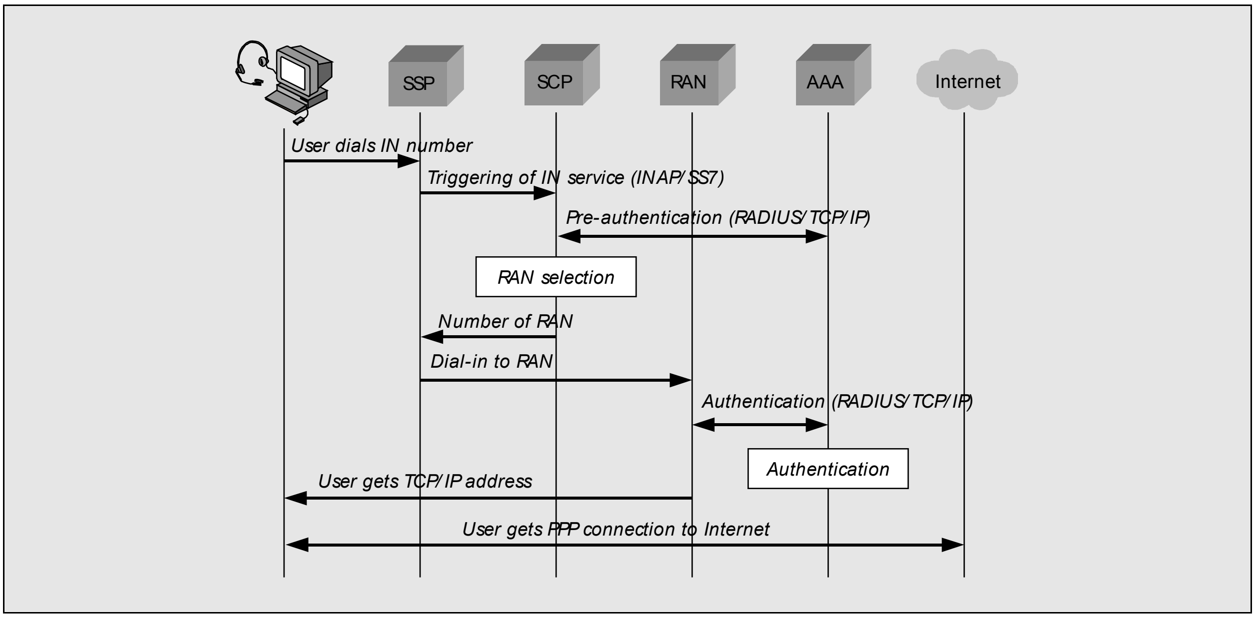
2.9.2.5.1 Service example: "PoP redirect" for optimized Internet access

"Pop Redirect" is an example of a "classic" IN number translation service, which is making use of up-to-date information which is (only) available in the SMC's AAA server.

When a PSTN user dials in on a RAN, the line is sometimes busy due to more users requesting for access than there are ports available. If the ISP is dialled through an IN number, the "Pop Redirect" service will interrogate the AAA server on port vacancy within a specific IP-VPN, and redirect the call to another RAN with free ports (Figure 2.9.8).

As the service level ("Quality of Access") a user is requesting and the price he is willing to pay for it may vary in time, subscriber profile may be managed individually.

Figure 2.9.8 – 'PoP Redirect' service flow

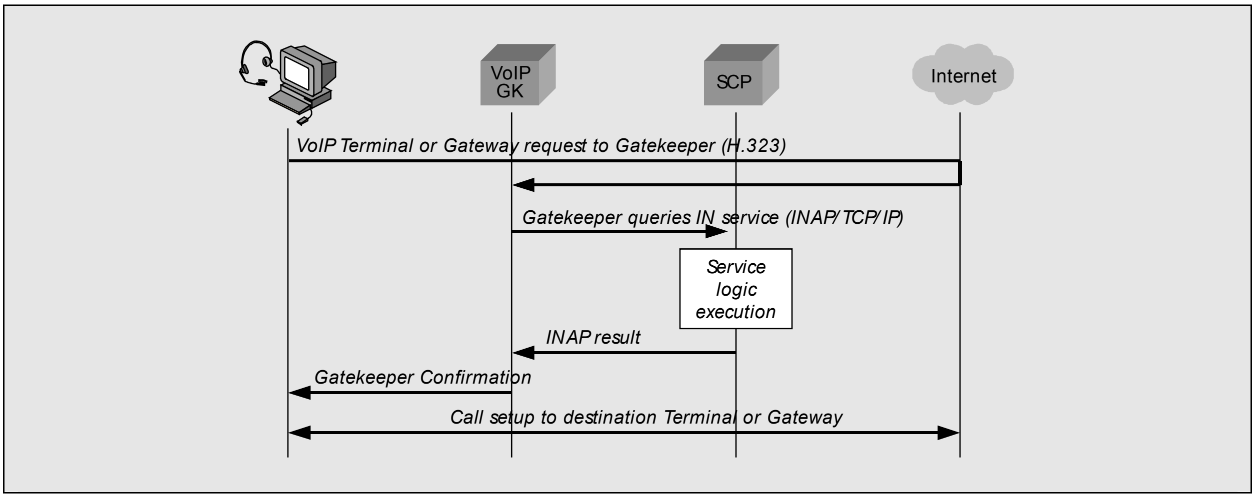


2.9.2.5.2 Service example: Back-end services for Voice-over-IP

To be able to deploy VoIP efficiently, it must be possible to offer "traditional" IN voice services to VoIP users in the same way they are offered to PSTN users (e.g. premium rate, freephone, UPN, voice-VPN, etc.).

To make this possible, the Gatekeeper (in this case located in the SMC) will address the IN service logic, over an INAP-like interface, to reuse as much as possible of the existing IN features and services (Figure 2.9.9).

Figure 2.9.9 – 'Back-end' service flow



2.9.2.5.3 Service example: Intelligent DNS

The Intelligent Domain Name Service (I-DNS) merges the industry-standard DNS with an IN services platform. This provides the flexibility to intelligently route Internet domain addresses.

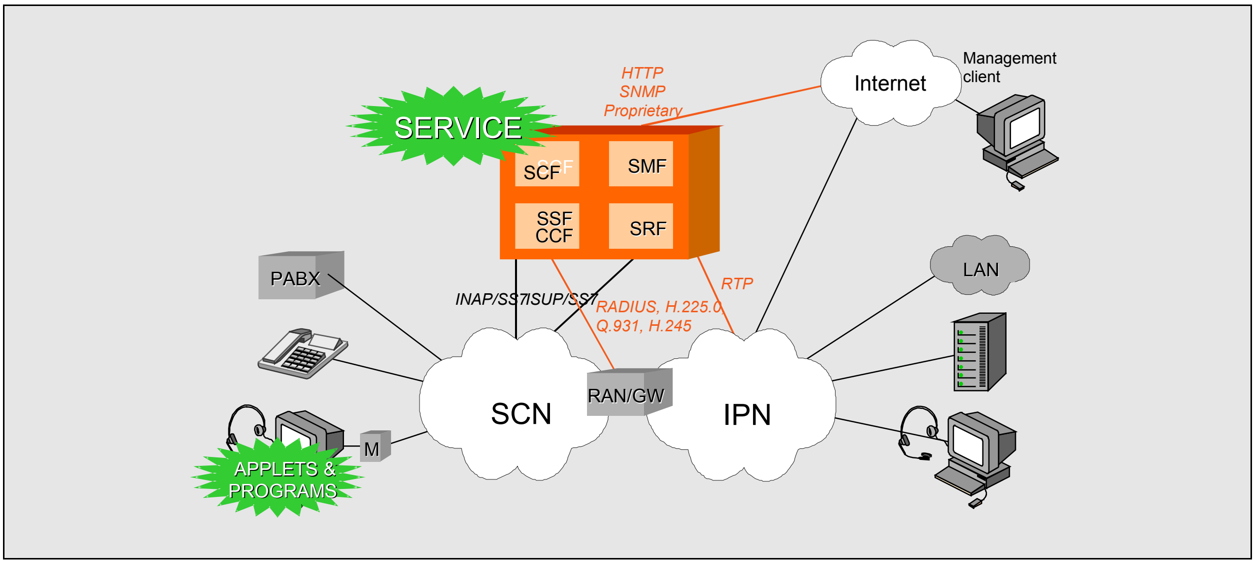
The Dynamic DNS is an alteration to the conventional name server that allows the marking of an entry in the database that will initiate a service on the SCP and wait for a response on a pre-designated port. As such the I-DNS is providing a kind of Service Switching Function, triggering the execution of an IN service script.

The service will allow ISPs, Telcos, and service providers to rapidly deploy revenue-generating services. Using the Intelligent DNS Server, ISPs can charge a premium rate for preferred connections and speeds. Plus, they can sell advertising at higher rates because it can be delivered based on criteria like the time of day or customer profiles. Along with generating additional revenues, the solution can also be used to enhance network performance and meet customer demands for reliability.

As an alternative, the Gatekeeper (or media Gateway controller) may also be implemented in the IP network as a Call Server. The latter is offering similar features as the Call Control Function (CCF) and the Service Switching Function (SSF) that can be found today in public telephony network switches.

There is a major role to play for the Intelligent Network in this context: as the IN's main functions are located (in both a logical and a physical sense) outside the respective sub-networks, the IN system may act as an Intelligence Platform for the combined voice-data network.

Figure 2.9.10 – IN integrated intelligence platform for VoIP



Evolution of the Intelligence Platform includes further integration of the IN, ISP servers and Call Agent features, together with management and clearinghouse functions into a unique *IP Service Node* (Figure 2.9.10). The functionality offered by this Internet-SN includes common databases, user profiles, service creation, provisioning and management, etc.

Different from the "back-end" scenario, the IN platform is able to handle "non-IN" interfaces, such as H.323, SIP and MGCP. This will allow the Service Provider to deploy services on multiple voice networks (e.g. PSTN and IP) while operating one single "front-end" platform for service control, service management and service creation.

This means, that the function of the Gatekeeper, including the Call Control, will be integrated with the IN platform, as such enriching the basic Gatekeeper functionality (as required by e.g. the H.323 standard) with full-IN features and services, including Virtual Private Networking, Calling Card Services, Interactive Voice Response, Unified messaging, etc.

2.9.2.6 Follow-up of standards evolution ("interoperate" step)

Because of the enormous growth of the Internet, the market potential of IP telephony, and the take-off of voice-data convergence services, most of the large standardization organizations are currently looking at IP and VoIP networks and services.

Some of the major initiatives in the area of Voice and Multimedia over IP are conducted in ETSI TIPHON (Network architectures for VoIP), ITU-T SG16 (Multimedia services and systems, H.323), IETF PINT (PSTN-Internet interworking, "click to…" services), MEGACO (de-compositioning of the Gateway into a transport and a control part, and defining MGCP – the Media Gateway Control Protocol), SIGTRAN (packet-based PSTN signalling over IP Networks) and MMUSIC (internet conferencing, SIP, the Session Initiation Protocol, etc.) working groups, iNOW! (an operator and vendor initiative to enforce VoIP interoperability), etc.

At this time, most of these standardization initiatives are converging, but there remains still a huge amount of work to be done to make the IP network as reliable (QoS), manageable (including charging and billing) and service rich as the traditional switched circuit networks.

Although the data world was initially reluctant to adopting 'Old World' telephony architectures and protocols, today there is a tendency to reuse, adapt and extend what is useful. In order to handle network congestion and operator interworking a strong interest for SS No 7 is to be reported. Together with SS No7, the role of the Intelligent Network is being re-evaluated and re-valued in an 'IP dominated' environment.

Many of the network architectures proposed and required by major (telecom and datacom) vendors and operators fall back on IN concepts, protocols and services. They appear as well in 'reuse', 'interwork' as in 'integrate' scenarios.

2.10 ITU STANDARDS

2.10.1 ISDN

2.10.1.1 General structure

- Description of ISDNs

I.120 (3/93)	Integrated services digital networks (ISDNs)
I.122 (3/93)	Framework for frame mode bearer services

- General modelling methods

I.130 (11/88)	Method for the characterization of telecommunication services supported by an ISDN and network capabilities of an ISDN

- Telecommunication network and service attributes

I.140 (3/93)	Attribute technique for the characterization of telecommunication services supported by an ISDN and network capabilities of an ISDN
I.141 (11/88)	ISDN network charging capabilities attributes

2.10.1.2 Service capabilities

- General aspects of services in ISDN

I.210 (3/93)	Principles of telecommunication services supported by an ISDN and the means to describe them
I.220 (11/88)	Common dynamic description of basic telecommunication services
I.221 (3/93)	Common specific characteristics of services

- Bearer services supported by an ISDN

I.230 (11/88)	Definition of bearer service categories
I.231	Circuit-mode bearer service categories
I.232	Packet-mode bearer services categories
I.233	Frame mode bearer services
I.241	Teleservices supported by an ISDN
I.250 ~ I.259	Supplementary services in ISDN

2.10.1.3 Overall network aspects and functions

- Network functional principles & Reference models

I.310 (3/93)	ISDN – Network functional principles
I.320 (11/93)	ISDN protocol reference model
I.324 (10/91)	ISDN network architecture
I.325 (3/93)	Reference configurations for ISDN connection types

- Numbering, addressing and routing & Connection types

I.330 (11/88)	ISDN numbering and addressing principles
I.340 (11/88)	ISDN connection types
E.165/Q.11.ter (11/88)	Timetable for coordinated implementation of the full capability of the numbering plan for the ISDN era (Recommendation E.164)
E.172 (10/92)	ISDN routing plan

- Performance objectives

I.350 (3/93)	General aspects of quality of service and network performance in digital networks, including ISDNs
I.352 (3/93)	Network performance objectives for connection processing delays in an ISDN
I.353 (8/96)	Reference events for defining ISDN and B-ISDN performance parameters
I.354 (3/93)	Network performance objectives for packet-mode communication in an ISDN
I.355 (3/95)	ISDN 64 kbit/s connection type availability performance

- General network requirements and functions

I.370 (10/91)	Congestion management for the ISDN frame relaying bearer service
I.372 (3/93)	Frame relaying bearer service network-to-network interface requirements
I.373 (3/93)	Network capabilities to support universal personal telecommunication (UPT)
I.376 (3/95)	ISDN network capabilities for the support of teleaction service

- ISDN traffic engineering

E.701 (10/92)	Reference connections for traffic engineering
E.711 (10/92)	User demand modelling
E.720 (11/88)	ISDN grade of service concept
E.721 (8/91)	Network grade of service parameters and target values for circuit-switched services in the evolving ISDN

2.10.1.4 User-Network Interface aspects

- ISDN user-network interfaces

I.410 (10/84)	General aspects and principles relating to Recommendations on ISDN user-network interfaces
I.411 (3/93)	ISDN user-network interfaces – Reference configurations
I.412 (11/88)	ISDN user-network interfaces – Interface structures and access capabilities
I.420 (10/84)	Basic user-network interface
I.421 (10/84)	Primary rate user-network interface

- Layer 1 Recommendations

I.430 (11/95)	Basic user-network interface – Layer 1 specification
I.431 (3/93)	Primary rate user-network interface – Layer 1 specification

- Layer 2 Recommendations

I.440/Q.920 (3/93)	ISDN user-network interface data link layer – General aspects
I.441/Q.921 (9/97)	ISDN user-network interface – Data link layer specification

- Layer 3 Recommendations

I.450/Q.930 (3/93)	ISDN user-network interface layer 3 – General aspects
I.451/Q.931 (5/98)	ISDN user-network interface layer 3 specification for basic call control

2.10.1.5 Inter-network interface aspects

- Inter-network interfaces

I.500 (3/93)	General structure of the ISDN interworking Recommendations
I.501 (3/93)	Service interworking

2.10.1.6 Operation and other aspects

- Maintenance principles

I.601 (11/88)	General maintenance principles of ISDN subscriber access and subscriber installation

2.10.1.7 Network management

M.3211.1 (5/96)	TMN management service: Fault and performance management of the ISDN access
M.3600 (10/92)	Principles for the management of ISDNs
M.3603 (10/92)	Application of maintenance principles to ISDN basic rate access
M.3604 (10/92)	Application of maintenance principles to ISDN primary rate access
M.3605 (10/92)	Application of maintenance principles to static multiplexed ISDN basic rate access
M.3621 (7/95)	Integrated management of the ISDN customer access
M.3660 (10/92)	ISDN interface management services

2.10.1.8 Signalling

- Basic services

Q.730 (9/97)	ISDN User Part supplementary services
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2.11 List of abbreviations

AAL	ATM Adaptation Layer
ANI	Access Network Interface
ATM	Asynchronous Transfer Mode
B-ICI	Broadband ISDN Inter-Carrier Interface
B-ISDN	Broadband ISDN
BRI	Basic Rate Interface
B-TE	Broadband Terminal Equipment
CAC	Connection Admission Control
CAMEL	Customized Application for Mobile Enhanced new Logic
CCAF	Call Control Agent Function
CCF	Call Control Function
CLP	Cell Loss Probability
CLR	Cell Loss Ratio
CRC	Code Redundancy Check
CS	Capability Set
DCE	Data Circuit-terminating Equipment
DLCI	Data Link Connection Identifier
DNHR	Dynamic Non-Hierarchical Routing
DNS	Domain Name Service
DSL	Digital Subscriber Line
DSN	Digital Switched Network
DSS1	Digital Subscriber Signalling System
DTE	Data Terminal Equipment
ETSI	European Telecommunication Standardization Institute
FCS	Frame Check Sequence

FMC	Fixed Mobile Convergence
FRDTS	Frame Relay Data Transmission Service
FUNI	Frame User Network Interface
GFC	Generic Flow Control
GSM	Global System of Mobile Communications
GW	Gateway
HDLC	High Data Link Control
Home UNI	Home User Network Interface
IDN	International Data Number
IN	Intelligent Network
INAP	Intelligent Network Application Part
IPN	Internet Network
ISDN	Integrated Services Digital Network
ISUP	ISDN User Part Protocol
ITSP	Internet (Telephony) Service Provider
LANE	LAN Emulation
LAPB	Link Access Procedure Balanced
LAPD	Link Access Procedure for D channel
LEX	Local Exchange
LT	Line Terminal
LUNI	LAN Emulation User network Interface
MTP	Message Transfer Part
N-ISDN	Narrowband ISDN
NNI	Network Node Interface
NT	Network Termination
NT-1	Network line Terminator
OSI	Open System Interconnection
PABX	Public Branch Exchange
PAD	Packet Assembler/Disassembler

PC	Personal Computer
PCM	Pulse Code Modulation
PDU	Packet Data Unit
PH	Packet Handling
PLMN	Public Land Mobile Network
P-NNI	Private Network-to-Node Interface
PRI	Primary Rate Interface
PSE	Packet Switching Exchange
PSPDN	Public Switched Packet Data Network
PSTN	Public Switched Telephone Network
PVC	Permanent Virtual Circuit/Connection
QoS	Quality of Service
RAN	Remote Access Node
REX	Regional Exchange
SCF	Service Control Function
SCN	Service Communication Network
SCN	Switched Circuit Network
SCP	Service Control Point
SDF	Service Data function
SDH	Synchronous Digital Hierarchy
SDU	Service Data Unit
SIB	Service Independent Building Block
SRP	Signalling Relay Point
SSF	Service Switching Function
SSP	Service Switching Point
STP	Signalling Transfer Point
SVC	Switched Virtual Circuit/Connection
TA	Terminal Adapter
TCP/IP	Transmission Control Protocol/Internet Protocol

TE	Terminal Equipment
TEX	Toll (Transit) Exchange
TUP	Telephone User Part
UNI	User Network Interface
URS	Universal Roaming Subscriber
VC	Virtual Circuit
VCI	Virtual Channel Identifier
VHE	Virtual Home Environment
VoIP	Voice over Internet
VP	Virtual Path
VPI	Virtual Path Identifier
VPN	Virtual Private Network
WAN	Wide Area Exchange
WLL	Wireless Local Loop

ANNEX 2A

China case study

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1 Background briefing

1.1 Status-quo of the country

The People's Republic of China is situated in the Eastern Hemisphere, located in the eastern part of Asia facing the Pacific Ocean on the east, the total area of the country is about 9.6 million square kilometers, corresponding to 6.5% of total land areas of the world. The length of its coastal lines is over 18000 Km. China is a unified country with many nationalities (altogether 56 nationalities), and Han nationality is by far the biggest nationality (about 94% of the total population). China consists of 23 provinces, 5 autonomous regions and 3 directly governed metropolitans. China’s topography is high in the west and low in the east, the topography is of diversity and complexity. The percentages of the various topographies in China are: 33% mountains, 26% plateau, 19% basins, 12% plains and 10% hilly lands.

China is of vast expanse and abundant produces. China is rich in such resources as water, creatures, minerals and geothermy. There are over 100 million hectares of cultivated lands, 319.08 million hectares of grasslands (available area of 224.34 million hectares) and 115.25 million hectares of forests in China. The forests cover 12% of total territory.

China is the most populated country in the world. China’s population was over 1.25 billion at the end of 1999. But the population in various places are distributed very unevenly with dense population in the eastern part especially (over 300 persons per square kilometer in the coastal areas), and sparse population in the western part, (just over 40 persons per square kilometer).

China’s national economy has been developing at fairly high speed, and its reform and opening-up policy has yielded prominent results and great achievements during Ninth Five-year Plan period. GDP of the first two years in this period exceeded 8% annual increase, while 7.8% and 7.1% GDP annual increase were obtained respectively in 1998 and 1999 with lower CPI. 1999 GDP valued at 8,319 billion yuan (RMB) i.e. 1000 billion USD and CPI 2.9% lower than that of 1998. China is vigorously pushing forward its modernization programs in industry, agriculture, national defense and science & technology. High-tech enterprises are springing up everywhere in China. Especially China’s telecom and information industry growth rate has surpassed that of GDP for many consecutive years. The rapid development of the information industry has enormous and favorable impacts on all the other industries and contributes a great deal to the national economy.

1.2 Administration and operating agencies for telecommunications

1.2.1 Ministry of Information Industry

The Ministry of Information Industry was founded on March 31, 1998, with merger of former MPT and MEI. MII is a functional department under the State Council governing the information industry. It executes many major government functions, such as:

- It formulates the government’s development strategy, guidelines, policies and overall plans of the nation’s information industry; and it exercises supervision and control over telecom and information service markets to ensure fair competition and universal service.
- It stipulates laws & regulations and issues administrative rules and supervises the enforcement of laws & regulations.
- It establishes technical policies & standards for the manufacturing industry of electronic and IT products, the communication industry and the software industry as well as for radio ad TV transmission networks.
- It formulates tariff policies for information industry and development plans for the informatisation of national economy.

- It takes charge of the nationwide distribution and management of such public communications resources as radio frequencies, satellite orbit positions, communication network numbers, domain names and addresses, and regulates radio frequencies, and implements licensing system etc.

The MII also supervises the State Post Bureau as authorized by the State Council.

The Ministry has 9 departments and 4 bureaus:

– General Office;
– Department of Policy and Regulation;
– Department of Planning;
– Department of Science and Technology;
– Department of Enterprise Restructuring and Operation;
– Telecommunications Administration Bureau;
– Department of Financial Regulation and Clearing;
– Department of Electronic and IT Products;
– Bureau of Military Electronics;
– Department of Informatization Promotion;
– Bureau of Radio Regulation;
– Department of External Affairs;
– Department of Personnel.

1.2.2 China major telecom operators

China Telecommunications Corporation is the largest telecom enterprise in China. It had nearly 110 million fixed telephone subscribers by the end of 1999. The voice, data, fax and other telecom services are offered in its public telecom networks and IP phone & data services are provided in its Internet. China Mobile Communications Corporation solely operates various mobile services, possessing roughly 94.5% of GSM mobile communication market.

With the approval by the State Council, the United Telecommunication Co. Ltd. (the abbreviated form of the name is Unicom) was formally founded on July 19th, 1994, which was jointly launched by Ministry of Electronics Industry, Ministry of Electrics Industry and Ministry of Railways, Unicom is an independent economic entity with legal personality, under the industry management of MPT in terms of Telecom business.

China United Telecom (Unicom) Corporation operates mobile business, possessing 5.45% of GSM mobile communication market and 3.25 million GSM subscribers and 6771 base stations at the end of August 1999, and also operates radio-paging services, possessing most majority of radio-paging market share, and operates Internet services as well. Jitong Communications Corporation operates data services and Internet services in its network.

1.3 Status-quo of China's communications development

Since the 1990s, China has accelerated the process of telecom reform and opening-up to the outside world. China's telecom industry has leapt from the take-off stage to high-speed development period. The official telecom statistics published at the end of 1999 shows that:

– the total number of China fixed network subscribers and mobile communication subscribers have reached 110 million and 43.24 million respectively;
– the total capacity of office exchanges has reached 17.10 million lines; and e-mail subscribers has amounted to 35.6 million.

The statistics issued at the end of 1999 shows that:

- the total number of public telephones has reached 3.008 million;
- the total capacity of automatic toll exchanges has increased to 4.928 million circuit terminals, up 2.1% and
- the total number of toll service circuits has reached 1.75 million.

The total length of fiber-optic cables reached 949,632 sheath kilometers, up 30%, and the total number of DDN ports was 484,665, up 28.9%. The high-speed tandem platform is provided for the domestic Internet. The overall operational quality of telecom network has been bettered and all the targets laid down for 1999 have been met.

Rapid development of China telecom industry has turned out the remarkable rise of penetration rates: China national penetration rate of fixed telephones has grown to 13 telephones/100 persons and penetration rate of main lines has increased to 8.64 main lines/100 inhabitants. And the penetration rate of mobile telephones has been 3.50 handsets/100 inhabitants by the end of 1999. The urban telephone penetration rate has reached 28.4 phones/100 inhabitants.

Table A1 Development of Major Telecommunication Capabilities of China

	Unit	1995	1996	1997	Growth rate of 1997 over 1996	Average annual growth rate 1992-1997 (%)	End of 1999
Total capacity of urban and rural telephone exchanges	Million lines	86.527	108.251	128.685	18.88	34.83	175.379
Total capacity of office exchanges	Million lines	72.036	92.912	112.692	21.29	43.44	153.461
Capacity of mobile telephone exchanges	Thousand lines	7967	15363	25857	68.31	124.54	81360
Capacity of digital mobile telephone exchanges	Thousand lines	1178	5592	14010	150.54	410.99	67956.5
Capacity of automatic toll exchanges	Thousand circuit terminals	3519	4162	4368	4.95	52.94	5032
Toll circuits	Thousand	736	998	1146	14.83	37.40	2299
Total length of toll optical cable	Thousand kilometers	108	133	155	16.54	61.75	250.756
Telephone main lines	Million	40.706	54.947	70.310	27.96	43.71	108.716

The governments at all levels attach importance to the gradual realization of the goal of universal telephone access service, 79.8% of rural administrative villages enjoyed phone access service. The total number of rural telephone subscribers reached 34.179 million, up 43%. The number of urban and rural public pay phones reached 3 million. In order to improve telecom network capacity and communication service quality in rural areas, SPC switches, pair-gain systems, wireless access system, microwave systems etc. are equipped in rural network. Even satellite system will serve some part of remote areas in the future. The universal telephone access service level in the eastern rural areas with developed economy has approached that of urban areas.

1.4 China's communication development policies

The sustained and rapid development of China's communication undertaking has been benefited from macro environment of reform and opening-up as well as economic growth. In the practice of past decade's reform and development, China has adopted a series of policies for effectively promoting the development in accordance with China's state situation and actual conditions of communication industry:

– The Chinese government has attached great importance to the development of communication undertaking and regard it as a prerequisite for economic growth and opening-up to the outside world, and has rendered policy support and tried every means to protect and promote the communication development. The governments at various levels have considered local communication infrastructure building-up as their own duties, therefore they provide the necessary conditions and guarantees for telecommunication construction and organize people from all walks of life to support telecom sector in the construction of communication networks;

– The overall plan of communication development has been worked out so as to ensure the coordinated telecomms development in the whole country. Priority is given to meeting the fast growing communication demands in the eastern coastal regions and urban areas, and at the same time, attention has been paid to the solution of communication development problem in vast middle and western regions with less developed economies. The transmission and switching, toll as well as local, of telephone and new services within telecom networks should be developed in a coordinated way;

– The concerted efforts should be made in building up a complete and uniform state public communication network, meanwhile the support should be given to other sectors' establishment of necessary private networks on the basis of needs as a supplement to the public networks;

– Business licensing systems are implemented for opening new domestic telecom service markets and some portions of radio mobile communication service markets and competition mechanism has been introduced; Opening the market of communication equipment and licensing system is implemented for connecting customer terminal equipment to the network, open tendering at home and abroad for major network equipment is expanded; at the same time, opening-up the communication construction market so as to speed up the construction;

– Graded accounting and graded administration are implemented within the communication enterprises, and on the premise of guaranteeing necessary centralization & uniformity and command & dispatch within the entire network, the rights for autonomous business operations are transferred to the communication enterprises in order to let them assume the responsibility of communication construction and business operation for their serving areas, and the employees' interests and business outcomes are bound together;

– With the support of state policies, telecom construction funds are raised by communication enterprises through multi-channels to ensure the necessary telecom investment intensity. Communication enterprises should improve economic effects, and strengthen their own accumulations and development abilities through improving business management and lowering the costs of construction and operation; on this basis, loans and rentals at home and abroad should be fully utilized; the initial telephone connection fee shall be charged following the state approval;

– Relying on science & technology progress and adoption of new technology from high starting point and modernization of communication networks should be accelerated; the qualified staffs' fostering should be effectively carried out so as to gradually set up a high quality communication force in the fields of construction, maintenance, business management and research & development;

– Adhere to opening to the outside world and actively introduce advanced equipment, technologies and capitals from abroad, employ the advanced business management experiences, and strengthen friendly cooperation and exchange with various countries in the world in the communication domain.

The above-mentioned communication policies have taken shape and developed in the practice of reform and opening-up to the outside world. The practice in the great development of China's telecom undertaking has indicated that these policies and measures tally with the actual situation in China and yield good results. The situation about China's communication industry will still change continuously with the in-depth reform of state economic system and gradual establishment of socialist market economy system. The telecom sectors should not only adhere to the past proven-effective policies with China's characteristics, but also carry out the earnest study on macro communication environment and employ the experiences of other countries for reference and lose no time in pushing forward the reform in communication industry and accomplish the transformation from extensive to intensive operation so as to meet the needs of greater development of communication undertaking.

2 Telecommunication networks and services

2.1 Telecom network development

2.1.1 Communication capability

China's total capacity of telephone exchanges has reached 160 million lines by the end of 1999, the network scale ranks the second in the world. By the end of 1998, all the cities above the county level have installed digital SPC exchanges and 99.8% of the overall network has become digital. As of end 1999, the total number of long distance circuits has reached 1.757 million, almost all the long distance circuits have become digital. The total capacity of toll automatic switches has reached 4.83 terminal lines and the total mobile switching capacity has reached 43.31 million subscriber lines. By the end of 1999, there have been 1,781,084 toll service circuits, 158.531 million lines of office telephone exchanges and 67.34 million lines of mobile exchanges and 1,827,999 GSM digital mobile communication channels and 315,239 analogue mobile communication channels respectively. The interconnected nationwide public multi-media communication network was basically completed with the bandwidth of the international gateway of the public Internet extended to 177 MHz and the 155 MHz broadband backbone ATM network in place which links up all the provincial capital cities.

2.1.2 Satellite communications

By 1995, China has had seven type A standard earth stations for satellite communications, and one Intelsat T&TC (Tracking and telemetering control) and standard reference station, over 9000 international satellite circuits have been established with 48 countries and regions; there had been 21 earth stations in the provincial capital cities, providing 7500 circuits, thus China's domestic satellite communication network is of a comparative scale.

China's VSAT services are also developing rapidly. In 1988, China began to adopt VSAT satellite communication technology. By 1995, P&T sectors had completed VSAT public communication systems with 700 VSAT stations and over 1000 circuits, providing VSAT communication services for the remote areas in Tibet, Sichuan, Guizhou, Yunnan and Guangxi. Meanwhile the sectors of coal, petroleum and banking have also set up their own private VSAT satellite communication networks. At present, nearly 10 thousand VSAT stations imported from a dozen of foreign companies have gone or plan to be going into operation.

During 1998, China Telecom continued to build up 15 new satellite earth stations and expanded existing 23 satellite earth stations, thus greatly enhancing the capability of satellite communication network. China domestic circuit terminals totaled 50,000 before the end of 1998. China international satellite communication services were opened to some other Southeast Asian and European countries in 1998. China Satellite business revenue has turned out 342 million yuan (RMB) by end 1999.

2.1.3 Construction of international fiber optic cables

China began to invest and take part in the construction of international optic-optic cables in 1989, and China-Japan submarine optic-optic cable construction was completed at the end of 1993. China-Korean submarine optic-optic cable was commissioned in February 1996. With the joint efforts made by China and the relevant parties, the Trans Asia-Europe land optic-optic cable (TAE) was put into operation on October 14,1998 after 5 year construction. In addition, the FLAG international submarine optic-optic cable with China participation and investment has also been commissioned.

2.1.4 Emergency communications

As an important part of the public network, the emergency communications has had a relatively perfect working system. For many years, the emergency communications has played a vital role in urgency rescue and disaster relieves and the country's great-event news reports. Till now, seven emergency communications bureaus have been set up in Beijing, Hubei, Shanghai, Shenyang, Sichuan, Xi'an and Guangdong, and the nation-wide emergency network has preliminarily taken shape. The emergency communications bureaux have been equipped with vehicle C-band and Ku-band earth station; INMARSAT A, M and B-type land stations; containerized SPC switching systems with 1000, 2000 and 4000 lines; single point to multi-addresses microwave circuits and portable digital microwave stations as well as 450 MHz and 900 MHz mobile telephone systems. The telecom offices in the provinces and autonomous regions have been equipped with 24-channel UHF and 100W single-side band short-wave communications equipment and the associate power supply systems. During the Ninth Five-Year Plan period, a relatively perfect nation-wide emergency communications network with the Ku-band VSAT system as the backbone and various vehicle-carried earth stations as the supplementary will be built up.

The mobile communication systems and microwave systems played an important role in emergent communications in flood-stricken areas during the period of fighting against flood in 1998. Advanced wireless communication technologies and systems are employed for emergency communications and yield good results.

2.1.5 Construction of supporting networks

China has set up No. 7 signalling networks covering the capital cities and relatively developed regions. As of end 1998, a nationwide SS7 network with 19 pairs of HSTPs began to take shape and signaling links in mesh network accounted for 80% of the total such links and carry a variety of services such as intelligent network etc. A digital synchronization network in 31 provincial cities independent of the service networks has been built up, capable of providing high accurate and highly reliable clock to various digital systems, and intra-provincial digital synchronization networks have also begun to take shape.

China Telecommunications Corporation had set up and put into operation some 300 local telecom management networks serving for 92% of the existing local networks by the end of 1998. The long distance PDH transmission management network was basically established and the construction of SDH sub-networks with three types of equipment related to SDH transmission management network was completed in 1998.

2.2 The development of telecom services

2.2.1 Overall level of telecom services

With an addition of 21.386 million local subscribers in 1999, the total number of local subscribers has reached 108.807 million with 74.628 million urban telephone subscribers and 34.179 million rural telephone subscribers. At the end of 1999, the mobile subscribers increased by 17.955 million and the total number of mobile subscribers has increased to 43.238 million, ranking the third in the world. By the end of 1999, there have been 0.268 million subscribers of DDN service and 6.02 million EDI subscribers, and there have been 1.198 million subscribers served by 169 multimedia network and 168,135 N-ISDN service subscribers. China Internet subscribers have amounted to 8.9 million and there have been 35.60 million e-mail subscribers (with 26.70 million free e-mail subscribers included) and 43.24 million mobile subscribers respectively.

And by the end of 1999, telecom service revenue has amounted to 243.3 4 billion yuan (RMB), up 21.1%.

Table A2 – Development of telecom services

	Unit	1995	1996	1997	Growth in 1997 over 1996 (%)	Annual growth rate from 1992 to 1997 (%)	End of 1999
Total telecom turnover	Billion RMB yuan	87.56	120.87	162.9	34.8	48.4	313.237
Long distance telephone	Billion	10.14	12.74	15.78	23.9	40.6	65.841
Domestic long distance telephone	Billion	9.7	12.24	14.97	22.3	41.2	19.42
International calls and calls to and from HK, Taiwan and Macao	Million	410	495.020	572.517	62.0	32.3	569.626
Number of local subscribers	Million	32.636	42.778	52.444	22.6	41.6	108.715
Residential telephones	Million	29.098	41.319	54.638	32.2	61.7	88.436
Public Pay Phones	Million	0.85	1.373	1.939	41.2	87.4	2.974
Mobile telephone subscribers	Million	3.629	6.853	13.233	93.1	137.0	43.296
Radio paging subscribers	Million	17.392	25.362	29.690	17.1	68.0	46.744
Packet switching subscribers	Thousand	28	56	85	51.8	_	109.144
EDI subscribers	Thousand	–	0.113	0.204	80.5	_	0.602

Note: 1 US dollar = 8.28 Yuan (RMB).

2.2.2 Mobile communications

In recent years, China's mobile communication services and networks have been developing at the fastest speed. China's mobile communication networks and mobile services are operated by two corporations i.e. China Mobile Communications Corporation (separated from China Telecom in later 1999) and China Unicom Corporation. China Unicom started GSM operation in June 1998, its digital mobile telephone network has covered 149 cities (including some just completed mobile networks and trial operated mobile networks). By the end of 1999, the total number of mobile subscribers has grown up to 43.238 million; the total number of digital mobile telephone subscribers has reached 38.289 million (33.077 million owned by China Mobile, 52.12 million owned by China Unicom). The amount of China mobile calls within 1999 has reached 65.7 billion (60.87 billion for China Mobile and 4.83 billion for China Unicom). In 1999, mobile communications yielded 71.32 billion yuan with 56.44 billion yuan by China Mobile Communications Corporation and 14.98 billion yuan by China Unicom. China mobile communication network has covered all the prefecture-level cities and 96% county towns with 43.238 million mobile phone subscribers by the end of 1999. The nationwide mobile communication intelligent network (IN) phase II expansion project has been completed in January 2000. This mobile IN network has launched automatic roaming prepaid service in 13 provinces covering over 150 cities and 4 million subscribers.

China radio-paging business has been developing very fast, especially in urban areas. There are a lot of radio-paging stations all over the country. The major radiopaging operators are China Telecom and China Unicom. China Telecom enjoyed an increase of 8.14 million new radio-paging subscribers, making the total up to 37.83 million at the end of 1998. China Unicom enjoyed an increase of 1.3 million new users, making the total up to 2.02 million. By the end of 1999, the total number of radio-paging subscribers has reached 47.17 million.

2.2.3 Data communications

China telecom public packet switched network (CHINAPAC) was completed and launched into operation in September 1993. By the end of 1996, CHIANPAC will have covered over 2200 cities and counties throughout the country with the total capacity of 0.12 million ports and will have gateways to 44 packet switched networks in 23 countries and regions. CHINAPAC is characterized of high line utilization rate, heterogeneous protocols support and interworking of various types of terminals and high network security and distance-independent communication tariffs etc., CHINAPAC is widely used by the banking services, governments, enterprises and commercial sectors etc. and is a technically matured basic data communication network with perfect functions and broad coverage area.

China public digital data network (CHINADDN) was completed and went into operation in October 1994. In 1998, CHINAPAC network and CHINADDN network have covered all prefecture-level cities and over 2000 county towns and some rural towns. By the end of 1999, there have been 108,000 packet switching subscribers and 239,490 packet switching node ports; 268,000 DDN subscribers and 484,665 DDN ports, 23,743 frame relay subscribers and 18,420 frame relay ports, 168,135 N-ISDN subscribers, and 169 public multimedia network consumer subscribers have reached 1.198 million, up 43.3%. Wireless data services have already gone into service in China.

2.2.4 New telecommunication services

Along with the stable growth of China national economy and the fast development of key telecommunication infrastructures such as mobile network, Internet network and intelligent network, a host of new telecommunication services are springing up at a quick pace. EDI service is gradually being replaced by e-commerce business. Many new telecom services have gone into service. With the approval of MII, IP phone services have been provided by China Telecommunications Corporation, China Unicom and Jitong Communications Corporation in 14 provincial capital cities (including Beijing, Shanghai, Tianjin).

In recent years, China Internet has been developing rapidly, e-mails are sent via Internet easily, the number of e-mail subscribers has rapidly increased to 35.60 million by the end of 1999.

China public fax store and forward service network (CHINAFAX) has covered all provincial capital cities. By the end of August 1999, the number of CHINAFAX subscribers reached 4,657.

The videoconferencing network has covered all the provincial cities and linked prefectural cities, several dozens of videoconferencing systems have been put into services in municipalities and all provincial capital cities for convening nationwide and provincial & municipal videoconferences.

China intelligent network (IN) networks first offer billing card calling (300) service, freephone call (800) service and VPN (600) service, and then IN networks offer Centrex (WAC), UPT, VOT and MAS services etc. By the end of 1999, IN network has covered all the provinces and autonomous regions except Tibet, and 300 telephone card service and 800 freephone service were available in 30 provinces with exception of Tibet. More and more customers use 300 telephone card service and subscribe to 800 freephone service.

China has already completed construction of domestic and international ISDN networks and has added ISDN functions into PSTN. By the end of 1998, N-ISDN had offered integrated voice, data and image services along normal telephone lines with long distance inter-networking realized in 25 provincial capital cities, and 25,533 subscribers have accessed to domestic N-ISDN. By the end of 1999, there have been 168,135 N-ISDN subscribers (only 25,060 N-ISDN subscribers at the end of 1998). The broadband multimedia network has already gone into service.

The main new telecom services are listed below, which have been provided in intelligent network, data communication network, Internet network, mobile communication network and ISDN network.

(1) Intelligent network services:

Phone card services (200 service and 300 service), freephone service (800 service), virtual private network (VPN) service and wide area Centrex service (WAC service) etc.

(2) Data communication services:

X.25 packet data network service, digital data network services, frame relay network service and electronic data interchange (EDI) etc.

(3) Internet services:

Internet access, IP phone, Internet web hosting, 163 ChinaNet access, 169 China public multimedia information network services, ISP service and electronic commerce etc.

(4) Mobile communication services:

900 MHz GSM telephone service, 800 MHz CDMA mobile communication service, Short message service, prepaid card service, voice mail service and wireless data service etc.

(5) ISDN (narrow-band & broadband ISDN) services and other services:

High speed data transmission; connections between remote workstations and LANs as well as interconnection of multi- LANs; multimedia workstation service; high speed image transfer service; videoconference; access to information databases; computer LAN/WAN interconnection; frame relay; videophone service; electronic financial & banking service; video-on-demand service; remote learning and tele-medicine services etc.

2.2.5 International telecom services

So far, China telecom carriers have opened new international telecom services such as IDD operator service and freephone service, telephone credits, N-ISDN, radio, cellular mobile telephone international roaming and high-speed digital private line services. By 2000, China will have completed the modernized telecom network with telecom capability of operating international telephone services, international intelligent services and international integrated services, and interworking with the global and regional optic-optic cable systems.

As of the end of 1998, China had direct communication links with 87 carriers of 72 countries. N-ISDN interoperability was realized with 11 countries and regions. China international telephone call duration within first 8 months of 1999 has reached 385.3 million minutes. The international 800 (ITFS) was extended to 21 countries and regions; the Global 800 (UIFN) accessible from 13 countries and regions; and international roaming was realized of the GSM network of China Telecom with 60 GSM operators in 38 countries and regions.

By the end of 1998, China had been connected by N-ISDN with Japan, USA, UK, Germany and Singapore etc. via 3 international gateways. By the end of 1999, international ISDN service had been provided between China and 9 countries and 2 regions such as USA, Japan, Germany, France, Australia and Singapore.

2.3 Experience and problems for introducing new services

Achievement known world-wide have been made in the development of China's telecommunication undertaking and the many excellent experiences deserve summing up. MII of China persists in unity, integrity and sophisticated ness and unified planning, system and construction, thus playing a directive role in the development of telecommunication undertaking. The various administrations and special bureaus have accumulated many good experiences. Some typical experiences are listed as follows:

- Clear-cut objectives and methods formulated. Some telecom administrations put new services development into annual target of telecom operations, 8 to 10 development or roll-out items are put forward each year and personal accountability is implemented according to assessment method for economic responsibility (up to bureau), and award methods for new service development and preferential method for key customer to use new services are laid down. The six types of new services such as voice, data, text, video (image), mobile and intelligent services have been developed fairly successfully.
- Restructuring, speciality management, division of work for responsibility. In order to accelerate the development of new services, new service operating mechanism is rearranged so as to solve the problem of repetitive construction and mutual rivalry for interests. The special service companies have been established to carry out special service development and operational management, for example, information industry company limited, integration department for intelligent systems and audiotex company operate and manage data and image communications, intelligent building construction and audiotex services respectively.
- Market research and prediction, and opportune development. The success or failure of new services to a certain extent depends upon prior market research and prediction. Therefore, the role of market prediction department should be fully played. Before developing each new service, the prediction report should be submitted to the leaders for their decision-making.
- Competition introduction and enhanced management. The monopoly of new service by telecom administrations has become historic situation due to the reform of telecom system and partial competition of services. Facing the competitive situation, all the telecom administrations take the road of mutual compliment of advantages and joint construction with increasing market share occupancy as their goal. The joint entities have been set up for opened services such as radio paging, VSAT, EDI etc, good results have been obtained due to multiparty participation and joint development on the basis of P&T as main force.
- Enhanced marketing, application roll-out. At the beginning, subscribers know very little about new services for time being, it is necessary to make extensive propaganda about new services. P&T administrations propagate new telecom services and new technologies in the age of information on the occasions of World Telecom Day, municipal communication construction leading group meeting and various expositions or consultative meetings.
- More and more ISPs are engaged in Internet services in China due to ever-growing computers access to networks and with the merits and features of various Internet services, e.g. low communication fees, large content acquisition and many useful applications etc., so the number of Internet subscribers is soaring in China.

The main problems for China to introduce new services are as follows: Introduction of technical equipment lacks global coordination because China's communication equipment market is a multi vendor market, thus bringing about the difficulties for interconnection and interworking between various platforms and second development of new services.

Also the propaganda for introducing some new telecom services has not been well done, thus many customers fail to understand the applications and features of the new telecom services. Such poor propaganda and promotion of new telecom services produce the negative effects on the new telecom service introduction and development as well as on the service revenue etc.

3 Current network development

3.1 Overview

The principle of network development is to take the development of telephone service and new telecom services as the keynote. The enhancement of comprehensive communication capacity of the entire network and improvement of network technological level and adoption of new technologies are regarded as focal points of development. China has been developing telephone network, data communication network, mobile communication network, Internet network & platform and intelligent network vigorously. China Internet and broadband multi-media networks are currently developing at very fast speed. China has set up various supporting networks and strong high-rate platform for China Internet. The internationally advanced DWDM optic communication technology has been introduced in all the capacity-expansion projects for 12 fiber optic trunk cables. As of end 1998, the total length of trunk fiber optic lines for long distance and local networks totaled 680,000 km, of which 170,000 km for long distance. China communication network is able to provide huge information channels and reliable communication platforms for the state economic information networks. China has built up a public multimedia communications network, and 155 MHz broadband ATM backbone network has been in place which links up all the provincial capitals.

3.2 Public Switched Telephone Network (PSTN)

China PSTN structure is composed of three level networks. No. 1 level network is the nationwide backbone network from the capital Beijing to all the provincial capitals and 4 municipalities. No. 2 level network refers to all the intra-province backbone networks reaching to their prefecture-level cities. No. 3 level network is composed of all local networks (322 local networks in total) from prefecture-level cities down to county towns and many rural administrative villages. China's PSTN network scale stands at the second largest in the world, with total switching capacity of 160 million lines.

3.3 China Internet network

Starting from 1995, ChinaNet and China Golden Bridge Network (GBN) can directly get access to the international gateway to provide commercial services. At present, 6 major Internet networks' commercial business operations have been approved by the State Council in China: ChinaNet, Cernet (China Education and Research Network), CHINAGBN and CSTNet (China Science & Technology Network), UNINET and CNCNet Statistics announced on January 19, 2000 show that China overall international gateway capacity for Internet services has reached 351 Mbit/s, connecting to the United States, Canada, Australia, UK, Germany, France, Japan and Korea etc. ChinaNet is the largest Internet operated by China Telecom with the capacity of 291 Mbit/s, and CHINAGBN with 22 Mbit/s, UNINET with 20 Mbit/s, CSTNET with 10 Mbit/s and CERNET with 8 bit/s respectively. And the Internet customers in China have been growing rapidly from 100,000 at the end of 1996 up to 8.90 million by the end of 1999, and this is expected to reach 32 million by 2002. As of the end of 1999, over 300 Internet service providers (ISP) have operated Internet services in China. 48,695 registered domain names, 15,153 WWW. Sites and 2300 registered web sites of governments at various levels have been used in China Internet business, with 3.50 million computers access to China Internet network. The four communication corporations (China Telecom, China Unicom, Jitong Communications Corporation and China Netcom Corporation) have been approved by the State Council to offer various Internet and IP phone services etc.

3.4 Toll trunk transmission networks

China's toll transmission network is currently divided into two classes: interprovincial trunk network and intraprovincial toll transmission network, having several characteristics as follows:

- The transition from analogue transmission system to digital transmission system has mainly been completed. Both high-capacity transmission system and digital transmission system for toll service circuits account for over 99%, the analogue to digital transition has in the main been completed.
- The structure of network is changing, the interprovincial trunk network is in transition from tree-type network to grid network, while intraprovincial ring-type or linear-type digital two level trunks have been built up in some regions.
- During the "Eighth Five Year Plan" period, PDH systems were vigorously developed both in interprovincial network and intraprovincial network, thus formed the toll transmission network with PDH equipment as main body. During the "Ninth Five Year Plan" period, SDH systems have been launched into operation in a large scale. SDH and PDH systems are compatible and coexisting by the year 2000. In order to facilitate the toll transmission network's transition from PDH to SDH, the expansion of fiber optic cable systems, upgrading and updating of equipment will progressively deploy SDH equipment, except for those PDH systems used on already laid optical cables and already commissioned PDH equipment.

Due to the uniform construction of optic-optic toll trunk cable networks in China, over 90% of prefectures and cities will be served by fiber optic trunk cable network, and SDH target network will ultimately form the three-level structure, Level one and Level two toll trunk networks will be combined into a single toll backbone transmission network.

In order to enhance the security of network, China's toll trunk transmission network will utilize many kinds of communication means with fiber optic cables as main means and satellite and digital microwave systems as auxiliary means.

By the end of 1998, China had basically completed the 8 vertical and 8 horizontal fiber-optic trunk lines linking 31 provinces, municipalities and autonomous regions nation-wide. The total length of fiber-optic cable lines in China has reached 1 million kilometers, among which 0.2 million kilometer long distance fiber-optic trunk lines and 5000 kilometer long distance fiber-optic trunk lines built by Unicom. SDH network has reached 31 cities above the provincial capital level, and intra-province SDH networks also begin to take shape. Seven digital SDH microwave trunk projects were completed in 1998. The total length of fiber-optic cables has reached 949,632 km sheath kilometers by the end of 1999. The total length of digital microwave links has reached 69,000 kilometers by the end of 1999.

3.5 Digital synchronization networks

The digital synchronization network of China Telecom consists of the HSTPs, LPRs and BITSs. The first and second phases of such network construction project have been completed, thus 31 provincial capital cities have built up their synchronization networks respectively, and the intra-provincial synchronization networks have begun to take shape.

3.6 Intelligent networks

China has its international intelligent network (IN) with 3 new international gateway exchanges for normal international telecom services and international IN services. China has combined its international IN network and domestic IN network. China's national IN network consists of SSPs, SCPs, a SMP and a SCEP. China's provincial IN networks have also been established in all the provinces and autonomous regions except Tibet.

3.7 Access networks

The majority of the access networks in China use local copper twisted pairs, and a few metropolis also employ a small amount of optic-optic subscribers for supporting digital subscriber loop carrier (SLC) systems. Since the latter half of 1990s, especially from 1998 on, China has made a huge progress in the application of FTTC, FTTB and FTTH. The application of optic-optic cables in access network has made a great headway in big and medium-sized cities and economically developed regions so as to promote informatisation of national economy and video communications. Beijing, Shanghai and Guangzhou are the model cases in point. For example, the application of FTTC and FTTB has also made a great progress in the telecommunication access networks. China has adopted advanced fixed ADSL or N-ISDN solutions, IP network, LANs and wireless access solutions (WLL) in local access networks. China has been vigorously accelerating FTTC, FTTB, FTTO and FTTZ construction with SDH and PON as the main transmission means in recent years and the years to come.

4 Development targets of China's telecommunication undertaking

4.1 Main targets for telecom industry development in the year 2000

Total turnover of telecommunication services: 260 billion yuan (RMB), up 21%

Total capacity of newly added fixed telephone switches: 20 million lines

Number of newly added fixed telephone subscribers: 18.50 million

Number of newly added mobile communication subscribers: 25 million

Number of newly added data and multimedia communication subscribers: 7.1 million

Penetration rate of national telephones: 16 telephones/100 persons

Penetration rate of urban telephones: 29 telephones/100 persons

Percentage of administrative villages enjoying phone access service: 85%

Production output of China-made SPC switches: 21 million lines

Production output of China-made mobile communication switches: 25 million lines

Number of China-made mobile handsets: 37 million.

CHAPTER 3

3 Mobile digital cellular networks and services

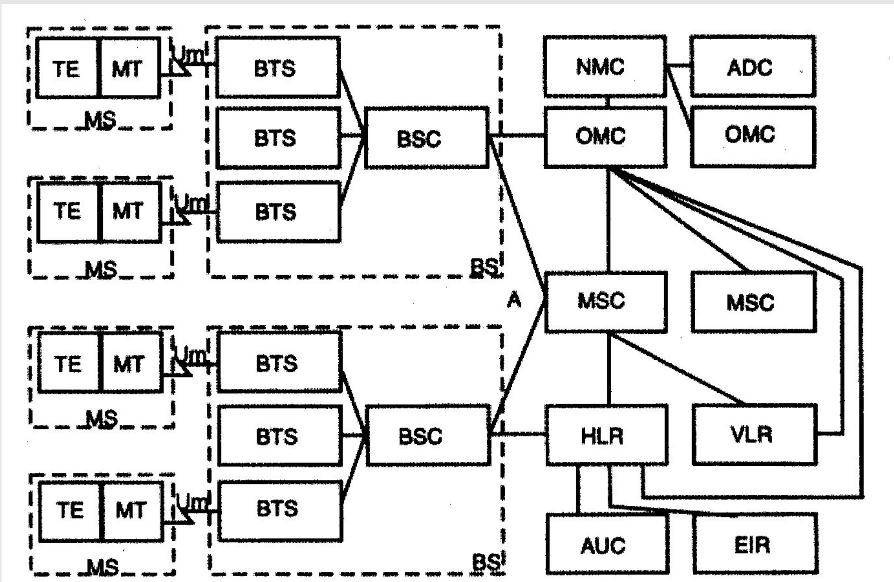
3.1 Global system of mobile communications (GSM)

3.1.1 Introduction

Following the standardization and launch of the Pan-European digital mobile cellular radio system known as GSM, it is of practical merit to provide a rudimentary introduction to the system's main features for the communications practitioner. Since GSM operating licences have been allocated to 126 services providers in 75 countries, it is justifiable that the GSM system is often referred to as the Global System of Mobile communications. The GSM specifications were released as set of thirteen recommendations (ETSI, 1988), which are summarized in section 3.2.8, covering various aspects of the system.

The system elements of a GSM public land mobile network (PLMN) are portrayed in Figure 3.1, where their interconnections via the standardized interfaces A and Um are indicated as well. The mobile station (MS) communicates with the serving and adjacent base stations (BS) via the radio interface Um, whereas the BSs are connected to the mobile switching centre (MSC) through the network interface A. As seen in Figure 3.1, the MS includes a mobile termination (MT) and terminal equipment (TE). The TE may be constituted, for example, by a telephone set and fax machine. The MT performs functions needed to support the physical channel between the MS and the base station, such as radio transmissions, radio channel management, channel coding/decoding, speech encoding/ decoding, and so forth.

Figure 3.1 – Simplified structure of GSM



The BS is divided functionally into a number of base transceiver stations (BTS) and a base station controller (BSC). The BS is responsible for channel allocation (R.05.09), link quality and power budget control (R.05.06 and R.05.08), signalling and broadcast traffic control, frequency hopping (FH) (R.05.02), handover (HO) initiation (R.03.09 and R.05.08), etc. The MSC represents the gateway to other networks, such as the public switched telephone network (PSTN), integrated services digital network (ISDN) and packet data networks using the interworking functions standardized in recommendation R.09. The MSC's further functions include paging, MS location updating (R.03.12), HQ control (R.03.09), etc. The MS's mobility management is assisted by the home location register (HLR) (R.03.12), storing part of the MS's location information and routing incoming call to the visitor location register (VLR) (R.03.12) in charge of the area, where the paged MS roams.

Location update is asked for by the MS, whenever it detects from the received and decoded broadcast control channel (BCCH) messages that it entered a new location area. The HLR contains, among a number of other parameters, the international mobile subscriber identity (IMSI), which is used for the authentication (R.03.20) of the subscriber by his authentication centre (AUC). This enables the system to confirm that the subscriber is allowed to access it. Every subscriber belongs to a home network and the specific services that the subscriber is allowed to use are entered into his HLR. The equipment identity register (EIR) allows for stolen, fraudulent, or faulty mobile stations to be identified by the network operators. The VLR is the functional unit that attends to a MS operating outside the area of its HLR. The visiting MS is automatically registered at the nearest MSC, and the VLR is informed of the MSs arrival. A roaming number is then assigned to the MS, and this enables calls to be routed to it. The operations and maintenance centre (OMC), network management centre (NMC) and administration centre (ADC) are the functional entities through which the system is monitored, controlled, maintained and managed (R.12).

The MS initiates a call by searching for a BS with a sufficiently high received signal level on the BCCH carrier; it will await and recognize a frequency correction burst and synchronize to it (R.05.08). Now the BS allocates a bidirectional signalling channel and also sets up a link with the MSC via the network. How the control frame structure assists in this process will be highlighted later. The MSC uses the IMSI received from the MS to interrogate its HLR and sends the data obtained to the serving VLR.

After authentication (R.03.20) the MS provides the destination number, the BS allocates a traffic channel, and the MSC routes the call to its destination. If the MS moves to another cell, it is reassigned to another BS, and a handover occurs. If both BSs in the handover process are controlled by the same BSC, the handover takes place under the control of the BSC, otherwise it is performed by the MSC. In case of incoming calls the MS must be paged by the BSC. A paging signal is transmitted on a paging channel (PCH) monitored continuously by all MSs, and which covers the location area in which the MS roams. In response to the paging signal, the MS performs an access procedure identical to that employed when the MS initiates a call.

3.1.2 Logical and physical channels

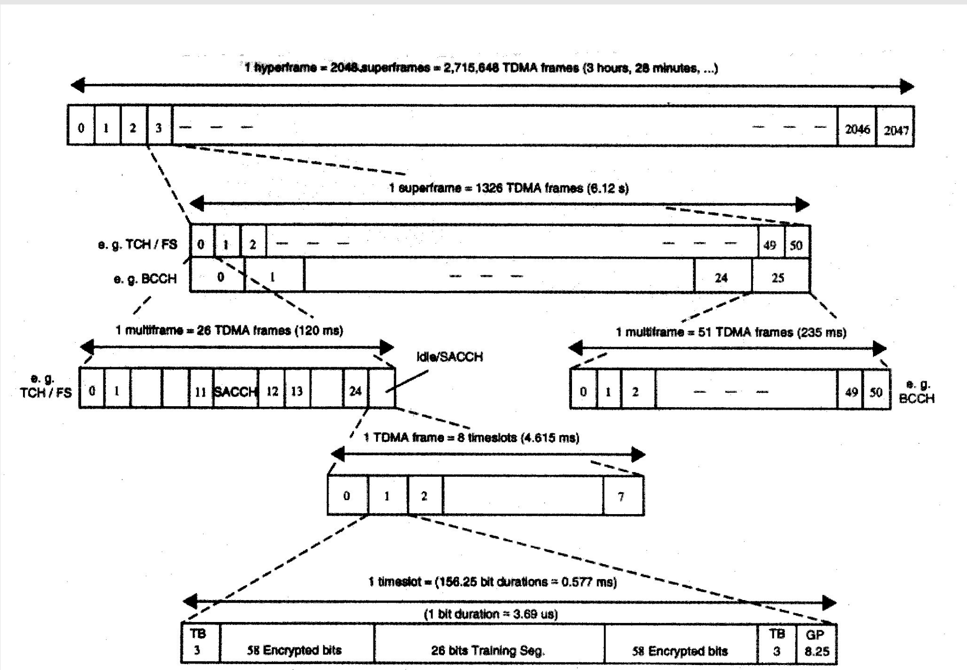
The GSM logical traffic and control channels are standardized in recommendation R.05.02, whereas their mapping onto physical channels is the subject of recommendations R.05.03. The GSM system's prime objective is to transmit the logical traffic channel's (TCH) speech or data information. Their transmission via the network requires a variety of logical control channels. There are two general forms of speech and data traffic channels: the full-rate traffic channels (TCH/F), which carry information at a gross rate of 22.8 kbit/s, and the half-rate traffic channels (TCH/H), which communicate at a gross rate of 11.4 kbit/s. A physical channel carries either a full-rate traffic channel, or two half-rate traffic channels. In the former, the traffic channel occupies one timeslot, whereas in the latter the two half-rate traffic channels are mapped onto the same timeslot, but in alternate frames.

A physical channel in a time division multiple access (TDMA) system is defined as a timeslot with a timeslot number (TN) in a sequence of TDMA frames. The GSM system, however, deploys TDMA combined with frequency hopping (FH) and, hence, the physical channel is partitioned in both time and frequency. Frequency hopping (R.05.02) combined with interleaving is known to be very efficient in combating channel fading, and it results in near-Gaussian performance even over hostile Rayleigh-fading channels. The principle of FH is that each TDMA burst is transmitted via a different RF channel (RFCH). If the present TDMA burst happened to be in a deep fade, then the next burst most probably will not be. Consequently, the physical channel is defined as a sequence of radio frequency channels and timeslots. Each carrier frequency supports eight physical channels mapped onto eight timeslots within a TDMA frame. A given physical channel always uses the same TN in every TDMA frame. Therefore, a timeslot sequence is defined by a TN and a TDMA frame number FN sequence.

3.1.3 Speech and data transmission

The speech coding standard is recommendation R.06.10, whereas issues of mapping the logical speech traffic channel's information onto the physical channel constituted by a timeslot of a certain carrier are specified in recommendation R.05.02. Since the error correction represents part of this mapping process, recommendation R.05.03 is also relevant to these discussions. The example of the full-rate speech traffic channel (TCH/FS) is used here to highlight how this logical channel is mapped onto the physical constituted by a so-called burst (NB) of the TDMA frame structure. This mapping is explained by referring to Figures 3.2 and 3.3.

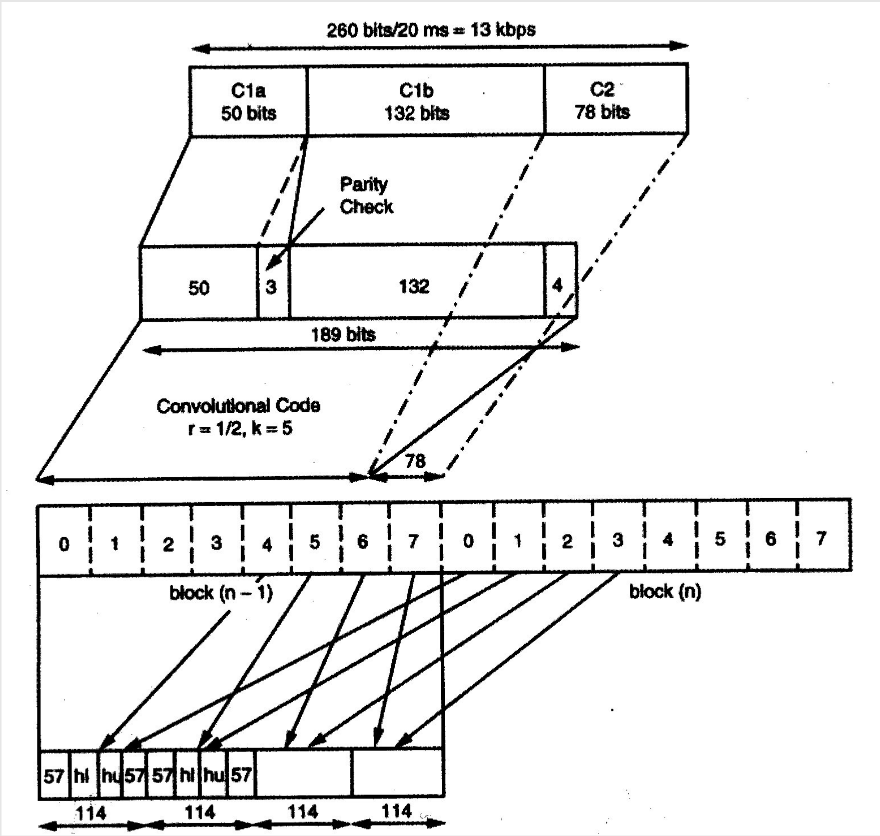
Figure 3.2 – The GSM TDMA frame structure



3.1.4 Transmission of control signals

The exact derivation, forward error correcting (FEC) coding and mapping of logical control channel information is beyond the scope of this chapter, and the interested reader is referred to ETSI, 1988 (R.05.02 and R.05.03) and Hanzo and Stefanov, 1992, for a detailed discussion. As an example, the mapping of the 184-b SACCH, FACCH, BCCH, SDCCH, PCH, and access grant control channel (AGCH) messages onto a 456-b block, i.e., onto four 114-b bursts is demonstrated in Figure 3.4. A double-layer concatenated FIRE-code/convolutional code scheme generates 456 bits, using an overall coding rate of R = 184/456, which gives a stronger protection for control channels than the error protection of traffic channels.

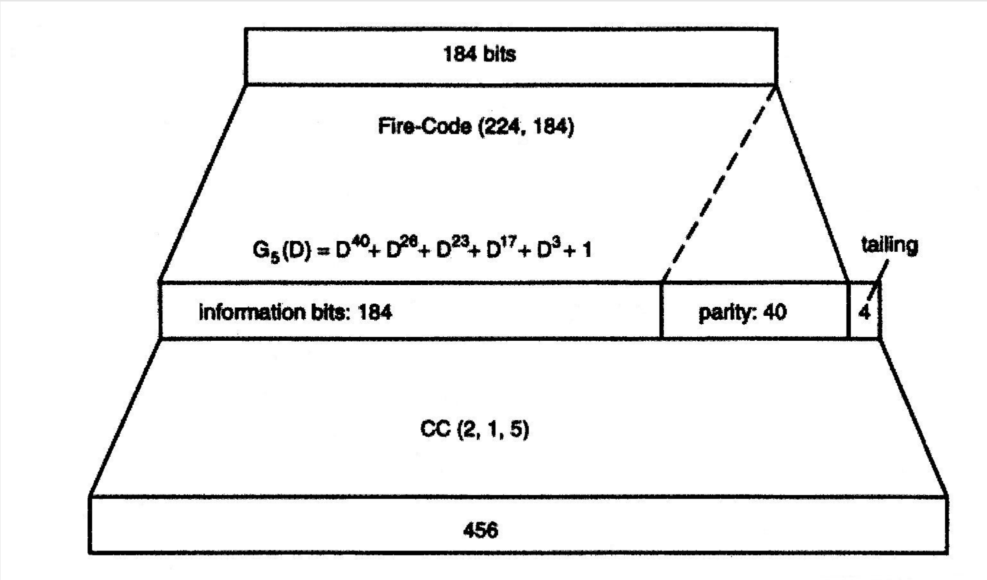
Figure 3.3 – Mapping the TCH/FS logical channel onto a physical channel



3.1.5 Synchronization issues

Although some synchronization issues are standardized in recommendation R.05.02 and R.05.03, the GSM recommendation do not specify the exact BS-MS synchronization algorithms to be used, these are left to the equipment manufacturers. A unique set of timebase counters, however, is defined in order to ensure perfect BS-MS synchronizm. The BS sends FCB and SB on specific timeslots of the BCCH carrier to the MS to ensure that the MS's frequency standard is perfectly aligned with that of the BS, as well as to inform the MS about the required initial state of its internal counters. The MS transmits its uniquely numbered traffic and control burst staggered by three timeslots with respect to those of the BS to prevent simultaneous MS transmission and reception, and also takes into account the required timing advance (TA) to cater for different BS-MS-BS round-trip delays.

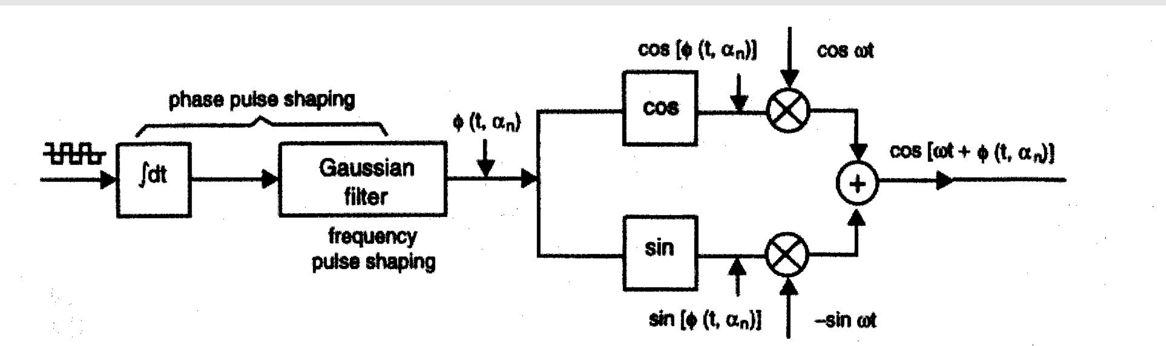
Figure 3.4 – FEC in SACCH, FACCH, BCCH, SDCCH, PCH and AGCH



3.1.6 Gaussian Minimum Shift Keying modulation

The GSM system uses constant envelope partial response GMSK modulation specified in Recommendation R.05.04. Constant envelope, continuous-phase modulation schemes are robust against signal fading as well as interference and have good spectral efficiency. The slower and smoother are the phase changes, the better is the spectral efficiency, since the signal is allowed to change less abruptly, requiring lower frequency components. The effect of an input bit, however, is spread over several bit periods, leading to a so-called partial response system, which requires a channel equalizer in order to remove this controlled, intentional inter-symbol interference (ISI) even in the absence of uncontrolled channel dispersion.

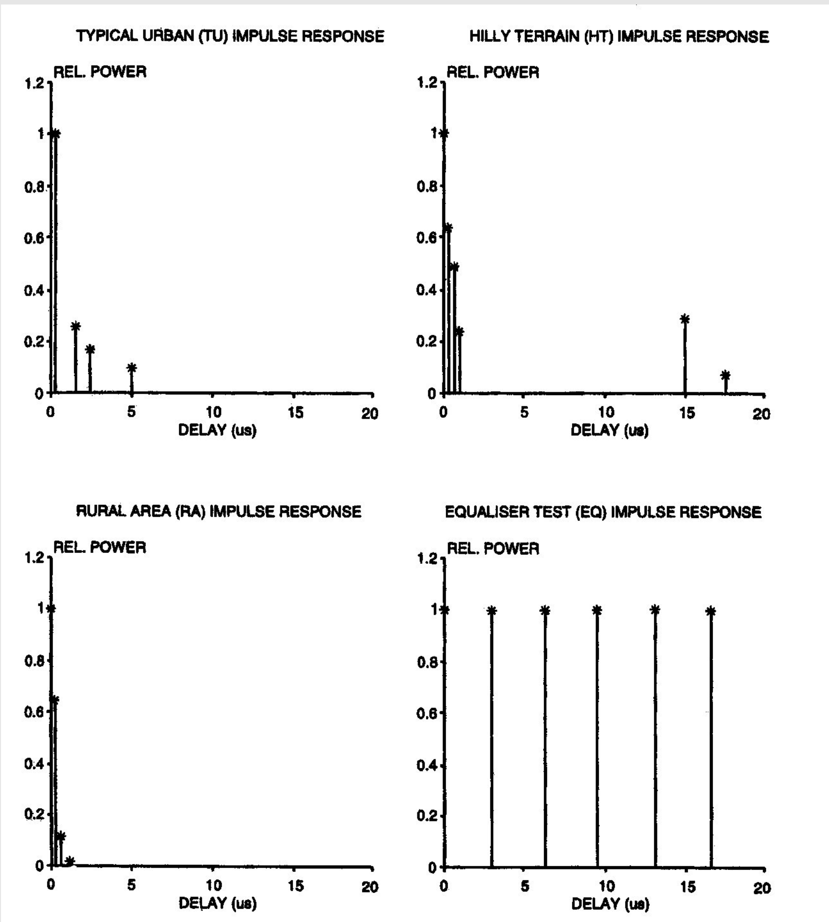
Figure 3.5 – GMSK modulator schematic diagram



3.1.7 Wide channel models

The set of 6-tap GSM impulse responses specified recommendation R.05.05 where the individual propagation paths are independent Rayleigh fading paths, weighted by the appropriate coefficient h_i corresponding to their relative powers portrayed in the Figure 3.6. In simple terms the wideband channel's impulse responses is measured by transmitting an impulse and detecting the received echoes at the channel's output in every *D*-spaced so-called delay bin. In some bins no delayed and attenuated multipath component is received, whereas in others significant energy is detected, depending on the typical reflecting objects and their distance from the receiver. The path delay can be easily related to the distance of the reflecting objects since radio waves are travelling at the speed of light. For example, at a speed of 300,000 km/s, a reflecting object situated at a distance of 0.15 km yields a multipath component at a round-trip delay of 1µs.

Figure 3.6 – Typical GSM channel impulse responses



3.1.8 Discontinuous Transmission

Discontinuous transmission (DTX) issues are standardized in recommendation R.06.31, whereas the associated problems of voice activity detection VAD are specified by R.06.32. Assuming an average speech activity of 50% and a high number of interferers combined with frequency hopping to randomise the interference load, significant spectral efficiency gains can be achieved when deploying discontinuous transmissions due to decreasing interferences, while reducing power dissipation as well. Because of the reduction in power consumption, full DTX operation is mandatory for MSs, but in BSs, only receiver DTX functions are compulsory.

The fundamental problem in voice activity detection is how to differentiate between speech and noise, while keeping false noise triggering and speech spurt clipping as low as possible. In vehicle-mounted MSs the severity of the speech/noise recognition problem is aggravated by the excessive vehicle background noise. This problem is resolved by deploying a combination of threshold comparisons and spectral domain techniques. Another important associated problem is the introduction of noiseless inactive segments, which is mitigated by comfort noise insertion (CNI) in these segments at the receiver.

3.1.9 Summary

The salient features of the GSM system can be summarized as follows.

Time division multiple access (TDMA) with eight users per carrier is used at a multi-user rate of 271 kbit/s, demanding a channel equaliser to combat dispersion in large cell environments. The error protected chip rate of the full-rate traffic channels is 22.8 kbit/s, whereas in half-rate channels it is 11.4 kbit/s. Apart from the full-and half-rate speech traffic channels, there are 5 different rate data traffic channels and 14 various control and signalling channels to support the system's operation. A moderately complex, 13 kbit/s regular pulse excited speech codec with long term predictor (LTP) is used, combined with an embedded three-class error correction codec and multilayer inter leaving to provide sensitivity-matched unequal error protection for the speech bits. An overall speech delay of 57.5 ms is maintained. Slow frequency hopping at 217 hops/s yields substantial performance gains for slowly moving pedestrians.

Constant envelope partial response GMSK with a channel spacing of 200 kHz is deployed to support 125 duplex channels in the 890-915 MHz up-link and 935-960 MHz down-link bands, respectively. At a transmission rate of 271 kbit/s a spectral efficiency of 1.35-bit/s/Hz is achieved. The controlled GSMK induced and uncontrolled channel-induced intersymbol interferences are removed by the channel equalizer. A set of standardized wideband GSM channels was introduced in order to provide bench markers for performance comparisons. Efficient power budgeting and minimum co-channel interferences are ensured by the combination of adaptive power and handover control based on weighted averaging of up to eight up-link and down-link system parameters. Discontinuous transmissions assisted by reliable spectral-domain voice activity detection and comfort-noise insertion further reduce interference and power consumption. Because of ciphering, no unprotected information is sent via the radio link. As a result, spectrally efficient, high-quality mobile communication with a variety of services and international roaming is possible in cells of up to 35 km radius for signal to-noise and interference ratios in excess of 10-12 dBs. The key system features are summarized in Table 3.1.

In 1990, by request of the United Kingdom, the specification of a version of GSM adapted to the 1800 MHz frequency band was added to the scope of the standardization group, with a frequency allocation of twice 75 MHz. This variant, referred to as DCS1800 (Digital Cellular System 1800) is aimed at reaching higher capacities in urban areas for example for the type of mass-market approach known as PCN (Personal Communications Network), Table 3.2.

Table 3.1 – Summary of GSM features

System feature	Specification
Up-link bandwidth, MHz	890-915 = 25
Down-link bandwidth, MHz	935-960 = 25
Total GSM bandwidth, MHz	50
Carrier spacing, kHz	200
Number of RF carriers	125
Multiple access	TDMA
Number of users/carrier	8
Total number of channels	1000
TDMA burst rate, kbit/s	271
Modulation	GMSK
Bandwidth efficiency, b/s/Hz	1.35
Channel equalizer	Yes
Speech coding rate, kbit/s	13
FEC coded speech rate, kbit/s	22.8
FEC coding	Embedded block/convolutional
Frequency hopping, hop/s	217
DTX and VAD	Yes
Maximum cell radius, km	35

3.2 International mobile telecommunications (IMT-2000)

3.2.1 Introduction

By the end of the year 1999 the cellular market reached 468 million users world-wide. This picture of the mobile market development is underlined by the dramatic growth of subscribers of the first digital mobile cellular system known as GSM, which counted for more than 250 million customers. In view of such market growth it is obvious that the situation has to be reconsidered in order to secure a long-term development of the mobile communications market into third generation services.

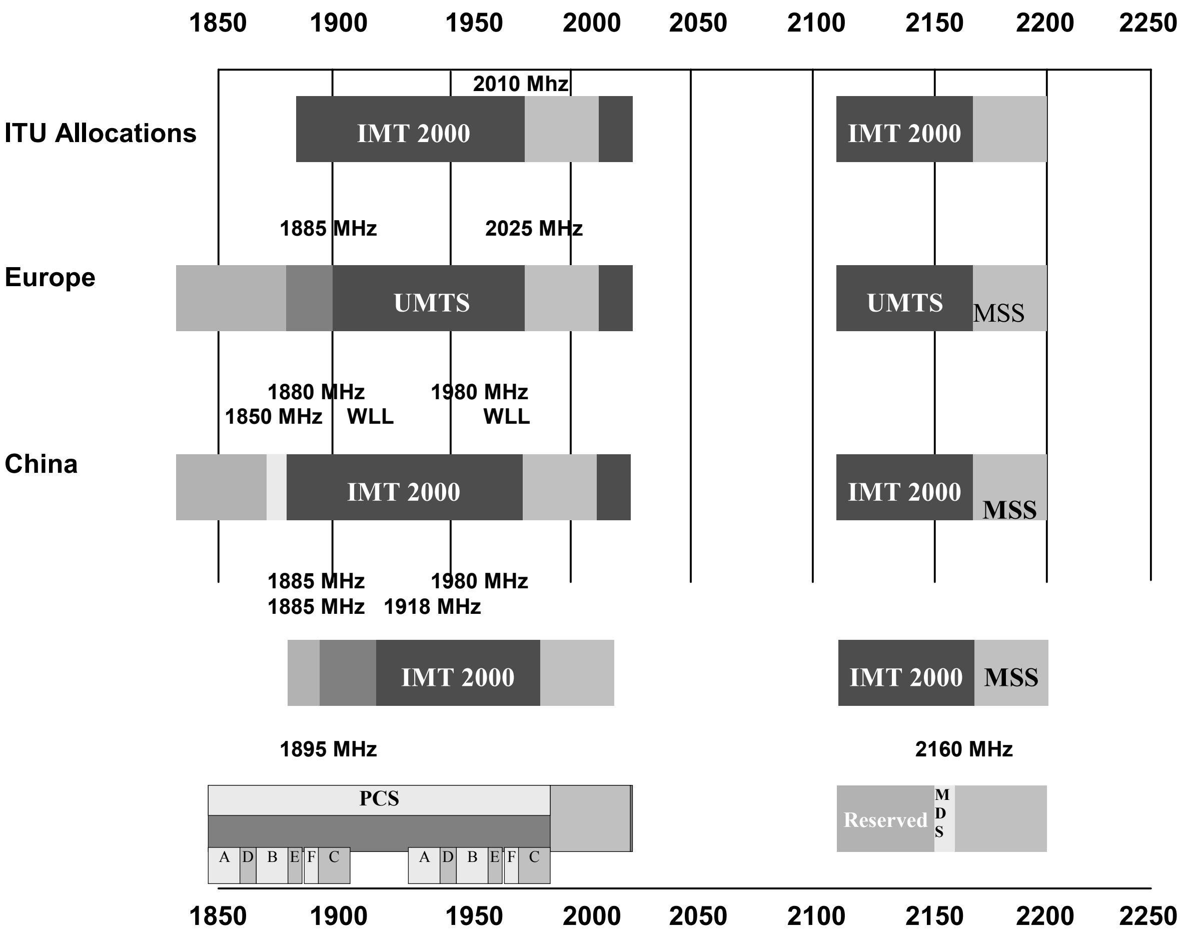
In the year 1992 it was not known yet what type of services the third generation would carry and even today, although more is known than in 1992, they cannot defined. Multimedia services will be a new market for telecommunications business in addition to the already developed speech and low data mobile communications. Also the Internet will be the main driver for mobile applications and it is important for the world economy to bring Internet onto the air. In the year 2002, when the first IMT-2000 services will start, Internet will have more than 500 million registered users world-wide. This user potential will be large enough to drive the applications forward in this business. Putting Internet (and Intranets) into the air adds mobility to this wire line market base which can be seen as a world wide mass market.

In this context, the international community has recognized that it is of great relevance to analyse the recent market developments and to verify, whether the available spectrum will be sufficient to satisfy customers' needs or not. It addition to 2nd generation bands the WRC-92 identified a total of 230 MHz of spectrum in the 2 GHz bands on a global basis (see Figure 3.7). These 230 MHz are split into 170 MHz for global terrestrial use and 60 MHz shared with satellite use with the understanding that IMT-2000 includes a terrestrial and a satellite component. [The name IMT-2000 indicates that the system will begin in the century and that it makes use of spectrum in the 2 000 MHz range]. More recently the World Radiocommunication Conference (WRC-2000) allocated further frequency bands for the terrestrial and mobile components of IMT-2000. For more information, please refer to the Final Acts of WRC-2000.

Table 3.2 – Summary of GSM and DCS features

System	DCS-1800
Multiple access	TDMA/FDMA
Frequency Band, MHz	
Uplink	1710-1785
Downlink	1805-1880 (UK)
RF channel Spacing kHz	
Uplink	200
Downlink	200
Modulation	GMSK
Portable transmit Power	
Maximum/average	1W/125 mW
Speech coding	RPE-LTP
Speech rate, kbit/s	13
Speech/RF channel	8
Channel Bit rate, kbit/s	
Uplink	270.833
Downlink	270.833
Channel coding	½ rate conv.
Frame, ms	3.615

Figure 3.7 – Frequency bands for IMT-2000



As shown in Figure 3.7 a number or regions in the world have converged in the direction of the WARC-92 agreement:

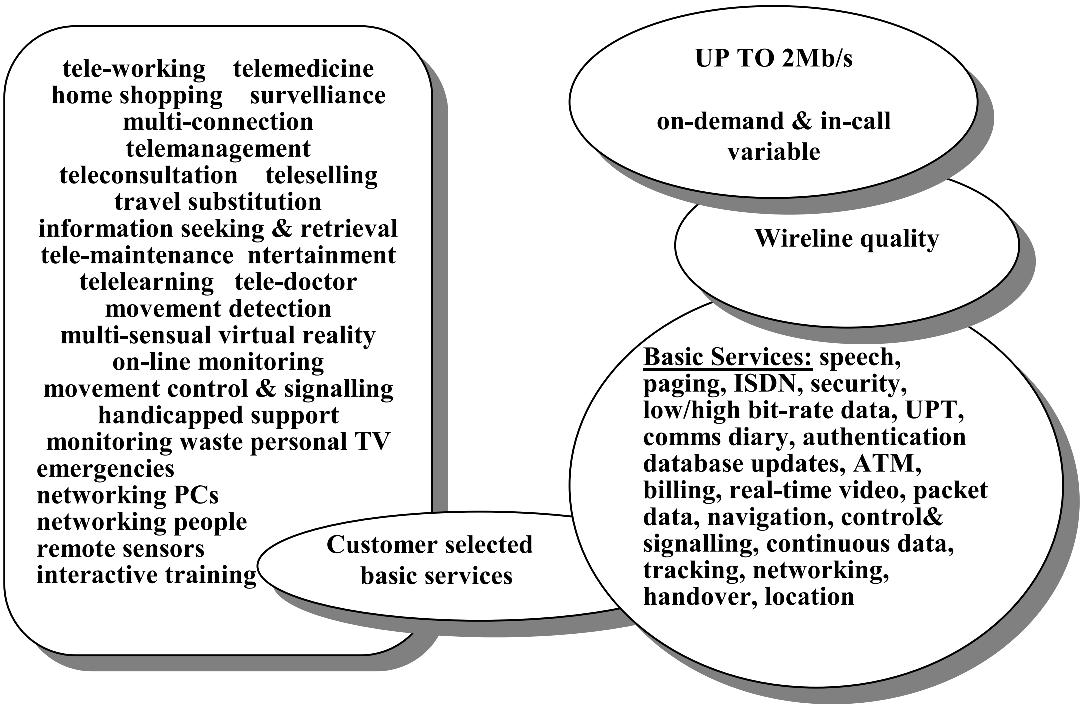
- CEPT in Europe can make available all the ITU spectrum except 15 MHz which are already allocated for DECT. This results in 155 MHz of spectrum for terrestrial services with an additional 60 MHz set aside for UMTS satellite services.
- In China the recent discussion of the UMTS Forum in China reflects the ITU allocations as being quite similar to those in Japan and Korea. It may by assumed that the major part of the ITU bands could be made available. Some segments are designated for wireless access systems. However, no final plan or decision has been made yet.
- Korea has already indicated spectrum allocations for paired and unpaired use: 1895-1920 MHz , 1920-1980 MHz, 2010-2025 MHz, 2110-2170 MHz.
- The Japanese Ministry of Post and Telecommunications MPT is planning to designate the WARC-92 spectrum for third generation systems in the same way as the Europeans with the difference, that the frequency band 1895 MHz to 1918.1 MHz is already allocated to PHS services.

- North America has a slightly different scenario. The introduction of PCS services and the auctioning led to a split into licenses of 2 × 15 MHz and 2 × 5 MHz up to 1980 MHz. This spectrum utilisation leads to the question how radio equipment can be harmonized with IMT-2000 services in Europe and in Japan and in the rest of the world. One example is that the Air Interface standard has to fit into 5 MHz frequency blocks.
- The remaining regions in the world such as Africa may continue with the WARC-92 decision. The are no indications in a different direction, which means that the ITU objective, to come to a world wide harmonized IMT-2000 spectrum allocation, is still valid for the most parts in the world.

3.2.2 The IMT-2000 system

System IMT is born as a vision. It is a vision that takes the personal communication user into the information society of the present century. (UMTS is a member of the IMT-2000 systems family). Processing and delivery of information, video and voice, fax and data between users and information providers characterise the information society of tomorrow (Figure 3.8).

Figure 3.8 – Customized Multi-Media



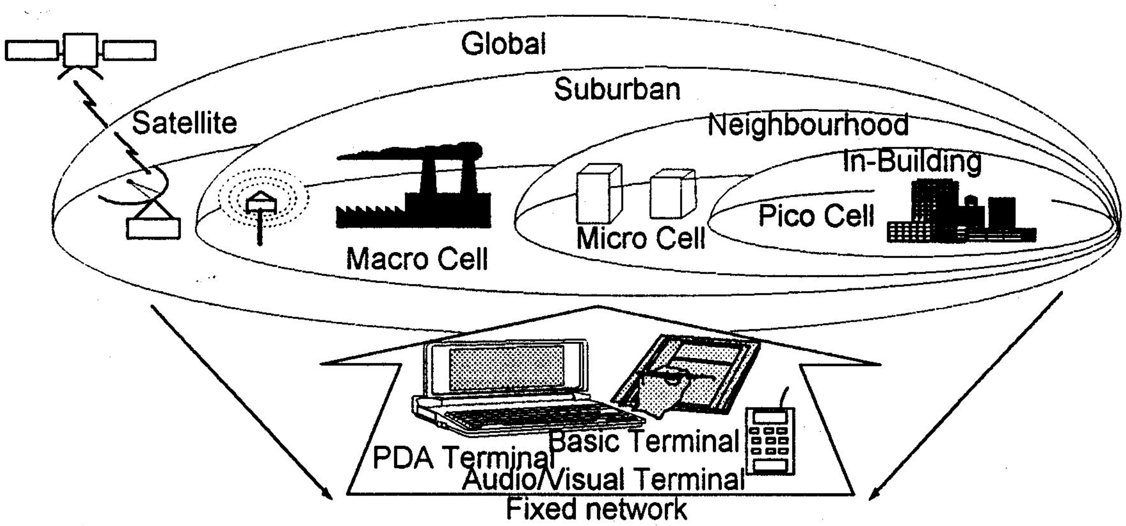
IMT comprises the 3rd generation of mobile radio system technologies dealing with broadband multimedia applications. The information age, however, is expected to generate demand for personalised multimedia telecommunications in which the customer bundles the available basic services before and during the communication. Flexible allocation of radio resources with unpredictable bit rate and asymmetric transmission throughput is required as well as high processing power in end user equipment. This is the challenge for the telecomms industry, as well as for the IT industry and probably the media market.

The world wide liberalization in telecommunications will enable mobile operators to offer fixed network services and vice-versa. In this situation a broadband-capable multi-environment IMT technology becomes essential to ensure mobile operators can compete in the resulting highly competitive telecommunications market.

In this context, some operators are already preparing for the convergence of fixed and mobile networks. They will benefit from developments such as network intelligence, service creation and personal numbering. Support of fixed and cellular network convergence is therefore a key IMT qualification for both operator and customer.

One of the main objectives of IMT is to integrate the heterogeneous world of different radio systems with different standards, different applications and features, cell sizes from pico cells up to hyper cells.

Figure 3.9 – Integrated Wired & Wireless Networks with Broadband Capabilities



IMT will offer access methods that are currently served by dedicated systems:

- Cellular public networks
- Cordless for domestic use
- Cordless terminal mobility
- Wireless PABX
- Wireless LAN
- Wireless local loop
- Private mobile radio
- Mobile data networks
- Paging networks
- Satellite systems
- Access anytime, anywhere

Positioning parameters for future service providers:

- Private … public
- Local coverage … global coverage
- Low mobility … high mobility
- Low data … high data
- Basic services … multi-media services

3.2.3 The mobile market

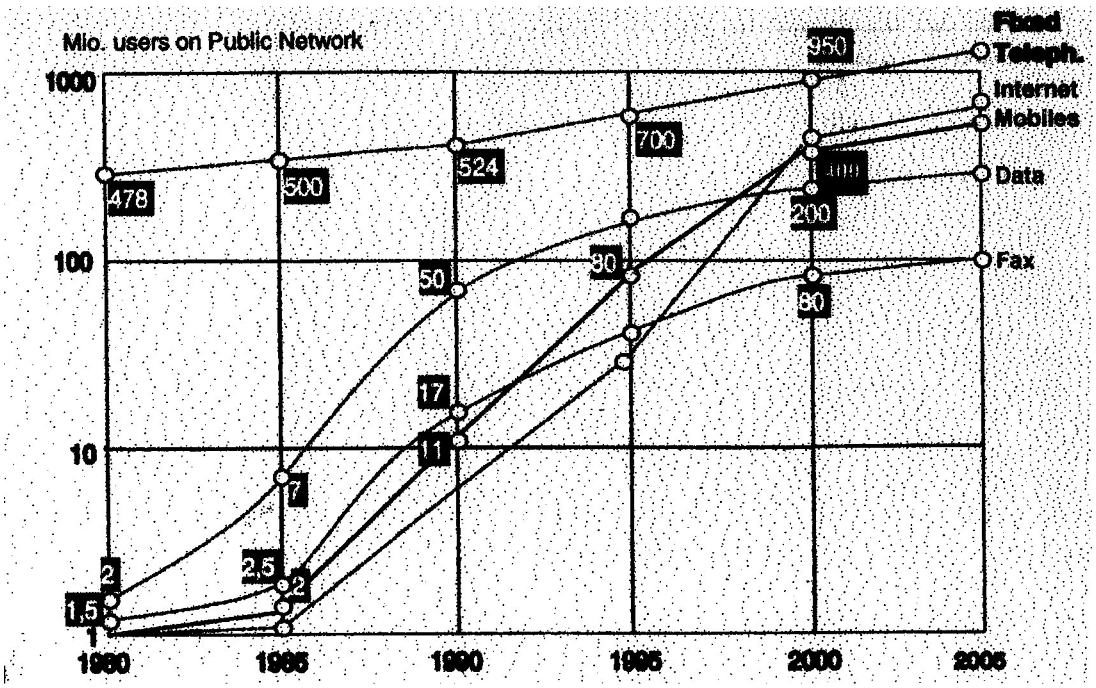
The IMT market is characterised by the need of many types of service. There are the current “voice-band” compatible services like fax and medium speed data. There will be audio-video services with higher bandwidth demands. And there will be multimedia services with asymmetrical traffic profiles. Such a scenario describes the market base for IMT. Mobility is another but dominant success factor for IMT as can be seen by the fast developments of mobile networks today. *The main questions considering a IMT market are:*

- Who are the users, what market segments will they come from?
- How is mobility affecting services?
- What kind of terminals will be used?

A market model needs to be developed looking at segments such as business and private, tariff schemes and price structures that need to be taken into account.

What about market and competition? Competition of suppliers, network operators or service providers? This is an important driver to develop the IMT market as already realized by the world wide liberalization in the telecommunications business. Regulatory items play an important role to boost the market for IMT services.

Figure 3.10 – Telecommunications Market Worldwide



If we look into the telecommunications market up to 2005 (Figure 3.10), we recognize a shift in the market potential from wire line services to mobile personal services and Internet-type services. The IMT market is planned to begin in 2005. There is no clear picture foreseeable today regarding combined audio-video services and multimedia services. But there are indications from the mobile market and Internet market developments. The work on UMTS must therefore concentrate on these issues in order to find the best way to penetrate the right market for a mass consumer business as the final goal. (GSM is a good example how to develop the personal mobile market successfully as it has already reached a global footprint).

3.2.4 The IMT Technology

It is recognized today that personal communications are mainly linked with a "voice-band" structured transmission capability. Personal voice communications are dominant, the world wide popular handhelds are mainly personal communications for one application and this is telephony.

Table 3.4 – The evolution of mobile technology

System Aspects	Existing 2 G Mobile Systems	New 3 G IMT-2000 Systems
Use of digital technology	Already used for modulation, speech and channel coding as well as implementation and control of data channels	Increased use of digital technologies
Commonality between different operating environments	Each systems is primarily optimized for its specific operating environment	Optimization of radio interfaces for multiple operating environments such as vehicular, pedestrian, intro-office, fixed wireless access and satellite, via a single flexible or scalable radio interface.
Frequency bands	Operate in frequency bands ranging from 800 MHz to 1.9 GHz, depending on the country	Use a common global frequency band
Data services	Limited to data rates below 115 kbit/s (WAP-GRPS-SMS)	Transmission speeds up to 2 Mbit/s
Roaming	Generally limited to specific regions, Handsets not compatible between different systems	Global frequency coordination and ITU standards will provide true global roaming and equipment compatibility
Technology	Spectrum efficiency, cost and flexibility limited by technology in use at time of system design	Spectrum efficiency, flexibility and overall costs all significantly improved.

In the year 2005 we may expect to see far more Internet-type users than voice users and technology development progressing towards adaptive codecs for video and voice.

IMT in the year 2005 has to provide the means to transport, switch and process applications for combined video, voice and data. Multimedia communication should be available at this point of time comparable to "Voice Handhelds" today for an acceptable price, volume and weight. The channel bandwidth for the user may vary from 16 Kbit/s up to 2 Mbit/s.

The positioning of IMT on the network infrastructure side can be considered in two parts:

The IMT Radio Part

IMT is likely to cover a large variety of radio environments from indoor to outdoor – satellite coverage included. Adaptation of the mobile terminal to a specific radio environment takes place through negotiation mechanism. The radio part must concurrently support multiple public and private networks, dynamic and asymmetrical user bit rate demands. The transmission bit rate objectives for IMT are determined by service requirements. It is proposed to reach bit rates up to 2 Mbit/s to the terminal in the micro/pico cell areas, up to 144 kbit/s or probably up to 384 kbit/s in macro cells. They should offer dynamic allocation of radio bearer services.

The IMT Switching Part

The IMT switching part comprises the core network and the value-added service functions including intelligent network capabilities. IMT will serve the user with many different interfaces for

- Public mobile networks
- Cordless systems including wireless PABX, wireless LANs, cordless Terminal Mobility (CTM)
- Wireless Local Loop
- Satellite PCNs
- Private mobile radio networks
- Mobile data networks
- Paging networks.

Parts of the IMT infrastructure will be operated by competing public carriers, other parts will be in private ownership on a non-regulated basis. A core set of standardized services will support the various applications. Open interfaces must also exist on the switching platforms to allow easy interworking. With IN, rapid creation and deployment of services can be offered spanning the core networks involved in IMT. Transmission and switching must be state-of-the-art technology. As IMT goes far into the century, in addition to circuit switching, TCP/IP and ATM will be the dominant switching principles.

3.2.5 Conclusions

The motivation for IMT results from recognizing the future developments towards multimedia combined with personal mobility. In addition to the technical innovations in the existing networks, only new broadband radio technologies can completely reflect such requirements. This needs to be combined with the achieved level of world-wide mobility in cellular networks (e.g. GSM) using network intelligence.

Convergence between fixed and mobile networks will arise which together with the upcoming demand for mobility independent from user location, needs to be developed in an evolutionary way. The 21st century customer will demand services independent from the access method.

3.2.6 Current ITU Recommendations for IMT-2000

ITU-R	M.687	MT-2000 Concepts and Objectives
	M.816	Framework for Services Supported by IMT-2000
	M.817	IMT-2000 Network Architecture
	M.818	Satellite Operation within IMT-2000
	M.819	IMT-2000 for Developing Countries
	M.1034	Requirements for the Radio Interface(s) for IMT-2000
	M.1035	Framework for Radio Interface(s) and Radio Sub-system Functionality for IMT-2000
	M.1036	Spectrum Considerations for Implementation of IMT-2000 in the bands 1,885-2.025 MHz and 2.110-2.200 MHz
	M.1078	Security Principles for IMT-2000
	M.1079	Speech and Voiceband Data Performance for IMT-2000
	M.1167	Framework for the Satellite Component of IMT-2000
	M.1168	Framework of IMT-2000 Management

	M.1223	Evaluation of Security Mechanisms for IMT-2000
	M.1224	Vocabulary of Terms for IMT-2000
	M.1225	Guideline for Evaluation of Radio Transmission Technologies (RTTs) for IMT-2000
	M.1308	Evolution of Land Mobile Systems Towards IMT-2000
	M.1311	Framework for Modularity and Commonality within IMT-2000
	SM.328	Spectrum and bandwidth emission
	SM.329	Spurious emissions
ITU-T	F.115	Service Objectives and Principles for IMT-2000
	F.116	Service Features in IMT-2000
	H.324	(Annex C) Mobile extension of H.324 (videotelephony)
	I.5xw	Network Interworking Between IMT-2000 and other Types of Network
	1.5xz	UPT/Mobile Interaction
	I.140	Attribute Technique for Characterization of ISDN services for IMT-2000
	I.340	ISDN Connection Types for IMT-2000
	Q.1541	UPT Stage 2 for Services Set I on CSI-1995
	Q.1701	Framework for IMT-2000 Networks
	Q.1711	IMT-2000 Network Architecture.

3.2.7 ITU Publications

Following ITU Publications could be of assistance in studying, planning and engineering mobile communications:

– Manual for Use by Maritime Mobile and Maritime Mobile-Satellite Services, 1999

– Land Mobile (including Wireless Access), Volume 2: Handbook on principles and Approaches on Evolution to IMT-2000/FPLMTS, 1997,

– Manual on Mobile Communications Development, 1997

– World Telecommunication Development Report – Mobile Cellular – World Telecommunication Indicators, 5th edition, 1999,

– GMPCS Reference Book, 2000

– WRC-2000 Resolutions

3.2.8 ETSI GSM Recommendations

R.00	*Preamble* to the GSM recommendations
R.01	*General structure* of the recommendations, description of a GSM network, associated recommendations, vocabulary, etc.
R.02	*Service aspects*: bearer-, tele- and supplementary services, use of services, types and features of mobile stations (MS), licensing and subscription, as well as transferred and international accounting, etc.
R.03	*Network aspects*, including network functions and architecture, call routing to the MS, technical performance, availability and reliability objectives, handover and location registration procedures, as well as discontinuous reception and cryptological algorithms, etc.

R.04	*Mobile/base station (BS) interface and protocols,* including specifications for layer 1 and 3 aspects of the open systems interconnection (OSI) seven-layer structure.
R.05	*Physical layer on the radio path,* incorporating issues of multiplexing and multiple access, channel coding and modulation, transmission and reception, power control, frequency allocation and synchronization aspects, etc.
R.06	*Speech coding specifications,* such as functional, computational and verification procedures for the speech codec and its associated voice activity detector (VAD) and other optional features.
R.07	*Terminal adaptors for MSs,* including circuit and packet mode as well as voiceband data services.
R.08	*Base station and mobile switching centre* (MSC) *interface*, and transcoder functions.
R.09	*Network interworking* with the public switched telephone network (PSTN), integrated services digital network (ISDN) and, packet data networks.
R.10	*Service interworking, short message service.*
R.11	*Equipment specification and type approval specification* as regards to MSs, BSs, MSCs, home (HRL) and visited location register (VLR), as well as system simulator.
R.12	*Operation and maintenance,* including subscriber, routing tariff and traffic administration, as well as BS, MSC, HLR and VLR maintenance issues.

3.3 Fixed-mobile convergence

3.3.1 Introduction

Increasing competition in the telecommunications world is forcing operators, incumbents and newcomers alike, to seek for new and attractive forms of services and to cut costs. Today, fixed and mobile operators are usually separate companies managing two different businesses. Even regulation is oriented to regulate fixed and mobile as different businesses. However, customers are the main driving force for telecom services development. They have requirements that can be described as:

– Always – on connectivity
– Number portability/single user address
– Service bundling
– Common billing/single bill for communication services
– Universal service profile (transparently upheld across different networks)
– Common point of customer service and management.

To deliver this will require that networks are mobility-enabled from the inside out – mobility must be built into all segments of the future communications networks.

In measuring up to the challenge, operators must ensure they have:

– A new flexible and scalable communications architecture that can meet today's and tomorrow's requirements for multiple services and multiple ways of accessing those services for the users
– Key partners that can manage all the systems integration work and telecommunications management systems and services required
– Superior technology to develop and deploy any new service swiftly and cost-effectively
– Mobility built into the core of their communications architectures to let users take full advantage of mobility-enabled networking independent of place or time.

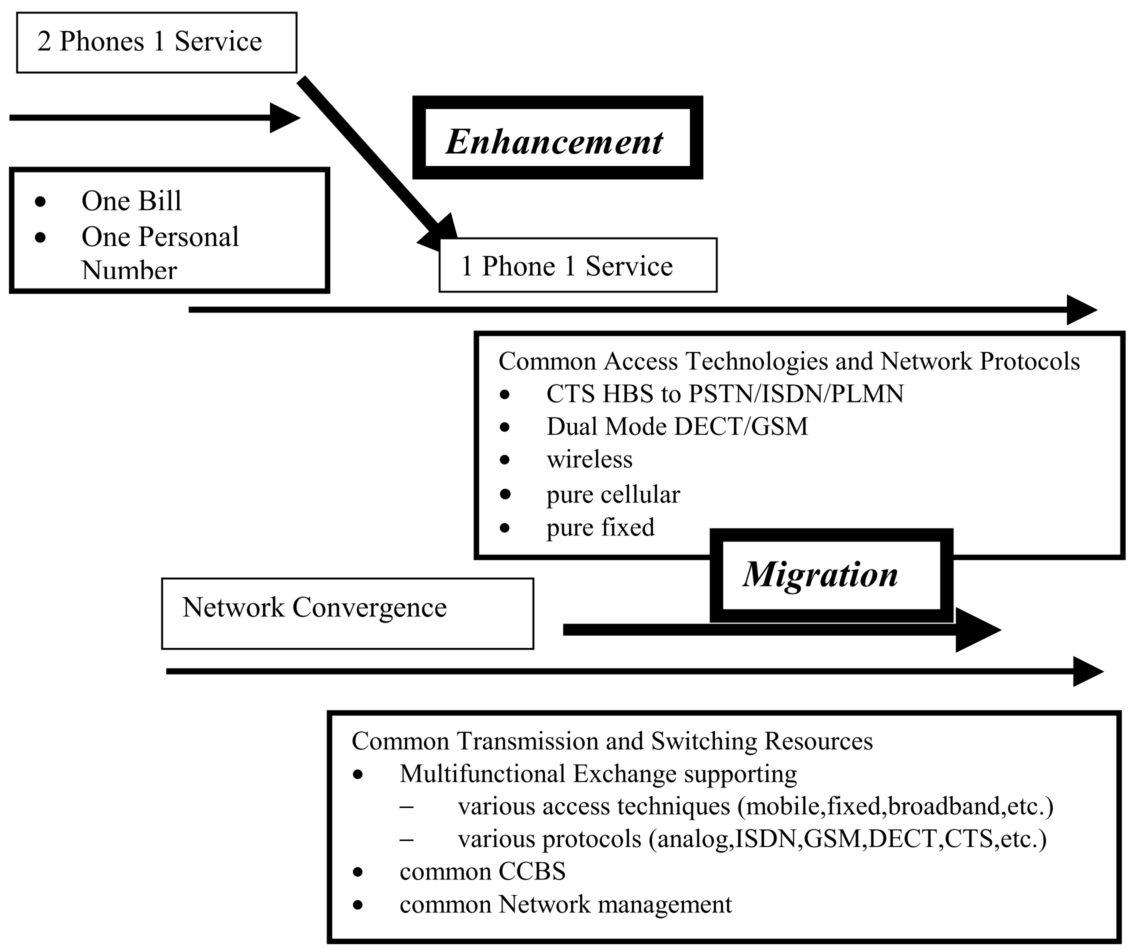
One of the attractive approaches is the convergence of fixed and mobile systems and services, termed Fixed Mobile Convergence (FMC), allowing the provision of communications services based on a combination of fixed and mobile technologies and streamlining of network facilities and operations.

FMC is an appealing evolution of today's heterogeneous communications world consisting of a variety of fixed, cellular, cordless and data networks. It is of major interest for telecommunications operators and a challenge for the telecommunications industry.

FMC is driven by the increasing demand for personal communication services and for higher bandwidth data applications on one hand and by the demand of services integration and transparency on the other.

FMC may be described as the integration of network and service capabilities, allowing the user to access a set of services in a consistent way irrespective of the terminal and the access point, i.e. by using public, private, fixed or mobile networks and enjoying a personal number and a unique bill. Particularly important is the capability to satisfy the desire of users wanting to roam between different networks whilst always being able to access the same set of services.

Figure 3.12 – Fixed Mobile Convergence



3.3.2 Approach for Fixed Mobile Convergence

The mid and long-term scenario for FMC is strongly tied to a service and network integration. This allows the provision of advanced 'personal services' such as one personal number, one bill, one voice mail, Internet and multimedia services.

Within this context the following technical issues are addressed:

– *Network level:* transmission and switching resources are shared to attach wired and wireless subscribers;

– *Service level:* offered services are equally available at all types of access;

– *Service Management level:* fixed-mobile services will be supported by an integrated open management platform with integrated billing and customer care systems.

The implementation follows a phased approach allowing for a smooth evolution in terms of network and service convergence as illustrated in the following Figure 3.12 starting from existing fixed and mobile networks:

The first phase offering for Fixed Mobile Convergence could be a package called '2Phones1 Service'. This package enables end-users to have access from different networks and terminals to a set of features including persona1 number, one bill and one voicemail.

2Phones1 Service is an Intelligent Network based solution (see more in sections 2.3 and 2.9 in Chapter 2) that allows the quick introduction of the service network-wide and to minimize the impact on existing networks.

The 1Phone1 Service package adds indoor "cordless" access to the above outlined service package, using multi-mode or multi-standard mobile stations together with the matching "home base stations".

In parallel to the first phase, which is more related to the service convergence, providers work on the network convergence. The strategy is to start with the integration of the transmission and switching resources and to continue to work on a common CCBS and Network management platform.

The migration step from package 1 features an optimization of the network in terms of resources such as access and network management facilities and network protocols.

In addition to the capabilities of phase 1, this package will support a wider range of applications.

Many switching platforms are upgradeable to broadband data and IP capability while its IN and Value-Added service platforms and applications will evolve in support of a harmonised and powerful service architecture enabling fast introduction of differentiating services across cooperating networks

The strategy fully supports evolution to UMTS that means the introduction of three related major innovations:

– A wideband cellular radio access;

– The convergence of fixed and mobile, telecom voice and data and IT, public and private and;

– A powerful service architecture.

3.3.3 Conclusions

Evolution of the telecommunication systems towards and standardization of UMTS should consider also the current convergence of networks. Adopting the requirements for FMC allows UMTS to be the future global communication system supporting not only a wide range of access technologies and network protocols but also a wide variety of services.

For competitive reasons future networks will evolve to hybrid systems supporting multi-functionality including a variety of features such as fixed and mobile telephony, mobility services, Internet access, VPN, Centrex, IN and narrowband/broadband services.

3.4 List of abbreviations

ADC	Administration center
AGCH	Access Grant Control Channel
ATM	Asynchronous Transfer Mode
BCCH	Broadcast Control Channel Handling
BCCH	Broadcast Control Channel
BS	Base Station
BSC	Base Station Controller
BTS	Base Transceiver Station
CCBS	Compilation of Call to Busy Subscriber
CNI	Confort Noise Insertion
CTM	Cordless Terminal Mobility
DECT	Digital Enhanced Cordless Telecommunication System
DTX	Discontinuous Transmission
ETSI	European Telecommunication Standardization Institute
FACCH	Fast Associated Control Channel
FCB	Frequency Correction Burst
FEC	Forward Error Correcting
FH	Frequency Hopping
FPLMTS	Future Public Land Mobile Telecommunications System
GSM	Global System of Mobile Communications
GMPCS	Global Mobile Personal Communications by Satellite
GMSK	Gaussian Minimum Shift Keying
HLR	Home Location Register
HO	Handover
IMSI	International Mobile Subscriber Identity
IMT-2000	International Mobile Telecommunications 2000 standard
ISDN	Integrated Service Digital Network
ISI	Inter-Symbol Interface
MS	Mobile Station
MSC	Mobile Switching Center
MT	Mobile Termination
NMC	Network Management Center
OMC	Operation & Maintenance Center
PABX	Public Branch Exchange
PCH	Paging Channel

PCN	Personal Communications network
PLMN	Public Land Mobile Network
PSTN	Public Switched Telephone Network
RFCH	Radio Frequency Channel
SACCH	Slow Associated Control Channel
SB	Synchronization Burst
SDCCH	Stand-alone Dedicated Control Channel
TCH	Traffic Channel
TCH/F	Traffic Channel Full-rate
TCH/H	Traffic Channel Half-rate
TCP/IP	Transmission Control Protocol/Internet Protocol
TDMA	Time Division Multiple Access
TE	Terminal Equipment
TN	Timeslot Number
UMTS	Universal Mobile Telecommunications System
UPT	Universal Personal Telecommunications
VLR	Visitor Location Register
WRC	World Radio Conference

CHAPTER 4

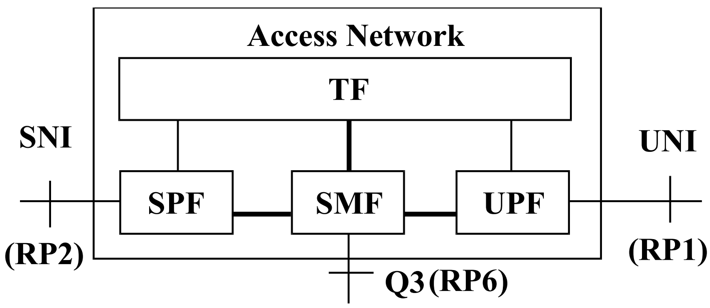
4 Access Networks

4.1 Access Network

4.1.1 Functional architecture of an Access Network

A transmission media independent architecture of the Access Network (AN) with the interfaces as the boundaries to other network entities is shown in Figure 4.1.

Figure 4.1 – Example of functional architecture of an access network



—	– User bearer and User signalling information
UPF	– User Port Function
SMF	– System Management Function
SPF	– Service Port Function
TF	– Transport Function
SNI	– Service Node Interface
UNI	– User Network Interface

The User Port Function (UPF) adapts the specific UNI requirements to the transport and management functions (termination of the UNI functions, A/D conversion, signalling conversion, activation/deactivation, testing of UNI, management functions, maintenance of UPF, handling of the user network bearer channels/capabilities).

The Transport Function (TF) provides the paths for the transport of common bearers between different locations in the AN and the media adaptation for the relevant transmission media used (multiplexing function, cross connect functions including grooming and configuration, management functions, physical media functions).

The Service Port Function (SPF) adapts the requirements defined for a specific Service Node Interface (SNI) to the common bearers for handling in the transport functional group and selects the relevant information for the treatment in the AN system management function (termination of the SNI functions, mapping of the bearer requirements and time critical management and operational requirements into the core function, mapping of protocols if required for particular SNI, testing of SNI, maintenance of SPF).

The System Management Function (SMF) co-ordinates the configuration management information from the Q3 interface to be distributed within the AN functional blocks (UPF, TF, SPF). Further it coordinates/adapts user signalling information and maps it to the transport function of the SN for call control. It also coordinates the fault and performance information within the AN for protection control.

Based on the functional architecture of an AN, Table 4.1 contains examples of interfaces for UNI and SNI.

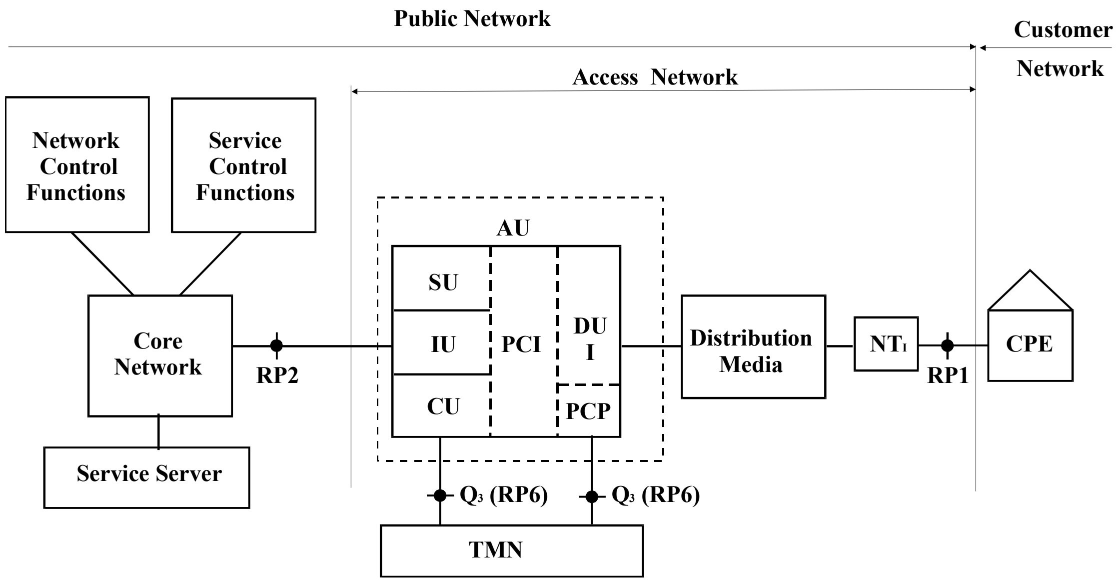
Table 4.1 – Examples of Specific Interfaces for UNI and SNI

Service	UNI (RP1)	SNI (RP2)
IP routing	Ethernet (e.g. IEEE802.3), 25 Mbit/s (I.432.5)	VB5.1
ATM switched virtual channel	25 Mbit/s (I.432.5), 155 Mbit/s (I.432.2)	VB5.1, VB5.2
Video-on-Demand	25 Mbit/s (I.432.5), 155 Mbit/s (I.432.2)	VB5.1
Switched video broadcasting	25 Mbit/s (I.432.5), 155 Mbit/s (I.432.2)	VB5.1
ISDN	64 Kbit/s (I.430), 1.5/2 Mbit/s (I.431)	V5 etc.

4.1.2 Access Network target structure survey

The primary purpose of developing present telecommunication networks is the intention to migrate to a network architecture offering all services in a cost-effective way over only one access point. Access network architecture, as a part of the whole telecommunication network fulfilling such requirements, is shown in Figure 4.2.

Figure 4.2 – Access Network target structure



The AN supports the transport of information, signalling interactive data and control bit streams between the CPE and the core network. Representing up to 60% of the infrastructure costs of telecommunication networks access technology is the key definer of what services can be delivered to the subscriber, making it the focal point in the quest for revenue and profit. In 1996 the access network accounted for 6 billion US$ of telecommunication business world-wide. It is growing at an average rate of approximately 27% per year. By the year 2000-2001 it will have a value of about 19 billion US$. In other words it will more than triple in five years. Due to that reason, it is necessary to pay a special attention to the access segment of the telecomm network in the process of telecommunication infrastructure modernization in developing countries.

The key point of this new network architecture is Access Unit (AU). The AU is a generic platform for different types of distribution technologies and services and connects the AN to the nodes of different core networks (data networks or the PSTN). Every model of the AN uses a special AU, which is composed of four functional sub-units: Distribution Unit (DU), Switching Unit (SU), Control Unit (CU) and Interface Unit (IU).

Such an AN architecture has three distinctive features:

1 *A common interface between the distribution units offering the narrowband and wideband services and the control unit*: This service independent interface, called Peripheral Core Interface (PCI), allows, on the one hand, a flexible fully interchangeable connection of different distribution units to other functional units within AU. This facilitates an individual upgrade of the equipment in the field according to the customer's needs. On the other hand it also allows an independent evolution of the control unit, switching unit and interface unit and the distribution units offering different services. For broadband services a similar interface based on ATM is applied.

   On a logical level the PCI is designed to be generic for all narrowband and wideband distribution units, i.e. independent from the services and interfaces like POTS, ISDN BRA and PRA, and leased line services. They can be mapped on the basic format of the PCI interface. Therefore, one PCI consists of a set of 64 kbit/s channels, which can be combined depending on the service type.

2 *A common control platform for all the distribution units*: This common platform, called Peripheral Control Platform (PCP), contains the basic control hardware and software parts that are common for all distribution units. Only the service specific parts are different. This concept makes it easier to add new distribution units and service types. Only the service specific parts have to be newly implemented, while the basic platform can be reused. Also the upgrade of common parts has to be done only once for the entire system. Thus, development cycles are shortened and the system stability is increased. Such a common control platform offers in generic way, intelligent functions of the AN for all the different distribution units such as administration, database handling, system maintenance, call processing support, error treatment, message handling, recovery handling, routine tests.

3 *A control platform for the control unit being derived from a central switch control platform*: Thus all the sophisticated features available for the switch platform are available for the AU. Only the hardware is scaled down due to the smaller performance requirements.

The new concept of the AU enables the offering of services and Telecommunication Management Network (TMN) facilities in a modular way, independent from the distribution media. In other words, the concept offers the flexibility of changing the distribution media without changing the equipment and the TMN operation system. Also, a simple expansion is possible in terms of new services or in terms of adding customers to existing services. These are key advantages due to the changing environment and the difficulties to get precise forecasts of the future service needs.

According to the consideration that future needs for transmission capacity requirements can reach 1 Gbit/s for the size of access area in terms of the number exceeding of about 2000 homes, such a network has to be served by one AU. Due to different access models the AU has to be suitable for the indoor as well as for outdoor applications.

As distribution media, applied technology and type of services define a particular model, a separate distribution sub-unit ($DU_{I = 1, 2, ..., 6}$) is provided in AU for each of them. It must be stressed that the only functional sub-unit dependent on the applied model is the DU. Other functional units in AU are general and common for all models. New services are a major driving force behind the evolution of the existing telecommunication network towards creation of the GII, in the part of AN. Due to that reason it is necessary to define and develop other alternative models, because it is clear that there is no single solution to the diverse needs. As a result of analytical research six AN models, according to the used transmission technology, primarily oriented towards provision of multimedia services for developing countries, have been defined.

MODEL 1: ***Provision of services over existing infrastructure***

In the existing networks with infrastructure based on metallic cables the customers for telephone, leased lines and N-ISDN services are connected to AU through DU1.

DU1 characteristics has to be:

- based on Recommendations G.702, G.703, G.730, G.740 and G.750 series for PDH transmission systems;
- fulfil Recommendation I.430 (transmission bit rate 192 kbit/s, line code 2B1Q), for Basic Access and Recommendations I.431 and G.730 (transmission bit rate 2048 Mbit/s, line code HDB3) for Primary Access for ISDN concept.

MODEL 2: ***The use of ADSL/VDSL to provide video bandwidth over copper pairs***

A possible way to increase the bandwidth and capacity, with the existing infrastructure is to use ADSL/VDSL technology through DU2.

ADSL technology enables the distribution of high-speed services over the existing twisted pair copper network without regenerators. Then in DU2 new modulation (DMT – Discrete Multi-Tone, QAM – Quadrature Amplitude Modulation, CAP – Carrierless Amplitude Modulation) and line code techniques (AMI, 2B1Q, HDB3) are used to support asymmetrical transmission between 1.5 Mbit/s (max. distance 5.5 km for conductor diameter of 0.5 mm) and 6 Mbit/s (max. distance 3.6 km for conductor diameter of 0.5 mm) in the downstream direction and upstream control channel of 16 to 640 kbit/s [6]. The ADSL will mainly be applied to distributive and interactive VoD services (it allows simultaneous viewing of two different video channels with MPEG1 compression or one channel of NTSC quality video with the forthcoming MPEG2 standard). If VDSL technology is used, DU2 has to be able to carry higher bandwidth services up to 50 Mbit/s (downstream) on short lengths (typically a few hundred meters).

MODEL 3: ***Provision of services over fibre cable networks using B-ISDN***

In cases where there is no infrastructure based on copper cables or where investments in new infrastructure are economically justified, it is necessary to employ optical fibre cables as distribution media. This enables the application of FITL technology (Passive Optical Networks, PON, or active star structures). In that case for provision of voice/data/video services, principles of B-ISDN are used. The DU3 sub-unit is designed for such situations.

For delivery of POTS and ISDN services in the FITL concept PON came to the forefront as a solution to the needs of the local AN. In that case DU3 has to be capable to receive up to $16 \times 2,048$ Mbit/s (480 is max. number of 64 kbit/s access channels) according to Recommendations G.703, G.704, G.732 and support a Byte Transport System operating at 20 Mbit/s, over two single mode optical fibres (operating wave length range 1260-1360 nm, fibre specifications ITU G.652). For the optical transmitters, due to economical reasons, Fabry-Perot-Lasers (–7dBm sensitivity) and for the optical receiver PIN diodes (–40 dBm sensitivity at BER of 10^{-9}, 27 dB dynamic range) are used. Maximum remote controlled CPE distance is 20 km.

MODEL 4: ***Hybrid fibre/copper access scenario***

If the telecommunication infrastructure is based on optical fibre cables, the distribution of interactive video and multimedia services is provided by DU4 (configurations HFC and FTTC, FTTH through Broadband PON-BPON, are acceptable for CATV operators and local exchange carriers, respectively). The provision of broadband services requires AN enabling bi-directional asymmetrical communication of interactive type. For the HFC solution, most used in modern AN networks in near future, DU4 consists of a set of devices for two-way transmission (an optical transmitter, DFB-Laser, for downstream path 47-860 MHz and one optical receiver, PIN diode, for each upstream path 5-30 MHz). The typical values for the DU4 are shown in Table 4.2.

Table 4.2 – Distribution unit features for HFC

Downstream path		
Frequency range	MHz	47-862
Amplification	dB	15-34
Impedance	Ω	75
Return loss	dB	>20
Amplification regulation	dB	0-20
Equalization band	dB	0-10
Output separation	dB	>20
RF output level (60 dB)	dBμV	95-121
for FTTB	dBμV	63-82
for FTTC	dBμV	110
S/N factor (max)	dB	8
Crossing current	A	5
Power supply	V	25-0 (remote) 220 (local)
Upstream path		
Frequency range	MHz	5-40 (30)
Impedance	Ω	75

MODEL 5: ***The use of the Radio In The local Loop (RITL)***

RITL technology for telephone services is becoming more and more important. Wireless communication offers very short installation times compared to wired connections. Local mobility is another important customer feature and this approach is also suitable for rural areas with a low customer density, where wireless access is more cost effective than wired. RITL access is made through DU5. DU5 characteristics depend on customer mobility and density, in selected areas RF band utilization (depends on regional specific regulations), channel capacity for transport, customer access method, type of service provisioning to the customer, etc. (for more details see section 4.2).

MODEL 6: ***Access using satellites***

If satellites are used for distribution of services to a greater number of customers it is necessary to use DU6. Digital technology will be used in the future for delivery of voice, data, and video services using satellites. The application of digital transmission and Ku band makes possible the use of small diameter antennas and it eliminates distortions and failures (interference, reflection) which are typical for analogue transmission. Due to these reasons, DU6 must provide digital processing, compression, multiplexing, encoding and QPSK (Quaternary PSK) or QAM modulation (see more in Fascicle 1, Chapter 2, section 2.4).

The IU is the common sub-unit for all the above Models and has a task to provide all necessary adjustments to connect AU with the transmission network and it comprises the whole range from plesiochronous digital hierarchy to SDH and ATM in an integrated manner.

Progress in technology and evolution of existing specialized networks into integrated services network affects the upgrading of the switching systems (in construction and performances to achieve lower prices). The SU is expected to provide the application of existing and future switching systems in AN in order to simplify design, manufacture and, especially, operation. It is divided into two parts: narrow band part providing bit rate of $n \times 64$ kbit/s and ATM part designed to allow the switching of channels with any bit rate. The main use for ATM is seen for interactive multimedia applications.

The CU is intended to support collection, transmission and processing of the AN data upon which the decision of the AN management can be based aimed at utilizing network elements to a maximum possible extent. The main management functions that CU has to provide are:

- *Fault management* is the set of functions enabling the detection, localization, isolation and correction of abnormal operation of the AN and its environment. It provides facilities for testing of equipment upon elimination of failure.
- *Performance management* supports functions which evaluate and report upon the behaviour of the telecommunication equipment and the effectiveness of the AN or AN element. The key element in performance management is the measurement of performance, because it is important for an efficient AN management to have the information about degraded operation of equipment in the AN elements in order to take preventive actions. Its role is to gather monitoring and correcting data of the AN elements. These data are used for AN quality of service and network element alarm criteria evaluation.
- *Configuration management* includes all functions necessary to bring elements of the AN into service, without installation, control the state of the network element (in service, out of service, stand-by), faulty equipment blocking and testing of newly installed equipment.

TMN controls the complete infrastructure of the whole access zone. Its main function is to provide control and monitoring over different services regardless of distribution media in a unified manner. Control units are installed in each network functional part. A CU in AU is connected to TMN via Q_3 interface with the associate protocol.

The physical interface in a reference point RP1 (between internal equipment on customer premises and AN) has to provide terminal equipment connection for CATV, B-ISDN (ATM), N-ISDN and PSTN. The $NT_{I = 1, 2, \ldots, 6}$ terminates the AN providing different access functions dependent on the distribution media used, but it must be service independent. In a reference point RP2 type of physical interface is V5.x (for services realized using SDH ring structure). At the beginning the V5.1 interface will play a significant role. Later the V5.2 interface will be used allowing statistical concentration within the AN and reducing the transport capacity needed for the transmission network.

4.1.3 An Approach for implementation scenarios

Many different scenarios can be applied for the deployment of AN architecture ranging for high-density urban areas through the suburbs and rural communities. They depend on approved development policies such as:

- *New operator*: the main goal in this scenario is to provide services as rapidly and cost effectively as possible. This scenario is becoming very important especially in developed countries.
- *Expanding capacity*: new demands for services can arise in developed networks. However, this scenario is typical for undeveloped areas, urban or rural, in under developed parts of the world.

- *Rural area*: in rural area 90% of customers are typically located within few kilometers of the exchange. The other customers are either clustered in small village clusters or a single customer at distances up to 25 km from the local exchange.

Therefore, it is extremely important to work out criteria to be used as a basis for estimating the appropriate time to start implementation projects of a particular AN scenario taking into account:

– communication technologies level in the country

– acceptable service cost for customer.

The number of main telephone lines, TV sets, personal computers and CATV customers indicates the communication technology level in any country (each per 100 inhabitants). Analysing and comparing the data in developed countries and in developing countries has shown that the right moment for the implementation of multimedia services is when the telephone density is 40 and when PC density is 14 as minimum. For the video on demand services implementation it is necessary to have 30 TV set density, while, at the same time, the CATV customer density must exceed 10.

It is difficult to determine the charges that have to be paid by customers for new broadband services to the main network operator. However, for estimation purposes, monthly telephone charge paid by residential customer in a country may be used as a starting point. In high income countries it ranged 8-22 US$, in middle income countries 0.4-13 US$ and in low-income countries 0.5-5 US$ for 1995.

As multimedia and video on demand services are very attractive for customers who are ready to pay the cost of such services their cost compared with the cost of telephone service should not be higher than double or triple telephone service cost.

Additionally, for an appropriate decision, an estimation of the cost of each technological solution should be identified. For the copper pair solution in developed countries, in rural areas, the cost of the AN is about 1200-1400 US$ per subscriber (digging, material, joints, commissioning). In cities the AN is always installed by the PTT and the average cost of the network in urban areas is 500-600 US$ per customer (this cost also includes the cost for the ducts).

The cost of new technologies is reduced year by year as the amount of production is increased. A rough cost estimation (prices for 1995) is given for PON FTTC and PON FTTB configuration and for RITL which are the most attractive technologies for the residential customers (see section 4.2. of this Chapter). The cost is for provisioning POTS (90% penetration) and ISDN (10% penetration services).

FTTC (ONU=32 equiv. telephone lines):	600 (urban)-1200 US$ (rural)
FTTB (ONU=32 equiv. telephone lines):	500 US$ (urban)
RITL (DECT):	400 (suburban)-500 US$ (rural)

Due to economical and technical reasons, the implementation of the AN target architecture must be done in phases. Based on analysis of the following aspects of the current situation

– in the core network,

– in the access network,

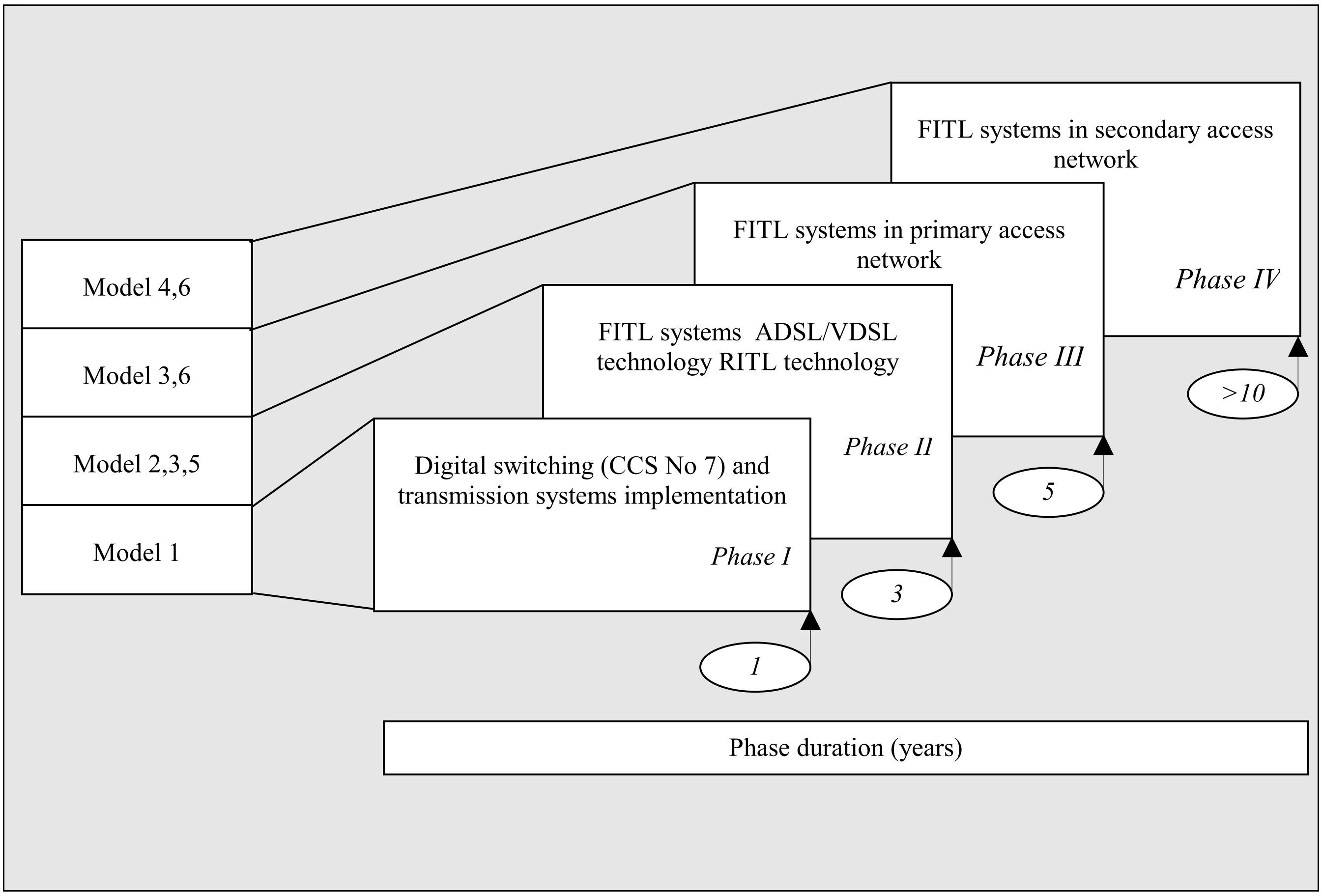
– in the CPE area,

– in the neighbouring countries,

– concerning existing services and available human resources for applying new technologies which should be used ,

a possible implementation scenario which can be suggested for developing countries is shown in Figure 4.3.

Figure 4.3 – Access Network target structure implementation scenario



In the first phase it is assumed that the implementation of digital transmission and Common Channel Signalling (CCS No. 7) has been completed, which means that two main preconditions for the realization of N-ISDN have been fulfilled. It enables the distribution of services over the existing infrastructure by using Model 1 and it takes a relatively short time for its particular application. The forecast time duration for this phase is one year. In the second phase, even in cases when the existing infrastructure built with metallic cables is developed and modern, the transition to FITL systems can be foreseen. In addition to high bit rates, the implementation of these systems makes it possible to plan transmission networks in a new manner. In the case of realization with SDH transmission systems, the transport through transmission network can be organized in three layers – national, regional and local, which drastically reduces the number of switching levels. At the national level, PON networks are convenient only for a limited use (in areas with high population density), while utilization of active FITL systems is recommended for future solutions due to migration of services towards B-ISDN. As optical fibre cables are built in the national network in this phase, besides Model 3, for distribution of services on the last 500 m to the customers utilization of ADSL/VDSL technologies – Model 2 should be used. In cases when there are customers willing to pay for fast realization of such demands for distribution of services, RITL technology Model 5 shall be used. The experience of developed countries, points to the necessity of trial projects, which provide necessary experience for both operator and customers and enables the restructuring of the domestic telecommunication equipment industry. Therefore, a three-year time period for the second phase is anticipated.

By analogy with telecommunication infrastructure built up of metallic cables, and when it is built up of optical cables, it is usual to define two levels of AN: the primary AN (the part between local exchange and distribution point) and the secondary AN (the part between distribution point and customer premises).

In the next, third phase, it is foreseen to provide implementation of FITL systems in the primary AN. The results of trial networks world-wide shows that in areas with higher population density (assuming 100 000 customers and switched video service) it is possible to achieve a cost of 1 437 US$ per customer in active double star with splitter network architecture (according to the ITU data, estimated investment per main telephone line is 1 500 US$) [13, 14]. It is assumed that this complex task can be accomplished within five years. Upon the completion of this phase, implementation of optical fibre cables in the secondary AN (FTTH) would be possible. It means, that Model 4 can be used for the distribution of services in the AN over the entire country territory. As well as development of FITL systems, in parallel, big investments are being made today in development of satellite communications. Because of that, it is difficult to predict now, but it is not impossible to expect, that in the course of eventual application of the proposed scenario, the provision of services using satellites (Model 6) could be available on economical basis. The deployment of Model 6 enables the realization of the strategic target of telecommunications (GII) within the shortest possible period.

4.1.4 ITU-T Standards

The following ITU-T Recommendations are important in study of Access Networks:

- Rec. G.902, *Framework recommendation on functional access networks (AN)*, Geneva, January 1997.
- Rec. I.375.1, *Network capabilities to support multimedia services: General aspects*, Geneva, June 1998.
- Rec. I. 375.2, *Network capabilities to support multimedia services: Example of multimedia retrieval service class-Video-on Demand service using an ATM based network*, Geneva, June 1998.

Draft Rec. I.375.3. *Network capabilities to support multimedia services: Example of multimedia distribution service class, switched digital Broadcasting (SDB).*

References

[1] ITU: STUDY GROUP 13, *Report 76*, COM13-R-76-E, Geneva, October 1996.

[2] ITU: STUDY GROUP 13, *Report 1*, COM13-R-1-E, Geneva, April 1997.

[3] ITU: STUDY GROUP 13, *Report 9*, COM13-R-9-E, Geneva, March 1997.

[4] Maher A.: *Spending time-to revenue*, Telecom Report, Vol. 20, 3rd Quarter 3.97.

[5] Olsen B. et al.: *PNO and CATV Operator Broadband Upgrade Technology Alternatives: A Techo-Economic Analysis*, Optical Fibre Communication Conference, OFC 96, San Jose, February 1996.

[6] Jankovic M., Petrovic Z.: *Access Network Target Architecture* Proc. of 4th IEEE International Conference in Multimedia Computing and Systems (ICMCS97), Ottawa, June, 1997.

[7] Auer E., Helmstädt D., Hoogendoorth C., Ohlendorf G., Schmidt L.: *A Generic Service Access Network Platform*, Proc. of XV International Switching Symposium, Vol. 1, Berlin, 1995.

[8] Reinhard F., Scholz M.: *Interactive Video-services Success Factors and Network Solutions*, Proc. of XV International Switching Symposium, Vol. 2, Berlin, April, 1995.

[9] Kwok T.: *A Vision for Residential Broadband Services: ATM-to-the-Home*, IEEE Network, September/October 1995.

[10] ITU: STUDY GROUP 13, *Report 8*, COM13-R-8-E, Geneva, March 1997.

[11] Bakmaz M., Petrovic Z.: *Access Network Architectures Comparison and Development Scenarios*, Proceeding of XIV Scientific/Professional Symposium on Novel Postal and Telecommunication Technologies, (in Serbian), Beograd, December 1996.

[12] Lee M.S.: *Digital Optical CATV Network: An Integrated Service Network for CATV, POTS and N-ISDN*, Technology Summit, Vol. 2., Telecom 95, Geneva 1995

[13] ITU: *World Telecommunication Development Report*, Information Infrastructures, World Telecommunication Indicators, Geneva, 1996, 1997.

[14] EURESCOM: *Project P614 Implementation Strategies for Advanced Access Networks,* Heidelberg, April 1998.

[15] Jankovic M., Petrovic Z.: *Scenarios for Building Global Information Infrastructure in Developing Countries*, Proc. of International Conference on Telecommunication (ICT98), Greece, June 1998.

4.2 Wireless access

4.2.1 Introduction

Wireless access to telecommunications networks has undergone revolutionary changes over the past few years, due in no small part to the rapid advances of radio technology since the commercial introduction of mobile cellular technology in the 1980s.

Despite their historical development from common threads of technology, for the purposes of this section a distinction is made between *mobile telecommunications* and *wireless access*. Wireless access is defined here as the use of radio to connect users from essentially fixed locations to networks of various kinds. We exclude from this definition the vast realm of mobile telecommunications that allow end users to move over considerable distances at considerable speed. These systems typically have switching functionality included. Access-only systems do not. Also excluded from discussion in this section are general-purpose transmission systems that *may* be used for access but are not exclusively designed for it.

By most accounts, fixed wireless telecommunications are headed for explosive growth. The industry had sales of US$ 103 million in 1998 and can be expected to grow to US$ 8 billion in 2007, according to Pioneer Consulting *[New York Times, June 14, 1999]*.

Fixed wireless access systems can coexist with mobile systems in a given area without problem if the radio spectrum needs of both are met. Indeed some (but not all) modern digital switches now have the capability to serve simultaneously as the MSC (Mobile Switching Centre) of a cellular mobile system and as the local exchange of a wireline and/or fixed wireless system. In some currently available product configurations, an MSC can support connections to mobile base stations and simultaneously support V5.2 connections to WLL systems. With increasing deregulation, regulatory agencies may allow, and operators may find attractive, the offering of both fixed and mobile service. The fact that both may be implemented simultaneously on the same switch, and both may be wireless, makes this combined service business particularly attractive. This convergence of fixed and mobile service offerings is predicted by some analysts to be a major trend over the next few years.

Most of the wireless access systems of today bring users access to a circuit switch, but we are now seeing of the emergence of products that brings users direct access to packet switches at various data rates.

Compared with any other wired technology, which needs the implementation of ducts or poles, the radio technology is, without doubt, much easier and less costly to install. But to these major advantages for the operator, some others as much more important can be added.

Those are:

- the concentration role of the base stations which, for the same number of subscribers necessitates fewer infrastructures,
- the inherent flexibility of the radio to automatically adapt the resource (number of radio circuit) to the traffic demand,
- the interest for the operator not to plan from the beginning where and who (residential or business) will be its future customers and therefore not to install unnecessary supplementary infrastructure (cables, ducts, poles ...etc.) which may never be used,
- the possibility for the operator to propose an immediate connection to any potential customer located within the coverage of the radio base station,
- in some cases, the possibility for the end user to acquire and install by himself its own radio terminal equipment,
- the possibility for the end user to connect and use the same subscribers terminals (telephone set, facsimile, answering machine, modem ...etc.) as on the wired network.

Regarding the two last points, it should be noted that service quality and performance are the key factors for the success of the Wireless operator. In any case, the subscriber does not know or even more does not care about the technology used on the network, like he does not know and care when he set a call across continents whether the service is provided via satellite or sub-marine cable or whatever technology.

The only important factor is that the service and the quality of service is of the same level or better as the one he uses on the wired local network.

4.2.2 Basic categories

Under this definition of wireless access, we note the emergence of a number of different applications and classes of product, based in part on the data speed they require or support. To categorize applications and products in such a rapidly evolving field is at best an instantaneous snapshot of dynamic movement. There exist and there are emerging products that arguably can fulfil more than one classification. Many of the low-speed access products of today promise to evolve into high-speed products tomorrow. Undoubtedly there exist, or will soon emerge fixed wireless access products that do not fall into any of these classes. But to understand their extent and potential, it is nevertheless helpful to enumerate the basic categories of fixed wireless access systems from a user's perspective as they exist today.

Five such Wireless Access categories and applications are the following:

1) **Wireless Local Loop (WLL).** This is the use of wireless access as a replacement for the final wired loop from a PSTN to residential and business subscribers located within a few kilometers of a telephone exchange. Typically these wireless systems support voice and low to medium speed voice band data calls today, and promise to support much higher data rates in the future. Typically these systems operate in the 1.9 GHz and 3.4 GHz bands, although some systems use the 800 MHz mobile and other bands. The subscriber density and coverage supported by these systems vary considerably. The most advanced WLL systems today can support the coverage, the traffic and the subscriber density needs of highly urbanized populations, as well as those of rural areas.

2) **Long Distance Wireless Access** as a means to provide telephone service to residential and business subscribers who are located at considerable distances, up to hundreds of kilometers from the local exchange. This application is often denoted as Point to Multipoint (PMP), because it uses radio to connect a single point (the local exchange) to many points (multiple terminal stations to which subscribers connect). Microwave radio systems for this application often operate in the 500 MHz to 2.5 GHz frequency range. Satellite systems that provide fixed wireless access are also now being deployed. Typically these are deployed in very remote areas where ground-based wireline or wireless systems cannot be economically deployed.

3) **High Speed Packet Data Internet Access**. This class of products is used to provide end users with very high-speed wireless data access (circa 1 to 2 Mbit/s) to data networks, including Intranets and the Internet. These systems use licensed bands such as 1.9 GHz and 3.4 GHz

4) **Wireless Broadband Access** for short range but very high-speed data (tens of Mbit/s) for businesses or public institutions. These systems generally operate in recently opened bands in the 10 GHz to 42 GHz range and can provide access at distances up to approximately 25 kilometers.

5) **Wireless Local Area Network Access** using radio to replace the cables of standard private local area networks. These systems can use unlicensed frequency bands, such as 2.4 GHz. They are typically intended for indoor use. Some systems offer outdoor radio adjuncts in order to link nearby buildings

The remainder of this section discusses these applications in greater detail. Emphasis is given to the first two, the most widely deployed applications of wireless access, now providing telephone service to several million subscribers worldwide.

4.2.2.1 Wireless Local Loop

The term “Local Loop” is generally used to mean all, or the final part of the access networks (primary and secondary), but the definition of the “Local Loop” depends usually on the structure of the network and on the cultural origin.

To remove the ambiguity, we will use the term “Local Loop” for the “Access + Distribution” networks.

The term “Access” sub-network is used to describe that part of the network between the subscriber premises and the first point of geographical distribution or circuit concentration.

The term “Distribution” sub-network is used to describe that part of the network between the first point of geographical distribution or circuit concentration and the Local Exchange.

The distribution or concentration point may not exist if the “Access” sub-network is directly connected to the Local Exchange.

So far, the reference point between the “Access” sub-network and the “Distribution” sub-network is not fixed and varies according to the network architecture and the Local Loop technology.

This also means that different technologies may be used for each of the two sub-networks. Hence, hybrid wired/wireless or wireless/wired combinations may be set up. A lot of configurations are possible. These will depend on topography, performance, services, costs, regulatory and environmental constraints, operator strategy, etc.

Figure 4.4 illustrates this Local Loop definition.

Cellular based Wireless Local Loop, the use of radio to replace the final wired loop from an exchange to subscribers’ premises, has been widely deployed only over the last three years. Driven by the many advances in radio technology and manufacturing process commonly associated with the mobile cellular industry, wireless local loop has recently become an economically attractive alternative to traditional wired outside plant. For operators of telephony networks, outside plant often constitutes the major capital expense. As shown in Figure 4.5 and Figure 4.6 the choice of WLL can impact over half of their typical investment expenses. The cost advantage that WLL offers over traditional wire fixed line can thus have a major impact on a service provider’s bottom line.

Figure 4.4 – Local loop definition

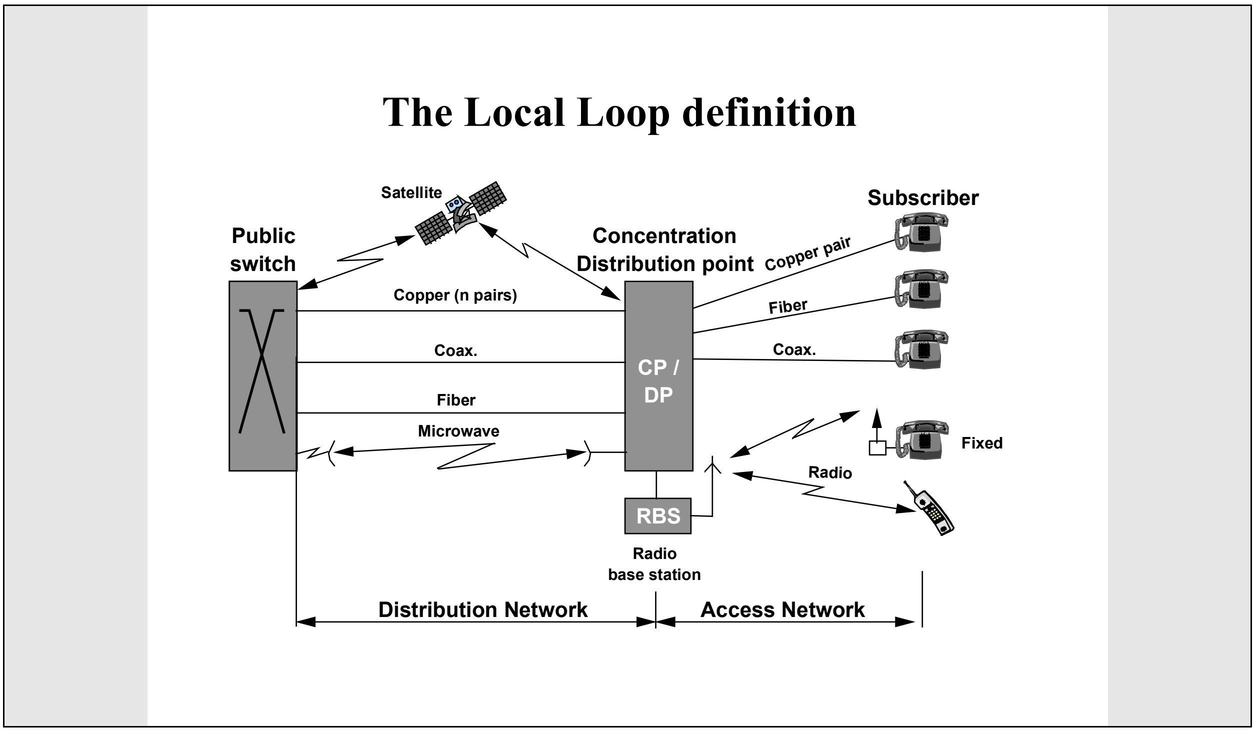


Figure 4.5 – Average Investment Distribution in a Fixed Line Network

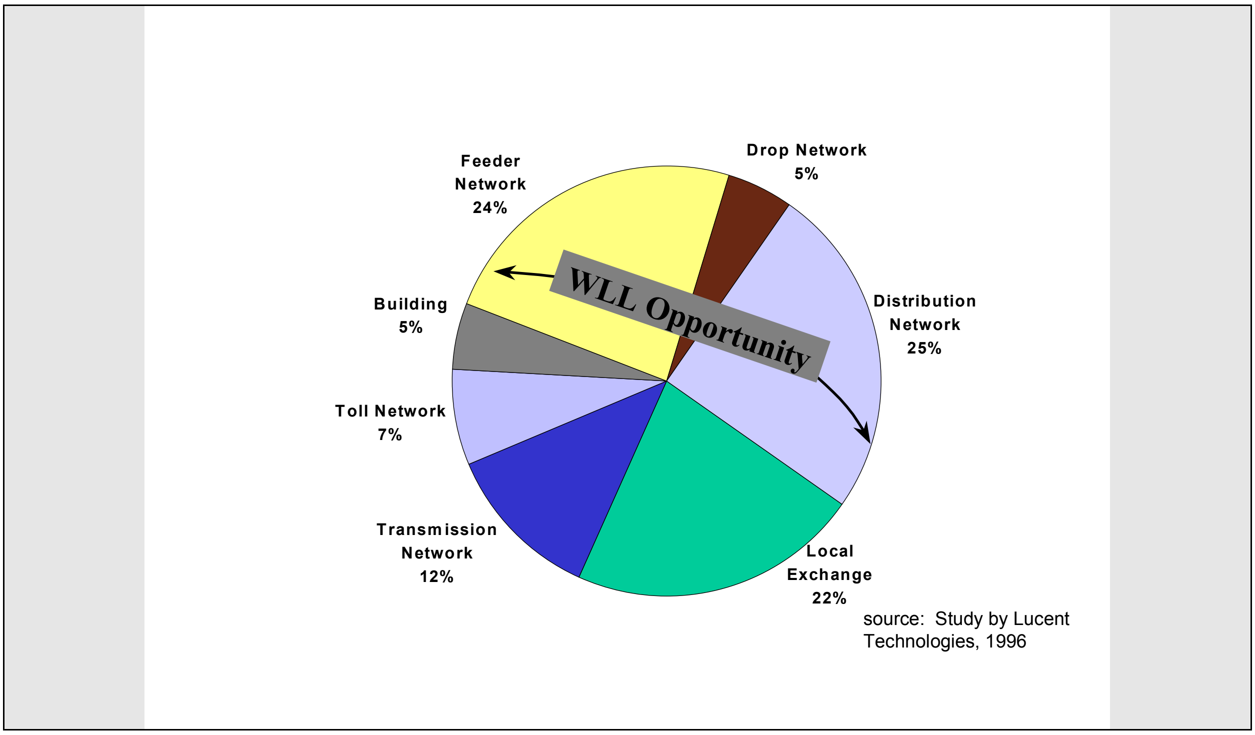
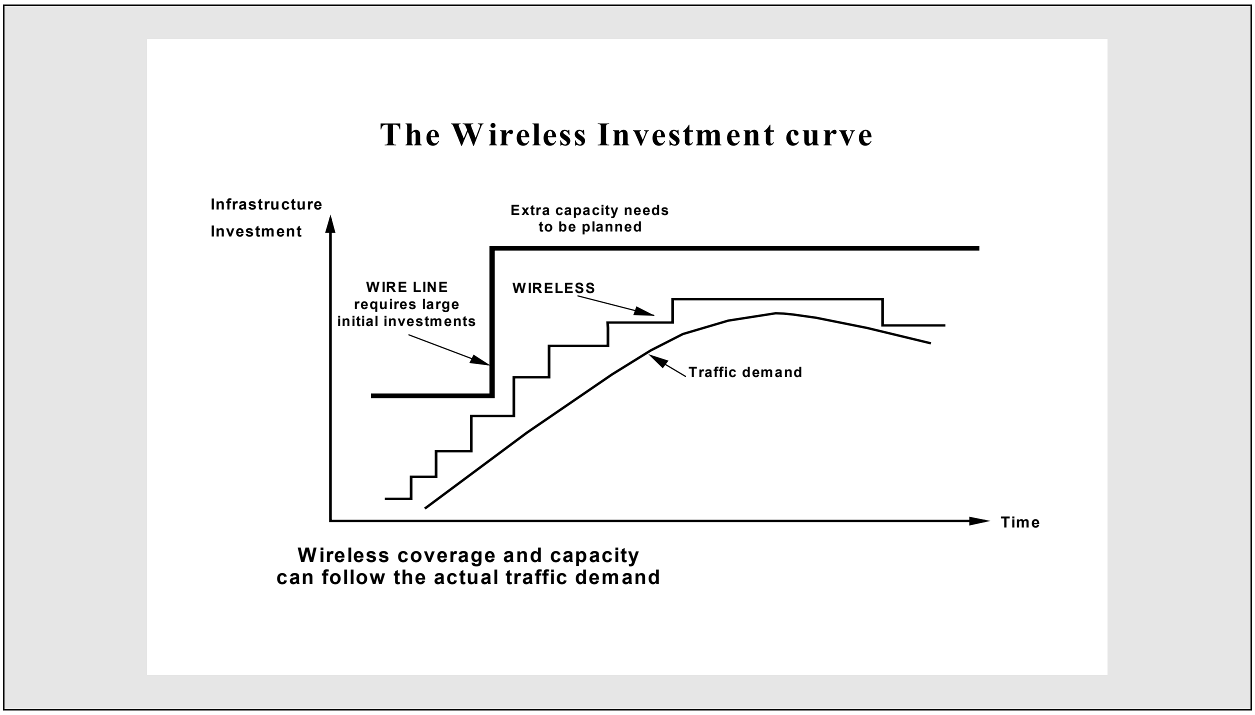


Figure 4.6 – The wireless investment curve



Although modern WLL technology shares some aspects of the common architecture of mobile systems, cellular technology, sectorisation, frequency reuse, low power, etc. the best of WLL technologies and products do not share the shortcomings commonly associated with today's mobile cellular telephony.

Mobile cellular networks, by their very nature, must spend considerable processing resources on the tasks of tracking the geographic location of users, and allowing their dispersion to undergo rapid dynamic change. With fixed subscribers, such tasks are not needed. The location of subscribers does not undergo dynamic change. Because the direction of a subscriber relative to a serving base station is fixed, WLL antennas may exploit the benefits of directionality. The best of WLL technologies and products can therefore provide significantly higher subscriber densities, higher call capacity and better quality of service than their mobile counterparts. Mobile cellular systems generally must compromise on voice quality by sampling voice at rates such as 8 or 13 Kbit/s. Purpose-built WLL systems often use higher sampling rates such as 32 or 64 Kbit/s yielding *toll grade* voice quality.

WLL systems are attractive as an alternative to wireline access because they generally can be deployed much more rapidly and at lower cost, yet provide equivalent or better service.

To be a true commercial substitute for wireline, WLL systems seek to provide *transparency.* WLL is most attractive when it behaves in a similar manner to high quality wireline telephony, but at considerably lower cost. This means that the dialling procedures, the voice quality, the access to and behaviour of subscriber supplementary services and the call set-up time closely match those provided by high quality wired lines.

The best of WLL technologies and products available today achieve excellent transparency, both for analogue as well as digital (ISDN) telephone service. Indeed, the highest complement that can be paid to a WLL product is for a typical end user not to be able to detect that a call is using a WLL line without visually noting the presence of an antenna.

Because WLL operates as a public outdoor radio technology, to reduce interference it must operate only in licensed radio bands. The exact frequencies under which WLL systems operate are therefore controlled by national, regional and international regulatory bodies. Public telephone service providers seeking to operate WLL systems generally must apply for radio spectrum in the locations in which they wish to operate. Common operating frequencies of modern WLL systems are in the 1.9 GHz and 3.4 GHz bands.

With many different WLL radio technologies on the market and systems with different qualities of service and different levels of transparency, there is a hesitancy by some operators to adopt WLL. But as the industry undergoes its inevitable shakeout, it is likely that WLL systems will become more standardized and generic, just as wireline technology is commonly perceived to be. Those WLL systems that are merely mobile cellular with the mobility turned off are pressured now to improve their transparency with wireline. Purpose-built WLL systems, which already have good transparency, are pressured now to standardize and align their operations and management systems with the rest of the network. Most significantly, the demand of operators that WLL systems support ever higher data rates requires vendors to continually evolve their systems. All these factors assure that we are likely to see both price declines and expansion of functionality in WLL systems as they continue to be deployed in the years ahead.

Figure 4.7 – Wireless Local Loop in the Republic of South Africa (Note the solar panel to power subscriber equipment)

In terms of markets, WLL equipment vendors have so far found their greatest successes in the *teledensity application*. This is the use of WLL as a means to expand rapidly and economically the number of telephone lines in a given location, providing basic telephone service in areas that previous had little or none. Figure 4.7 very practically suggests the impact that WLL can make in bringing more of humanity into the world’s telecommunications network. It is therefore of no surprise that the greatest numbers of WLL lines installed to date are in developing nations of Asia, Africa and Latin America.

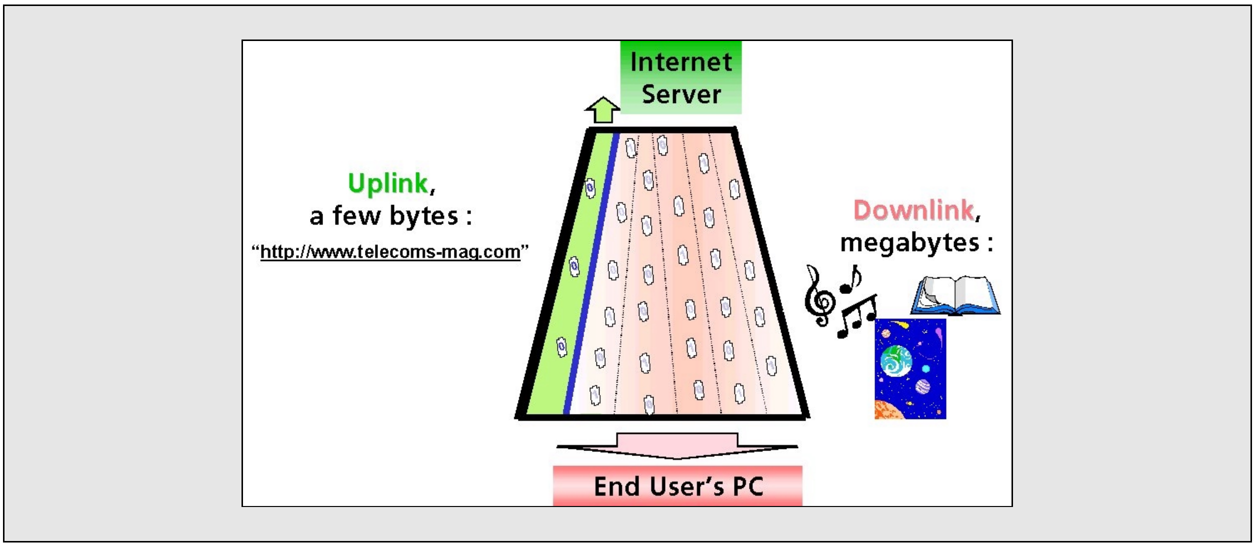
Despite having their best success providing basic telephone service in developing nations, WLL equipment manufacturers are driven to continually update their equipment in order to provide customers with more advanced services, to match those that can be provided by the newer wireline technologies. As technologies such as V.90 modems, xDSL, and cable modems are deployed, WLL systems are pressured to match their capabilities. Only systems using the most modern digital radio technologies, such as DECT, and other TDMA and CDMA technologies are likely to maintain significant WLL market share. For even in the least developed areas, urban and rural, there is both a need and a demand for modern data services such as Internet access at ever increasing data rates.

The requirement to support continually higher data rates suggests that the introduction of packet technologies over WLL radio interfaces will become commonplace in the next few years. Instead of connecting only to traditional circuit switches, we are likely to see WLL systems directly interface to IP routers as well. It is the ability of packet technology to increase the sharing of radio resources, particularly useful in handling bursty data, which drives the interest in applying packet technology to WLL. With increasing deregulation, traditional as well as new operators may seek to provide both circuit switched telephony services as well as packet switching for services such as Internet access.

In the long term, many analysts predict a full transition of telecommunications networks from circuit to packet technologies such as IP and ATM for all services including voice telephony. While such a transition is likely to occur over an extended period of time, it is clear that the WLL systems of today are already preparing to meet this challenge.

With the Internet as a major instigator of the requirement for high-speed data access, it is interesting to note the asynchronous nature of most Internet data exchanges. Today an Internet web user typically sends a relatively small amount of data in the uplink (PC to ISP) direction. This might consist of a few mouse clicks or the typed entry of a web address such as http://www.telecoms-mag.com. The response in the downlink direction (ISP to PC) to that relatively small amount of data is often a large amount of text, graphic, audio or video data, such as the display of a web page with complex graphics (Figure 4.8).

Figure 4.8 – Asymmetric Flow of Internet Data



Thus the flow of information in user access to the Internet is commonly quite *asymmetric* in nature. Radio technologies that can dynamically adapt to asymmetry have a distinct advantage over those that do not. In particular, if the duplexing of two-way communications is achieved by means of time division duplex (TDD), it is significantly easier to adjust to asymmetry *in real time* than with frequency division duplex (FDD).

On the horizon, WLL systems are likely to continually incorporate various new technological advances such as *smart antenna* technology, the dynamic alternation of the shape of electromagnetic propagation, to improve performance. A number of methods for this have been demonstrated. For WLL systems, greater capacity will be achieved by reduced interference and more efficient use of radiated power. Here again, products and radio technologies that can incorporate these advanced techniques are likely to find a competitive advantage over those that cannot.

4.2.2.2 Fixed wireless access over long distance

There is another category of fixed wireless access which can bring subscribers service from a telephone exchange when the subscribers are located at distances considerably greater that those of a standard local loop. Systems that do this by wireless means have existed for decades, and are used in both developed and developing nations.

A popular technology for this has emerged over the last decade, TDMA point to multipoint (PMP) microwave radio. Under such systems, an interface unit is located near an exchange. From this station, there can be multiple microwave radio hops of up to 50 km using TDMA radio, commonly in the 1.5 GHz or 2.5 GHz band, to stations that provide connection points for wired telephone sets. Systems providing such access for telephone subscribers even *hundreds of kilometers* distant from the exchange are in use today (Figure 4.9). Under the most advanced systems, even ISDN service can be offered to these very distant subscribers. More recently, some systems have added WLL "tails", so that even the last connection from the final radio station to the subscriber's premises may also be provided by wireless means

The price of these systems varies considerably because their configurations, subscriber densities, coverage areas and services can vary over a very wide range. The price may range from a few hundred to a few thousand dollars per subscriber. As a strategy to provide service to rural and remote areas, operators may deploy these systems until the subscriber growth in a given community reaches a level where it becomes economically viable to deploy a small exchange or the remote module of a distant exchange. At such a time the WLL tails already in place may continue to be used to provide access to the new exchange.

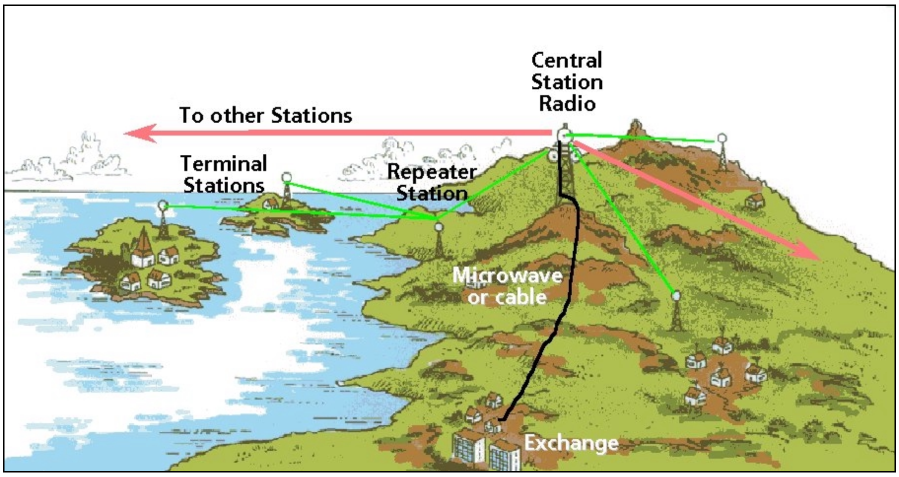
In this category of fixed wireless access over very long distances there are also systems that use earth satellites to provide access to a network. Configurations vary considerably. VSAT (Very Small Aperture Terminals) satellite technology may be applied to support voice and data services to remote communities that cannot be economically accessed by cable or ground-based microwave radio. When the traffic from such a community does not justify the leasing of a permanent satellite radio channel, DAMA (Demand Assigned Multiple Access) technology may be deployed to optimize satellite usage. Thus satellite resources are only allocated as needed. This makes it economically viable to provide access to a very small number of subscribers in extremely remote areas.

4.2.2.3 High speed packet data internet access

A third interesting application of fixed wireless access that is now emerging is very high speed Internet access using packet data technology. Some WLL products that are currently used primarily for voice and voice band data are based on technical standards that support high-speed packet data. Some of today's WLL circuit technology systems promise to evolve soon to support packet data as well. But there is also emerging a class of products that are designed from the beginning to support very high-speed wireless packet technology with IP and PPP protocols. For these products, internet/intranet access and virtual private networks between business locations are primary applications. Voice calls may or may not be supported.

These access systems may be used by operating companies that seek to compete with the high speed Internet access offered by cable TV providers and DSL connections. Customers for these products include Internet Service Providers, wireless telephony service providers, PTTs and competitive access providers. End users may be residential or business.

Figure 4.9 – Wireless access over long distance title



In addition to providing high-speed data access into public networks these systems may also be used to support virtual private networks between geographically distributed business locations.

4.2.2.4 Wireless Broadband Access

4.2.2.4.1 Introduction

At the leading edge of fixed wireless access technology today, access by broadband wireless is now emerging. These systems support very high data rates, in the range of tens of Mbit/s, for voice and data applications for business customers. Mono-cellular, line-of-sight technology is used to relay huge amounts of data from business premises into operators' networks. Up to 25 km distance can now be achieved, depending on climate and spectrum. This technology allows operators to avoid the long lead-time and great expense of laying fibre optic cable in order to connect their networks to business buildings in urban and suburban areas.

Wireless Broadband Access operates towards the high end of commercially available radio spectrum, 10 GHz to 42 GHz, with somewhat different licensed bands allocated in Europe and North America. Included in this application is Local Multipoint Distribution Service (LMDS), a particular frequency band (28 GHz) within the overall category of wireless broadband access.

While this technology has not yet been widely deployed, a recent estimate by the Stategis Group for the infrastructure market for LMDS alone in the United States, is US$ $8 Billion in the next ten years. In the USA, a developed economy by all measures, only one tenth of the office buildings are currently connected with optical fibre, leaving great opportunity for wireless broadband access.

Potential applications include, but are not limited to, video-on-demand, interactive video, and Internet access. Purchasers of wireless broadband access equipment are likely to include PTTs, local exchange carriers (LECs), inter-exchange carriers (IXCs), Internet service providers (ISPs) and new network operators. End users are initially likely to be small and medium size businesses that cannot justify the cost of leased optical fibre.

As a market entry strategy, an operator might use wireless broadband to establish an initial base of broadband business customers. The modular flexibility of wireless access, allowing incremental investment and quick revenue return permits an easier market entry. Once a particular geographic location has sufficient end-users generating enough revenue, the operator might then chose to make the investment in fibre. The wireless access equipment may then be re-deployed elsewhere, in a locale where the operator seeks to do business.

Ultimately wireless broadband may prove attractive to residential customers as well. Advanced interactive video services and very high speed Internet access are seen as likely applications. With fibre to the home estimated to cost several thousand dollars per customer, wireless broadband solutions might prove very attractive.

A short description of some European wireless broadband access systems contained in Annex 4A.

4.2.2.4.2 Wireless Broadband Access System architecture

The architecture in Figure 4.10 has been built considering only three parameters which best differentiate the services provided. From the users point of view they characterize for the users how the system can meet their needs.

- Uni./bi-directional: this is the parameter that separates the world of broadcasting from the telecommunication world, where communications are mostly bi-directional. The services provided by unidirectional systems are limited, although in some cases, a return channel can be added via bidirectional systems.
- System mobility: the system will serve a person or a place, depending on whether mobility is provided or not.
- Typical coverage: it characterizes for the users the range of moving of the terminals.

4.2.2.5 Wireless Local Area Networks

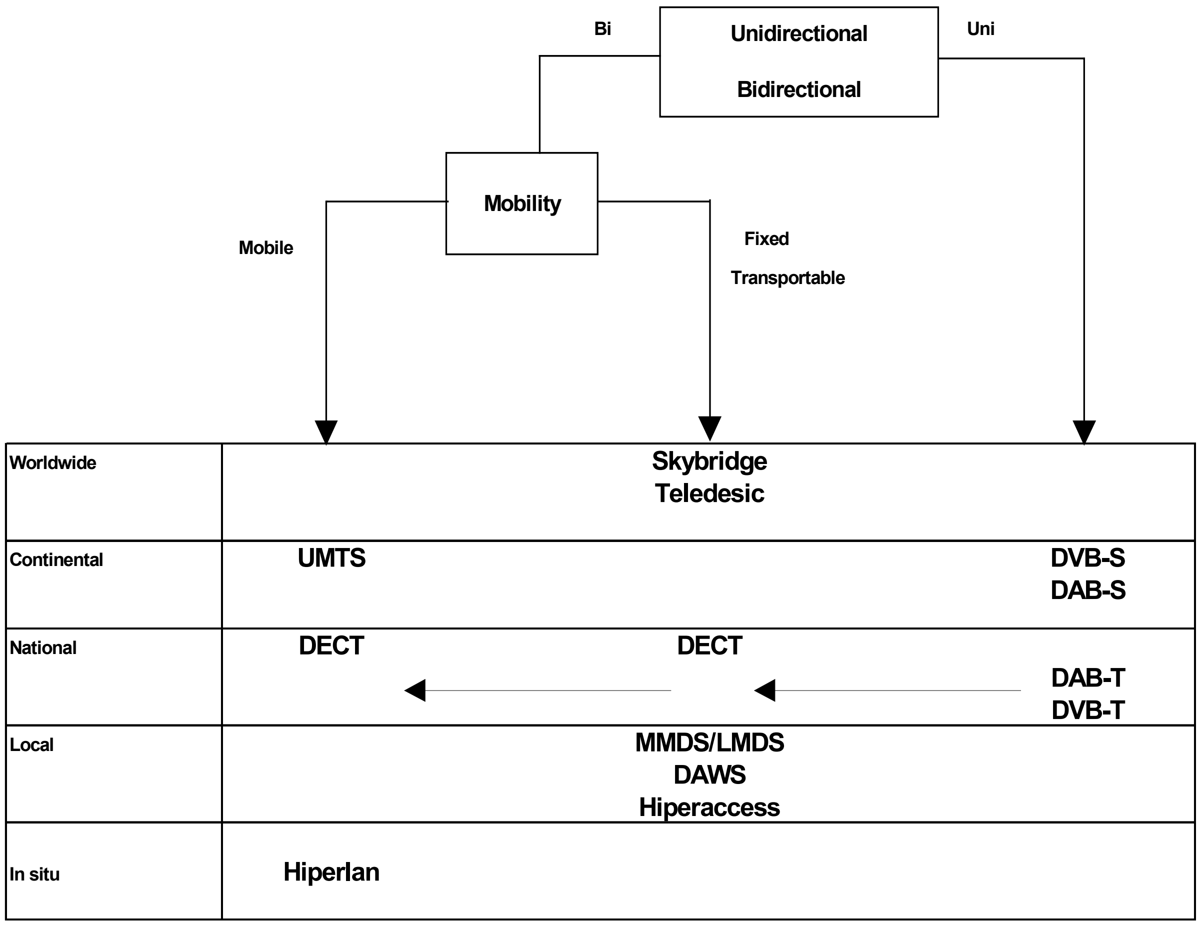
A survey of the landscape of wireless access could not be concluded without mention of another class of products that has recently emerged commercially as the wireless alternative to in-building local area networks (LANs) for data communication. Because LANs are typically operated in an indoor environment, an unlicensed frequency band (e.g. 2.4 GHz) can be used. These systems allow terminals to be easily moved from one space to another yet remain connected to the LAN. Businesses, schools and government offices are typical customers for these systems. There are available today wireless LANs that match the data speed capabilities and reliability achieved by wired LANs. They offer the key advantage of allowing office equipment (terminals, PCs, printers, etc.) to be relocated within a building much more easily.

4.2.2.6 Conclusion

Wireless access has emerged in recent years as a viable alternative to wired access in a wide variety of applications. If there is a common thread to the progress made in this field, it is that the advances made by wired access technology can now quickly be matched by wireless equivalents, which generally can be deployed more rapidly and at lower cost. Because wireless access equipment is above ground, it is easily accessible to technicians and thus easier to maintain. Because it is installed in discrete locations, its security concerns are often less than those of wireline access. In those cases where subscriber demand declines, such as businesses moving out of a building, wireless access equipment can be recovered and re-deployed, something that typically cannot be done with underground cable.

What we are seeing in wireless access today is due in part to the tremendous commercial success of mobile cellular telephony, which fostered great advances in radio technology and amassed the capital and interest in expanding the applications of wireless technology.

Figure 4.10 – Wireless Broadband Access System architecture



The first applications of wireless access have been to provide basic voice telephony. This application has proven quite successful in lowering the cost of providing telephone service and thus allowing the rapid expansion of teledensity in the less developed nations of the world. With the replacement of voice by data as the driving engine of modern telecommunications, wireless access is rapidly evolving to support ever-higher data rates using packet technology.

Thus wireless access brings the hope of access to modern telecommunications to that half of humanity that has never made a telephone call. But it also furthers the advancement and deployment of very high-speed data services in the most developed areas of our planet. In both domains, wireless access is one of the most exciting arenas in the telecommunications world today.

4.2.3 Radio technical solutions

4.2.3.1 Microwave Point-to-Multipoint (PMP) systems

Such digital systems are available today from a number of manufacturers, and are mainly used to provide telecommunications services to isolated subscribers or small communities in rural areas.

There is no Common Air Interface Standard for such systems, but only «coexistence» Standards defining the access method and the spectrum mask. They also comply with ITU- R Recommendation 756.

The physical layer is normally based on 2 Mbit/s transmission, with a total capacity equivalent to a multiple of 2 Mbit/s PCM system (30 traffic channels, each of 64 kbit/s bandwidth). Some systems are also available using 4 Mbit/s transmission and provide 60 traffic channels at 64, 32 or 16 kbit/s.

Access is by TDM (downlink) and TDMA (uplink) with assignment of the channel on demand and using a Frequency Duplex arrangement (FDD).

PMP systems operate typically between 1 and 3 GHz in normal «fixed service» allocations (see ITU-R Recommendation 701).

Compared with cellular or Cordless, PMP systems offer poor spectrum efficiency. However this comparison is slightly unfair, since PMP systems offer full 64 kbit/s transparent channels and the ability to provide the user with several channels (for example for ISDN 2B+D), whilst cellular systems provides narrow-band channels with specialized speech coding and data rates limited today to 9.6 kbit/s.

PMP systems meet well the requirements for WLL application as they have been specially designed for local loop wireline replacement mainly in rural areas. They can operate at very long range, typically up to 50 km in a single hop. They can also be extended using repeaters over hundreds of kilometers in a “tree” configuration.

Since the protocol is based on PCM, traffic is carried in 64, 32 or 16 kbit/s, and the system is therefore fully transparent to normal speech-band services, and some equipment are capable to support full ISDN 2B+D. Network termination equipment can then provide a wide range of conventional interfaces, from 2 wire POTS through 4 wire analogue to ISDN.

In conclusion, the PMP solution is a cost-effective way to extend existing wired digital networks or modernize old analogue networks, providing the customer with the same quality and grade of service as on the wired network. It also provides the user with all advanced services, from POTS to ISDN (2B+D).

Finally, the economics of existing application of PMP systems tends to show that they are ideal for use in sparsely populated areas.

An example of PMP architecture is shown in Figure 4.11.

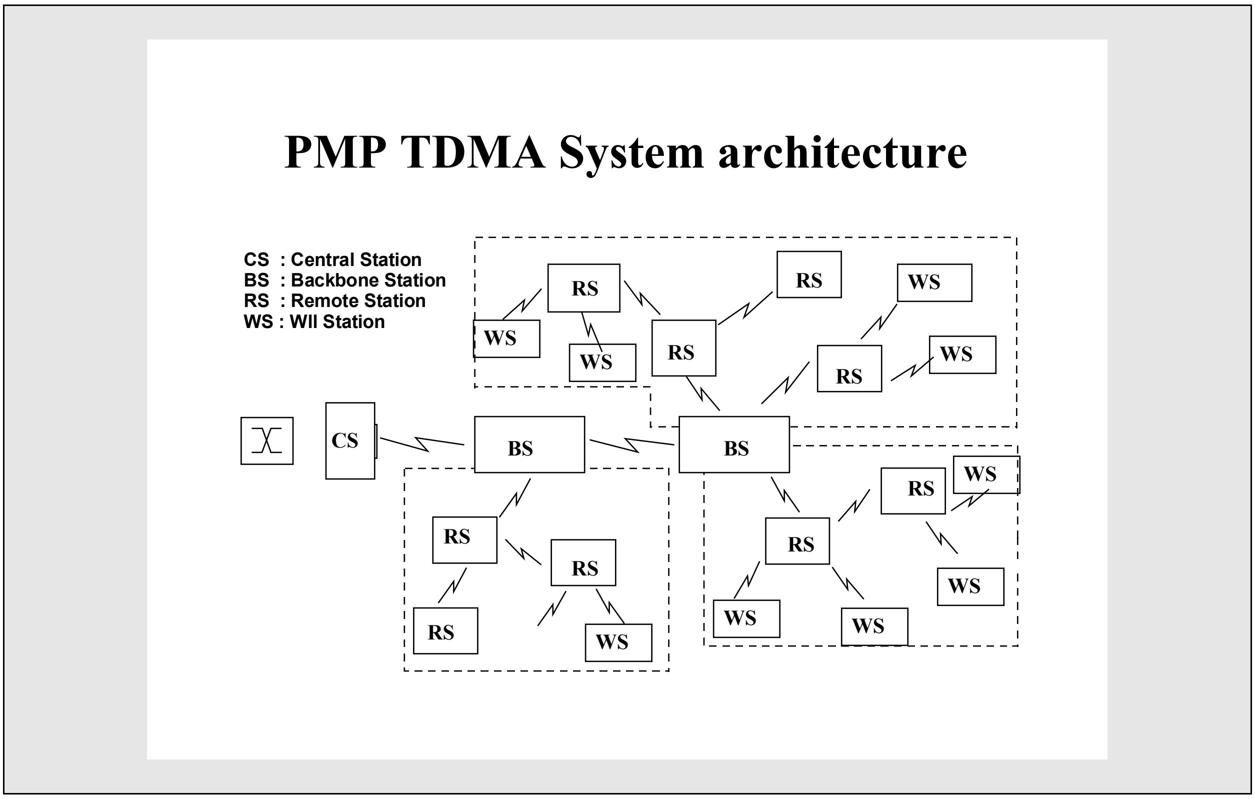
4.2.3.2 Digital cellular systems

Current cellular technologies are designed for macro-cellular applications and restricted traffic densities. Hence cellular technologies can provide feasible solutions for remote, rural and sub-urban WLL deployment. However, high traffic densities require micro-cellular or short-range radio technologies and cellular frequency re-use planning becomes complex.

The typical architecture of a mobile digital Cellular WLL system (see Figure 4.12) includes the following functions:

- the Mobile Switching Centre (MSC) which ensures the switching function and the roaming function within the MSC and between MSCs;
- the Vehicle Location Register (VLR) and Home Location Register (HLR) which the data bases used to manage the roaming and the local mobile subscribers;
- the Authentication Centre (AC) and the Equipment Identification Register (EIR);
- the Base Station System (BSS) which manages the radio resources and includes:
    - the Base Station Controller (BSC)
    - the Base Station Transceivers (BTS)
- the Mobile Station (MS) and the Terminal Equipment (TE).

Figure 4.11 – An example of PMP TDMA system architecture



The main characteristics of interest when looking at Digital Cellular systems used for WLL application, can be summarized as follows:

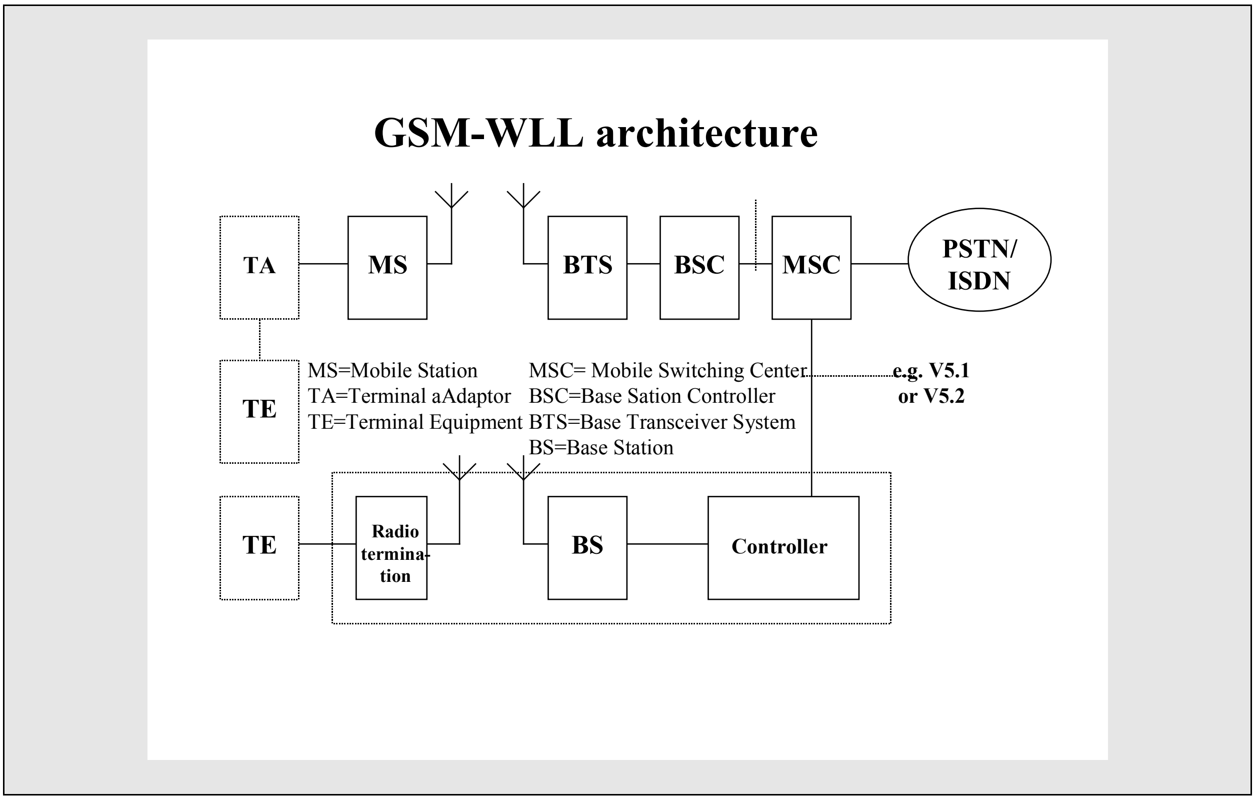
– they operate in either 800/900 MHz (IS 54, GSM) or 1800 MHz (IS 95, DCS1800) and support mobile subscribers over a cell radius of approximately up to 30 km;

– as voice transmission is the most important, and the main bulk of service, specific voice Codec are used over the air interface to provide a good radio spectrum efficiency and robustness to the radio environment (fading, interference... etc.). These Codec use up to 13 kbit/s speech encoding and, even with the recent improvements in coding algorithms, do not provide the equivalent speech quality as the wired network;

– regarding the services, they do not provide voice band data and fax services in a transparent way. GSM for example supports data services up to 9.6 kbit/s. It also supports most of the ISDN standard voice and supplementary services and support ISDN signalling, but does not provide ISDN 2B+D and has capacity restrictions in ISDN bearer services;

– the architecture of the network, as described here above includes costly Switching and Mobility management functions which are unnecessary when used only for fixed users. Of course Digital Cellular systems may be used to serve simultaneously mobile and WLL customers in the case where the provided services, i.e. speech, fax, and low speed data, are sufficient and acceptable. This may be the case when serving isolated subscribers, for emergency purposes or temporary implementation.

Figure 4.12 – GSM-WLL architecture



As with analogue cellular, derived fixed digital cellular systems connecting for example the MSC to the PSTN (A1 interface) or a special BSS including a specific controller and connected to the Local exchange via a V5.X interface can be developed. However, even though the price of such equipment may be attractive, the inherent characteristics of the cellular remain.

It must finally be noted that improvements and new developments are foreseen in the near future which could, if implemented, provide enhanced capacity and performances more in line with WLL requirements. These new features relate for example to:

- New 16 kbit/s Codecs for specific WLL application and providing better speech quality, better transparency to DTMF signals, lower delay if optimized for stationary propagation environment, etc.
- Support for higher bit rates (115 kbit/s) and basic ISDN rate using concatenating time slots.
- Terminal monitoring using the mobility management procedure.

In conclusion, the use of Digital Cellular for WLL application leads to the following strength and weakness evaluation:

- Strengths:

– wide coverage (especially when operating in 800/900 MHz) up to approximately 30 km from the BST;

– Open and existing standards which provide low costs and interoperability/multisourcing of the terminal equipment;

– secure authentication and encryption;

– set of standardized supplementary services, including ISDN;

– well known and proven technologies.

- Weaknesses:
- – speech quality does not meet the fixed network service quality standard;
- – limited data throughput with respect to fixed network and competing technologies;
- – no/poor transparency to voice band services;
- – low (even though better than PMP) spectrum efficiency compared to more specialized technologies.

4.2.3.3 New Fixed Wireless Access (FWA) Systems

Among the new proprietary Fixed Wireless Access Systems appearing on the market, Direct Sequence Code Division Multiple Access (DS CDMA) are the most promising.

DS CDMA is a spread spectrum technique in which multiple subscribers occupy the same spectrum simultaneously. Individual channels are coded by multiplication with a spreading sequence, and recover by correlation at the receiver side. Compared with a TDMA system where the allocated resource is time, or with a FDMA system where the resource is frequency, in a DS CDMA system the resource is the signal power, relative to the noise of the other subscribers.

DS CDMA operates currently in the 3 frequency bands: 1.9 GHz (US PCS), 2.4 GHz and 3.4 GHz to 3.6 GHz with range of 2.5 km in urban area up to 6 km in rural areas.

Compared to narrowband CDMA (2×1.25 MHz) for mobile application, DS CDMA (2×5MHz) is optimized for fixed application and offers significantly better bearer services in terms of Bit Rate and Bit Error Rate (BER).

So far, DS CDMA can offer data bandwidth from 16 to 144 kbit/s with a BER of 10-6 compared to 8 to 13 kbit/s with BER of ~10-3.

Moreover, DS CDMA can support continuously variable quality of service at different bit rates on a single air interface. This feature makes DS CDMA radio systems very attractive as a replacement for copper, since it provide a simple mean to allocate radio resource according to the needs of individual services being carried.

Thus, in a DS CDMA system, a reduction in the number of users accessing the system is translated into a gain in the Grade of Service (GOS) for the remaining users. If the system is fully loaded, all users will obtain their rated BER performance, when it is less loaded, all users can experience a much lower BER. This inherent characteristic can be used to provide exceptional overloading service, e.g. emergency service, without dropping in-service calls.

In terms of services, DS CDMA supports 16, 32 or 64 kbit/s speech coding, voice-band data up to 28.8 kbit/s and ISDN 2B+D.

As for Cellular systems, a strengths and weaknesses analysis gives the following results:

- Strengths:
- – flexible resource allocation, up to ISDN 2B+D;
- – service transparency: Dial tone, Fax group 3, Voice data band up to 28.8 kbit/s, ISDN 2B+D (fax group 4, video conferencing), etc.;
- – robust radio interface;
- – low delay in transmission;
- – wide coverage;
- – spectrum efficiency.

- Weaknesses:

– requires spectrum allocation increment of 2 × 5 MHz minimum;

– proprietary systems and air interfaces;

– variable GOS according to the traffic supported;

– capacity compromised by long range operation.

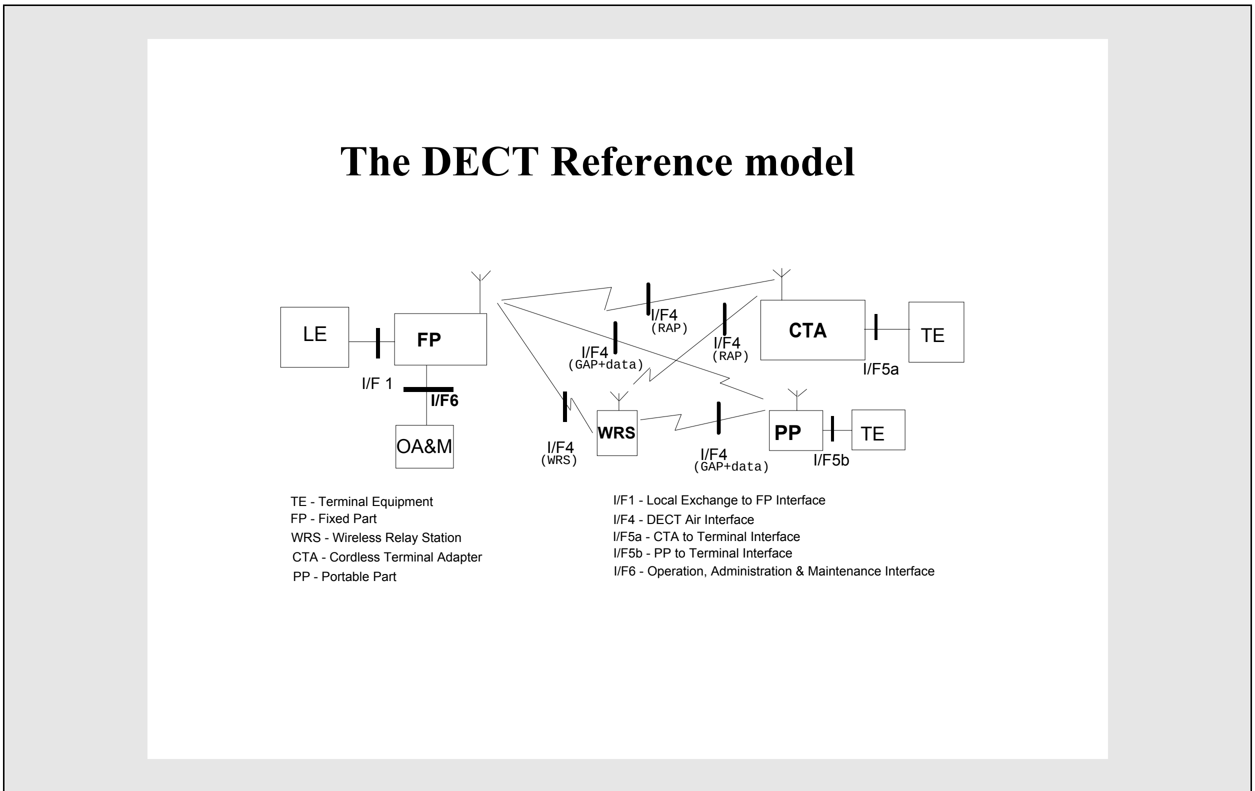
In conclusion, DS CDMA is a very potential solution for fixed wireless access both in terms of capacity, variety and quality of services and spectrum efficiency.

4.2.3.4 Cordless technologies

Current Cordless technologies have been designed to provide low complexity and high traffic capacity solutions for micro-cellular arrangement. Such systems can be successfully applied to WLL applications. Among existing Cordless, DECT is one of the most advance technologies which copes with all the WLL requirements with respect to services aspects, operational conditions, spectrum efficiency and regulatory environment, but also to its ability to interconnect with either fixed or mobile networks and make provision for future evolution towards the 3rd Global Mobile generation.

In terms of architecture, DECT is a wireless access to the local network in extent and is connected to the Local Exchange Figure 4.13. On the contrary of a cellular network, DECT does not include the switching function, which is carried out in the Local Network.

Figure 4.13 – The DECT Reference Model



With regards to operational characteristics, DECT makes use of specific technical features, which permit high Grade of Service (GOS), high performance and very efficient use of the spectrum. Among others, these features are:

– a multi-carrier TDMA and a decentralized radio resource management which is the basis of the very efficient and rapid Dynamic Channel Selection (DCS) made at the terminal level;

– the DSC which greatly improves the performances and the capacity of the system in short range cluttered environments where fixed channel planning becomes very difficult to achieve.

In such very short coverage and high traffic density spots, and thanks to DSC, DECT WLL networks will not need extensive frequency planning studies. Moreover, continuous DSC during the call, e.g. for hand-over, will ensure that the channel allocation is continually optimized to the local conditions:

– the signalling channel characteristics i.e. high speed, robustness, sensitivity and link specific, which provide DECT with a very efficient, secure and reliable signalling transmission;

– the use of repeaters to extend the fixed WLL coverage.

Regarding the applications, DECT supports the following services:

– Voice telephony is provided using a 32 kbit/s ADPCM codec fully complying with ITU-T Recommendation G.726.

Also the ADPCM speech or signalling channel can transparently carry DTMF tones.

– Voice band data and facsimile.

Currently available voice band modems are not capable of unrestricted operation on ADPCM coded channels. However facsimile (groups 2 & 3) is supported, but resulting transmission rate is likely to be 7.2 kbit/s or less.

The complete operation of all voice band modem equipment can be assured either by providing a 64 kbit/s DECT channel or by the use of appropriate terminal adapters.

– Analogue leased lines are provided as permanent connections by the PSTN and supported by DECT.

– ISDN. When standardizing DECT, ETSI has produce a DECT-ISDN profile providing a complete DECT-ISDN inter-operability. So, DECT double slot structure is used to provide user information channels of n*64 kbit/s with values of n up to 10. Two double slots may be combined with a single slot to provide a 144 kbit/s liaison suitable for ISDN 2B+D.

Like for other technologies the strength and weakness analysis applies:

- Strengths:

– Dedicated frequency bands in Europe: 1880-1900 MHz and similar or very closed in other regions;

– High capacity in hot spots;

– Transparency to voice band data up to 4.8 kbit/s;

– Capability up to ISDN 2B+D;

– Secure and authentication encryption.

- Weaknesses:

– Range limited by RF power;

– Sensitivity to delay dispersion.

4.2.3.5 Satellite technologies

Numerous technical advances in satellite communication systems in the recent past years have enabled more cost-effective use of satellites systems. These key technical advances include:

– the development of architectures based on non-geostationary orbits, using links characteristics allowing small low cost user terminals;

– reduction of size, weight, power consumption and cost of stations/user terminals (VSATs, USATs) for use with geostationary satellites and large scale D Assigned Multiple Access (DAMA) Systems.

The types of satellites communications systems that has emerged as alternative to the extension of terrestrial networks for access to the PSTN in rural areas of developing countries include:

– Conventional geostationary satellites systems in the Fixed Satellite Services (FSS) such as Intelsat and other national or regional systems used in conjunction with a large scale DAMA system, advanced VSATs and USATs and one or more high capacity gateway earth station for interconnection with the terrestrial PSTN;

– the big LEO global MSS (GMPCS) such as Globalstar;

– Global MSS (GMPCS) systems using non-geostationary Intermediate Circular Orbit (ICO);

– Global MSS (GMPCS) systems using elliptic orbits, such as Ellipso;

– Regional geostationary systems in MSS and similar systems proposed for Africa and Asia;

– Inmarsat geostationary MSS system and future evolutionary extensions;

– Wide coverage non geostationary global satellite systems such as Teledesic;

– Little LEO systems such as Orbicom and Final Analysis which are very cost effective in providing store-and-forward services such as Paging and Electronic mail in unserved areas.

For more details, see Fascicle 1, Chapter 2.4.

4.2.4 ITU Recommendations and Publications

The following ITU-R Recommendations are important for studying Wireless Access Systems:

- ITU-R F.1488 (Pink Doc. 9/1005) – Draft new Rec. F.[Doc. 9B/100] – Frequency block arrangements for fixed wireless access (FWA) systems in the range 3 400-3 800 MHz – (Questions ITU-R 215/8, 125/9)

- ITU-R F.1489 (Pink Doc. 9/1006) – Draft new Rec. F.[Doc. 9B/136] – A methodology for assessing the level of operational compatibility between fixed wireless access (FWA) and radiolocation systems when sharing the band 3.4-3.7 GHz – (Questions ITU-R 140/9, 215/8)

- ITU-R F.1490 (Pink Doc. 9/1007) – Draft new Rec. F.[Doc. 9B/135] – Generic requirements for fixed wireless access (FWA) systems – (Questions ITU-R 140/9, 215/8)

- ITU-R F.1499 (Pink Doc. 9/1016) – Draft new Rec. F.[9B/BWA] – Radio transmission systems for fixed broadband wireless access (BWA) based on cable modem standard – (Questions ITU-R 215/8, 140/9)

- ITU-R M.1450 – (Pink Doc. 8/1014) – Draft new Rec. M.[8A9B-T4/DD] – Characteristics of broadband radio local area networks (RLANS) – (Questions ITU-R 212/8, 142/9)

- ITU-R M.1454 – (Pink Doc 8/1040) – Draft new Rec. M.[8/95] – E.i.r.p. density limit and operational restrictions for RLANS1 or other wireless access transmitters in order to ensure the protection of feeder links of non-geostationary systems in the ... – (Questions ITU-R 212/8, 142/9, 284/4)
- Recommendation ITU-R F.701-2: Radio-frequency channel arrangements for analogue and digital point-to-multipoint radio systems operating in frequency bands in the range 1.350 to 2.690 GHz (1.5, 1.8, 2.0, 2.2, 2.4 and 2.6 GHz)
- Recommendation ITU-R F.754: Radio-relay systems in bands 8 and 9 for the provision of telephone trunk connections in rural areas
- Recommendation ITU-R F.755-2: Point-to-multipoint systems used in the fixed service
- Recommendation ITU-R F.756: TDMA point-to-multipoint systems used as radio concentrators
- Recommendation ITU-R F.757-2: Basic system requirements and performance objectives for fixed wireless access using mobile-derived technologies offering basic telephony services
- Recommendation ITU-R M.819-2: International Mobile Telecommunications (IMT-2000) for developing countries
- Recommendation ITU-R F.1098-1: Radio-frequency channel arrangements for radio-relay systems in the 1 900-2 300 MHz band
- Recommendation ITU-R F.1103: Radio-relay systems operating in bands 8 and 9 for the provision of subscriber telephone connections in rural areas
- Recommendation ITU-R F.1104: Requirements for point-to-multipoint radio systems used in the local grade portion of an ISDN connection
- Recommendation ITU-R F.1105: Transportable fixed radiocommunications equipment for relief operations
- Recommendation ITU-R F.1244: Radio local area networks (RLANs)
- Recommendation ITU-R F.1332-1: Radio-frequency signals transport through optical fibres
- Recommendation ITU-R F.1399: Vocabulary of terms for wireless access
- Recommendation ITU-R F.1400: Performance and availability requirements and objectives for fixed wireless access (FWA) to PSTN
- Recommendation ITU-R F.1401: Frequency bands for FWA systems and the identification methodology
- Recommendation ITU-R F.1402: Frequency sharing between a land-mobile wireless access (MWA) system and a fixed wireless access (FWA) system using the same equipment type as the MWA system.

The following Handbooks issued by ITU-R are useful in planning, engineering and developing of wireless access networks:

1 *Wireless Access Local Loop*, Volume 1, Handbook on Land Mobile (including Wireless Access), ITU, 1996

2 *Principles and Approaches on Evolution to IMT-2000/FPLMTS*, Volume 2, Handbook on Land Mobile (including Wireless Access), ITU, 1997.

3 "*Introduction of New Technologies in Local Networks*", ITU Guidelines, Geneva 1993.

4.2.5. List of abbreviations

AN	Access Network
ADPCM	Adaptive Differential Pulse Code Modulation
ADSL	Asymmetric Digital Subscriber Line
ATM	Asynchronous Transfer Mode
AU	Access Unit
BRA	Basic Rate Access
BRAN	Broadband Radio Access Network
CAM	Carrierless Amplitude Modulation
CATV	Common Antenna Television
CDMA	Code Division Multiple Access
CPE	Customer Premises Equipment
CU	Control Unit
DAB	Digital Audio Broadcasting
DAMA	Demand Assigned Multiple Access
DAWS	Digital Advance Wireless Service
DCS	Dynamic Channel Selection
DMT	Discrete Multi-Tone
DS CDMA	Direct Sequence Code Division multiple Access
DSL	Digital Subscriber Line
DTMF	Dual Tone Multifrequency
DU	Distribution Unit
DVB	Digital Video Broadcast
FDD	Frequency Division Duplex
FITL	Fiber in The Loop
FTTC	Fiber to The Curb
FTTH	Fiber to The Home
FWA	Fixed Wireless Access
GII	Global Information Infrastructure
GOS	Grade of Service
HDSL	High speed Digital Subscriber Line
HFC	Hybrid Fiber Coax
IP	Internet Protocol
ISDN	Integrated Service Digital Network
ISP	Internet Service Provider
IU	Interface Unit
LEO	Low Earth Orbit
LMDS	Local Multipoint Distribution Service
MMDS	Multipoint Microwave Distribution System
MPEG	Motion Picture Experts Group
MSS	Mobile Satellite System/Services
N-ISDN	Narrowband ISDN
PCI	Peripheral Core Interface
PCP	Peripheral Control Platform
PDH	Plesiochronuous Digital Hierarchy
PMP	Microwave Point to Multipoint System
PMP	Point to Multipoint

PON	Passive Optical Network
POTS	Plane Old Telephone System
PRA	Primary Rate Access
PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RITL	Radio in The Local Loop
SDH	Synchronous Digital Hierarchy
SMF	Service Management Function
SNI	Service Node Interface
SPF	Service Port Function
SU	Switching Unit
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TF	Transport Function
TMN	Telecommunication Management Network
UNI	User Network Interface
UPF	User Port Function
VDSL	Very high speed Digital Subscriber Line/Loop
VLR	Vehicle Location Register
VoD	Video on Demand
VSAT	Very Small Aperture Terminal
WLL	Wireless Local Loop

References:

1) A. Scott Berman, *"Wireless Access: The Landscape Today, The Horizon Tomorrow"* Bell Laboratories, TRT Lucent Technologies.

2) Guy Cayla, *"New wireless technologies for rural and remote areas"* Lucent Technologies, Paris.

3) World Telecommunications Development Reports – ITU 1996.

4) Telecommunications Indicators for the Least Developed countries – ITU 1995.

5) C. Garnier – Telecom 95 – Rural Telecommunications: the quest for the Missing Link.

6) G. Cayla – Telecom 95 – Wireless Local Loop: At last the last mile.

7) European Standards Institute ETSI – 1992 – ETS 300175 DECT.

8) European Standards Institute ETSI – 1994 – ETR 139 Radio in the Local Loop.

9) European Standards Institute ETSI – 1993 – ETR 308 DECT: services, facilities and configurations for DECT in the local loop.

10) European Standards Institute ETSI – 1996 – ETS 300765-1 & 2 DECT Radio in the local loop (RLL) Access Profile (RAP) Parts 1 & 2.

11) Ovum 1994 – "The Local Loop market, technical and regulatory strategies".

ANNEX 4A

European Wireless Broadband Access Systems

1 BRAN (Broadband Radio Access Network)/Hiperaccess

ETSI Project BRAN is preparing the Hiperaccess standard and a report defining the architecture and objectives has been already approved. Hiperaccess is based on the following objectives:

– Services: telephony, data, multimedia, videoconfrence;

– Spectrum: above 10 GHz;

– Offer Broadband (25 Mbit/s, approx.) wireless access, to small- and medium-size companies and to individuals; ATM or IP transmission protocols are considered, competing with xDSL access and modems associated with cable distribution systems;

– Make signal transmission on Hiperaccess systems transparent, so that they can adapt to many applications;

– Use standard radio and network/user interfaces, ensuring wide distribution by various manufacturers;

– Benefit from the use of standard parameters (that allow a high integration level) and from the size of the targeted market to obtain a low unit cost.

The foreseen Hiperaccess applications concern high bit rate data transmission, mainly for access to the Internet, videoconferencing and video on demand, in addition to voice and ISDN access. In view of the above-mentioned technical requirements, the Hiperaccess terminals would not be individually assigned but would be covered by a general license. The protocol will allow real time sharing of the overall system capacity among the various users. The operator, however, would be assigned a frequency band through a license, and the frequency use would thus be shared. The identification of the frequency bands in which Hiperaccess can be implemented without co-ordination is under study; the bands that are subject of the project of the European Radio Committee (ERC) on the fixed microwave access are being examined first. The objective is to define a harmonized band in Europe. The main steps in the work program of the BRAN project team are the approval of the first Hiperaccess draft standards (Physical Layer Technical Specification: September 2000, Data Link Control TS: December 2000) and all the test specifications should be available by 2002. The main characteristics to be defined concern the radio interface, the protocol for using the ATM and/or IP and the user interface.

2 DAB

DAB (Digital Audio Broadcasting) is a technology resulting from the work of a EUREKA project (EU147), the consortium of which gathers about fifty members. It allows the transmission of high quality radio programs, typically of Compact Disc quality, along with service data (PAD – Program Associated Data) to fixed, transportable or mobile receivers.

DAB is an ETSI standard (ETS 300 401). Two standards are identified in ITU: DAB A for EUROPE and DAB B for the USA.

The frequency bands used for DAB transmission are either the VHF bands (170-240 MHz), or the L band (1.5 GHz) shared between terrestrial and satellite transmissions. The range of a DAB transmitter is equivalent to that of a TV transmitter, i.e.: 20 km (L band) and 80 km (VHF).

The downlink rate is about 1.5 Mbit/s with OFDM modulation. The multiplex contains 6 high quality radio programs with program associated data. The compression method used is MPEG2 audio layer 2.

Tests carried out in vehicles equipped with a DAB receiver associated with a digital TV decoder, demonstrated the feasibility of TV program transmission to moving vehicles, with limited quality (900 Kbit/s allocated to video). In the same way, the use of the Internet was demonstrated by associating a GSM phone for the uplink with a DAB multiplex containing the encapsulated IP stream for the high data rate downlink (1.5 Mbit/s).

The DAB services are implemented in various countries including Germany, Belgium, Great Britain, Sweden, etc. In France, five cities were equipped for the World Cup. Implementation is going on, with a strategy aiming to cover the most populated areas first.

Receivers of fixed type as well as car radio type exist, but the current price (around € 1000) limits implementation. In 1999, a second receiver generation has been introduced. The price is that of a top-of-range AM/FM receiver, i.e. between € 270 and € 450. The antenna is a whip antenna.

3 DAWS

Taking into account the market demand to fit the wireless world capacities and data rates to that of the fixed networks, ETSI encourages the emergence of new generations of infrastructure evolving from the existing standard progress.

From January 1997, ACTE 36 requested a report on the DAWS (Digital Advanced Wireless Services) concept. The EPT 4 report that had been introduced at ACTE 37 in March 1997, resulted in a request for normalization by ETSI. This is why a significant number of ETSI members decided to contemplate an evolution of the TETRA PDO (Packet Data Optimized) standard to offer full mobility and roaming, with wireless ATM rates up to 155 Mbit/s. This evolution was named DAWS and was studied by the ATM Forum.

About ten contributions on the DAWS feasibility study are known to-date and a full size demonstration was made during the 7th CEPT Conference, in Copenhagen from May 5 to 7, 1998.

Mobility is now one of the functions expected from the future portable “Wireless WEB Surfers” which will offer direct image transmission, as well as automatic locating of vehicles or persons.

DAWS thus comes within the scope of the high data rate mobile service segment and will offer services of the high data rate wireless local loop: telephony, data, multimedia, video, broadcasting, mainly intended for professional users.

In terms of market, considering that 5% of the worldwide telephony will integrate the Internet at the end of the millennium, the potential of DAWS is already estimated to 5 million users.

The LLC (Logical Link Controller) and MAC (Media Access Controller) aspects are under study, following a first technical report issued in January 98. The current schedule makes it possible to expect that a harmonized standard will be published by the end of year 2000.

DAWS provides various wireless access capabilities to the Internet. DAWS base stations can be directly connected by operators to the Internet to offer their clients global high-speed access to the Internet. System administrators can implement access points on extended corporate sites to offer Intranet access to the personnel.

Also, an access point can be installed home to offer residential high speed wireless access to the Internet. Last, police and army forces can use DAWS terminals to access appropriate IP networks.

DAWS thus offers full “seamless” mobility in the areas covered by a DAWS base station or having an access point.

To date, the 5 GHz band, and especially the 5.150 GHz-5.700 GHz band is under study to determine any possible sharing between its current users and DAWS.

The definition of harmonized frequencies by CEPT conditions the implementation of DAWS, including the preparation by the European Union Commission of Common Technical Regulations.

DAWS, by offering full mobility and multimedia access with rates up to 155 Mbit/s, integrates the ATM interface with fixed networks.

4 DECT

DECT (Digital Enhanced Cordless Telecommunications), as a European standard, has experienced a fast development since 1994. DECT standard allowed the use of wireless technology in residential telephony applications, in private sector, and in public environment, in both fixed wireless access applications as well as limited mobility applications (CTM for Cordless Terminal Mobility).

ETSI established for DECT a series of profiles for the various applications covering voice (32 kbit/s), fax (28.8 kbit/s), and data services both for voice band and for digital transmission (64 kbit/s). New profiles also provide packet data services with asymmetrical bit rates (up to 552 kbit/s maximum for downlink and 24 kbit/s for uplink). Standards under development now focus on the study of multimedia profiles, and the definition of the 2 Mbit/s radio interface. Adding such new profiles enables to build multiservice fixed wireless access systems enabling voice communication and access to Internet services.

The use of DECT in the public environment mostly focused on the residential and SOHO sectors (more than 1.5 million lines in the world), whereas the use for large companies was reduced to wireless exchanges with mobility features. The radius of the fixed wireless access system cells is limited to 16 km (under line of sight conditions). The maximum traffic that can be delivered by a base station is about 80 Erlang. For applications with mobility feature, the coverage radius is limited to 500 m. For year 1997, DECT represented 31% of orders for fixed wireless access worldwide.

The fixed wireless access networks based on DECT can have local coverage (single-cell), regional coverage (multiple-cell), or national (multi-system) coverage and are designed to build access networks.

A European Directive (1991) approved the usage of the 1 880-1 900 MHz band for DECT in Europe. In the rest of the world, the allocated bands are, depending on the countries: 1880-1900, 1900-1920 and 1910-1930 MHz. For the fixed wireless access applications, there are also equipment in the band 3.4-3.6 GHz. The DECT technology allows shared use of the spectrum by several applications and different operators. The DECT Forum recommends a maximum of 2 fixed wireless access public operators for 20 MHz.

The fixed access terminals are available in single- or multiple-line versions.

5 DVB

DVB (Digital Video Broadcast) is a European consortium created in 1993, now grouping over 230 members. This consortium is intended to prepare the standardization of digital television:

- DVB-S: Satellite transmission standard (ETS 300 421)
- DVB-T: Terrestrial transmission standard (Microwave) (ETS 300 744)
- DVB-C: Cable transmission standard (ETS 300 429).

The standards are defined by ETSI.

DVB-S and C are used everywhere. DVB-T is competing with the US (ATSC) and Japanese (ISDB) standards. Australia selected DVB-T, the decision is pending for Argentina and Southeast Asia.

The transmission channel band is the same as for analogue television (6, 7, 8 MHz) and allows transmitting 24 to 30 Mbit/s (from 4 to 10 programs). The “taboo” channels can be used.

DVB-T allows the implementation of services (TV, associated data such as the "TV Guide", and data broadcasting) to fixed, transportable or mobile terminals (e. g. vehicle equipment). The target price for a home receiver is typically that of a current top-of-range receiver. The television set could integrate either Terrestrial and Satellite reception, or Terrestrial and Cable reception. The antennas used are traditional Yagi or whip antennas. The radio technology used is the COFDM, including convolutional channel coding.

Great Britain has been broadcasting since November 15, 1998. Sweden, Italy and Spain will come next. As for France, the decisions have not been reached yet. In Germany, a test involving about forty transmitters will soon validate reception by mobiles.

Studies are now being conducted to implement a microwave return channel. Many services related to this return channel will be deployed, including video-shopping, Internet, pay TV. Internet services are already offered, associating a telephony uplink and downlink of several Mbit/s.

A transmitter typically covers an area of about fifty kilometers. The implementation of SFN (Single Frequency Network) networks allows continuous reception within a region or along a motorway.

The frequency bands used are the UHF and VHF bands (470 to 890 MHz).

DVB-S makes use of the capabilities of satellite transponders and allows data rates from 2 to 72 Mbit/s in the Ku and C bands. The modulation mode used is the QPSK, associated with convolutional channel coding. Many satellite program ranges are operated. The coverage is related to the characteristics of geo stationary satellites. In France, the major digital bundles: TPS, CANAL Satellite and AB SAT are using the EUTELSAT (HOT BIRD) and SES (ASTRA) satellite bundles, respectively.

The receivers are fixed and currently require the use of a specific decoder. In the medium term, the digital decoder will be integrated in the TV set, whose price should be equivalent to a top-of-range set. The antennas used are dish antennas with 50 to 60 centimeters minimum diameter.

In the medium term, the receivers could be mixed:

– Terrestrial + Satellite
– Terrestrial + Cable.

6 Hiperlan

In December 1996, ETSI published the ETS 300 652, called Hiperlan (HIgh PERformance Local Area Network) type 1, for use in the 5.2 GHz band allocated without specific license to wireless local area networks in Europe and the United States. Hiperlan thus can use more than 20 Mbit/s in each of the 5 adjacent channels of this band (7 in the USA), which allows to make an actual multimedia local area network, with terminals derived from the standardization and therefore interoperable.

The high data rate (Ethernet compatible, 10 Mbit/s) and the standardization of Hiperlan by ETSI are the factors which make Hiperlan successful when addressing the professional and residential markets. Today, more than 90% of corporate local area networks operate under Ethernet 10 and 100 Mbit/s. Hiperlan is the natural radio extension of these infrastructures.

A significant growth of the wireless LANs is expected through Hiperlan, especially in the professional and residential sectors, by offering data rates compatible with the current multimedia applications.

Residential distribution, as an extension to the wide band access networks, requires a flexible high performance solution, well accepted by the final user. The wireless telephony offers, as well as the wireless alarm systems, contributed to the success of radio solutions in residential environments. This trend should be confirmed with the introduction of new interactive and multimedia services and the explosion of computer technology at home and in the small and medium-size companies.

An Hiperlan product designed following ETSI standard ETS 300 652, is the only which can offer, in the short term and at low cost:

- A real local area network;
- Compatibility with the 10 Mbit/s Ethernet network;
- Useful user data rates higher than 10 Mbit/s;
- Coverage from 50 to 100 m.

The Hiperlan type 1 standard has been designed to ensure system interoperability between different manufacturers. Hiperlan products allow connecting terminals one to another, or to a wired infrastructure network, without any bit rate compromise and with maximum flexibility and transparency. They accept mobility up to 10 km/h. The distance between two systems can be up to 100 m and an "automatic repeater" mechanism extends the coverage up to the hidden nodes or nodes remote from the network.

Furthermore, thanks to its intrinsic high data rate characteristics (frame transmission priority handling mechanism with respect to service classes), Hiperlan type 1 is well adapted to ATM and/or Internet (IPv6) flow transmission within the radio cells of a local area network and allows, already today, to anticipate the predicted convergence of Information Technology and Telecommunications.

ETSI created in 1997, in replacement of RES10, the BRAN group in order to conduct in parallel the studies for the emergence of the Hiperlan type 2 standard (wireless ATM local network), the Hiperaccess standard (high data rate wireless access) and the Hiperlan type 4 standard (very high data rate, point-to-point, also referred to as Hiperlink). It is commonly believed that these standards will not be published before 2000-2001.

Hiperlan type 1 therefore positions in the short term on an existing mass market. It is the origin of the first technological developments in the 5 GHz band, which can be used by the other Hiperlan standards and the harmonizing initiatives of the IEEE 802.11 in the same band.

7 MMDS/LMDS

MMDS (Multipoint Microwave Distribution System) and LMDS (Local Multipoint Distribution System) are wireless wideband systems, respectively operating in the 2.5-2.686 GHz and 26-28 GHz or 40.5-42.5 GHz frequency ranges.

Traditionally, MMDS used to be unidirectional, but it is progressing toward bi-directional systems and there is an LMDS variant, called MVDS (Multipoint Video Distribution System), which is unidirectional. By definition, the downlink is a broadcasting type channel (point-to-multipoint) and the uplink is a point-to-point link.

The transported services are multimedia services (voice, data, Internet, video services), with the capabilities offered by the interactivity feature of the return channel. The standard used is the DVB standard (Transport Stream). Tests are being conducted to use OFDM modulation, in a European project named CABSINET.

MMDS has a coverage of about 50 km with a transmission capacity of about 450 Mbit/s/sector (120 programs).

LMDS has a coverage of about 5 km with a transmission capacity of about 2.7 Gbit/s/cell (500 programs).

The data flow is divided into 6, 7 or 8 MHz channels, each enabling data rates up to 45 Mbit/s.

One benefit of the MMDS/LMDS systems is that they can substitute for or complete the wired network of a city, thus making unnecessary to dig trenches for laying cables. This technology can be considered as a virtual cabling offering the same services.

In some countries, the LMDS/MMDS technology is attractive due to the short coverage and to the possibility to offer different services or contents per sector or cell.

The receivers equipped with a specific decoder are fixed, with small size outdoor antennas (15 cm diameter).

The transmitter installation costs are low and the price of a decoder is equivalent to that of a DVB-T receiver, i.e., in the medium term, about € 270.

8 SkyBridge

The SkyBridge system allows offering real-time access to interactive services such as:

- Fast access to the Internet and other on-line services;
- Teleworking and access to remote servers, Intranet networks and LANs;
- Videoconferencing and videophone;
- Telemedicine;
- Entertainment services: video on demand, electronic games, etc.

SkyBridge can also provide:

- A point-to-point link infrastructure.
- Infrastructure links for:
  - telephony networks;
  - wireless access interconnections;
  - mobile communication station interconnections.

The SkyBridge system can also be used to offer enhanced narrowband services (telephony – data transmission).

9 Teledesic

The Teledesic Network supports bandwidth-on-demand, allowing a user to request and release capacity as needed. This enables users to pay only for the capacity they actually use, and for the network to support a much higher number of users.

Service providers will set end-user tariffs, but Teledesic expects them to be comparable to those of future urban wireless services for broadband access.

With an availability of 99.9% or higher enabled by Teledesic 40 degree elevation angle, and a design to support millions of simultaneous users, Teledesic will provide a cost of service by channel comparable to existing urban services.

The Teledesic Network will seamlessly extend the existing terrestrial, based-based infrastructure to provide advanced information services anywhere on earth. Customers will range from the information workers unwilling to be confined in increasingly congested cities, to countries connecting voice lines from remote cellular sites, to multinational corporations connecting branch offices throughout the world into their existing global enterprise networks. Whenever and wherever institutions and individuals want access to the like-like telecommunications services currently available only in the most highly developed urban areas, the Teledesic Network can provide seamless connectivity.

10 UMTS/IMT-2000

The 2nd generation of mobile telecommunications opened the way to the age of mobility. The world discovered the benefits of "handheld" phones, both for professional and private use.

Some figures illustrate this success:

– 260 million mobile subscribers worldwide, including more than 100 millions for GSM;

– continuously increasing penetration rates,

However, the 2nd generation systems have two drawbacks:

– they cannot be used throughout the world;

– their capacities and rates are limited.

UMTS (Universal Mobile Telecommunications System) is a European candidate to the IMT-2000 family (International Mobile Telecommunications for year 2000). It is being standardized by ETSI; the system radio interface, called UTRA, was approved by ETSI at the beginning of 1998: it will combine two duplex modes: time division and frequency division. All the members of the IMT-2000 will be interoperable; the data rate on UMTS will reach 2 Mbit/s.

UMTS/IMT-2000 will thus meet the demand of the market which, after discovering mobility, now wishes to combine mobility with data transmission. For example:

– database access / use /downloading;

– access to Internet type data networks;

– advanced electronic mail;

– transmission of animated images,

With the high data rate and mobility it provides, UMTS brings a solution to the wireless access problem, which has the advantage of suppressing the "load break" which today exists when switching over from the mobile cellular phone to the fixed, even cordless, phone: there will be a single terminal.

The first UMTS licenses have been issued in 1999 in Finland, for commercial start in 2001. A total of 60 authorizations is expected to be delivered from now to 2003.

It is generally admitted that the deployment of the UMTS will take place under different conditions than the GSM: the GSM replaced limited 1st generation networks which had many drawbacks (random propagation, large terminals, etc.) and the success of GSM was such that the operators had to invest heavily to build networks to meet the demand.

UMTS will take its place more gradually, starting with sites where the demand is high, to make up, as is commonly called, "UMTS islets in a GSM ocean". These islets will then extend to cover all the territories. The terminals will allow roaming between the two systems as long as required.

UMTS networks are complete networks (access, switching, mobility management) of non-limited coverage (completed, as required, by satellite coverage). The cell sizes can vary from a few tens of meters to a few kilometers, both outside and inside buildings.

ITU identified for IMT-2000 the following frequency band, called "core" band:

– 1920-1980 MHz coupled with 2110-2170 MHz ($2 \times$ 60 MHz), (terrestrial);

– 1885-1920 MHz and 2010-2025 MHz (50 MHz), (terrestrial);

– 1980-2010 MHz coupled with 2170-2200 MHz ($2 \times$ 30 MHz), (satellite).

For the terrestrial segment, the trend is to allocate to each operator $2 \times$ 15 MHz in the paired bands, plus 5 MHz in the non-paired bands for the initial deployment phase. The allocation of bands "without license" is being discussed.

Since the market surveys have shown that these quantities would become insufficient by 2005, extension bands are searched for.

Terminals, of portable type, will be on demand multimode to allow roaming between the UMTS and the 2nd generation systems, or multiband to cover the various frequency bands used by mobile systems.

CHAPTER 5

5 Network and service management

5.1 Demands for new network management approach

Operation, administration and maintenance (OA&M) are classical methods for control and supervision of telecom networks. The rapid network developments in recent years with the large number of technologies planned or in use, multi-vendor environments and fast introduction of new services require improvement of OA&M towards telecommunications management which covers more advanced processes. These include fault location, configuration, performance, security, accounting and planning and management including network and service provisioning. The main objective of telecommunication management is to make the best utilisation of the available telecommunication resources. To ensure inter-operability among different management systems and to meet the demand for extensive management functions the ITU has developed a new management concept called Telecommunications Management Networks, TMN.

TMN is based on the Open System Interconnection (OSI) management concept. It uses a standard language to communicate, caters for multi-vendor environments and meets traditional operation and maintenance needs such as provisioning, testing, data collection and analysis, fault locating, network and service restoration and bandwidth capacity management. Benefits are anticipated in reducing operational costs, enhancing flexibility of operation, administration and maintenance and providing services in a timely and competitive manner.

5.2 TMN standards and references

The standardization of TMN principles started 1986 based on the pioneering role of the ITU and has resulted in a range of ITU-T Recommendations describing TMN in general as well as Recommendations on specific equipment, network and service management topics. TMN standardization work has not yet finished and continues at present in numerous standardization bodies. ITU Recommendation M.3000 as tutorial gives an overview of TMN Recommendations (see Figure 5.1).

Network management systems are also under study in other standardization organizations and forums such as:

– International Standardization Organization (ISO);

– TeleManagement Forum (TM Forum);

– ATM Forum (ATMF);

– Object Management Group (OMG).

Figure 5.1 illustrates the major standardization organizations impacting TMN.

The ITU document “Improvement of maintenance, guidelines for new approach using TMN” gives more details on the TMN architecture, implementations and can be used for developing specific strategies of network management.

Figure 5.1 – Example of relation between TMN-related Recommendations

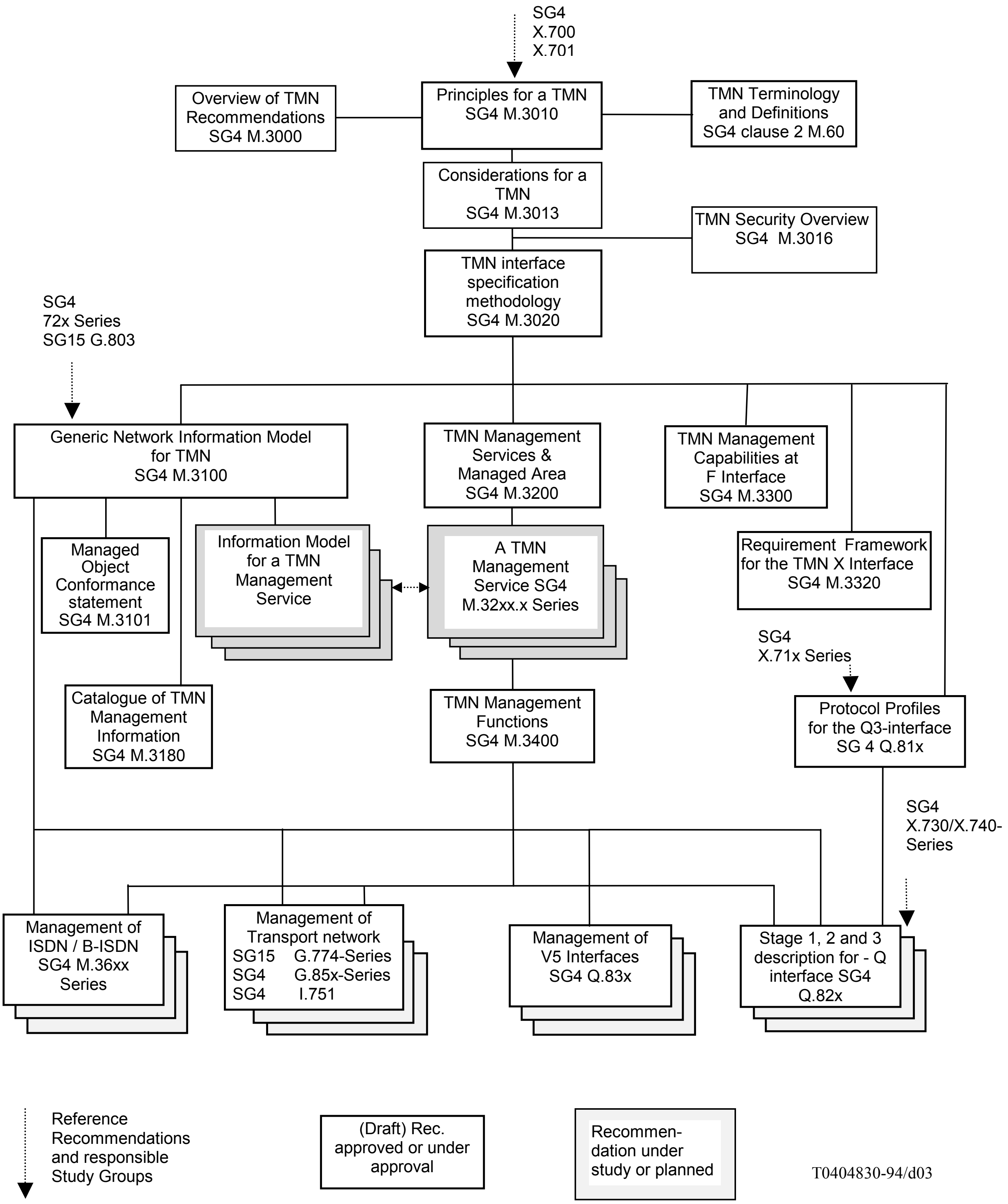
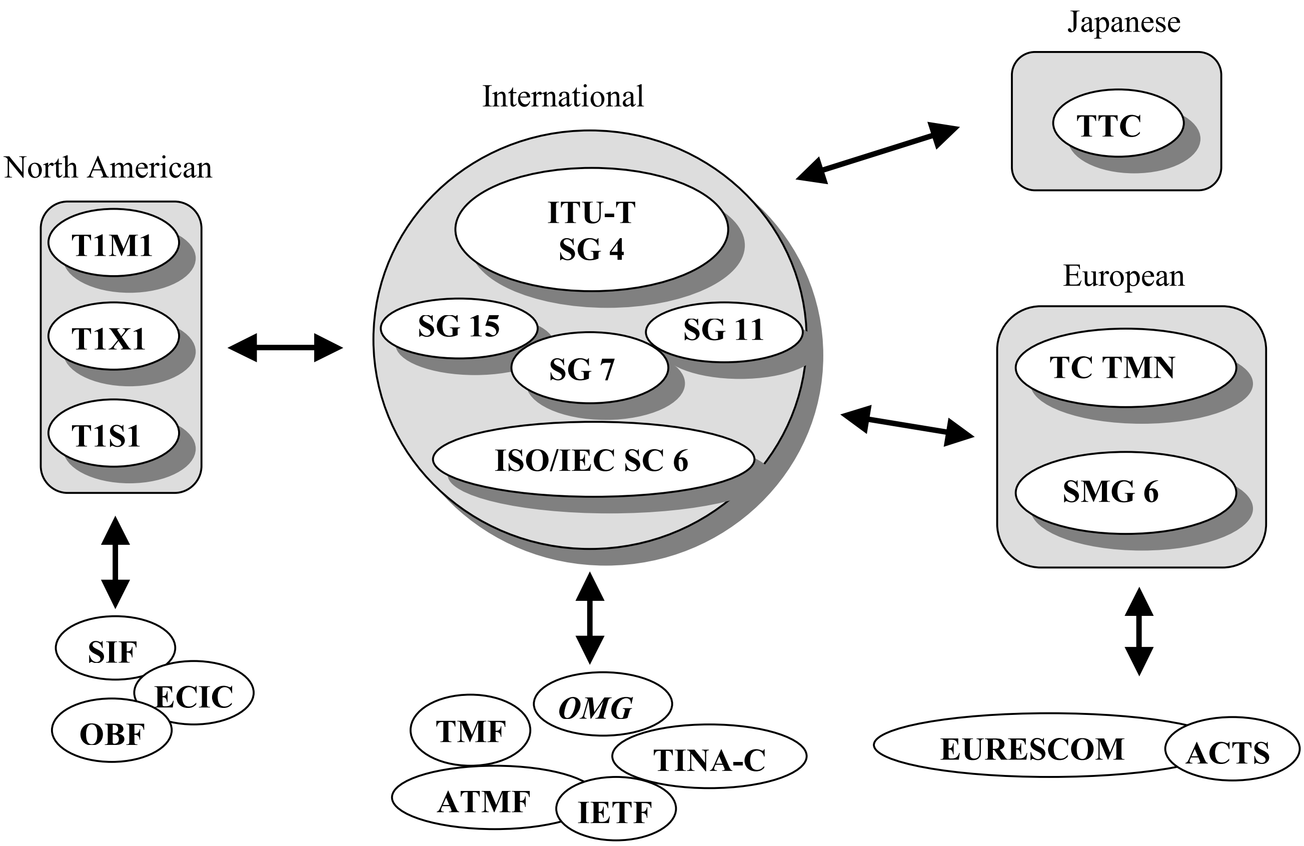


Figure 5.2 – Major Standards Organizations Impacting TMN



Industry Forums and Consortia

The scope of the work of major standardization organization is explained in more details in the section 5.5 of this Chapter.

5.3 TMN principles

TMN is a new concept, developed by management and computer specialists during international standardization activities in several standardization organizations, with the ITU-T having the lead role. New tools had to be applied leading to models which can be difficult to understand for readers not familiar with abstract problems. To make this chapter understandable for all categories of managers and engineers a minimum of TMN basic theory has been included.

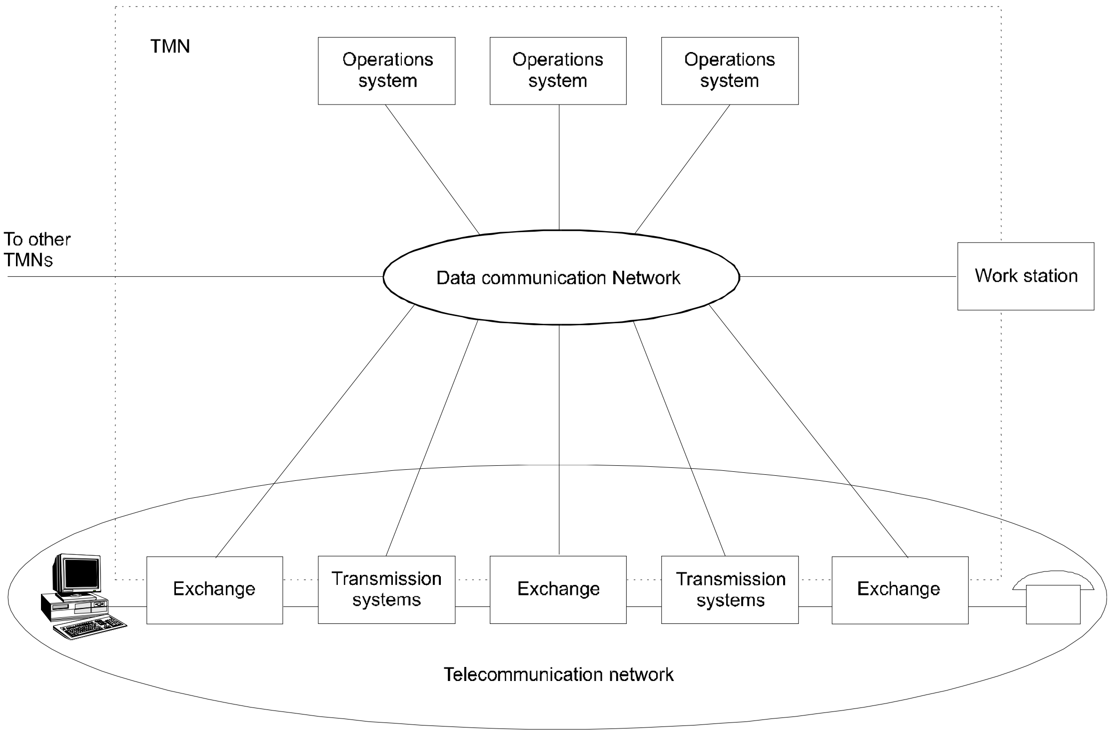
The TMN is a very broad concept, as illustrated in Table 5.1 as an example.

Table 5.1 – Example of items included in the TMN approach

TMN hardware:	**Computers**
	Terminals
	Communication Systems
	Management Interfaces
	Network Equipment
TMN software:	**Management Applications**
	Management Information Bases
	Message transfer
Application fields:	**Public and Private Networks**
	Telecommunications Services
	Digital and Analogue Transmission Systems
	Digital and Analogue Exchanges
Functional areas:	**Performance Management**
	Fault Management
	Configuration Management
	Security Management
	Accounting Management

TMN is conceptually a separate network that interfaces a telecommunication network at various points for measurement, monitoring and control as indicated in Figure 5.3. In principle the management functions are separated from the telecommunication functions. The borderline of TMN separates the parts of the telecommunications equipment that is involved in communication from those parts that are required for management.

Figure 5.3 – General Relationship of a TMN to a Telecommunication Network



Source: ITU-T Rec. M.3010

TMN is intended to manage all kinds of telecommunication equipment (e.g. transmission and switching equipment), telecommunication support equipment (power supply, air conditioning and security equipment) and itself. TMN as a tool supports network operators and intends to offer easy to understand human/machine interface routines. The broad concept of TMN can be described using different architecture aspects (see Table 5.2).

Table 5.2 – Description of TMN Aspects

• **The functional architecture**	**describes the functions involved in the information exchange between operator and managed equipment.**
• **The physical architecture**	**describes how the functions can be distributed to the different hardware entities of the managing TMN equipment.**
• **The information architecture**	**treats the relationship between the manageable resources in the managed equipment and the abstract representation of the resources in data bases. The information architecture describes the handling of the data base information.**
• **The logical layered architecture**	**permits to divide complex management activities into less complex activities, which can be allocated to various management layers.**
• **Management functionalities**	**are a collection of the various management tasks of operators**
• **Data Communications**	**are responsible for the information transfer between the various physical TMN entities (messages across management interfaces).**

The aim of the TMN architecture is to enable operators to minimize reaction time to network events, optimizeoptimize the flow of management information, allow for geographical distribution of control and to improve service assistance and interactions with customers.

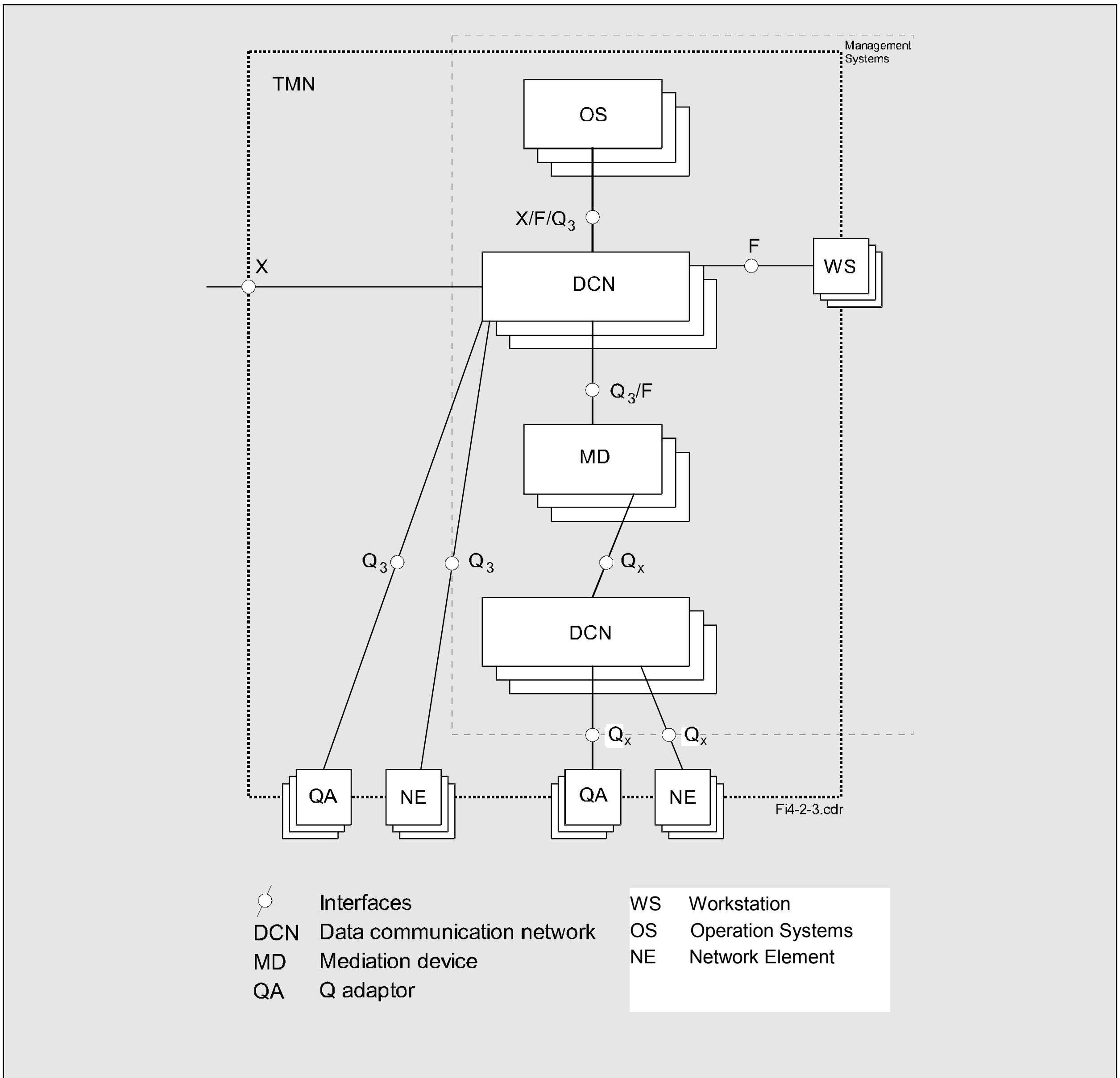
- ***TMN Functional Architecture***

The Functional Architecture provides a mechanism to describe and understand the management processes without the need to identify the physical systems. It describes the distribution of functionalities within the TMN to allow the creation of functional building blocks from which a TMN of any complexity can be implemented. The architecture defines Function Blocks containing Functional Components, which in detail characterize the particular function of the blocks.

- ***TMN* Physical Architecture**

The TMN physical architecture provides mechanisms to describe the architecture of Management Systems, Network Equipment and Management Interfaces etc. used to implement a TMN. The Function Blocks and their associated Functional Components can be implemented in a variety of physical devices. Devices are connected across Management Interfaces Q3, F and X interfaces as illustrated in the simplified Physical Architecture for a TMN in Figure 5.4. These interfaces correspond to the Reference Points of the Functional Architecture and facilitate interconnection independence of devices or suppliers. It is across these interfaces that management information (both requests and results) flow in the form of structured data messages.

Figure 5.4 – TMN physical architecture



Source: ITU-T Rec. M.3010

- ***TMN Information Architecture***

The Information Architecture describes the nature of the management information, which has to be exchanged between Function Blocks. It is based on the Manager/Agent concepts developed for OSI systems management. An Object Oriented Information Model is established which presents an abstraction of the resources (physical or logical) being managed. An Information Model leads to an abstract representation of managing and managed processes. A model involves:

- Management Information Base (MIB) containing a collection of Managed Objects with all their properties, e.g. abstractions of manageable resources.
- Operation Systems (OS) involved in management applications, e.g. maintenance of transmission equipment

- Protocols for the message transfer of maintenance related information for managing and managed processes.

- ***Logical Layered Architecture***

The Logical Layered Architecture (LLA) enables complex management functionalities to be split into less complex parts, grouped into Logical Layers. Logical Layers describe the functions within and the relationship between layers. The Management functionalities, involving NEF, MF and OSF, can be related to five Logical Layers:

- *Network Element Layer (NEL)* responsible for the management of atomic units and functions within NE.
- *Element Management Layer (EML)* responsible for control and co-ordination of a subset of network elements on an individual NEF basis (management information being exchanged between network OSFs and individual NEFs), and control and co-ordination of a subset of network elements on a collective basis (OSFs may provide a single entity view of a group of NEFs and may manage the connectivity between NEFs). Typical functions are e.g. maintaining statistical, log and other data, communication with adjacent layers (NEL, NML).
- *Network Management Layer (NML)* responsible for control and co-ordination of the network view of all NEs in the network and for complete visibility of networks involving e.g. statistical, log and other network related data, communication with adjacent layers.
- *Service Management Layer (SML),* responsible for contractual aspects of services provided to customers involving e.g. service order and complaint handling, invoicing and communication with adjacent layers.
- *Business Management Layer (BML),* responsible for the total enterprise involving e.g. support of investment decisions for telecommunication resources and management and communication with lower layers.

- ***Management Functionalities***

A TMN is intended to support a wide variety of management areas that cover the planning, installation, operations, administration, maintenance and provisioning of telecommunications networks and services. Management functionalities supporting that have been divided into five functional areas:

- Performance management (collection, buffering and delivery of operating statistics, network optimization).
- Fault management (fault recognition, fault isolation, fault reporting, logging).
- Configuration management (equipment installation, setting of status and parameters, configuration of bandwidth).
- Accounting management (collection, buffering and delivery of charging and accounting information).
- Security management (administration of authorization functions, protection against intrusion from the public telecommunications networks).

These areas provide a framework within which the appropriate applications can be determined so as to support the Administration's business needs.

The management activities of operators are in many cases similar and attempts are made to harmonize and standardize these activities as TMN Management Services (Recommendation M.3400), as shown in Figure 5.5. TMN Management Services can be related to TMN managed Areas. TMN Management Services are composed of TMN Management Functions and TMN Management Function Sets (Recommendation M.3200). The TMN Management Functions are transmitted in the form of messages across the management interfaces.

Figure 5.5 – Example of the TMN Management Services

TMN Users

Management Services \ Telecommunications Managed Areas	Switching Telephone Network 1	Mobile Communications Network 2	Switched Data Network 3	Intelligent Network 4	CCSS No. 7 5	N-ISDN 6	B-ISDN 7	Dedicated and Reconfigurable Circuits Net. 8	TMN 9	IMT-2000 (FPLMTS) 10	Access and Terminal eq. Net. 11	Transport Network 12	Infrastructure 13
Customer Administration	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		
Network Provisioning Management	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Work Force Management	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tariff, Charging and Accounting Administration	✓	✓	✓	✓		✓	✓	✓		✓			
Quality of Service and Network Performance Administration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Traffic Measures and Analysis Administration	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	
Traffic Management	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	
Routing and Digit Analysis Administration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Maintenance Management	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Security Administration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Logistics Management	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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Source: The ✓ sign in each crosspoint only means that the Telecommunications Managed Area in the column needs the Management Service indicated in the row. The set of signs in a column defines which Management Services could be used to accomplish the management of the correspondent Telecommunications Managed Area. Figure 5.5 shows an example of relations applied to maintenance, in particular to Alarm surveillance.

Data Communication

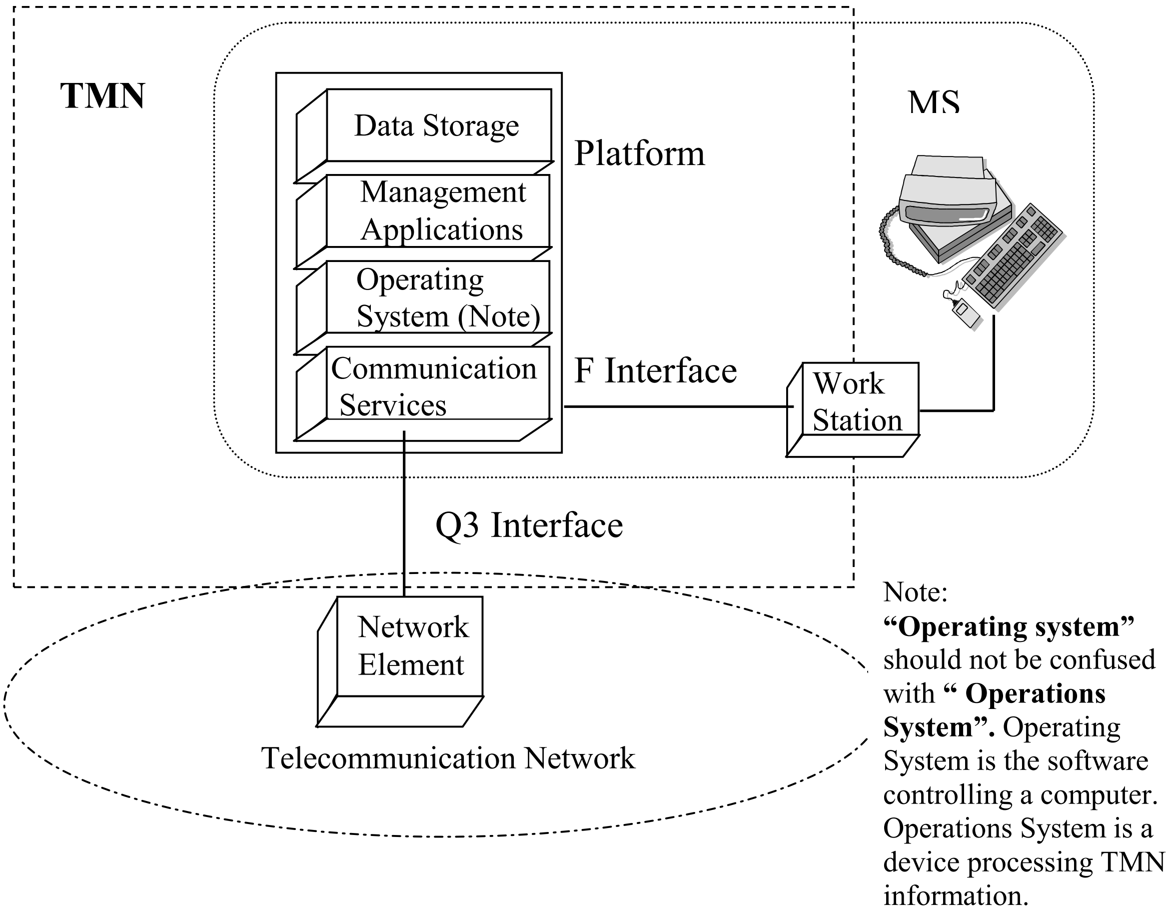
The TMN uses Open Systems Interconnection (OSI) profiles to transfer information between systems. The DCF Protocol Suites are defined in Recommendations, Q.811, Q.812 and G.773. The 7 layer Data Communication Function (DCF) implemented in a Data Communication Network (DCN) handles the messages belonging to TMN Management Functions. The Message Communication Function (MCF) consists of the 3 lower protocol layers.

It is proposed to include an option to use a TCP/IP protocol profile in the revised Recommendation for lower layer protocol profiles for Q3 and X interfaces. Internet TCP/IP protocol is used frequently for local DCN applications (LAN).

5.4 TMN implementation

The practical realization of the TMN leads to a demand for TMN conformant Management Systems, which apply the ITU Recommendations for TMN, but are not part of TMN Recommendations. However existing practice leads to the implementation illustrated in Figure 5.6, which illustrates a simplified Management Systems in relation to TMN and the managed telecommunication network.

Figure 5.6 – Typical Management System Configuration



The Management Systems consists of a computer platform and computer terminals, containing:

- The computer hardware with interfaces to the user (operator) and the managed telecommunication network.
- The computer software including the computer operating system, the management applications, the data storage (management information base) and the communication services to user and network.

Due to the geographic distribution of the managed network even Management Systems can be distributed leading to distributed processing.

Management Systems developed using the Logical Layered Architecture can contain various parts, each part responsible for the management in a certain management layer. The resulting physical architecture typically consists of following Management Systems:

Element Manager System (EMS)

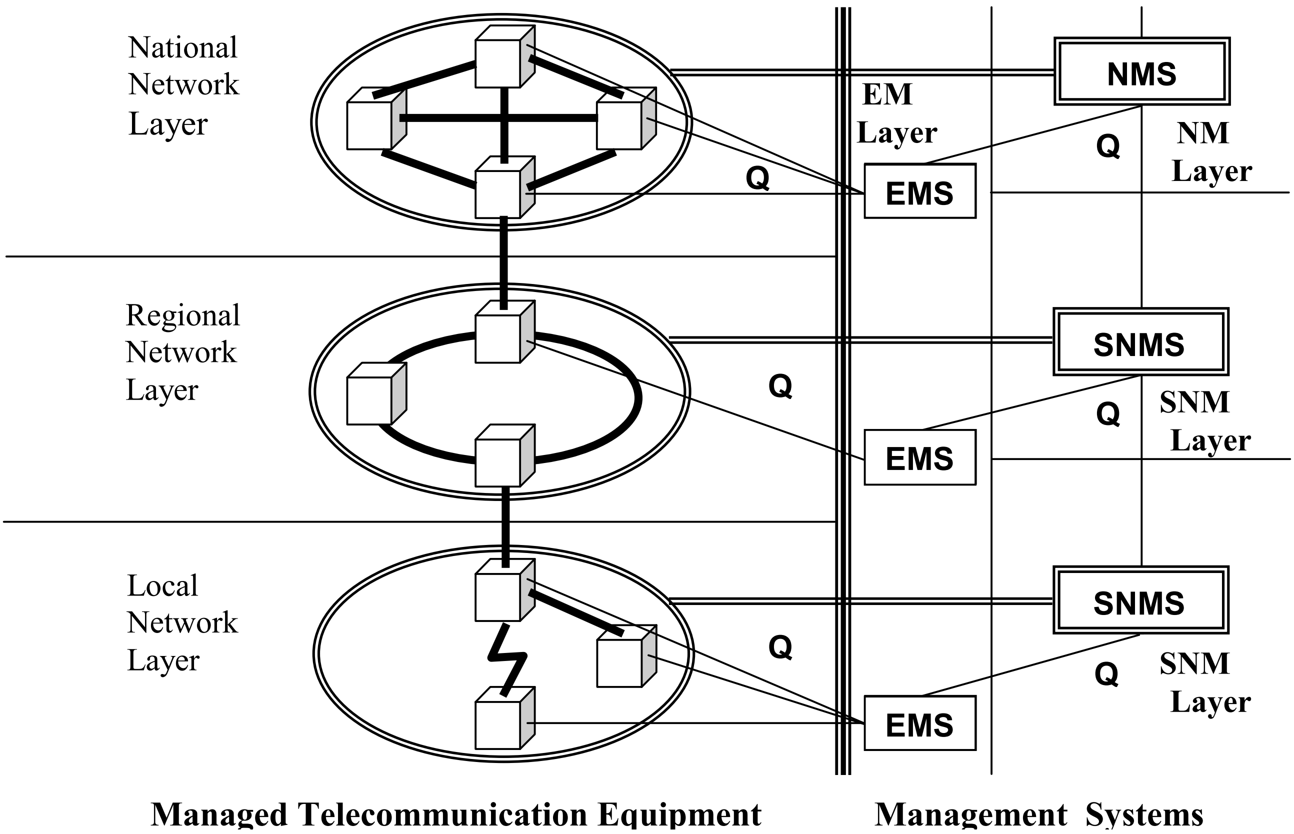
Network Manager System (NMS)

Service Manager System (SMS)

Business Manager System (BMS)

At present only EMS and NMS are offered by vendors, either as separate parts or co-located in one equipment (Management System). SMS is used for simpler services e.g. Leased Line Service, a TMN version of BMS is not yet in common use.

Figure 5.7 – Example of Managed Transport network



Depending on the hierarchy of networks, e.g. local, regional and national networks, a hierarchy of corresponding Network Manager Systems can be defined leading to the number of Subnetwork Manager Systems (SNMS), which are hierarchically connected to NMS. An example deployment of MS for transport network is shown in Figure 5.7.

Some of the EMS and NMS functions are listed in Table 5.3.

Table 5.3 – Example of EMS and NMS functions

Element Manager System Functions:

- *NE Map construction and Map management*
- *Control of a subset of NEs*
- *Security management*
- *Trouble information (failure location, type, repair procedures)*
- *Gateway function to the Network Management Layer and WS*

Network Manager System Functions:

- *Network Map construction and Map management*
- *Control of Network or Subnetwork*
- *Security management*
- *Collection of accounting data*
- *Gateway function to the Service Management Layer and WS*

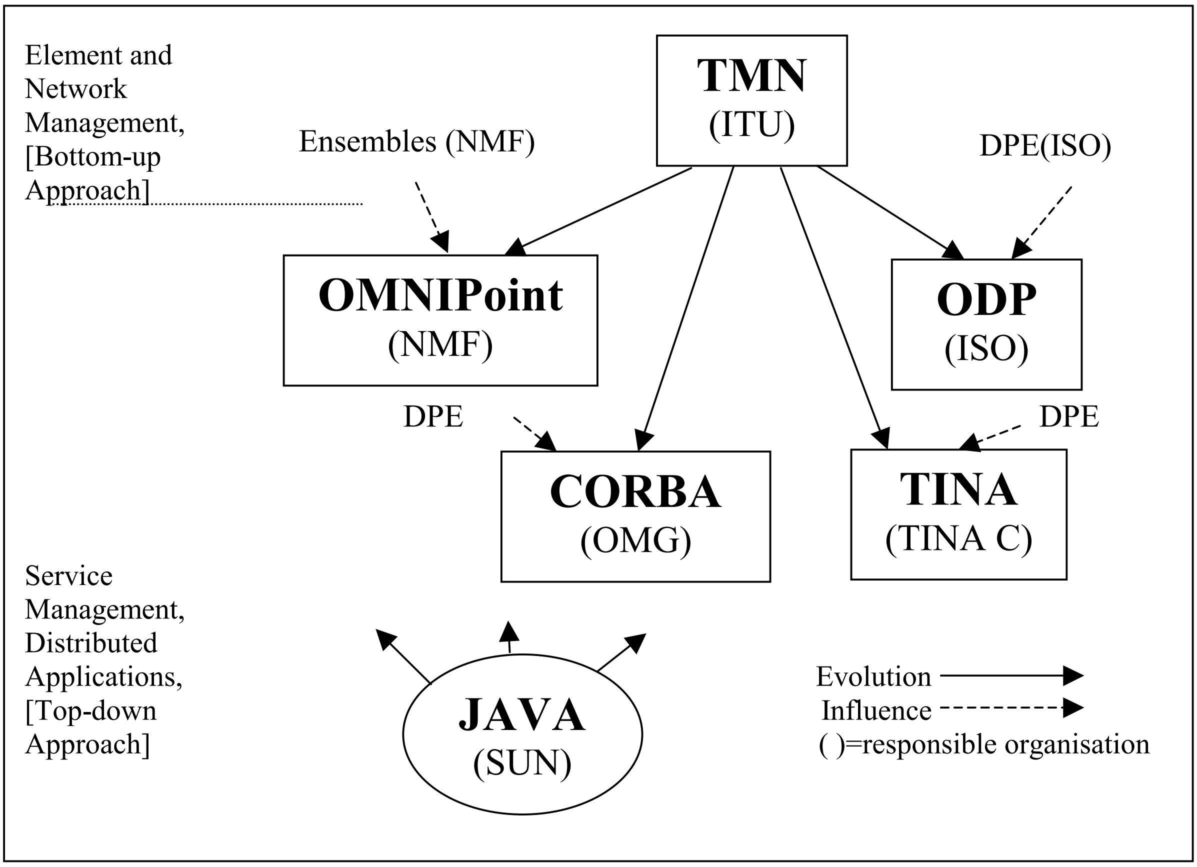
The use of management functionalities leads to information transfer across management interfaces. The question is which of the Management System interfaces must be TMN compliant? In the cases of Q3 interfaces the ITU standardized approach can be used for the majority of information exchanges. The communication in the local DCNs, however, is often based on market available SNMP or proprietary interfaces, which can lead to more economic solutions.

What computer platform is suitable for TMN applications? Experience has shown that the design should be as technology independent as possible, but at the same time the functionality and limitations of the platform have to be considered. Existing platforms often are not tailor-made for the TMN and require software for management applications and additional tools, both which should be provided by the platform vendor.

5.5 Evolution of management tools

The ITU and ISO developed during the last study period the basic TMN standards for Element Layer, Element Management Layer and Network Management Layer. During TMN implementation processes it was found that in spite of the all-encompassing intentions of TMN this technology was not suitable for complicated management cases. As a consequence various standardization bodies and groupings had to develop new methodologies for extending the management tools. A number of organizations are still involved in the evolution of management tools based on TMN, as shown in Figure 5.8.

Figure 5.8 – Simplified Evolution of Management Tools



5.5.1 TeleManagement Forum (TM Forum)

TM forum is an international non-profit organization serving the communication industry. Its mission is to help service providers and network operators automate their business processes in a cost and time-effective way. Specifically, the work of the TM Forum includes establishing operational guidance on the shape of business processes, agreeing on information that needs to flow from one function to another, identifying a realistic systems environment to support the interconnection of operational support systems, enabling the development of a market and real products for automating telecom operations processes. It makes use of international and regional standards when available, and provides input to standards bodies whenever new technical work is done. (www.tmforum.org)

5.5.2 International Organization for Standardization (ISO)

ISO has been addressing the Distributed Processing Environment (DPE) to solve problems related to distributed management. Open Distributed Processing (ODP) has been developed based on DPE. ODP extends TMN and to simplify the approach to complex problems the ODP Reference Model uses different Viewpoints. Each Viewpoint is described with its own language. Their typical use and users are shown in Table 5.4 below.

Table 5.4 – ODP viewpoints

Viewpoint	Used by	Used for
Enterprise	System procurers and corporate managers	Business requirements (network structure and management)
Information	System users and analysts	Information modelling (determines rules, constrains, static relationships)
Computational	Application designers and programmers	Functional decomposition of objects (programming functions, data types, static relationships)
Engineering	Operating systems and communication designers	TMN physical configuration (determines location of information and computational entities)
Technology	System vendors	Configuration, installation, maintenance of supporting technologies (physical network implementation)

5.5.3 Object Management Group (OMG)

The OMG has developed the Object Management Architecture (OMA) leading to the Common Object Request Broker Architecture (CORBA) for user/vender co-operation based on components for universal applications. TMN describes the large number of relatively simple managed objects related to the Network Element Layer. However, in the Service and Business Layers there exists a relatively small number of very complex Objects with complex interactions, which are difficult to handle with TMN. CORBA has been developed with the aim to describe the management of complex objects in a Distributed Processing Environment.

The Manager Agent Process as defined in TMN requires the same language and understanding between Manager and Agent, i.e. Shared Management Knowledge – SMK. CORBA extends Manager Agent Processes to generalized Client/Server Processes that permit new transaction processes, roaming agents, multimedia data management, self-managing data entities and intelligent middleware.

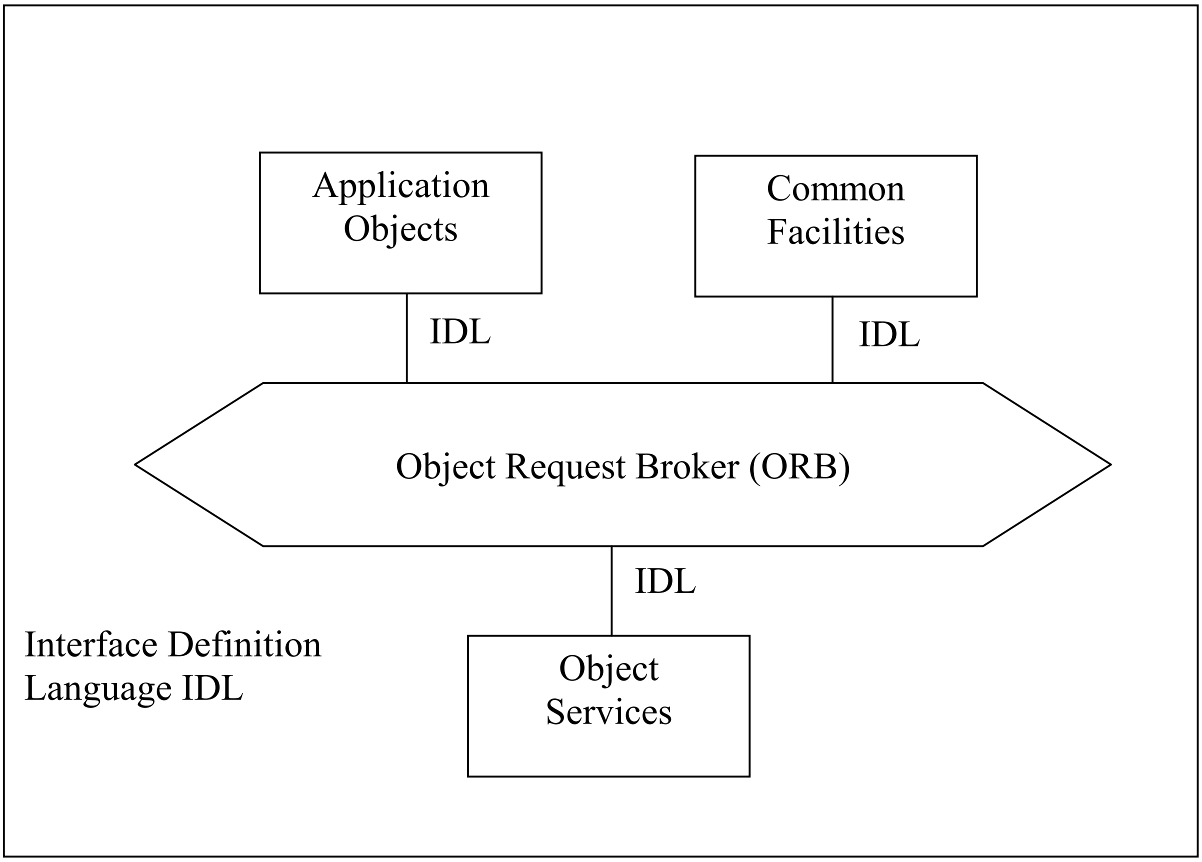
The functions are based on the concept of Components, which are pieces of software being independent of language, implementation, tools, operating systems, vendors, network applications and locations.

The Components are marketable entities, are part of complete applications and can be used in unlimited combinations. They act like Managed Objects and they are defined by their interface.

The CORBA Reference Model as illustrated in Figure 5.9 contains an Object Request Broker – ORB, which is connections use the Interface Definition Language – IDL, which defines for each Component its interface, attributes, inheritance, naming, operations, services and syntax.

The ORB is the middleware establishing Client/Server relation between Components (Objects). Components can communicate with each other in different languages, at run time and can invoke services.

Figure 5.9 – CORBA Reference Model



Common Facilities handle User Interface (for e.g. editing services), Information Management (for e.g. document storage), System Management (for e.g. component installation) and Task Management (e.g. workflow and rules). Common Facilities are usable in a general way for different areas belonging to for example telecomms, health service, retail and finance services.

Object Services describe Component details such as Life cycle, naming, events, transactions, relationships and licensing.

Application Objects permit specific end-user applications in addition to Common Facilities and Object Services and offer frameworks to model complex systems

5.5.4 TINA – Consortium (TINA-C)

The TINA Consortium has developed the Telecommunications Information Network Architecture (TINA) that defines an open architecture for telecom distributed software applications. TINA/C consist of Operators, Telecom and Computer vendors. TINA is based on TMN with the intention to improve TMN in areas of distribution, interoperability, dynamic roles, reusability and consistency. Some of the improvements are shown in Table 5.5.

Table 5.5 – TINA improvements of TMN

TINA	IMPROVED TMN
Protocols	CMIP and SNMP
Dynamic Role	– A Managed Object can perform management actions – A Manager can be managed – Manager/Agent relationships can be dynamic
Concept	– Management concept can be applied to services – Service concept can be applied to management

TINA offers a unified approach with Component categories such as Service Components (e.g. user agent, session manager), Resource Components (connection coordinator, resource manger) and Elements (switching and transmission equipment, protocol converter).

For this purpose TINA uses Distributed Processing Environment and Viewpoints (Engineering, Information and Computational Viewpoint).

5.5.5 JAVA

The presentation of management functions at work stations and computer terminals has been using the evolution of the Internet, which offered in the:

1970s E-mail functions

1987 World Wide Web (www), simplifying the access to Internet

1995 JAVA, a programming language for the creation of programs

1996 Javascript for controlling of programs and

1998 www + Javascript for the creation of dynamic www pages.

Java offers advantages for the presentation of management applications, such as:

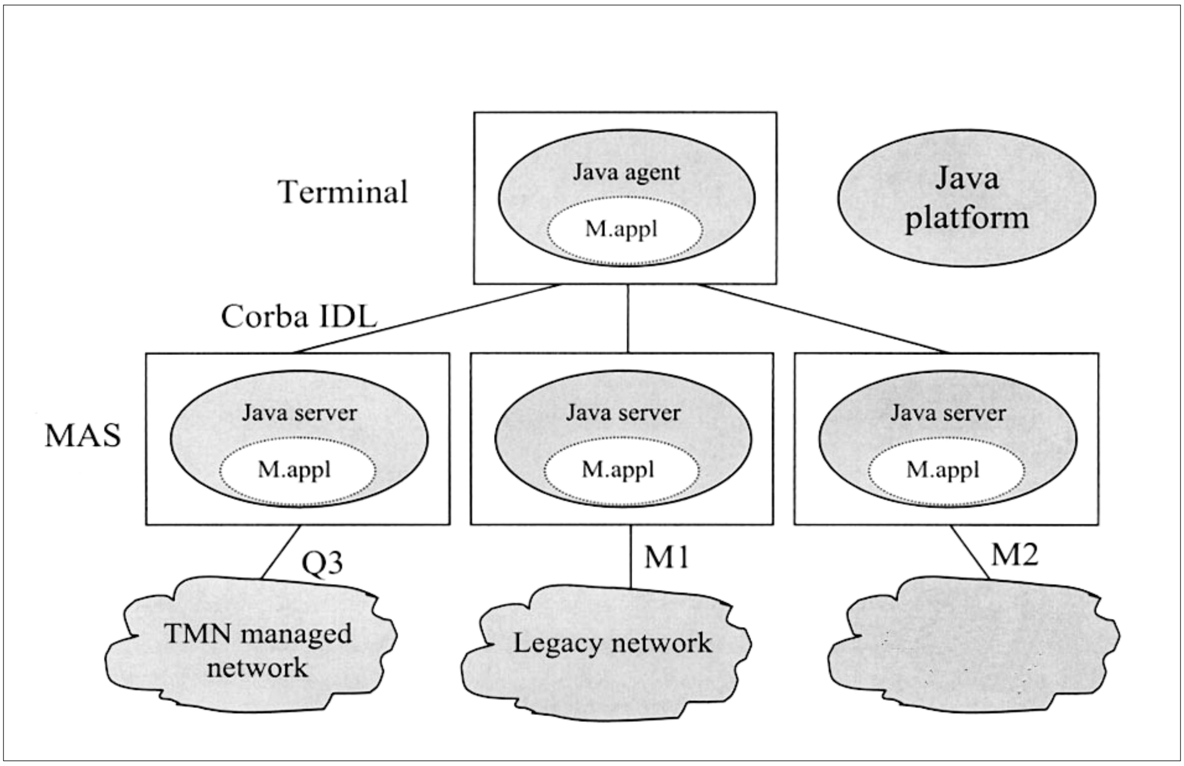
Simplicity	Similar to C++
Object oriented	Suitable for distributed management applications
Platform independent	Universal software platform
Dynamic	Automatic downloading of new versions
Technology independent	Coexisting with existing and new technologies.

A Java agent offers:

- Pro-active actions without human influence
- Automatic and remote updating, e.g. via internet
- Management via web browser
- Scalable matching of different network sizes and types.

Figure 5.10 shows an example of network management with Java. Different types of managed equipment with different types of management interfaces can be connected to the same Java agent.

Figure 5.10 – Network Management with Java



5.6 Conclusion

The efforts of the various bodies in the area of network and service management have resulted in the development of platforms for essentially TMN and CORBA services. Available platforms offer TMN and CORBA functions, which can simplify greatly the work of system developers and operators, such as e.g.

– Event correlation and filtering, features which an reduce the umber of alarms,

– Managed Object Modelling based on interactive browser using graphical guidelines,

– Agent and Manager developing tools, using the GDMO model for generation and testing,

– Topology services used for object relationships leading to integration of multiple applications.

Literature:

1 A Technical Strategy: *Implementing TMN Using OMNI Point, NMF.*

2 *The "Ensemble" Concepts and Format*, Forum 025, Issue 1.0.

3 *Telecommunications Information Networking Architecture, (TINA)* IEEE/IFIP 1994 Network Operations and Management Symposium.

4 *Rural Telecommunications, Volume III-Basic Aspects, Problems, Criteria, Instructions and Suggestions Concerning Maintenance of Rural Telecommunications Networks,* 1994.

5 *An Overview of Open Distributed Processing* Premira Mullan, ATT Bell Laboratories.

6 Robert Orfali, *The Essential Distributed Objects Survival Guide.*

7 Aaron E. Walsh, *Java for Dummies*, IDG Sweden Books.

8 Todd Goldman, *Network Management* Global Telephony, Nov. 1997.

9 Guide for the Introduction of a Computerised Subscriber Management System (CSMS), ITU 1st edition, 1999.

10 *Guidelines for a new approach using Telecommunications Management Network (TMN), ITU-D.*

5.7 List of abbreviations

TMN	Telecommunications Management Network
ATM	Asynchronous Transfer Mode
BML	Business Management Layer
BMS	Business Manager System
CORBA	Common Object Request Broker Architecture
DCF	Data Communication Function
DCN	Data Communication Network
DPE	Distributed Processing Environment
EML	Element Management Layer
EMS	Element Manager System
GDMO	Global Definitions of Managed Object
IDL	Interface Definition Language
ISO	International Standardization Organization
LAN	Local Area Network
MO	Managed Object
MIB	Management Information Base
MS	Management System
MD	Mediation Device
MCF	Message Communication Function
NE	Network Element

NEL	Network Element Layer
NML	Network Management Layer
NMS	Network Manager System
OMA	Object Management Architecture
OMG	Object Management Group
ORB	Object Request Broker
ODP	Open Distributed Processing
OSI	Open Systems Interconnection
OS	Operation System
QA	Q Adaptor
SML	Service Management Layer
SMS	Service Manager System
SMK	Shared Management Knowledge
SNMP	Simple Network Management Protocol
SNMS	Subnetwork Manager System
TM Forum	TeleManagement Forum
TCP/IP	Transmission Control Protocol/Internet Protocol
WS	Work Station

ANNEX 5A

Line Test and Measurement System by Thomson CSF
(Mirabel System)

1 Introduction

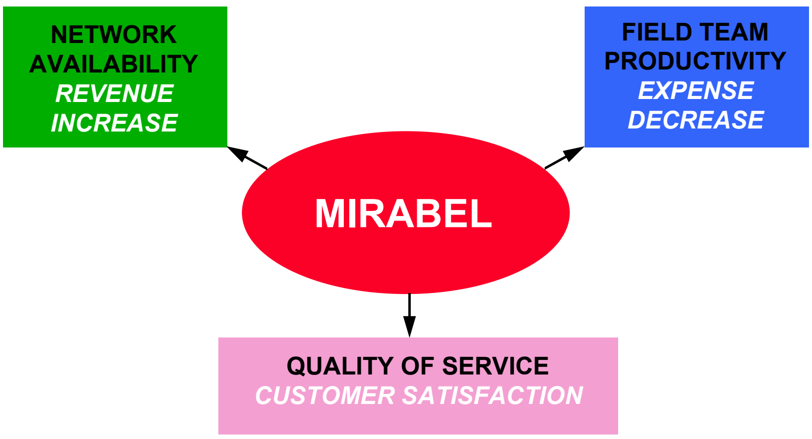
This Annex shows an example of a TMN-like implementation in line test and measurement systems.

1.1 Background

Tough competition is presently prevailing among telecommunications operators (Telco's) in many countries. For this struggle the fighters rely on two arms, tariff and quality of service. Proposing an attractive tariff is a key issue to catch new customers and providing a high Quality of Service is a major factor to keep them. But, even if the tariff is attractive, no customer would accept being deprived of service for days. The Quality of Service is becoming increasingly of paramount importance.

Even if a variety of tools is available for maintaining the local network, including Switch built-in facilities, these Tools usually lack consistency and may not be considered as 'systems'. They often depend on the type of switch and require special training and expertise. The goal of MIRABEL designers was thus twofold: they wanted to develop, on the one hand, a comprehensive system integrating all functions and, on the other, an easy-to-use interface, that requires no special expertise.

Figure A1 – Advantages of MIRABEL



Finally, the benefits from MIRABEL are threefold:

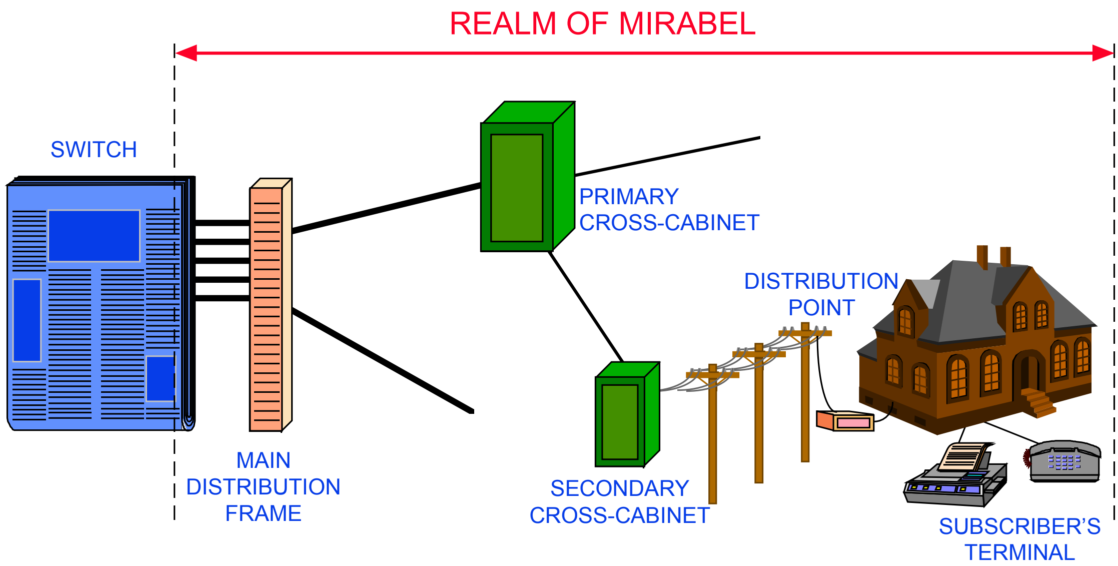
- The Customer's satisfaction increases proportionately to the Quality of Service.
- The income from the network increases, since no revenue comes from a line that is out of order.
- The expense for maintenance decreases, owing to the improvement of the field team productivity.

1.2 Key features

The basic function of MIRABEL is the **identification** and **localization** of defects (failures, improper installation, etc.) in the subscriber lines, from the switch down to subscribers. The domain of MIRABEL thus includes:

- The Subscriber's Lines Interface Circuits (SLIC) at Switches (Main Exchanges or Remote Subscriber Units).
- The Main Distribution Frame (MDF).
- All Cross-Cabinets and wire segments on the path to the subscribers.
- The telephone instruments.

Figure A2 – Realm of MIRABEL



MIRABEL considers copper lines only, since the process is based on electrical tests. Any type of copper wires may be monitored. Even in the case of ISDN lines the wires are tested from an electrical point of view.

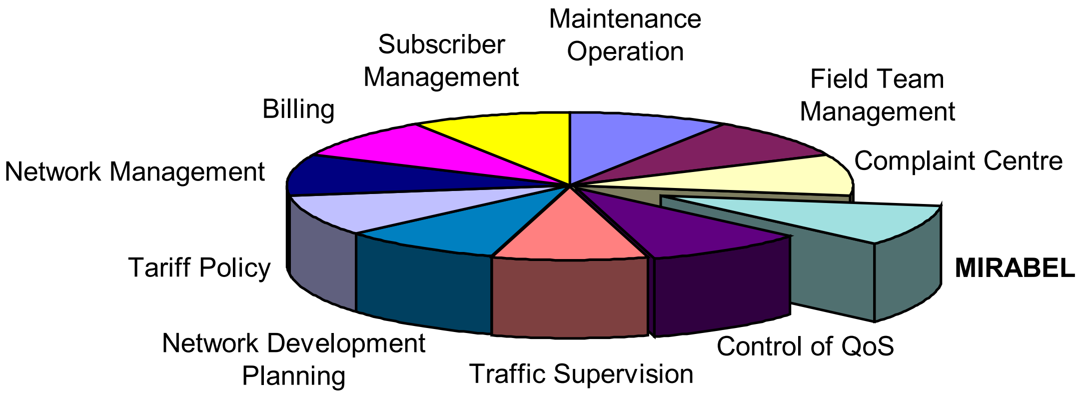
MIRABEL is capable of testing switched lines as well as dedicated (leased) lines.

After executing a series of electrical tests, the system reports not only the electrical values, but also a **diagnosis**, including the type and localization of the defect. This is a major advantage, since the traditional tools provide only a range of electrical values that nobody can use, except telecommunications experts. The diagnosis (for example "short-circuit in Cabinet No. 23") is understandable by Clerks or Workers not having any special expertise.

The system can execute not only single tests, on request from a Clerk or a Field Officer, but also batches of tests in order to periodically assess the network and unveil hidden defects that have not yet generated failures. Therefore, MIRABEL is suitable for curative as well as preventive maintenance.

MIRABEL interacts with the Customers Care System and takes part in the global information system of the Telco. The Test & Measurement facility is clearly a key feature as well as billing, tariff management, marketing management etc.

Figure A3 – MIRABEL and the Global Information

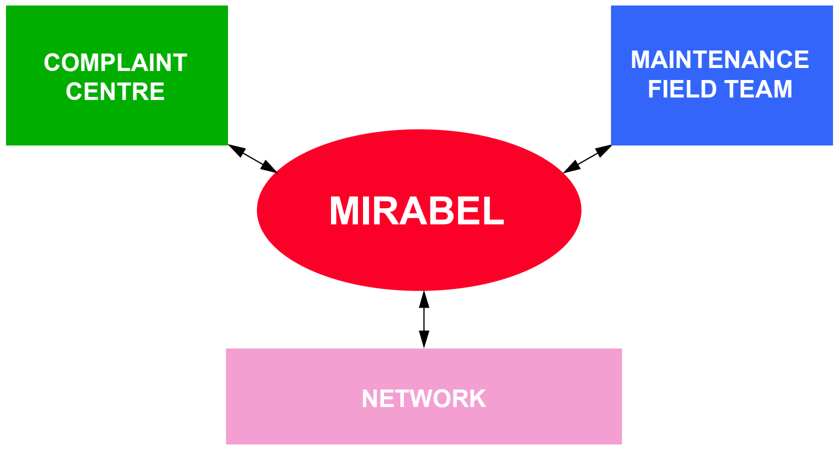


2 Architecture

MIRABEL is not only a precise measurement tool, but also a comprehensive information system, that interacts with three major entities, namely:

- The Complaint Centre, that directly interfaces with the subscribers and collects all data related to failures.
- The Maintenance Field Team, that is in charge of mending the local network.
- The Public Switched Telephone Network (PSTN).

Figure A4 – MIRABEL Interfaces



2.1 Network Interface

Line tests are executed by a device named "Test & Diagnosis Unit" (TDU), which is an instrument developed and design to measure a wide range of electrical characteristics in the subscriber line. Each TDU is linked to a Switch, through 'Test Trunks' (up to 24), that are facilities available on most Switches.

The TDU's are installed at a very short distance from the Switches[1], in order to avoid any important change in the electrical characteristics of the lines that would decrease the measurement accuracy.

All TDU's are controlled by "Main Control Units" (MCU), that are computers running software especially developed. Every TDU is linked to one MCU through either the PSTN or a Wide Area Network (TCP/IP or X25) or a Local Area Network. The number of MCU's depends mainly on the Telco's organization.

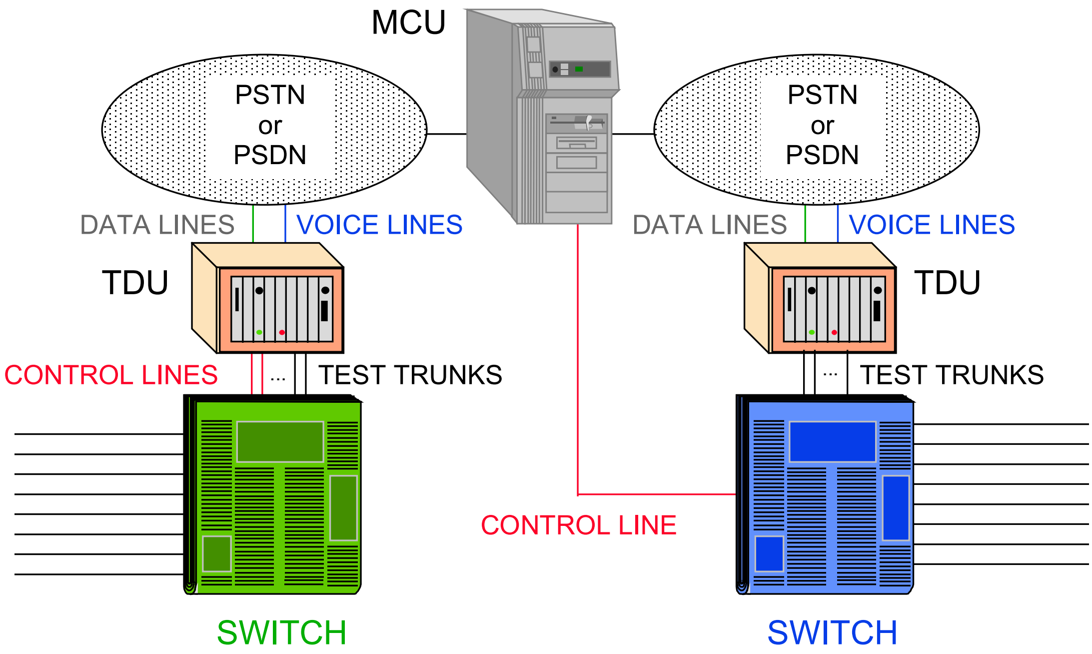
The MCU drives the tests according to a 3-step process:

- The MCU accesses the Switch and requests that a given subscriber's line be connected to one given Test Trunk[2]. Then the MCU accesses the TDU and launches a test.
- The TDU executes the test and reports the measured values and the diagnosis to the MCU.
- The MCU accesses the Switch again and requests that the subscriber's line be released.

[1] Main Exchange or remote Subscriber Unit, depending on the Switch configuration.

[2] Without charging the Subscriber.

Figure A5 – Network Interface



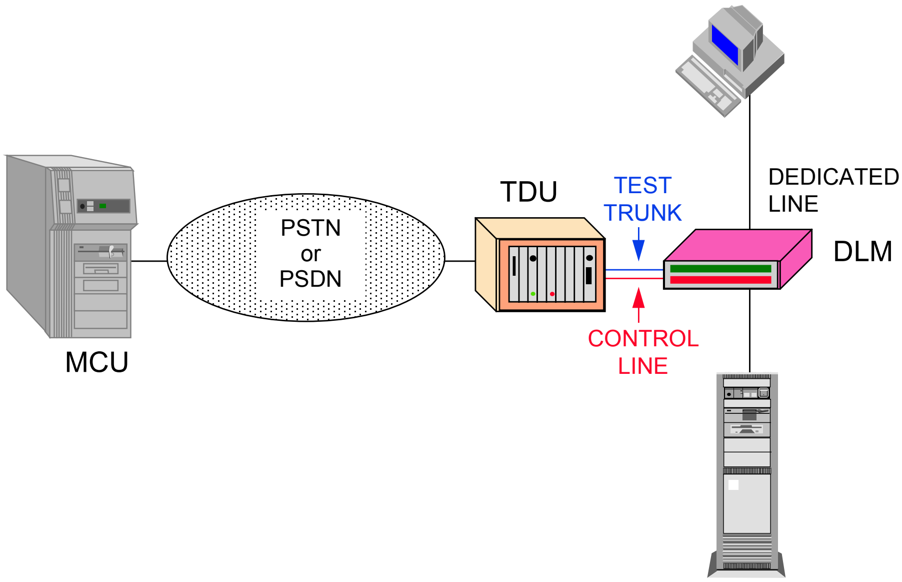
The MCU accesses the Switches either directly through the network, or through the TDU, depending on their Maintenance Facilities. For instance, all electro-mechanical Switches are accessed through TDU's.

The method for controlling a switch depends on each type of equipment. DASSAULT AT has developed a variety of interfaces for electronic as well as electro-mechanical switches from many manufacturers (Alcatel, Ericsson, NEC, Siemens, Lucent Technologies, etc.). New interfaces for specific Exchanges can be easily developed.

In addition to the subscriber lines, MIRABEL is able to test dedicated lines, owing to a "Dedicated Line Matrix" (DLM), inserted in the line.

The DLM is controlled by the TDU. The tests are driven by the MCU according to the 3-step process. Each line end may be tested separately.

Figure A6 – Dedicated Line Interface



2.2 Complaint Centre Interface

The Complaint Centre is the first user of MIRABEL since any subscriber facing a line problem calls it. Usually, the answering Clerk files the complaint and forwards it to an expert in charge of analysing the failures. Later, the problem is fixed by the Field Team on the basis of a report from the expert.

Finally the Field Team reports back to the Complaint Centre.

Using MIRABEL, the process is much faster, since:

- The Clerk receiving the complaint tests the subscriber's line in real-time and is apprised of the problem. He (or she) is then in a position to reply properly ("I see what your problem looks like. It is due to …"). Such information greatly increases the customer's confidence.
- The diagnosis that has been established is forwarded to the Field Team immediately.

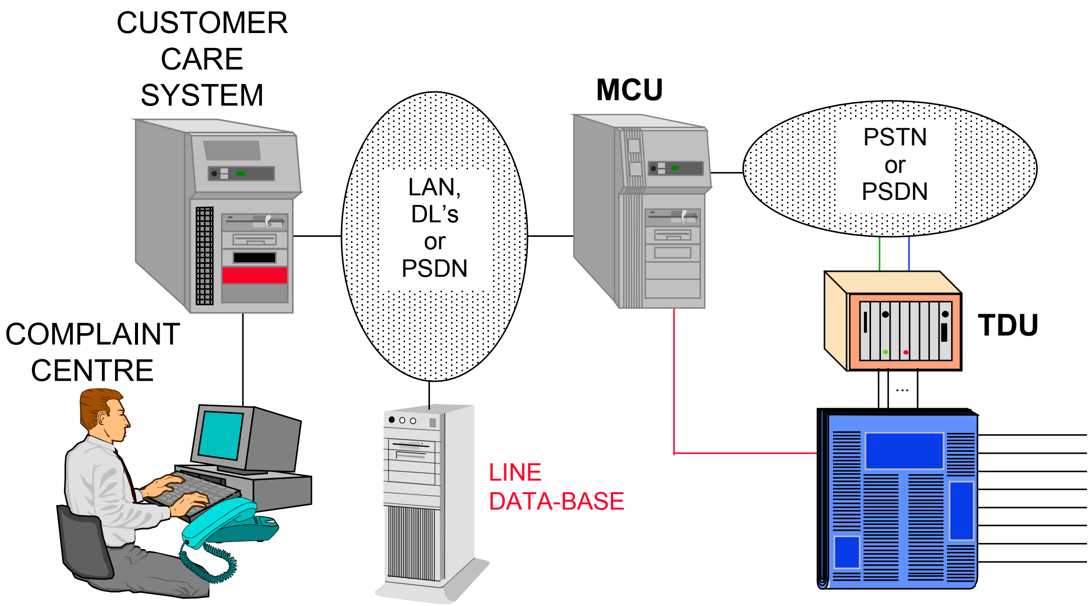
The Complaint Centre Software is not included in MIRABEL. This software is usually a part of the 'Customers Care System' and gives major inputs to the Global Information System. Nevertheless, it may provide interfaces to:

- **Proprietary Software from Telcos**. This requires specific studies and development, in co-operation with the Telco and/or any third party.
- **Customer Care Systems that the Telcos procure from the market**. It has already developed such interfaces.

- **Software especially developed** according to specifications of Telco's, to meet particular requirements.[3]

The MCU's are linked to the Telco's Information System through either a Wide Area Network (TCP/IP or X25) or a Local Area Network (LAN). The choice depends on the size of the network and the Telco's organization.

Figure A7 – Complaint Centre Interface



Owing to the integration, the Clerks access the Customers Care facilities (Subscription Data Base, for instance) and MIRABEL by means of a single Man-Machine-Interface.

The Information System from the Telco takes advantage of the integration, by collecting data related to the failures and processing statistical data.

In turn, if the Information System from the Telco includes a 'Line Description Data-Base', that describes the structure of the subscriber lines (cables and cross-cabinets), MIRABEL uses these data to improve the localization of failures. For example, instead of displaying "failure at 1500 meters from MDF" MIRABEL reports "Failure in Cross-Cabinet No. 17", which is much more understandable from an operational point of view.

3 For example, a special software was developed for a Client to handle Chinese characters.

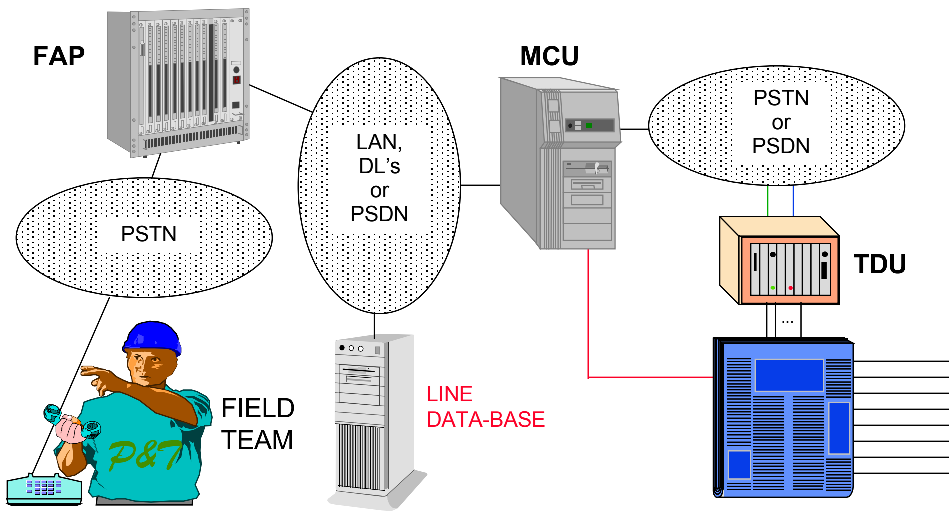
2.3 Field Team Interface

While working, the Field Officers may interactively use MIRABEL in order to analyse a defect and assess, in real-time, the result of repairing. This greatly improves the efficiency and productivity of the Field Team.

They access the System through a "Field Access Point" (FAP) with the help of a telephone instrument or possibly a portable PC.

The FAP includes a Voice Response Unit that helps the Field Officers to control the tests using a simple telephone instrument, cond with a DTMF keyboard, by means of a voice menu. In this case, the FAP reports the diagnosis and the measured values in voice mode.

Figure A8 – Field Team Interface



In case of uncertainty, MIRABEL advises the Field Officer to go further, suggesting, for example: "Setup a loop in Cross-Cabinet No. 13 and re-test".

When a failure is considered as fixed, it is good practice to request a last re-test as a final conclusion.

3 Services

MIRABEL offers two services:

- **Single Tests**; that are the basis of the 'Curative Maintenance'.
- **Batch of Tests**; that are the basis of the 'Preventive Maintenance'.

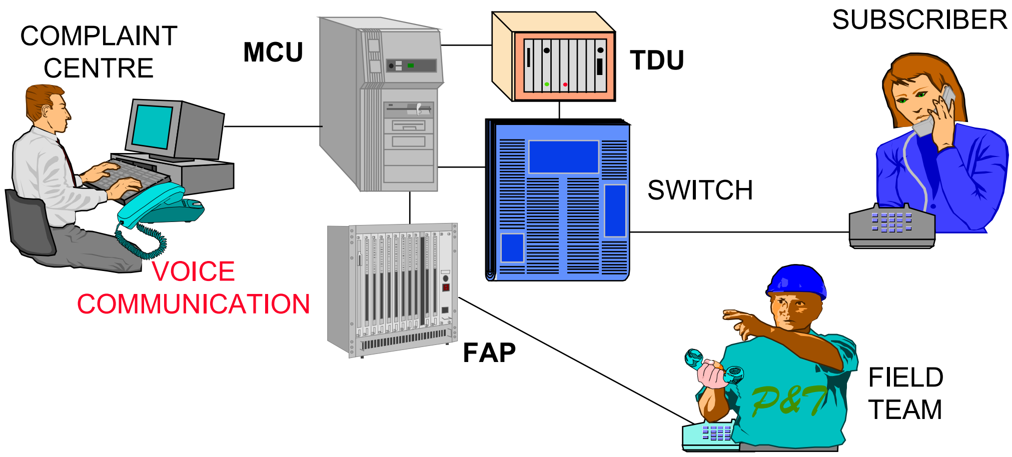
3.1 Single Tests

A single test is executed every time a line fails, launched either by a Complaint Centre Clerk or a Field Officer.

A 'Basic Test' is an operation automatically executed by MIRABEL according to the data entered by the Clerk or the Field Officer. The result of a Basic Test is reported within a few seconds. The Clerk or the Field Officer may execute a sequence of Basic Tests in order to refine the result. A test may also be processed in co-operation with a Field Officer or possibly the Subscriber. Such an interaction is required, for example:

- In case of a defect in the telephone instrument the Clerk may request the Subscriber (or any helper) to depress every key in turn. The Clerk checks the result from his (or her) desk.
- In case of a complicated failure the Field Officer may request a helper to set up a loop at a given Cross-cabinet, prior to re-testing a line.

Figure A9 – Single Test



In order to work interactively, Clerks and Field Officers access the line in voice mode. When a defective line is under control of a TDU for testing, the TDU may be called through the PSTN, in order to establish an end-to-end voice communication without interrupting the test.

Typically this feature is used by a Clerk who tests a telephone instrument. The Clerk may then talk to the subscriber even though the test is still in progress.

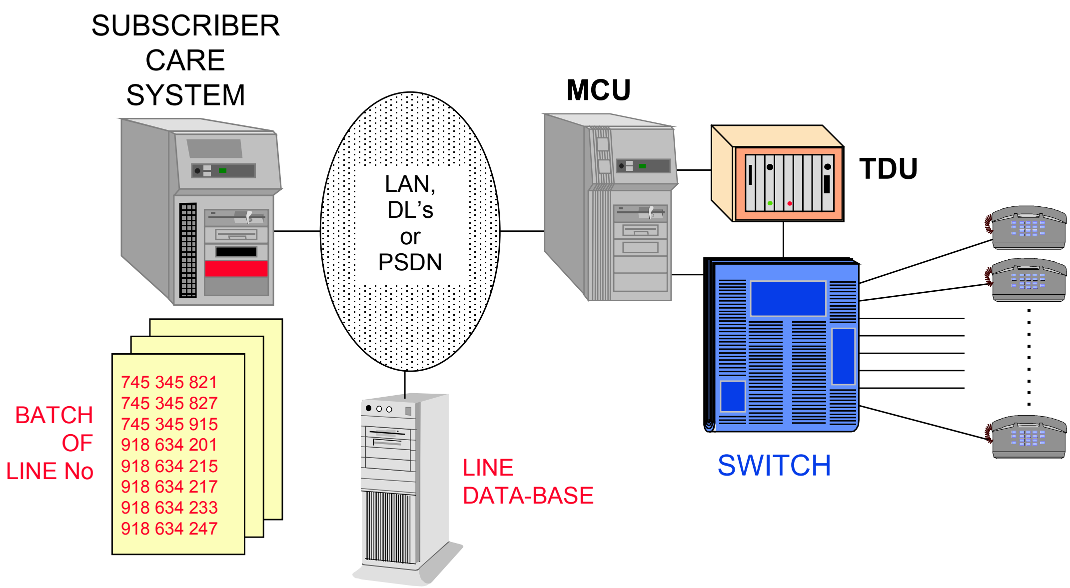
3.2 Batch of Tests

Even if rectifying failures is of paramount importance, preventing them is even more significant to the service provider, from all points of view.

MIRABEL helps to control the quality of lines because of its in-built capability to undertake repeated test campaigns, executed in off-peak hours, typically during night hours. To perform campaigns of test, the maintenance team has to define batches of line numbers and dates-and-times for execution. Each batch is then automatically tested.

The Maintenance Team may, for example, divide the network in a series of batches, each of them being tested during a different night, in order to fully test the network within one or two weeks. When all batches are tested, the cycle restarts. The Telco then gets an image of the network that is periodically refreshed.

Figure A10 – Testing a batch of lines



Every time a Batch is tested, all faulty lines are reported. To deem that a line is defective, two methods are available:

- A range of correct values for each electrical characteristic is defined. The set of all correct values are considered as a 'Gauge'. Because all local loops do not require the same quality (Voice only, Voice and data, etc.), every subscriber's line may be assigned a particular Gauge. Up to 16 Gauges may be entered for one local network (managed by one MCU). During the tests, every measure is compared to the corresponding range of correct values and any discrepancy is reported.

- During the test of a batch, all measured values of a line are compared to the 'Reference Values' of the same line. The Reference Values are collect during specific batches of test, executed when the Network is poised as correct. This process allows the detection of any abnormal evolution of the network.

Many hidden defects are unveiled during campaigns, mainly due to slow phenomena, such as water getting into cabinets, oxidization, etc. The Operator is therefore aware of the behaviour of the Network and can undertake appropriate corrective actions before the failure occur.

CHAPTER 6

6 Planning aspects

This Chapter considers the planning aspects concerned with the introduction of new technologies and services. In view of the importance of telecommunication systems to the welfare of the national economy, planning should be considered an essential activity for any country. In this Chapter, the planning aspects for radiocommunication systems have been considered separately because they involve management of a finite natural resource (the radio frequency spectrum). However, it is recognized that national telecommunication infrastructures are designed to provide a seamless integration of radiocommunication services provided by radio and non-radio systems. Radiocommunication Service is defined in the Radio Regulations and refers to particular categories of spectrum use, each separately defined, for example "Mobile Service" or "Fixed Service". However, this Handbook deals with radio and non-radio telecommunication "services" (with a non-capitalised "s"), meaning end-user services (e.g. facsimile or data or type of radio system such as cellular radio).

ITU-D and ITU-R have many publications (Handbooks, Reports and Recommendations) that provide an in-depth treatment of the issues briefly introduced below. A list of the relevant publications is given in section 6.8.

6.1 Radio aspects

6.1.1 Spectrum management and use

A brief outline of the fundamentals of radio spectrum management is given in the following sections in order to provide an understanding of the framework in which new technologies and services may be introduced into the radio spectrum. Much of this information has been summarized from the ITU-R Handbooks for "National Spectrum Management" and "Spectrum Monitoring", which offer a thorough explanation of the processes and requirements involved. The terms used relating to Radiocommunication Services are defined in the Radio Regulations, particular attention is drawn to the meaning of the terms *Allocation* (S1.16) and *Assignment* (S1.18).

6.1.1.1 General aspects of the radio frequency spectrum

Radiocommunication has become an essential part of everyday life. Radio-communication systems, operating from satellite as well as terrestrial platforms, are used in a growing number of services such as national defence, public safety, broadcasting, business and industrial communications, aeronautical and maritime communications and navigation, and personal communications. Radiocommunication is often necessary where no other form of communication can be used, for example in mobile applications or where wireline communication is not available (such as in rural areas) or has been disrupted (such as in emergency and disaster aid situations). In addition to telecommunication systems, increasing use is being made of radio-based systems for environmental management, in particular remote sensing applications for protection of essential natural resources.

6.1.1.2 International spectrum management

At the international level, because radio waves travel across national boundaries and many radio systems operate on a world-wide basis to support international communications, trade, and travel, the international community has developed, as radio technology has developed, a structure for coordinating activities and for cooperatively preventing interference. A single organization known as the *International Telecommunication Union* (ITU), a specialised agency of the United Nations, has been created by participating nations. The ITU is governed by a single International Telecommunication Convention and supplemented by Telegraph Regulations, Telephone Regulations and Radio Regulations, each having the status of an international treaty.

The Table of Frequency Allocations, given in Article S5 of the Radio Regulations, allocates the useable radio frequency spectrum (9 kHz-275 GHz) in bands of radio frequencies to the forty or so different Radiocommunication Services. World Radio Conferences (WRCs) consider *inter alia* changes to the Radio Regulations in a cyclical period (currently every two years) of preparatory work by the ITU Radiocommunication Sector. Most WRCs will have on their agenda consideration of parts of Article S5, including the Table of Frequency Allocations, with a view to adjusting the allocations between different Radiocommunication Services, taking into account new requirements and technology.

6.1.1.3 National spectrum management

At the national level, to obtain the benefits of this natural resource, each country must develop methods to manage the spectrum to ensure efficient and effective coordination between different services and to meet the immediate and long-term demand from existing and new radiocommunication services. Although no two administrations are likely to manage the spectrum in exactly the same manner, the fundamental elements, described in Appendix 2 [*extract from ITU-R Spectrum Management Handbook, Edition 1995*] are essential to all approaches. Without them, the implementation of radio services will almost certainly be hindered.

6.1.1.4 Spectrum requirements for environmental management

Management of the environment for sustainable development has become a major world-wide issue as a result of the Rio meeting. More recently the World Meteorological Organization scientific International Panel on Climate Change (IPCC) has issued its second report, confirming the global warming trend and exposing projections for climate development well into the future. The projections are still lacking of detail, but is has been concluded that the impacts on the living conditions of major populations will be very important, if not unprecedented.

In addition to global effects such as general rise of sea level, “climate” is expressed locally as the daily “weather”. This is a very dynamic expression. The evolution of seasonal or daily weather patterns resulting from climate change is not yet understood in any detail on regional or local scales. As a consequence, reasonable long-term predictions of many critical parameters are not possible. One may mention just a few examples: duration of the rainy season, strength of the monsoon, frequency and severity of the tropical storms, length of the growing or heating season, depth and duration of ground frost or snow, areas affected by environmental emergencies such as flooding or drought. These factors evolve dynamically as the result of climate change, driven through mechanisms of cloud, sea current, wind and precipitation patterns.

Simultaneously, the spectacular development of information technology makes it easier to benefit from results of science and of the daily observations to manage activities affected by the environmental conditions and events. This is seen as an increase of value of these information products. Public services improve and new commercial markets are born. The new technology observation systems produce huge amounts of data. Increasingly, automatic collection, analysis and distribution of environmental data is a significant producer of content for telematic systems. Operational systems to collect and distribute this information are global in a very true and real sense. It has been one of the driving forces in technological development in many of the least developed countries of the world.

To be successful, this world-wide system requires resources. Telecommunications systems bandwidth is needed, but seldom poses major problems. In contrast, access to suitable bands of radio frequency spectrum has developed into an issue. Radio spectrum is needed for several purposes. Telemetry of observations from remote locations and utilization of the interactions of electromagnetic waves with parameters of environmental interest are already part of the daily routine. Increase of these needs and requirements can only be satisfied in good cooperation with other users of the spectrum.

Specific Telemetry Applications

Environmental monitoring has developed early into a global activity under the auspices of several United Nations specialized agencies (for example UNEP, WHO, IOC, UNESCO, WHO, IAEA). In fact, most of these agencies have an interest and have developed capability in the environmental matters. As many of the phenomena do not respect national frontiers, several truly global monitoring networks have evolved. Increasingly, these networks report in electronic and real time formats.

Many of the systems, such as hydrological or meteorological stations and ocean observation buoys, are located in remote areas and produce too low traffic volumes to interest commercial telecommunications operators. This has led to the establishment of specialized, satellite-based systems operated in conjunction with space-based remote sensors. This activity needs to be intensified with new types of measurement and an improved geographic coverage. Major international programs, such as the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS) are in preparation. These developments signify total investments approaching 10 billion USD.

Some of these systems involve also high operating costs. The daily weather forecasts are essentially based on data supplied by the international radio sonde network. Some 1,000 observing stations launch twice every day an expendable high precision instrument, carried by a balloon to altitudes of 30 km or more. These instruments transmit data on atmospheric pressure, temperature and humidity. Their movement is tracked by radar or navigational aids to provide wind profiles. These systems operate on designated radio frequencies in the 403 MHz and 1 680 MHz regions. Technical cost/performance constraints on the radio sonde are extreme. They have to achieve exceptional accuracy unprotected, outdoors, from –90 to +60 °C, yet weigh very little.

An increasing importance of the oceans is reflected in developments of aircraft droppable instruments to take in situ measurements, including use of high flying remotely piloted air vehicles (AUAV’s).

Telemetry and telecommunications technology are at the fundamental level shared with other services. Environmental applications, however, require in many cases specific performance mandated by necessary sensor locations.

Remote Sensing Applications

Remote sensing technologies are the rapid expansion area in environmental monitoring. These technologies produce vast amounts of data, often in easily visualized image formats.

Quantitative use of remote sensing data requires, however, effective support from in situ instruments for calibrations.

Remote sensing is always based on interactions of electromagnetic waves with atmosphere, ocean, soil or vegetation. These interactions are different in various parts of the spectrum. Consequently, several optimal frequencies for remote sensing need to be allocated. Space-borne radar systems for observations of vegetation and ocean properties are also in development, although the emphasis in those applications has traditionally been on optical wavelengths.

Remote sensing applications require extreme system sensitivity both in the radiometric and the active measurement modes. The basic physical interactions are weak, and often ambiguous due to interfering phenomena. From this point of view there is similarity with requirements for astronomy research. In fact, several techniques originally developed for astronomy have already been adapted for environmental measurements and data processing. In spectrum management, this imposes severe constraints. In most cases, remote sensing systems cannot share spectrum with other types of service but dedicated bands must be assigned to them. The needs tend to be global. Many of the systems are installed as low orbit satellites, some others as ground-based global networks.

Remote sensing systems present major advantages compared to in situ sensors. They provide good area coverage, rapid updating of data and access to otherwise inaccessible areas. They also favour centralized data processing. Unfortunately, all known systems also have severe limitations with respect to the parameters which can be measured, the accuracy, representativeness of measurement or capability to operate in adverse environmental conditions. Investment costs are often a limiting burden.

Recommendations

Effective management of natural resources and the environment, prevention of disasters and sustainable development necessitate maintenance and further evolution of adequate, cost-effective systems of measurement and monitoring. The special needs of this function must receive most careful attention in decisions of frequency spectrum management and telecommunications system planning.

The development of radiocommunication services is entirely dependant on the availability of the radio-frequency (RF) spectrum, a natural resource that is available equally in every country. It is a resource that holds great potential and can be used to increase the efficiency and productivity of a nation's work force as well as to enhance the quality of life. However, it is a finite resource limited by technology and management capability. Great capacity can be found within the spectrum if it is properly organized, developed, and regulated, both at international and national level, to avoid interference and facilitate the introduction of new radiocommunication systems or users.

6.1.2 Coexistence between systems, frequency coordination between neighbouring countries

6.1.2.1 Coexistence and interference

As the radio spectrum is a finite resource and, in an increasing number of cases, there is insufficient to meet the demand, it is necessary for systems to share parts of the spectrum. However, spectrum sharing can result in interference. The Radio Regulations (No. S1.166) define *interference* as "the effect of unwanted energy upon reception in a radio communication system, manifested by any performance degradation, misrepresentation, or loss of information which could be extracted in the absence of such unwanted energy". Coexistence between new and existing systems is achieved if the interference between them can be reduced to an acceptable level by providing sufficient isolation in the dimensions of frequency, time, spatial location or signal orthogonality. There is a variety of regulatory and technical tools available to assist the spectrum manager in this task. However, the increasing demand for spectrum and the complexity of new technology requires continual improvement of existing tools, and the development of new techniques to supplement them.

6.1.2.2 Frequency allocation

The Table of Frequency Allocations, given in Article S5 of the Radio Regulations, provides the first level of frequency separation by allocating different frequency bands to those Radiocommunication Services that are considered to have mutually incompatible technical characteristics and operational requirements. The Table also provides some spatial separation by allocating some frequency bands to different Services on a regional basis.

Most countries have their own National Table of Frequency Allocations, based on the international Table. Within an allocation to a Service, there may be sub-allocations of spectrum for different national users. For example, a country may decide that a particular international allocation to the Mobile Service should be sub-allocated on a national basis to provide separate frequency bands for the mobile systems of public, private or defence users.

6.1.2.3 Frequency assignment

Within these allocations, frequencies may be assigned to stations. Again, the objective is to introduce new systems using, as appropriate, one or more of the techniques to provide isolation.

6.1.2.4 International frequency coordination

International coordination is required (and, in some cases, is mandatory) for frequency assignments that are to be used where there is a possibility of interference to (or from) the systems operated by other countries. Such uses include: space systems, broadcasting, systems operating below 30 MHz and most systems in border areas. The Radio Regulations contain internationally agreed general rules and procedures that advise administrations how to exchange information and how to take all necessary steps to ensure that harmful interference will not occur. The procedures may be broadly sub-divided into the acts of coordination, notification, examination by the ITU Radiocommunication Bureau and, finally, registration in the Master International Frequency Register (MIFR).

The coordination procedures vary, according to the Service and frequency, from individual assignments to the development of regional (allotment) plans. Regional plans are required to ensure equitable access to spectrum or geostationary orbit locations, for a particular Service (e.g. broadcasting), where the countries in a region have different timescales for implementation of the Service. Each country declares its anticipated requirements, usually at a specially convened planning conference or meeting. The task of the planning conference is to incorporate each country's declared requirements as "allotments" into the plan, within the limits of the spectrum available and technical characteristics of the Service. Once the plan is agreed, the allotments are protected according to the technical and regulatory procedures contained in the plan. Each country may then convert its allotments into assignments according to its own pace of development.

In addition, Article S6 of the Radio Regulations offers the scope for two or more administrations to establish "Special Agreements" on the use of the spectrum. These have the advantage that they may contain detailed technical procedures relevant to the administrations concerned, for example use of a common digital terrain database and special propagation models for mountainous border areas.

In accordance with Article S6, the ITU should be invited to participate in the development of such agreements and should be notified when they come into force. The international mandate of the ITU is to favour such meetings by providing technical or regulatory advice that can assist neighbouring countries to reach their own agreements on coordination issues.

6.1.3 Planning the introduction of new radiocommunication systems

6.1.3.1 Principles and definitions

Spectrum planning can be categorized in terms of time (short, long term, and strategic) and in terms of the areas covered (spectrum use, and spectrum management systems). The various categories of planning relevant to spectrum management are defined as follows:

- **Short Term Planning:** For issues needing resolution or systems to be implemented within about 5 years.
- **Long Term Planning:** For issues needing resolution or systems to be implemented within about 10 years.
- **Strategic Planning:** For the identification of a limited number of key issues which require concentrated spectrum management attention.
- **Spectrum Use Planning:** For spectrum use issues i.e., allocation, assignment, standards, etc.
- **Spectrum Management System Planning:** For spectrum management techniques, analysis methods, organization, resources, computer implementation, etc.
- **Service or Network Planning:** For specific systems' characteristics and operations. Service or network planning is often left to the service or network operator.

6.1.3.2 Planning for the introduction of new systems or technologies

Many new systems will require access to the spectrum in the future, resulting from growth of existing networks, new applications for existing technology and new applications made feasible by new technology. Of course, changing needs may result in reduced demand from some users and new technology may improve spectrum efficiency, permit systems to transfer to higher frequency bands where there is more bandwidth and less demand, or offer economical non-radio alternatives. However, the reduction in spectrum demand is unlikely to balance the increase. Administrations will need to determine whether new systems can coexist with existing systems and if not, decide how to deal with the competing demands for the same parts of the spectrum.

When planning to change spectrum use two factors that will have a considerable influence on timing are:

- any major new technology development or change of use that cannot be accommodated within the international Table of Frequency Allocations will require action to get the issue included on the Agenda of the next appropriate WRC;
- the likely considerable operational and financial impact on the existing users and the usually necessity to agree transition arrangements between the users concerned.

Long term or strategic plans have a key role to play here by identifying:

– important new technologies;

– technical or regulatory developments in other countries;

– potential impact (e.g. on existing users);

– the technical or regulatory changes required; and

– milestone objectives to enable their introduction.

6.1.3.3 Planning tools for optimizing networks

6.1.3.3.1 Technical tools

As mentioned in 6.1.2, the increasing demands on the spectrum and the need for greater spectrum sharing result in more emphasis on the need for more sophisticated planning tools. In general terms, these will enable the isolation between systems to be calculated with greater precision and confidence, with the overall objective to ensure that frequencies are assigned making optimum use of the spectrum.

The increasing complexity of spectrum management demands the introduction of computer aided technology for data base management, frequency assignment, interference analysis and monitoring. ITU-R Study Group 1 has the responsibility for facilitating the collection and dissemination of information concerning computer programs identified by the Study Groups for the implementation of relevant Recommendations that use automated processes for their proper application. The Study Group is also responsible for implementing Recommendation No. 31 (WARC-79) which specified that a Handbook on "Spectrum Management and Computer-Aided Techniques" should be prepared and revised periodically.

6.1.3.3.2 Economic-based tools

In countries that face a heavy demand for access to the spectrum, Administrations are having to deal with competing demands for the same parts of the spectrum. In such cases and despite having effective spectrum management systems, Administrations are considering alternative solutions, based on economic approaches, because technical approaches alone do not provide a complete answer.

It is recognized that the use of the spectrum makes a substantial contribution to a country's economy, through the provision of services and equipment, efficiency gains for radio users and job creation. Therefore, economic factors should be allowed to have an influence on decisions concerning how the spectrum is used, particularly for those frequency ranges and geographical areas where demand exceeds supply. Some countries are experimenting with various types of "market force" approach.

The addition of economic approaches to the spectrum manager's toolkit will be a considerable change from the traditional technical analysis methods and caution in their application is advised. ITU-R Study Group 1 has published a report, "Economic Aspects of Spectrum Management" (1997) about ITU-R SM 2012, describing the methods, issues, implications and countries' experiences with regards to ITU-D Study Groups meeting in 1997.

6.2 Non-radio aspects

6.2.1 Service demand and traffic forecasting

Services commercially introduced in the last decade or resulting from the latest technologies are called "new". Some of them are offered over the existing network with an enhancement of the original use for which the network was intended. Others, the newest, are carried over the ISDN and other new network platforms.

Non-voice telecommunication services offer point-to-point and point-to-multipoint communications involving real time and store and forward information transfer. Some of these services also involve external providers. Their quality and success depend on network infrastructure, data base management, consultation friendliness, screen page presentation, and so on. Some services, like audio conferencing and video conferencing, combine a number of voice and non-voice features.

To prepare for the introduction of new services (see Chapter 2, section 2.8. and 2.9), in addition to their technical description, specific applications, basic network requirements, accesses, terminals and environment, the demand and the opportunity to offer them must be analysed in detail. Traffic models ought to be built. Other considerations deal with the choice of the most appropriate technical systems, the impact on network dimensioning, operation, maintenance and staff training, economic feasibility, tariffs, legal aspects, scope of future evolution.

Most of these tasks rely on data gathering, which is greatly facilitated if an information system is used. In some cases, available data are not sufficient to derive the trends and evaluate all parameters required to perform new service forecasts. In any case, the administration policy concerning traditional and new service offerings is essential to derive the implementation strategy. Advanced techniques enable dynamic handling of variable mixtures of services at different bandwidths, gradual new service deployment, variable bit rate traffic processing and insensitivity to inaccuracies in predictions of the mix in service demand.

Each country or operator should consider the pros and cons of particular service offerings. The existing infrastructure, network capabilities to provide the services and the necessary modifications of the local network infrastructure must be carefully evaluated, from both technical and economic points of view. The existing economy and tariff policy, the technical and operational environment and experiences in other countries may influence decisions on new service offerings.

Demand forecasting

Classical methods for telephone subscriber forecasts are based on measurements of socio-economic factors and telephone resources and taken into account socio-economic prognosis. The general methodology may be applied to new service introduction, although the models can not be directly applied if there is a lack of experience and of historical or reliable data.

To study the relationship between socio-economic activities and needs for new services, a meaningful estimate of the demand should be made. This is a difficult step when the market is limited or when information technology lacks sophistication and expertise in such a way that customers are not aware of the new service potential.

Parameters for new service demand models are the number and geographical distribution of user installations and the number of terminals per installation.

These parameters are derived performing, market segmentation and surveys. Market segmentation is the first step to estimate the impact of the many variables involved in voice and non-voice service forecasts. Answering questionnaires, the few customers involved in a survey express their intentions concerning a service for which they can only imagine, with difficulty, its usefulness.

It is neither feasible nor necessary to analyse use, behaviour or the impact of the different parameters related to a service over the whole population. Such analyses can be performed on a sample of users where the various population segments are represented.

A telecommunication subscriber sample is a statistical information system on subscribers and telecommunication resources that allows the analysis of relationships between economic life and telecommunication development. To assure that it is representative, it should be obtained by stratification of the different market segments and then take at random a certain number of elements in each segment. In general, households are classified into socio-professional categories and establishments are classified per sector of activities and size in number of employees.

Experiences of countries where new services have significant penetration, or new technologies are being implemented, may guide the search for a pragmatic service demand evaluation, provided that the economic structures could be comparable.

The demand for each service must be evaluated. Simple rules could be adopted to evaluate particular service demand and connections. As an example, to derive ISDN connections at an early stage of service development, if no more precise information is available, it could be reasonable to assume that strong candidates for ISDN connections are a-priori Private Branch exchanges (PBXs). Then, from their traffic observations, their renewal or extension projects and forecasts concerning new PBX installations, it is possible to roughly evaluate the number of ISDN connections as shown in Table 6.1.

Table 6.1 – An ISDN access provisioning rule

Traffic in Erlang	Number of channels (Trunk lines)	ISDN access proving
Less than 10	Between 2 and 12	BRA per 2 channels
Between 10 and 16 For low growth For high growth	Between 13 and 20	 1 BRA per 2 channels 1 PRA
More than 16	More than 20	1 PRA per 30 channels

Note: BRA = Basic Rate Access
PRA = Primary Rate Access (see more in Chapter 2)

Traffic forecasting

New service traffic forecasting is based on subscriber demand and traffic per subscriber parameter forecasting. Direct traffic measurements on new services are seldom available or could be misleading in the early stages of service introduction.

As the user has different services available to transmit information, and the same bearer service is offered for different teleservices, it turns out that it is more important to forecast communication needs than services selected to communicate.

A profile for traffic volume parameters should be provided, for example total minutes of network utilization per month in the case of videotext. Subscriber experience influences both holding time per call (which decreases with increasing user expertise) and the number of calls (which increases with new applications of the service). The telematic behaviour of old and new subscribers may modify the average traffic per subscriber. Tariff structures also influence traffic per subscriber and may characterize a population.

For network sizing, new service traffic volumes must be estimated. Parameters such as busy hour traffic demand, call attempt rates, bandwidth requirements, depend both on the nature of the new service and on the network solution used to provide the service. Once significant parameters have been identified, the derivation of parameter values from overall traffic demand volume can be done on the basis of service characteristics, parallels with existing services and expected evolution over time. Some services require segmentation into user application groups with separate traffic parameters for each group.

The ITU-T Recommendation E.508 (Forecasting new telecommunication services) classifies new services, gives the forecasting parameters and develop different forecasting methods to derive their demand and generated traffic. The E.730 Series of ITU-T Recommendations are intended to provide methods relating offered traffic and Grade of Service objectives in order to allocate sufficient resources for ISDN planning and design.

For planning purposes and network resource dimensioning, for the sites to be linked, traffic matrices should be built to express the traffic between sites, by volume and direction. Matrix values can also express the number of PCM systems required to carry the traffic between sites.

6.2.2 Numbering

Numbers are needed for the provision of switched telecommunication services, both switched telephone services and packet-switched data communications. Numbers must be controlled and allocated in such a way that competition is not affected. The providers of switched services must be able to obtain numbers from the government or its designate by means of a transparent and non-discriminatory procedure.

Before defining non-discriminatory numbering schemes, criteria have to be established which define the term “non-discriminatory numbering”. These attributes may be divided into the following four groups:

- Adequate capacity

Numbering schemes should have enough capacity to number present and future services and subscribers, capacity for geographic and non-geographic numbers including personal numbers, capacity for carrier access codes and short numbers and service access codes for commercial and non-commercial services.

- Equal access

Numbering in the liberalized market should be administered by an independent body, reciprocity and symmetry between network operators and between service providers should not be constrained on numbering grounds, numbering schemes should guarantee the same dialling procedure for all corresponding network operators and service providers, numbering should be transparent, schemes should allow all applicants a non-discriminatory access to numbering resources.

- User-friendliness

From the users’ point of view the number portability is an important issue, i.e., the opportunity for users to retain the same number when they switch to another operator. Such a system would be beneficial to the user, and would promote competition.

- Harmonization

Numbering schemes should allow for migration from national service numbers to pan-regional and/or global service numbers and they should allow for harmonization of service access code, carrier selection prefixes and possibly PCS numbering at a regional level[1].

Number allocation should occur on the basis of long-term plans drawn up by the government. The plans will seek to ensure, as far as possible, that certain applications are recognizable in certain numbers (e.g., special call rates). Although no lack of numbers may be forecast to occur at a specific time, allocation must be done in an orderly and efficient manner.

One important issue that is arising is number portability, i.e., the opportunity for end-users to retain the same number when they switch to another operator. Such a system would be beneficial to the user, and would promote competition.

(For more information see UNDP Handbook on Network Planning Volume 1 "Fundamental Technical Plans" Chapter II).

6.2.3 Planning tools for optimizing networks

The objective of computer-aided network planning is to develop telecommunication network planning capabilities in all interested organizations, particularly in developing countries, in order to increase their self-reliance in this field.

Programme No. 5 of the Buenos Aires Action Plan (World Telecommunication Development Conference – WTDC-94) invites the Administrations to participate in the ITU Programme named PLANITU. Participation in these activities will promote the acceptance of globally standardized tools, including the further development of ITU software (PLANITU), for telecommunication network planning, reduce duplication of software development and maintenance, and facilitate cooperation between Members. Administrations participating in this programme will have network planning unit(s) established and work procedures organized, network planning software installed, and staff trained in traffic engineering and network planning activities.

6.3 Common aspects for radio and non-radio networks

6.3.1 Present regulatory and policy experience

In view of the strategic and financial importance of a national telecommunication system, most countries operate a regulatory regime for their telecommunication networks. Traditionally, these networks have been operated as government controlled monopolies and the main purpose of the regulations has been to protect the network from physical or financial damage and tariffs have been set to recover government investment. The rapid development of new technology, in particular digital processing and mass mobile communications, enables new options to deliver existing services and the possibility to provide new services. In parallel, this has created a market demand from customers seeking a wider choice of service, quality, technology and price. Governments have therefore been faced with the need to create a new regulatory environment that stimulates private investment and encourages innovation in the main market sectors:

– Content

– Service provision

– Network provision

– Customer equipment

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[1] See *Interim report of national numbering schemes on their openness to competition*, CEPT, European Telecommunications Office (21 March 1997), p. 7.

Various direct and indirect options are available for governments. Some have introduced full or partial competition in all or specific market areas and found that where competition has been permitted, networks gave grown, prices have fallen and innovation stimulated. Others may decide that aggressive competition is not appropriate and prefer friendly partnership arrangements, for example Build Operate Transfer concessions. The different approaches and aspects are considered in more detail in the following sections.

Regulatory implications for new services and technologies

It is generally agreed that policy makers and regulators have responsibilities for the pace of innovation. The extent to which licensing or regulatory provisions need to be changed is dependant upon the general policy of the government concerned, in particular whether a monopoly or competitive environment is chosen. A further consideration is the regulatory model the government chooses to adopt, of which there are three basic models[2]

- *Regulator as Patron*

An activist approach in which the regulator identifies what it considers to be promising innovations or innovators, gives priority access to the necessary resources (funding, spectrum etc.) and removes institutional obstacles.

- *Proactive Removal of Obstacles*

An approach which does not seek to "pick winners", but nevertheless actively seeks not only to ensure that regulation itself does not obstruct promising innovation but also to act pro-actively to provide a general environment (as regards, for example, radio spectrum allocations, technical standards or interconnection of different organizations' networks).

- *Arms Length Approach*

An approach that seeks to minimize the role of the regulator in decision-making about regulation in which the regulator rarely takes the initiative on matters concerning service innovation, but will respond to initiatives from the PTOs or other interested parties (e.g. telecommunications users, resellers or providers of value-added services). This may occur if they need the regulator to take specific action (for example, allocating and/or assigning radio frequencies) before an innovation can proceed.

The three approaches described above can be applied to the following main regulatory aspects that need to be considered to promote the introduction of new services and technologies:

Licensing

Licensing becomes a more important issue in a liberalized environment and is normally applicable only to the service provision or network operator market sectors. The main decisions are: which services should be liberalized and whether there should be a limit to the number of licenses.

As an alternative to the "first-come-first-served" approach, a system of **selective licensing** can be employed. If the regulator intends to license only one or a few operators (either for policy reasons or because of physical limitations such as radio spectrum availability), preference may be given to applicants who have proposed or are able to demonstrate innovations which have technical, economic or social advantages. However, selective licensing is rarely adopted, because of a number of disadvantages: one being that the regulator requires appropriate expertise to evaluate the proposals; the other is that there may be no real scope for innovation if the system to be licensed must conform to either national, regional or international standards.

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[2] The changing role of government in an era of telecommunication deregulation. ITU Briefing Report No. 2: Universal Service and Innovation: Fostering Linked Goals through Regulatory Policy.

Preferential licensing may also be used to assist new entrants to gain a market position in competition with a dominant PTO. For example cable TV companies may be licensed to provide additional telecommunications facilities whereas the PTO may be prohibited from providing entertainment for a limited period.

The introduction of new mobile satellite systems will provide telecommunications bandwidth on demand on a global basis. Such systems therefore provide an ideal technical solution to telecommunications in rural areas where there may be no local alternative. Governments whose national operators have technical or economic difficulties in meeting universal service obligations may wish to consider suitable licensing arrangements to enable mobile satellite terminals to operate on its territory. For this matter, ITU has established a Memorandum of Understanding to facilitate arrangements for Global Mobile Personal Communications by Satellite, including Regional Systems (GMPCS-MoU).

Network interconnection

New entrants to the telecommunication market, whether providing network, services or equipment, will need to interface to the incumbent network. Regulatory policies controlling interconnection arrangements between new entrants and the incumbent operator(s) will have a major impact on the operational or economic feasibility of innovations. The basic requirements will be to set up service level agreements, for example to ensure that new entrants do not suffer undue delay in connection or repair or have to comply with excessive technical conditions. On the other hand, the established operator will need assurance that interconnected equipment or services do not damage the network or present a safety hazard to his operatives.

6.3.2 Standard-setting and innovation

In this section we are concerned only with the impact of standardization in telecommunications on the pace of innovation, and what (if anything) the regulator could or should do about it. However, a brief statement of the fundamental view of the role of standards underlying our discussion of these issues may be helpful.

There is a widespread belief that the quality and value of any kind of goods or service can be improved by setting and enforcing common standards on all its producers. For instance, standardization and the consequential interchangeability of parts are the *sine qua non* of mass production. Nevertheless standardization is not a free lunch: it is always costly and always risky.

Standardization is always costly, no matter how it is done. A government may set a standard without previously consulting those whom it will affect and without incurring much cost in deliberating on what the standard should require. Despite that, the government will incur costs, perhaps substantial, in policing the standard; and those who are subject to the standard will incur costs in conforming their behaviour or products to the standard.

At the opposite extreme, where the standard is set and enforced by negotiation and cooperation of the parties subject to it, without any intervention by government, costs are still present. Negotiation takes time and effort, which are costly, and costlier as negotiation is prolonged. Besides, almost every party to a successful negotiation typically settles for an outcome more or less distant from his ideal or his initial bargaining position – and that distance often represents a real cost. Nor is it the case that standards arrived at by negotiation are necessarily self-policing. Just as many parties to a voluntary cartel have strong incentives to cheat, so the parties to a negotiated standard may need to incur costs to enforce it.

Standard-setting, besides, is risky. If some parties among a larger group of players voluntarily adhere to a standard, they run the risk that a majority will reject that standard in favour of some quite different one; and the former may then be forced to convert their operations at some expense. The risks attending the choice of a "wrong" standard, or of a "right" standard at the "wrong" time, turn into costs, sometimes lethal costs. And there are many different ways in which a standard may be "wrong"[3].

Stability and Inter-Operability

For all the reasons just described, standard setting is one of the fundamental roles of a telecommunications regulator, though sometimes the regulator may "forbear" and leave a specific choice of standards to be determined by voluntary agreement among industry participants, or by marketplace competition. In the context of innovation in services, technologies and network architectures, the standardization role that the regulator plays is important and ambiguous, even paradoxical.

On the one hand, adoption of a standard may stimulate innovation by enabling entrepreneurs to have confidence in the technical environment they will operate in, thus reducing their perceived risks, and thereby encouraging them to take initiatives and invest. To take the example of an entrepreneur providing specialized telecommunications and data services for telemarketing, the entrepreneurial costs, and thus real and perceived risks, would be minimized if the interfaces to the PSTN are rigidly standardized. (In the United States, the relevant interfaces are specified under the Open Network Architecture – policy, and vary somewhat from state to state. Many smaller companies argue that this imposes significant unnecessary costs and other competitive disadvantages on them).

On the other hand, standardization that is premature, or excessively detailed or inflexible, may itself inhibit innovation. The US example of standardization of interfaces through ONA, whilst reducing the perceived risks associated with interconnection, and consequently appearing to promote competition, may discourage innovation that relies on functional, rather than technical, integration.

Another important consideration in setting standards is timeliness. It is already recognized that the time required for an international body like the ITU to formulate an international standard is such that they are unable to keep pace with the state of technological development. In order to combat this problem, at least in part, Regional Standards Organizations (RSOs) have been established. The formation of the RSOs indicates clearly that global solutions are not timely, and even these organizations are finding it hard to keep up with users' demands and technological development in a "limited" part of the global networks.

Large manufacturers and telecommunications system providers are offering attractive new services, based on proprietary technology, that are gradually being accepted as the norm. Waiting for these services to be embraced on a global basis through the existing international standards process slows growth and reduces the efficiency of commerce.

The options for regulatory policy with respect to standardization are:

a) No regulatory intervention: Not intervening at all, so that PTOs or other participants in the telecommunications service industry (e.g. providers of value-added services and manufacturers or software houses) in effect negotiate the standards.

   Advantages

   - The principal advantage of this approach is that the regulator is not required to keep pace with the rate of technological change and thus does not impede it.

   Disadvantages

   - Participants may fail to agree on standards through negotiation.
   - Some participants may collude to agree on standards that discriminate against other participants.

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3 See for instance the literature cited by Besen and Johnson, 1986.

- As marketplace competition increases, the prospect of standards emerging through majority usage is limited. The larger the number of participants in the market, the less likely they will be able to agree on standards.

b) Intervention by exception: Intervening by exception when these industry parties are unable to agree standards.

Advantages

- This option combines the advantage of the "no-intervention" approach in that entrepreneurs are not bound to pre-determined standards, but subsequent to regulatory intervention the parties may be required to conform to a particular standard, thus limiting the proliferation of multiple standards.
- The facility whereby the regulator can intervene in the process of standard negotiation may also serve to ensure that the larger operators do not abuse their dominant position to the cost of smaller operators.

Disadvantages

- The intervention process may be costly to the participants and to the regulator in terms of time and effort required to agree on an appropriate standard. The opportunity cost to the innovator in spending time negotiating standards may be significant, and if the process is not resolved in short order, the value of the innovation may be significantly eroded.

c) Official standards for some services: Requiring the industry to implement standards for some services while allowing services or interfaces not complying with the standards to co-exist.

Advantages

- These will simplify the process of negotiating standards and reduce the levels of effort required to agree on standards.
- Selective standardization can be used by the regulator to ensure that access to the infrastructure is not an impediment to competition. The US adoption of ONA standards is an example.

Depending upon the market structure, partial standardization or multiple standards may best meet the economic objectives of producers. For example, it is too much to expect there will ever be a single LAN standard, or a single operating system standard. Similarly, where the motivation for producers to agree is to reduce asset specificity, as in the use of LAN controller chips, firms will try to differentiate themselves by using these standard components in different ways. Both firms and government actors need to have realistic expectations regarding the extent of standardization likely in any particular case.

Disadvantages

- Creates divisions within the industry. Participants will not be treated equally as some will be required to conform to prescribed standards whilst others are not.
- Gives participants the opportunity to abuse the standards process to advance their own economic interests, for example by exerting pressure on the regulator to adopt their particular standard industry-wide.
- May encourage participants to develop services that are substitutes to ones governed by standards and thus require the regulator to redefine the scope of the standards.

d) Mandatory standards: Selecting standards that are made mandatory for the industry.

Advantages

- Conformity. This option eliminates ambiguity in standards and avoids difficulties associated with competing systems using incompatible technologies.

Disadvantages

- Lack of knowledge on part of the regulator re progress of technological development
- Impedes functional innovation
- If the regulator chooses to adopt broad international standards there is a danger that these will not be appropriate to significant differences between countries and even between regions within countries.

The potential disadvantages of mandating innovators to conform to pre-determined standards have been demonstrated by the Japanese government's imposition of standards for the development of high definition television (HDTV). The Japanese, who have been working to develop HDTV for two decades, have put forth an analogue system (to conform to Japanese standards) that may need to be replaced by a digital system being developed in the US (to conform to international standards). This situation highlights the risk taken in setting a policy before the public has had any experience with a technology, in that innovation may ultimately be retarded because the policy cannot take future technological developments into account.

6.4 Elaboration of development plans

6.4.1 Relation with other ITU publications

The introduction of new technologies in the general network concerns network design, engineering and planning as well as equipment installation.

Several ITU-D publications address market segmentation, demand forecasting, traffic modelling and forecasting, the impact of network dimensioning and other aspects of the introduction of new services methods for network planning, optimization and minimization of costs, and provide guidelines to study the introduction of new services, particularly in developing countries. For example:

- GAS 3: General Network Planning, published in 1983.
- GAS 10: Planning data and forecasting methods, published in 1987.
- GAS 11: Strategy for the introduction of a public data network in developing countries, published in 1987.
- GAS 12: Introduction of new non-voice services in developing countries, published in 1992.
- Competitive Transformation of Telecommunication Organizations – MANDEVTEL, 1997.
- Useful Reading for Director and Managers – General Principles of Telecommunication Management, (Volume I), 1993.
- Useful Reading for Director and Managers – General Principles of Telecommunication Management, (Volume II), 1996.
- Strategic Planning, 1993.

Therefore, the next sections only mention a few facts to be taken into consideration for the elaboration of development plans.

Related matters have also been addressed in ITU publications dedicated to particular aspects of the network, e.g. switching and transmission systems, rural telecommunication network planning.

6.4.2 Turning points in telecommunication development

The development of digital transmission techniques in the early 1960's was a significant turning point, potentially leading to a reduction of costs.

In the 1970's, the Pulse Code Modulation (PCM) technology was introduced. Primary rate systems were not economical for lines shorter than 20 to 25 km; further advances of electronics allowed the reduction of this distance to 6 to 8 km by the early 1980's, giving the possibility of some applications in the local network.

Another important turning point happened in the 1980's. Optical fibres began to be introduced in telecommunication networks, firstly multi-mode and then single mode. Optical cables were also used in the local network, mainly in field trials, sometimes for specific applications. These experiments demonstrated the peculiar characteristics of optical fibre cables usage in this part of the network and the related problems.

Optical fibres offer an enormous bandwidth in small sized cables and, in association with digital transmission systems they can support a wide range of different services. These two technologies enable a wide variety of customer services. To the network operator they offer the possibility of new network configurations, which are less expensive, easier to operate and maintain.

In addition to the cable systems, radio systems are also used, particularly in situations when there are some obstacles (like mountains, rivers, lakes) or difficulties in reaching customers (isolated settlements) or when mobile telephones are required. The importance of radio systems is still growing in this field of application.

Modern means of wireless communications provide connections and give additional possibilities of mobile/fixed communication services.

6.4.3 New technology and network planning

Network development is a continuous and evolutionary process, requiring extensive planning and implementation strategies to optimize existing. and future telecommunication resources and service provisioning.

Until recently, planning goals were mainly network optimization and expansion, to satisfy the anticipated demands in established services, following a fixed time schedule. At present, network design must consider capacity and quality criteria to satisfy service demands that are only partially known or, to some extent, expected.

The deployment of optical fibre, the introduction of SDH and relatively new transmission and switching techniques, cellular and point-to-multipoint radio, open up new alternatives for efficient network design and development. The advantages offered by new technologies concerning network investments, operation and performance need to be thoroughly estimated.

Planning aims at determining network evolution over a defined period enabling the operator to satisfy the forecast demands as well as those spontaneously expressed, which may be diverse, with especial capacity and quality features. One of its goals is to globally diminish the operator's economic risk, by defining network evolutionary steps along with the technological evolution and enabling to economically cater for current and new service offerings. In some cases, this last point is essential to avoid customer migration towards other operators either because they offer these new services or more attractive tariffs.

However, the farther the target, the lesser the confidence that can be given to the data upon which the plans are built. Therefore, it is essential to define an intermediate target, aligned with the final target, where the internal and external factors influencing the plans and the technological evolution are the best known and demand forecasts the more realistic, or at least when both aspects can be reliably evaluated.

The possibilities offered by new technologies lead to an increased quality of network engineering, enhanced operation facilities and higher performance, resulting in a relative decrease of global investments and operation costs, thus enabling the operator to lower service tariffs. Additional revenues can be reasonably expected since a wider range of services, at lower cost and of improved quality, is offered to users.

Integrated planning is necessary to design and built a network with capacity, resilience, flexibility and survivability, as well as the possibility of satisfying customer needs as soon as they are identified.

Planners must have in mind all network evolutionary aspects in order to prepare as far as possible the necessary network infrastructure that will facilitate the evolution towards broadband and the new services.

The planning methodology is addressed in the ITU "General Network Planning" manual (Geneva, 1983). Since switching planning issues and the advantages of new technologies have been already discussed in other chapters of this manual, this section aims only to underline some aspects of transmission network development plan elaboration, especially in, relation with the introduction of SDH.

New services demand and traffic forecasts are basic inputs for network development plans. Resource dimensioning relies upon the accuracy of access demand and traffic forecasts, which are the parameters to derive traffic matrices between sites. In spite of their importance, forecasting matters are only briefly addressed in this publication.

Network planning based only on minimization of costs in initial investment expenditures for established services has a very small potential for mid and long term benefits and runs the risk of excluding the possibilities of revenues for emerging new services and demands. In addition, deregulation does not facilitate network planner's tasks because of the uncertainty of expected market shares. Yet, excessive prudence restricts future possibilities and eventually restrains the operator's capability to react against competition.

The implementation of digital technology was undertaken between the 1970s and the 1990s in most countries. In spite of the complexity of the technical and economic aspects of evolving telecommunication networks to full digitalisation, this process did not really modify the network architecture and basic transmission media.

The present evolution of transmission media, based on optical fibre and SDH deployment, induces deep changes in the network infrastructure, architecture and management.

6.5 Definition of short, medium and long term development scenarios

With reference to the study period, solutions should be proposed corresponding to short term, medium term or long term planning. Plans must be periodically updated to incorporate new technology and service evolution.

Short and medium term plans should be consistent with long term plans and must contain the initiating process, decisions already taken on equipment to be installed, services to be provided and the first steps to prepare the network development towards the envisaged target. This is usually called operational planning.

Two phases of network development may be distinguished:

- A medium term period – the first development phase – where the characteristics of network evolution should follow a more or less well defined policy in an assessed technical environment. For example, rules concerning the implementation of an optical infrastructure, removal or renewal of a defined kind of equipment, network organization for the next five years, should be known and taken in account accordingly. During this phase, the intermediate target network should be reached. In this first phase, confidence can be given to demand estimation, equipment costs and technology evolution. Plans for short and medium term time frame would be meaningful. Investment priority should be given to SDH implementation.

- long-term period – the second development phase – where the target network objectives should be achieved, if no further reasons intervene to modify it. The representation of the target network and the elaboration of a strategy for evolution have to be consistent with the network evolution planned during the first phase such as evolution towards a Global Information Infrastructure – GII (see ITU-T Recommendations Y.100, Y.110 and Y.120)

For some time in the second phase, the network remains traditional: PDH equipment and infrastructure still rely on metallic cables and microwave links. However, metallic cable links are to be replaced by optical fibres when necessary and every new link has to be built either by optical fibre or new SDH microwave systems. Yet, if evolution towards an SDH equipped network should be envisaged, secondary rings subordinated to the implemented primary rings are to be considered.

6.6 Economic evaluation

To allow a comparison of the different solutions, an economic evaluation of each scenario should be carried out, considering global costs and revenues. However, if financial aspects are important, they are not the only criteria to be examined. Efficient network flexibility and management should be dominant factors.

To perform the cost evaluation, it is useful to distinguish between investment and running costs:

- For each scenario, all investment costs such as the generated by existing capability extension, equipment renewal policy and creation of new routes should be added over the whole study period. In an existing network, each new link implementation has to replace an existing route, link or capacity. Divested cable and/or equipment has to be inventoried and evaluated in both residual (re-use) value and operating costs. This enables the planner to assess the economic impact of each new link creation.
- Running, costs consist of logistics, operation and maintenance expenses. Whereas operation costs rely mainly on organization aspects and are, therefore, difficult to ascertain as such, maintenance costs are rather network and equipment related. Consequently, for network evolution, maintenance costs are the most significant. They concern copper cable, optical fibre and microwave links, office equipment, such as multiplexers, supervision, digital distribution frames, and so on.

Finally, a synthesis should be made based on the cost comparison of the various proposed scenarios, services, evolution possibilities and revenue assessment.

6.7 One approach for development plans for local transmission networks

Once the traffic demand has been evaluated for every year of the study period, to elaborate long term development plans (for a local area, a region or a country) the first step consists in the establishment of a thorough inventory of the existing network. These data may be already available in operational services.

A consistent renewal policy in both infrastructure (switching centres, transmission nodes, cables, microwave links,) and system domains must be set up, based on expected or assumed equipment life cycle, in phase with a national or operator specific procurement policy.

The next step establishes a target network frame, consistent with the switching, transmission and operating evolution through the planning period, and determines the main stages to reach it.

Another important step is the determination of an intermediate target network, consistent with the target network established in the previous step, and the trajectory to attain it. For feasibility and reliability reasons, the intermediate target network should be placed at three or four years ahead. Therefore, this first crucial planning phase engages both the planner – who proposes an intermediate target structuring the network – and the operator – who approves and finances it. Once this is assumed, the planner has to determine the further network evolution until the final target – worked out and possibly readjusted – is achieved, i.e. within five to ten years or more.

Switching technology, organization and equipment deeply influence architectural transmission choices. The availability of new generation switching equipment and the related renewal of older and out-dated switching systems modify the network configuration and, as a consequence, transmission system requirements.

Decisions concerning ring or bus configurations are based on the amount of traffic internal and external to the service area where the planned network is going to be developed. The risk and consequences of isolation of each site in case of node or link failure should be systematically evaluated while determining the network configuration, to avoid as far as possible major service disruptions over the concerned sectors; for that purpose, a threshold of subscriber numbers not to be isolated should be fixed by the operator.

An efficient network configuration will be determined only after several iterative studies and attempts to elaborate long term plans fitting the strategic policy for the general network development. In particular for large networks, these studies can not be realized without appropriate tools and computer programs which have to be developed or updated to perform network planning tasks.

6.7.1 Objectives of development plans

Planning tasks must be aligned with the general telecommunication development policy and if defined with the specific policy concerning local networks. Therefore, the foreseen evolution and decisions concerning the trunk network have to be examined to determine the general objectives of local network development plans.

Network planning general objectives are the following:

– **Demand satisfaction** including new service offerings and the consequent traffic pattern. All types of access to the public switched network have to be taken into account in long term equipment plans, because they need specific connection equipment and have their own traffic features and evolution. Among these, a distinction has to be made between analogue connections, accesses to telex, videotext, BRA and PRA ISDN, PBX digital connections. On the other hand, leased lines, whatever the supported services will be, gateways with cellular radio system networks, data networks or any other type of existing or anticipated networks have to be considered.

Once access requirements and traffic volumes are known, the demand can be expressed in transmission resource requirements.

– **Quality enhancement** in all parts of the network and especially on longer links, for instance through the deployment of optical fibre cables in the structuring part of the network. If fibre is further planned for long distance and distribution networks, optical connectivity is to be sought and optical fibre implementation in the concerned local areas should be carried out consistently.

Availability and quality criteria for services to be provisioned may need specific equipment. This has to be consistent with the renewal policy mentioned earlier.

– **Network organization**, operation and management following the above requirements, automation of OAM&P in switching and transmission facilities.

– **Service protection**. The modern telecommunication world requires a high degree of survivability for advanced services and relies more and more on security even for POTS. Therefore, measures have to be taken to protect the whole information flows from disruption and quality of service lowering.

6.7.2 Scope

Development network plans for local networks should cover subscriber infrastructure and equipment, transmission, switching facilities, buildings and power supply.

In urban or rural networks, whereas subscriber loop plans are elaborated for each elementary area (served by connection units or their equivalent), master plans covering switching, transmission, building and power plant are elaborated for each local area (served by one local exchange or by a set of local exchanges).

Detailed subscriber and traffic forecasts for each local area are required, including the basic telephone service, leased lines and special services. Dimensioning of buildings, cable ducts, switching, transmission equipment and power plants should be performed. Plans derived from this data describe the operations to be carried out over periods of 3, 5, 10 and 15 years.

Network operation, administration and maintenance are also to be considered as fundamental aspects of planning completion. Therefore, development plans must cover the evolution scheme of required manpower and training as well as the Operation Administration and Maintenance (OAM) organization towards Telecommunication Management Network (more details see in ITU guidelines "Improvement of maintenance guidelines for a new approach using telecommunications management network (TMN)").

A similar procedure may be applied to elaborate development plans for regional or national networks. However, data can be given in a more aggregated manner and methods must be adjusted to each particular case.

6.7.3 Internal and external factors

A number of factors influences network planning; they are external and internal to the operator.

Factors external to the operator to be considered include:

- New service evolution in both a steady growth and high quality requirements;
- The assessment of single-mode optical fibre as the major transmission support medium;
- Emergence of the SDH concept and equipment;
- Perspectives of ATM introduction in a foreseeable future;
- Perspective of Local Information Infrastructure – LII (see Annex 6C)
- Switching evolution towards large multiservice switching machines;
- Regulatory aspects such as deregulation of telecommunication operators, allowing a new market share by several operators based on market;
- Radio frequency allowance compliant with international agreements concerning their utilization (e.g. the 2 GHz plan migrating from current microwave usage to mobile radio).

Factors internal to the Operator or the country include:

- General network development strategy of the operator;
- Decisions on network restructuring and organization;
- New infrastructure and equipment renewal policy.

Based on these factors, other considerations arise, for instance

- Fibre costs diminish, becoming competitive over copper cable, especially if repeater requirements are considered;
- Equipment costs will significantly vary with SDH overall deployment. As an example, for a point-to-point application, PDH and SDH are already cost comparable at 140 Mbit/s and 155 Mbit/s, respectively. In add-drop applications, this may occur already at 34 Mbit/s for PDH and 155 Mbit/s SDH;
- Management issues, service offering possibilities and operation oblige planners to reconsider the use of radio links in areas where optical fibre cables may be deployed even at a higher investment cost.

Moreover, overall operation and maintenance costs for the whole network will diminish since:

- The network infrastructure shrinks to a better structured topology, i.e. the ratio between the planned and the existing cumulative length of cable routes serving the local exchange area may be around 70%; in developed local exchange areas shrunken ratios may achieve 30%. Thus, less cable links are to be maintained and the structuring part of the network is new.
- The amount of equipment will be lower when SDH is implemented instead of PDH.
- Operation and maintenance processes will be progressively automated as SDH network elements are deployed over the network; provisioning will be largely software controlled when SDH management will be fully standardized, i.e. in the second half of the decade.

Evolution can even be accelerated or reinforced by Local exchange service area consolidation. Eventually, this leads to transmission network topology optimization and an adequate SDH implementation.

Major telecommunication operators will drastically reduce PDH equipment orders. Consequently, PDH equipment costs are likely to increase, whereas SDH equipment costs show decreasing trends.

6.7.4 Determination of priorities for implementation of new technology

The implementation of new technologies can not be done simultaneously in all parts of the network. A chronological order for work has to be established, consistent with service offerings and demand. The network may therefore be subdivided into a “Primary Network” and a “Secondary Network”, by a selection of nodes classified beforehand. The introduction of new technologies concerns first and foremost the primary network.

Node classification, which is essential for the proposed network partition, is to be based on criteria such as:

- Major network structuring functions (e.g. technical hubs);
- Importance of the considered node in terms of switching equipment features, service provisioning, traffic, ISDN accesses, leased lines, future or anticipated evolution;
- Location (e.g. in the vicinity of a “primary cable” link).

Only main nodes should be constituents of the primary network. The secondary level of the network will contain the remaining sites once the primary sites have been assessed. A significant number of nodes should be left to constitute these small secondary networks around the respective primary nodes (see Annex 6A).

6.7.5 Equipment Provisioning

Basic SDH equipment will consist of Terminal Multiplexers (TM) and Add Drop Multiplexers (ADM). When required, these network elements may include internal cross-connect functionality.

For this purpose, network functions have to be determined for each node in order to select the adequate network element. These functions are:

- transfer of signals,
- insert and/or drop signals from an aggregate line signal,
- cross-connection,
- adaptation (to another hierarchy or digital level as required).

Broadcasting (transfer of an incoming, signal onto several outgoing ports) may be included in cross connect functions.

In each network node one or more of these functions have to be performed. The installed SDH network elements must therefore contain these node specific functions. Since network elements are basically versatile, they may evolve, e.g. from a single repeater (assuming only a transfer function in the node) to a real ADM and even further to a small local Digital Cross Connect (DXC). This smooth in-service, network element functional upgradability is one of the major advantages of the implementation of SDH network elements in the transmission network, which thus becomes evolvable and flexible.

6.7.6 Link and network upgrade

Two different upgrading aspects are to be considered:

- Synchronous network evolution (e.g. a bus evolving to a ring).
- Capacity upgrading to cope with growing demand.

Network evolution

The following options are available:

- New node insert in a bus or ring: The corresponding ADM installed is connected to both “East” and “West” fibre pairs. This is possible without traffic disruption either by using the line protection facilities (bus or unidirectional ring properties). The former protection path becomes the new operating path.
- Bus extension: A TM is installed in a new line coding node and connected to the assigned fibre pair, whereas the former TM is cond as an ADM by adding. the respective line interfaces and control unit. Thus, the existing TM has not to be moved to the new line end but evolves on site. This is possible without traffic disruption.
- Bus to ring completion: Through stepwise bus evolution, as previously described, and once the last fibre link is installed, both the two TMs closing this segment are cond to ADM by adding the respective line interfaces and control unit. Thus the ring is completed and the management system takes into account the new network configuration.

Capacity upgrading

Capacity upgrading can be done by:

- STM-1 ring, extension: When the fixed threshold (e.g. 63 primary rate signals) is achieved, a second ring has to be implemented. In SDH this is possible by adding an extra ADM in the hubbing node, connected to a second fibre pair; the designated ADMs of the existing ring are then moved to this new fibre pair and a second ring is then established doubling the transmission capacity. This evolution is possible in-service.
- STM-1 to STM-4 extension: There are network elements which are particularly suited for this upgrade and the operator has to select carefully this equipment, taking account of both in-service and in-rack upgrade properties. At least two STM-1s should be made accessible in the ADM and these should be freely selected giving the network element the most flexible features, i.e. the universal use in any node of the network.

Remarks

Only SDH gives the network and the network elements the upgrade possibilities mentioned above and demonstrates the SDH flexibility and ability to respond to any network requirement and evolution.

Further, all these upgrades and evolution are performed through a two level process: a hardware level involving fibre and network element implementation and a software level involving the network management system to take account of new configurations at the network element and/or the network level.

6.7.7 Conclusion

SDH based facilities, offering significant advantages over current plesiochronous systems, will coexist with the present PDH equipment and progressively replace it. In the future, these facilities will be able to carry broad-band services that require end-to-end control and high transmission quality assessment.

On the other hand, the future of copper cables, plesiochronous equipment and micro-wave technology is uncertain. SDH equipment availability and suitability for small sites is another issue to be solved. Other questions arise such as the future of optical switching, duality of SDH/ATM on the access part of the network, optical fibre penetration rate in access networks, impact of mobile communications, new service demand and traffic etc.

Since the implementation of SDH equipment is a technological discontinuity, its planning must be elaborated with care. As synchronous equipment becomes established within the network, the benefits it brings become apparent. Network operation costs diminish as a result of equipment and hardware reduction, increased efficiency and reliability and more automatic and better organized maintenance.

If the cost component is important in investment choices, quality, flexibility and fast response of the network to the very highly evolving, demand should be decisive when considering development alternatives. Satisfaction of planning general objectives and a qualitative evaluation related to service provisioning possibilities and staff training are also decisive arguments.

Co-ordinated actions should be undertaken between commercial and planning services for the choice of primary nodes, respecting the commercial strategy and medium term forecasts concerning advanced services. This choice should drive the planner to con the intermediate target.

To cope with all the recommendations and remarks here proposed, the two phased and two levelled network approach is likely to be the best suited.

In the first development phase, the most important is to structure the network. To respond in a coherent manner to network and service requirements, bus structures should link the most important nodes, offering SDH accessibility (and what it implies in survivability and quality of service) to the major part of access lines (e.g. 75% of the total number of telephone lines) and almost 100% of existing or forecast business sites. In the second development phase, bus will gradually evolve to rings at the pace allowed by financial constraints.

Because of its particular features, rings of synchronous multiplexers can structure the junction network.

The assessment of relevant OAM&P (OAM and Provisioning) features embedded in the deployed equipment should allow a fairly new and fully managed local network, at least in its primary network.

6.8 List of relevant ITU and other publications

ITU-D Sector

Rural Telecommunications – Volume I (GAS 7).

Manual on the Economic and Technical Impact of Implementing a Regional Satellite Network – 1983 (GAS 8).

Case Study on the Economic and Technical Aspects of the Transition of a Complete Analogue National Network Moving to a Digital Network – 1988 (GAS 9A).

Handbook on Case Studies on the Digitalisation of Regional Networks – 1992 (GAS 9).

Handbook on the Progressive Introduction of ISDN in a National Network – 1992 (GAS 9).

Economic and Technical Aspects of the Transition from Analogue to Digital Telecommunication Networks – 1984 (GAS 9).

Planning Data and Forecasting Methods – Volume I – 1987 (GAS 10).

Planning Data and Forecasting Methods – Volume II – 1987 (GAS 10).

Strategy for the Introduction of a Public Data Network in Developing Countries – (GAS 11).

Strategy for the Introduction of a New Non-Voice Telecommunication Services in Developing Countries – 1993 (GAS 12).

Restructuring of Telecommunications for Development: Evolution, Policies and Trends – 1994.

Rural Telecommunications, Volume I – Radio Systems in Rural Areas (1994).

Rural Telecommunications, Volume II – Switching, ISDN, Financing Aspects and Use of Fibres for Rural Networks (1994).

Rural Telecommunications, Volume III – Basic Aspects, Problems and Criteria, Instructions and Suggestions Concerning Maintenance of Rural Telecommunications Networks (1994).

Strategic Planning (1993).

Methods for Evaluating New Digital Inter-exchange Transmission Systems as a Guide to National Network Planning – 1988 (GAS 3).

Economics and Technical Aspects of the Choice of Transmission Systems – 1986 (GAS 3).

General Network Planning – 1983 (GAS 3).

ABU-FES-ITU Seminar: "Adoption of New Media Technologies: Trends, Opportunities and Issues" – Kuala Lumpur, 20-21 February 1995.

Seminar on New Technologies in Sound and TV Broadcasting – Brasilia, 1994.

Manual on Mobile Communication Development – Geneva, 1997.

ITU-R Sector

Handbook on Spectrum Monitoring (1995).

Handbook on National Spectrum Management (1995).

Handbook on Digital Television Signals: Coding and Interfacing within studios (1995).

Handbook on Satellite Communications (Fixed-Satellite Service) – Second Edition 1988.

Supplement No. 2 to Handbook on Satellite Communications: Computer Programs for Satellite Communications (1993).

Supplement No. 3 to Handbook on Satellite Communications: VSAT Systems and Earth Stations (1995).

Construction, Installation, Jointing and Protection of Optical Fibre Cables (1994).

Introduction of New Technology in Local Network (1993).

Handbook on Transmission Planning (1993).

Handbook on Outside Plant Technologies for Public Networks (1992).

Handbook on Land Mobile:

Volume I: Wireless Access Local Loop.

Volume II: Principles and Approaches on evolution to IMT-2000/FPLMTS.

ITU-T Sector

Optical Fibre System Planning Guide (1989).

Application of Computers and Microprocessors to the Construction, Installation and Protection of Telecommunication Cables (1994).

ITU-T Recommendations – Series E: Overall Network Operation, Telephone Service Operation and Human Factors.

6.9 List of abbreviations

ADM	Add Drop Multiplexer
DXC	Digital Cross Connect
GII	Global Information Infrastructure
GMPCS	Global Mobile Personal Communications by Satellite
HDTV	High Definition Television
LAN	Local Area Network
LII	Local Information Infrastructure
OAM&P	Operation, Administration, Maintenance and Provisioning
ONA	Open Network Architecture
PCM	Pulse Code Modulation
PDH	Plesiochronous Digital Hierarchy
PSTN	Public Switched Telephone Network
PTO	Public Telecommunication Operator
RSO	Regional Standardization Organization
SDH	Synchronous Digital Hierarchy
STM	Synchrony Transfer Mode
WRC	World Radio Conference

ANNEX 6A

Alcatel's approach for Network Planning for Developing Countries

1 Introduction

Telecom networks in the developing countries are based on core switching networks with hierarchical structures and point-to-point transmission. However, these networks cannot meet the rapid growth in demand for traditional and new services which is characteristic of these countries. Consequently, there is a need to plan and deploy flexible evolvable network infrastructures that can adapt to meet this rapidly changing demand.

The introduction of digital switches that can handle non-hierarchical traffic schemes, Synchronous Digital Hierarchy (SDH) transmission, and modern access techniques mean that existing network architectures will have to change, posing major challenges to the operators.

Figure A1 – Relationship between design tools and network layers

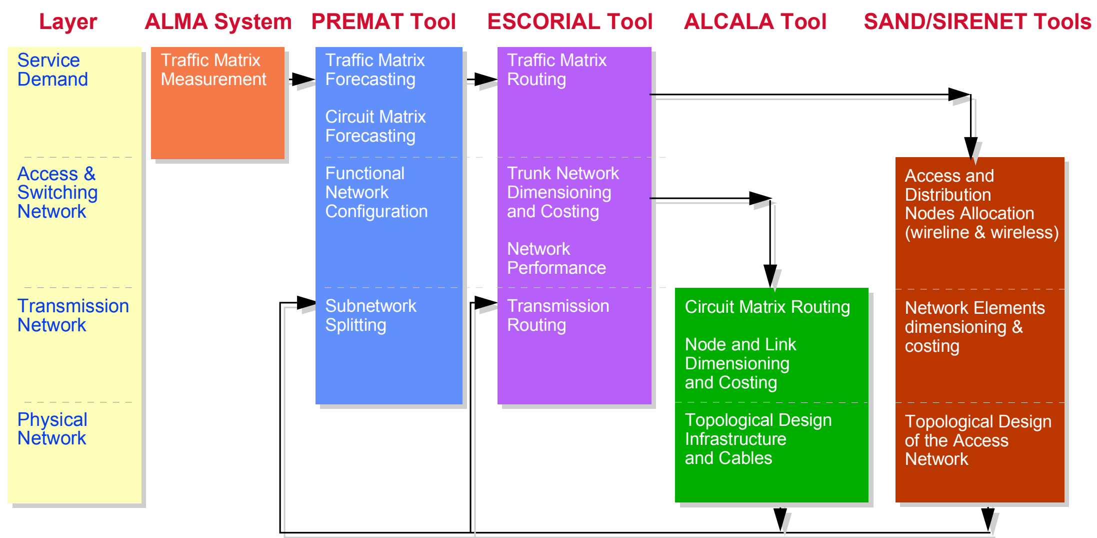


Figure A1 illustrates the sequence of tasks, and the related planning tools, involved in planning a national area. The planning process is iterative because the network structure changes during the planning period, affecting both the solution and costs (switching, transmission and access). For example, the transmission network solution produced by the ALCALA tool can modify the transmission cost and configuration assumed in the ESCORIAL network model. Second iterations of the switching network design (ESCORIAL) and transmission network design (ALCALA) refine the optimal global network design and evolution.

Furthermore, network traffic can change during the planning period as services evolve, quick actualisation of traffic with management systems (ALMA) and application of the telecom planning system [1,2] with the tool chain (PREMAT, ESCORIAL, ALCALA, SAND/SIRENET), allows the network operator to define and optimize network evolution.

2 Demand Forecasting

The PREMAT tool includes forecasting methods and algorithms to define network demand evolution based on the actual demand matrix; it can calculate the network demand matrix for any year in the planning period. Starting with network service data and traffic measurements, the traffic matrix between existing exchanges can be calculated; it is also possible to determine the total traffic originated and terminated in each exchange service area.

Prediction techniques based on incremental changes in activity in similar zones can forecast the demand increase per zone. Based on the demand distribution, the projected network can be cond, service areas reassigned and the total future traffic per area estimated. Once this information has been compiled, the planner can select from PREMAT's six basic mathematical models (Double Factors, Unitary Traffic, Matritial, Interest Factors, Affinity Factors, Similarity Coefficients) and three combined methods to obtain the future traffic matrix distribution.

PREMAT considers all the traffic flows in a multiservice network (voice, circuit, packet, Intelligent Network, Internet, etc.). Several service class matrices can be integrated in the final one. Integration can be done in the present matrices or the projected matrices.

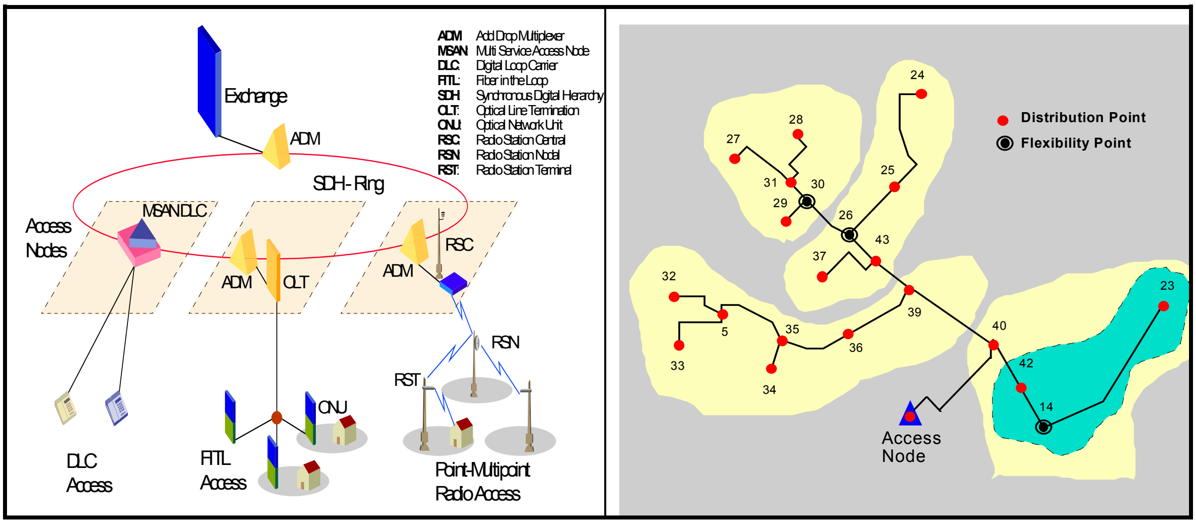
Network evolution is supported by methods and facilities for splitting the global matrix into smaller matrices, corresponding to subnetworks, and for matrix integration with area reassignment.

3 Access Network Structure

In most developing countries, the national telecom network is a multi-level network. This will evolve to a modern two-level network consisting of an upper transit interurban and international nodal network level and a local level that includes urban/metropolitan or regional/rural networks. Countries are structured into nodal areas that cover regions, with nodal switches concentrating the long-distance (interurban and international) traffic. Local/metropolitan networks also have a two-level structure, consisting of transit exchanges that manage the urban or interurban traffic and local exchanges for subscriber access.

Subscriber access was traditionally based on copper cables to a local exchange or Remote Subscriber Unit (RSU). Rapidly growing networks can now justify solutions based on multiservice access network (see Figure A2) using technologies like Fibre In The Loop (FITL) and Digital Enhanced Cordless Telecommunications (DECT).

Figure A2 – Structure and one of the topologies of the access network



Regional/rural networks consist of primary switching units that are accessed via RSUs or Point-to-MultiPoint (PMP) and DECT radio systems.

Access network planning is used to select a suitable access solution, allocate the Network Elements (NEs), and dimension the NEs and transport subsystems according to demand. This includes services and their distribution, taking into account the demography and geography of the subscriber area. This planning process consists of four fundamental steps [3].

The first considers demand characterization for services, based on the requirements imposed by individuals or groups of subscribers.

The second step leads to a description of the functional network, estimating and/or optimizing the number, type and size of service areas, taking into account those areas inherited from the switching layer.

The third step focuses on optimizing the dimensioning of the technology that is used for communication between subscribers and the network termination units. This connection could be provided by a range of technologies, such as copper, fibre or radio links. It should be emphasized that radio technology has acquired considerable importance in rapidly developing countries because of its low cost, rapid deployment and resource limitations.

Finally, a fourth step optimizes the technology used to connect the network terminating units to the Public Switched Telephone Network (PSTN). This includes both the equipment installed in the node and the network topology (see Figure A2).

This approach was implemented in the SAND and SIRENET tools that Alcatel uses to plan its wireline, wireless and mixed access solutions [3, 4].

4 Switching Network Design

The next planning step is to optimize the trunk network for hierarchical or non-hierarchical structures, select the best configuration for the planning year, and define how the structure will evolve [5].

4.1 Design Tools

The ESCORIAL tool set uses the traffic matrices calculated by PREMAT to define the optimal trunk network for the appropriate year, together with the transition phases. The tool models apply to the switching and transmission layers of the network.

Traditionally, two network models have been distinguished: functional and physical. The first deals with traffic routing, and the second with the routing facilities:

- *Switching network model:* Considers the logical network structure (alternative routing schemes and traffic models) for network dimensioning in accordance with the network grade of service objective and the combined switching and transmission costs in order to optimize network economics.
- *Physical network model:* Considers the costs of the transmission network (cable infrastructure and transmission systems), represents the geographical layout of the network. It selects the minimum cost paths for node-to-node interconnections.

Hierarchical networks

The ESCORIAL-H module [6] is used to optimally dimension multi-level hierarchical trunk networks with a maximum of 1152 exchanges. It implements methods and algorithms [7] for dimensioning one-way/two-way links and network optimization based on marginal costs. Studies have shown the accuracy of the results.

Non-hierarchical networks

The ESCORIAL-N module [6] is used to design, analyse, optimally dimension and cost circuit-switched two-level networks using non-hierarchical sequential traffic routing in the upper transit level. As an option, it can dimension the network with trunk reservation parameters, different routing schemes and different levels of physical or functional security.

Trunk reservation protects the first traffic offered to a link to prevent network instability and service degradation as a result of overloads.

The network structural security option implements switching security by duplicating transit exchanges and link interconnections in the upper level, and transmission security by providing two separate physical paths per route. Another option analyses the network for different (planner defined) trunk group dimensions, and calculates the grade of service for each origin-destination pair.

4.2 Network Transition

Countries in which traffic demand is growing rapidly need a switching network which has the flexibility to allow rapid evolution, and adequate security to prevent network performance being adversely affected by service interruptions. The cost of achieving these objectives is of prime importance because of the limited financial resources of many developing economies.

The Alcatel tool set can evaluate various structures and alternatives, based on least-cost network evolution, ranging from multi-level hierarchical networks to two-level non-hierarchical networks. Evaluation is carried out in two phases. The first phase cons the upper network level, reducing the primary, secondary and tertiary network levels to a single (fully digital) level equivalent to the interurban transit level of non-hierarchical networks. The whole network is evaluated by splitting the country transit service areas and regrouping the network exchanges (homing to transit exchanges).

For the same time frame, exchanges in the network lower level that concentrate interurban traffic (urban and rural areas) are selected and exchanges are digitized. This significantly reduces (by about 25%) the number of exchanges to be considered in the two-level long distance network.

To optimize the alternatives, the upper level network model considered is a complete mesh network interconnecting the nodes of the upper level and using alternate non-hierarchical traffic routing schemes. The lower level is connected to the upper level by a star network, complemented by direct connections to other exchanges when economically justified (only high traffic routes will be selected).

The second phase considers the link interconnection between upper and lower level switches, including switch digital replacement in particular cases, rehoming switches to other transit regions and interconnection to the new transit switch. In selected cases, links with other regions will be established. These changes will be implemented in the medium term.

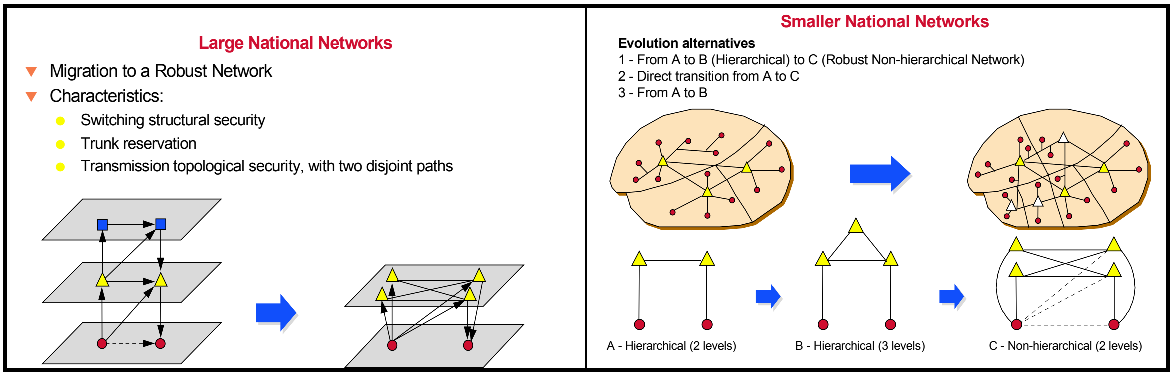
The result of this network evolution is a two-level network with non-hierarchical sequential traffic routing in the upper level (see Figure A3).

Modern multiservice networks impose stringent grade of service and availability requirements. Structural security network models [6] have been used in such cases (e.g. the PSTNs in Spain [8] and France); network evolution follows the same two phases.

5 Transmission Network Design

The introduction of SDH technology in the transport network is a major step, which follows the logical evolution of networks in rapidly growing communities. ALCALA is a tool for designing transmission infrastructures and SDH solutions.

Figure A3 – Evolution of a multi-level hierarchical network to a two-level network



5.1 Design Tool

ALCALA uses the services circuit matrices produced by ESCORIAL and PREMAT to calculate the topological design of the physical network (infrastructure and transmission cables). In doing so, it optimizes the assignment of SDH network equipment: Add/Drop Multiplexers (ADMs), Digital Cross Connects (DXCs), Optical Line Terminations (OLTs), regenerators, etc. The objective is to design, optimize and cost SDH transmission networks. This planning process is supported by a methodology, developed by Alcatel, which structures the overall process in steps: topological design of the physical network, network configuration, optimized circuit routing, equipment dimensioning, costing, and demand availability analysis [9].

ALCALA designs highly survivable networks using SubNetwork Connection Protection (SNCP) and Multiple Section Protection Ring (MS-SPRING) protected ring networks, as well as meshed networks with different protection and restoration mechanisms, such as path diversity, hot standby, and direct paths. The most suitable ring structures are generated semi-automatically by ALCALA [10], which simultaneously considers various transmission speed demands. Optimal dimensioning is done on the basis of a flexible multivendor equipment catalogue.

5.2 Transmission Network Evolution

In line with evolution of the core switching network, the long distance transmission network will also have a two-level structure.

The upper level, which concentrates the traffic and requires bigger bandwidths, can justify mesh or ring network structures. The tool evaluates each network case and selects the optimal solution (see Figure A4).

The best solution for interconnecting the upper and lower levels will be a star or multi-ring network, or a combination of the two. Evaluation and selection are supported by the tool.

The tool model applies to the physical (infrastructure, carriers) and transmission layers of the network in such a way that it equates transmission network design to the switching network configuration. As an example, A5 illustrates an SDH solution for a relatively low bandwidth transmission backbone, which could be starting point for a developing country. In this case, the network could be implemented using ADM equipment.

Figure A4 – Transmission network layering: core and regional networks

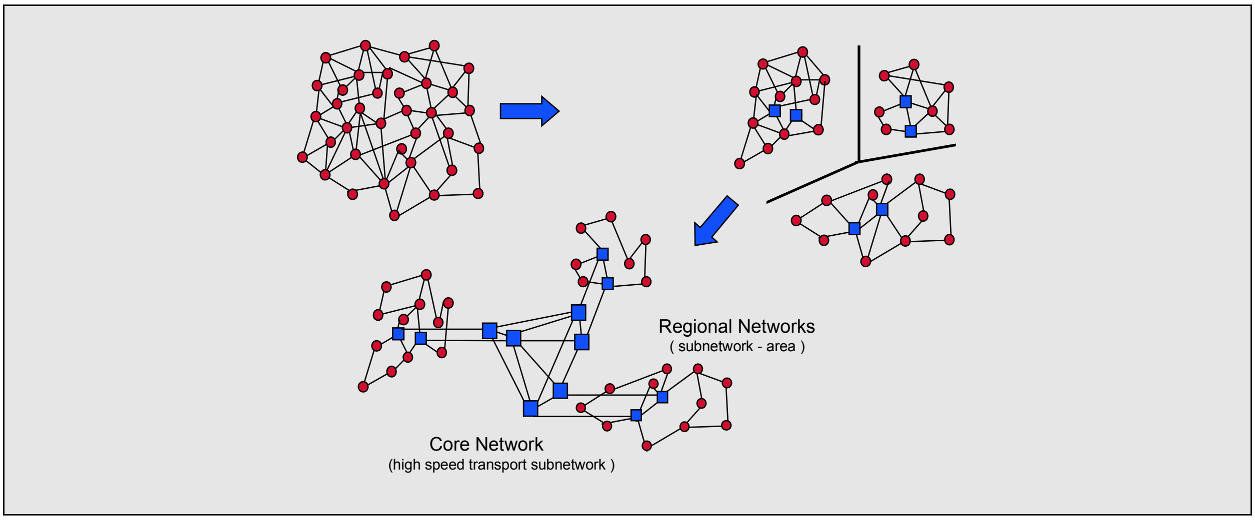
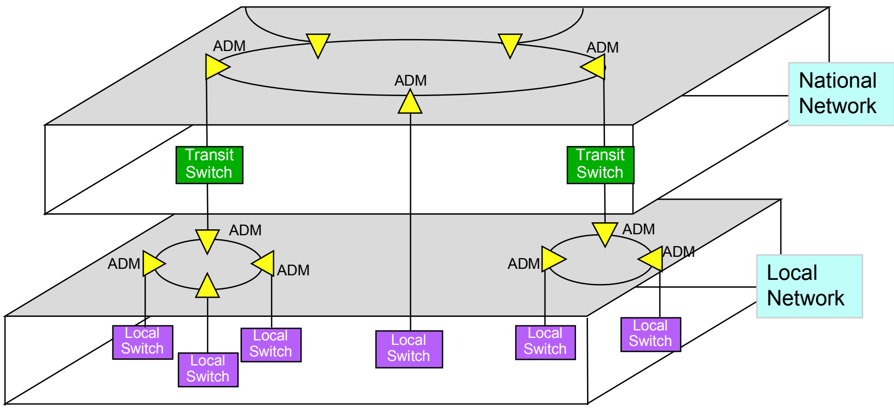


Figure A5 – Two-level ADM-based solution



ALCALA supports two network design tasks, the first of which is configuration and topological design. Taking into account the switching configuration and existing outside plant constraints, it selects suitable mesh or multi-ring network structures.

The second task is SDH equipment dimensioning and interconnection to the switches, taking into account the required protection schemes. All the proposed solutions are optimized from the cost point of view.

6 Traffic Measurement and Management

Using the traffic measurement facilities (implemented in the switch nodes or network management system), the actual traffic matrix can be calculated. Alcatel ALMA traffic [11] uses the Traffic Data Analysis System (TDAS) to calculate the network traffic matrix.

The network traffic data collection system provides the following measurements:

– Traffic flows per exchange (originated, terminated, incoming, outgoing, transit).

– Traffic flows per trunk group (incoming and outgoing).

– Traffic interest factors. The traffic per destination for each exchange.

The traffic data processing and analysis system uses this traffic data to process the information for reference days of the year or to calculate statistical mean values along the year. The result is the actual network point-to-point traffic matrix and the interest factors matrix. In addition, the Traffic Analyst uses the forecasting tools provided by the statistical analysis system to forecast (for each traffic zone/exchange area) the number of subscribers and the total traffic (originated/terminated) for a given moment or year in the future. This data is used as the input to PREMAT

7 Network Examples

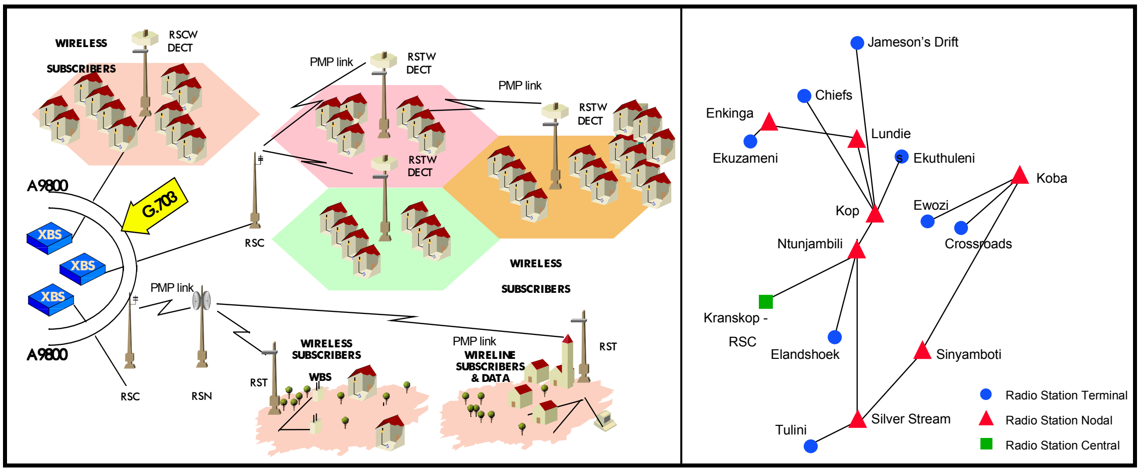
New technologies are now bringing telecommunications to many of the world's developing countries. The first step is to determine the most appropriate solution for each country. Here Alcatel network planning can be a decisive asset, helping national operators to make the right choices regarding the evolution of their telecom networks.

The following real case studies, chosen from many [12], show how Alcatel is helping to bring telecommunications to people all over the world.

7.1 Access Network Planning in South Africa

In South Africa, basic telephone services are being brought to communities in rural areas and small townships by an Alcatel 9800/DECT overlay network.

Figure A6 – Alcatel 9800/DECT integrated solution showing a diagram of the Kranskop area



Alcatel is providing 288 000 lines of radio access equipment to the South African operator Telkom. The rural area of Kranskop (see Figure 6) has been selected as a pilot planning application with the objective of the exercise to locate and dimension the Alcatel 9800/DECT equipment. An exchange (Radio Station Central or RSC) serves the whole area via a point-to-multipoint microwave network.

The Alcatel 9800 system consists of a base station controller, a central controller, 17 remote base stations, 34 DECT base stations and 500 DECT first generation wireless network terminals.

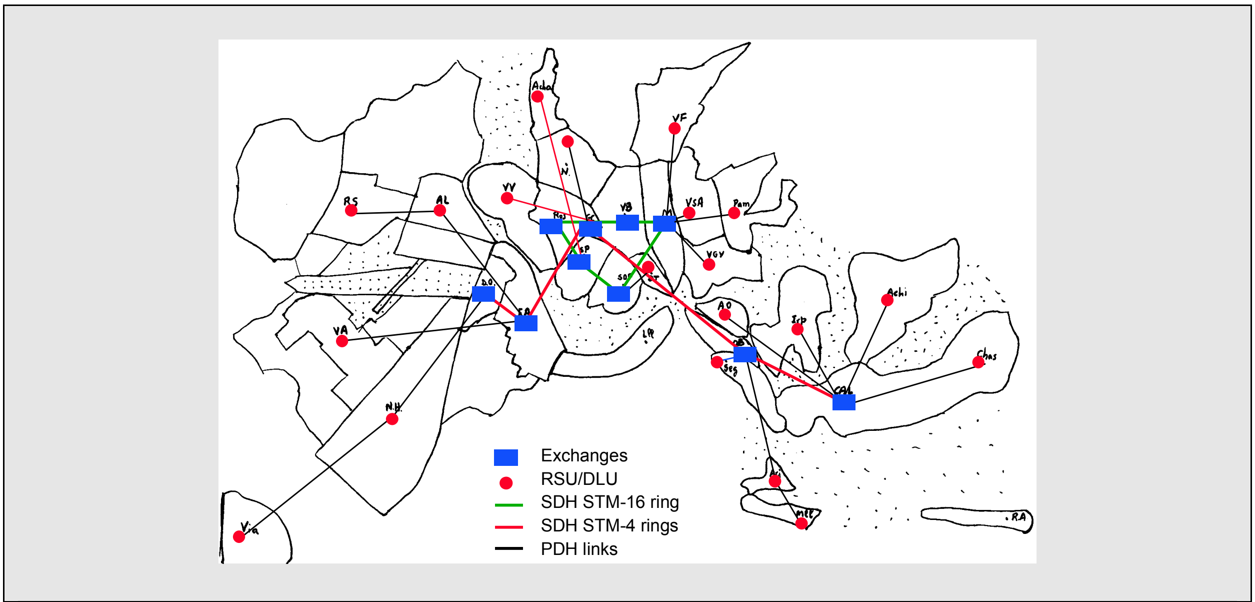
In this case, the network planner used the SIRENET tool to design the optimal solution. Features of the tool include: coverage plots for single or multi-site networks; local electromagnetic compatibility and spectral analysis; interference maps, frequency assignment and cellular planning; different propagation models; optimization procedures for station location, dimensioning, etc; and a range of databases (cartographic, frequencies, equipment, sites, stations, regulations).

7.2 Metropolitan Switching Network for La Paz

The metropolitan area of La Paz in Bolivia has a population of 1.36 million with a telephone penetration rate of 9%. COTEL, the telecom operator, is planning to fully digitize the network (40% of lines are analogue) and expand it to meet a 33% increase in demand over the next 3 years.

Network planning started with a macro demand forecast and traffic characterization to define the telecom service objectives for the year 2000.

Figure A7 – La Paz metropolitan network



Switching network design led to the definition of a two-level network configuration with ten switches (three new) and an access network consisting of RSUs, DLUs (see Figure A7) and a radio access overlay network.

Transmission network design resulted in an SDH 3-ring structure interconnecting the exchanges and a mix of existing Plesiochronous Digital Hierarchy (PDH) and new SDH links for the access network.

Alcatel's network planning tools and expertise supported the main results of the study, which provide the telecom operator with clear solutions to its need for network evolution.

7.3 SDH Transmission Network Design in Bangladesh.

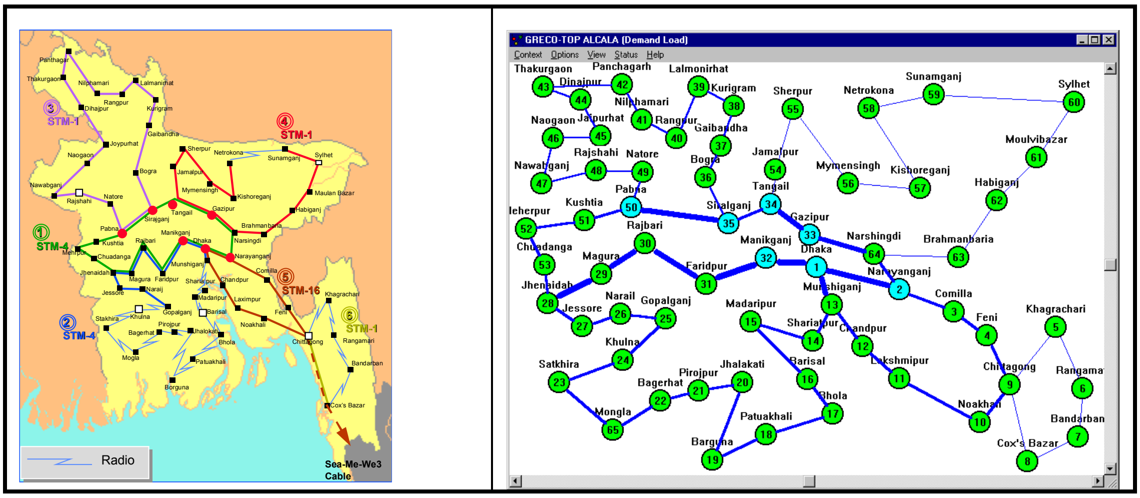
Bangladesh is one of the most populated countries in the world, with 126 million inhabitants at a density of 875 inhabitants per square km. Overall development is frequently limited by economic factors. Bangladesh has a Gross Domestic Product (GDP) of 265 US$ per capita, a relatively low inflation rate of 4%, and annual growth of 5.7%.

Currently the telecom network has about 450 000 installed lines, more than third of which have been supplied by Alcatel in the past three years. The penetration rate is just 0.37%. The backbone transmission network is based on point-to-point PDH radio links which interconnect more than 100 transit and local switches.

The Bangladesh Telephone & Telegraph Board (BTTB) faces the difficult and complex task of defining the future network in the face of network evolution, the introduction of new telecom services (mobile, data transmission, Internet, etc.) and new telecom actors (private fixed and mobile). Any solution must provide an effective telecommunication network that takes into account local geographic conditions (the country is crossed by numerous rivers and streams) and existing infrastructures (installed equipment, highways, bridges, etc.).

One of the most important components of the network is the transmission backbone. BTTB took a strategic decision to move away from point-to-point PDH and implement a resilient nationwide structure based on SDH technology. Two main questions had to be answered: "What would be the best design for the target SDH network?" and "What would be the optimum evolutionary strategy, starting from the existing transmission network?".

Figure A8 – Planning the Bangladesh SDH transmission backbone network



Alcatel, as the major telecom supplier to Bangladesh, has undertaken a planning study to provide solutions to both these questions, taking into account a variety of economic, geographic and technological factors. This study included the following major stages: existing network analysis, including QoS; traffic data collection and reconstruction; demand forecasting; switching network evolution planning; and SDH backbone transmission network design. Planning and design of the SDH backbone were carried out using sophisticated network planning tools, in particular, ALCALA. B8 shows one of the solutions generated by ALCALA for further analysis and implementation.

8 Conclusions

Telecom operators in developing countries are faced with the challenge of defining their future needs for network capacity and services. This problem is made more difficult by the fact that many of these networks are growing rapidly. Alcatel is helping many of these operators both to develop network solutions that will meet their immediate needs and to define optimal evolutionary strategies.

Sophisticated planning tools are the key to achieving these objectives. The methodology and tool chain solves the problems of analysing network evolution in the switching, transmission, and access networks.

The integration of network planning and traffic management data systems make it possible to obtain practical network solutions very rapidly, ensuring that the planning process keeps abreast of frequent changes in traffic or network requirements.

9 References

[1] *Telecommunication Planning System for Integrated Design of Modern Networks*, by M. de Miguel, O. Gonzalez Sotto and J.M. Silva, 6th World Telecommunications Forum, Technical Symposium, Geneva, 1991.

[2] *Planning of Competitive Networks*, by P.A. Caballero and O. González-Soto, Alcatel Telecommunications Review, Telecom 95 issue, 1995.

[3] Access Network Planning: *Methodology and Tools*, by E. Lafuente and JL. Roncero, Alcatel Telecommunications Review, 3rd Quarter 1996.

[4] *Multilevel Local Access Network Design,* by A. Nitchiporenko, J. Barbas and A. Marin. 15th International Teletraffic Congress (ITC-15), Washington, USA, 1997.

[5] *Solutions for Telecom Network Evolution to non-hierarchical structures*, by M. de Miguel, A. Nitchiporenko, I. Puebla, 15th International Teletraffic Congress (ITC-15), Workshop Traffic Engineering for Developing Countries, Washington, USA, 1997.

[6] *ESCORIAL, the tool for planning advanced National Networks with security*, by M. de Miguel, A. Bartolome, F. Martín. 13th International Teletraffic Congress (ITC-13), Copenhagen, Denmark, 1991.

[7] *Some aspects of the dimensioning and optimization of digital networks in both-way circuits*, by M. de Miguel and F.J. de los Rios. 10th International Teletraffic Congress (ITC-10), Montreal, Canada, 1983.

[8] *Evolution strategy of the Telefonica Network*, by J. Linares. NETWORKS´89, Majorca, Spain, 1989.

[9] *Planning of High Capacity Transmission Networks with Flexibility*, by E. Lafuente, C. Alcazar and A. Lardies. NETWORKS'94, Budapest, Hungary, 1994.

[10] *Efficient Ring Creation Procedure for Design of SDH/SONET Transmission Networks*, by A. Nitchiporenko, A. Mata-Rodríguez and J. Yañez. 5th Int'l Telecommunication Systems Modeling Congress, Nashville, USA, 1996.

[11] Alcatel 1340*, ALMA-Traffic Management*, Doc 2580001 (Edit 02), Alcatel 1997.

[12] *Network Planning in Low Density Areas*, by P.A. Caballero, Alcatel Electrical Communication, 1st Quarter 1995.

ANNEX 6B

An example of a strategy for local information infrastructure planning

A common characteristic of developing countries regarding the development of telecommunication infrastructure, and especially the introduction of new telecommunication services, is uncoordinated planning as a consequence of a lack of a strategy. There are several reasons for this: lack of financial resources, limited number of sufficiently qualified personnel, undefined regulations which primarily in regard to new services have no chance to match the international standards and, by historical inheritance, monopoly of incumbent PTO.

As far as the concept of the Information Society is concerned, it is very difficult to define it, especially in developing countries. The visions outlined are transformed differently into strategy and policy frameworks, depending on the situation in the particular country. It is clear that in developing countries, at this moment, rapid integration into the Information Society (IS) can not be planned. However the definition of a strategy which, in some later implementation stage will make this integration easier, must be considered in time. Implementation of Local Information Infrastructure (LII) represents a very significant part of such national IS strategy. Its consideration includes a number of components which must be analysed:

– existing situation in the core network (core segment);
– existing situation in the access network (local segment);
– requests for new services;
– available technologies;
– available human resources to apply new technologies;
– financial capabilities.

On the basis of such analyses an adequate strategy for building local telecommunications infrastructure capable of supporting IS applications in developing countries must be defined through the following main segments, mutually correlated in a manner illustrated in Figure B1:

1. recognition of end users' requirements;
2. government and regulator actions in creating an environment favourable for IS;
3. identification of appropriate access technology;
4. implementation of financial techniques necessary for new investments.

Such a strategy must be a part of an overall governmental policy regarding other aspects of IS deployment, which should be institutionally managed.

Elements of LII Strategy

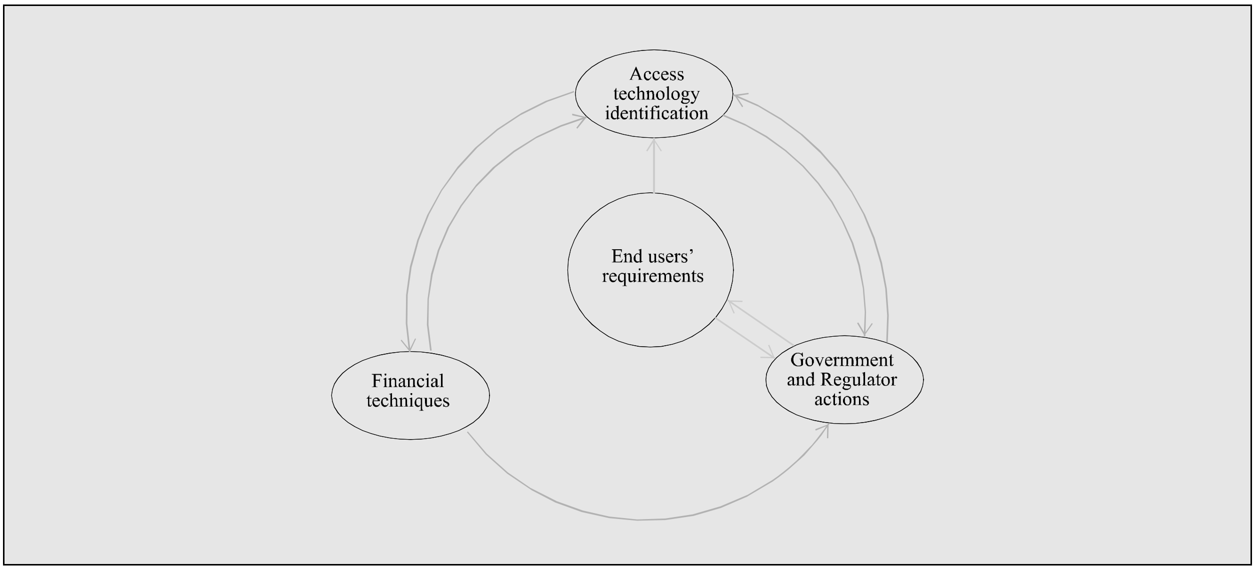
1 End User's Requirements

It is well known that most telecom users in developing countries are voice services oriented and have not yet obtained the experience for using and handling other types of information. However the emerging deployment of computers by the existing telephone subscribers and the establishment of many small and medium-scale companies, using information systems for business support, pose new demands on all involved in service provision. These new types of users expect:

– easy access to information, entertainment, education possibilities and communication;
– cheaper communication;

– possibility of choice between different service and content providers and last but not least;
– to have other choices than leased lines to access National Information Infrastructure (NII), or even Global Information Infrastructure (GII).

Figure B1 – Segments of LII Strategy



Thus, users are surrounded by decisions and solutions being drawn up by governments, regulators and operators, as well as service and content providers. Therefore the strategy for starting of LII implementation must capture existing knowledge and experience of user behaviour and needs, as well as their motivations for LII. In this way information on potential customer bases, attractiveness of different services and economic aspects of user requirements will be provided. It will enable exact understanding of user positions and will be used for supporting and guiding other segments of the strategy.

2 Role of Government and Regulator

The governments of developing countries must view the process of IS implementation as an opportunity for modification of the counties economic structure. The government, in the first place, has to realize that the IS economy paradigm is driven by knowledge-intensive sectors which directly utilize information and communication technologies. Thus, it is necessary for the government to intensify activities on promoting such multimedia industries which can contribute to attracting investments and create employment. Also, encouraging market development is one of the main preconditions for that process which has to be government initiated.

To achieve these goals the government has to define its own national info-communication policy based on:

– Encouragement of private sector investments;
– Promotion of competition;
– Creation of a flexible regulatory environment with independent regulator;
– Promotion of a strategy for Universal Service Obligations (USO).

The last item is of special interest for developing countries. Usually, universal access is understood as obligation imposed on the PTO to provide telephone access to every one who asks for it, for the same access fee everywhere in the country in the same time period. The role of the regulator is to assure this obligation. On the other side, regulator should be aware of new user's requirements and considered changes in regulation towards new definition of Universal Service supporting advance services for users who are able to pay for it.

For this reason, a full understanding of:

– the needs of customers or communities for infocommunication,

– the means of meeting these needs with new technical and service solutions,

– the validation of the use to which the communications is put,

– which infrastructure (the existing or new) will support the implementation of infocomunication services, and

– which sequences and timing are required to provide new type of universal access for advance services.

will help to formulate an appropriate approach for implementing Universal Service and Universal Service Obligation. Depending on the situation in the country, the approach to supporting new entrants at the local level may vary from strict Universal Service Obligation to no USO.

Apart from that, a regulator has a number of other tasks in preparing an adequate environment for IS promotion and its implementation from local to national level. These include:

– creation of a flexible regulation framework in order to facilitate entry for new network operators,

– promotion of access to info-communication services by creating a suitable tariff policy,

– preparation of standards to enable easier network and service modernization towards implementation of a new LII and national/GII,

– implementation of contract principles between interconnected partners in case of multi-network strategy in local loop.

3 Access technology identification

It is well known that IS applications although becoming easier to use require more bandwidth. Even in developed countries this represent a serious constraint, since their networks can hardly cope with increasing end user's demand for local-access bandwidth. Of course, the problem they have could be used in developing countries to help the prevailing strategy that is based on "leapfrogging". Thus eliminating entire stages of local network development in the setting up an adequate infrastructure avoiding unnecessary delays.

Table 1 illustrates various access networks, presently available for high-speed (wide-bandwidth) digital (data) access. For a long time, analogue modems were the only available solution for obtaining access to backbone networks. Where developing countries are concerned, it is still the technology with the highest deployment. Fortunately modem speeds have increased, approaching 56 kbit/s downstream and 33 kbit/s upstream, with standardized 34 kbit/s modems still dominant for dial-up remote access.

However, in the past few years new access technologies have emerged, providing full-duplex high-speed access at speeds of several Mbit/s and offering new opportunities especially for developing countries. These are xDSL networks, cable modem networks, various optical networks, wireless networks and satellite networks. Table B1 also shows typical speeds obtained using specific types of access network.

Table B1 – Characteristics of different access technologies

Access technology		Provided services		
		Voice	Data	Video
Dial-up PSTN + modem		1 channel	9.6 kbit/s to 33.6 kbit/s	Slow
BR-ISDN		1 channel	64 kbit/s or 128 kbit/s	Video conference
Cable modems		Possible	2 Mbit/s to 10 Mbit/s (one-way)	Broadcast
xDSL	HDSL	30 channels	2 Mbit/s	Video conference
	ADSL	1 channel	640 kbit/s – upstream 6 Mbit/s – downstream	On demand
Optical fibre		up to 100,000 channels and over	up to 10 Gbit/s	multi-HDTV, interactive
Wireless		Variable	up to 128 kbit/s	Depending upon type
Satellite		Depending upon type (128 kbit/s to 40 Mbit/s)		

It is obvious that access technologies can be classified into two categories, wireline and wireless. Each of them can be separately analysed from the point of view of the specific requirements, resources and availability in developing countries. In order to be able to choose the access technology necessary to meet the particular implementation challenges following criteria have to be considered:

– already existing network structure (core and local),
– demands for IS services,
– costs of implementation,
– capability of delivering broadband services,
– technological complexity of access network,
– performance of services offered by certain access technology,
– ease of planning ,
– ease of network growth through modularity,
– ease of access from the end user side.

A significant correlation exists between the choice of access technology and the other segments of LII strategy that makes the choice even more difficult. However using given criteria, comparison of all relevant wireline and wireless solutions will show that some of them have significant advantages where developing countries are concerned. For example WLL represents one of the most suitable new possibilities for delivering broadband IS applications to end users in a fast cost-effective way. Its advantages can be summarized as:

– lower initial investments,
– lower operational costs,

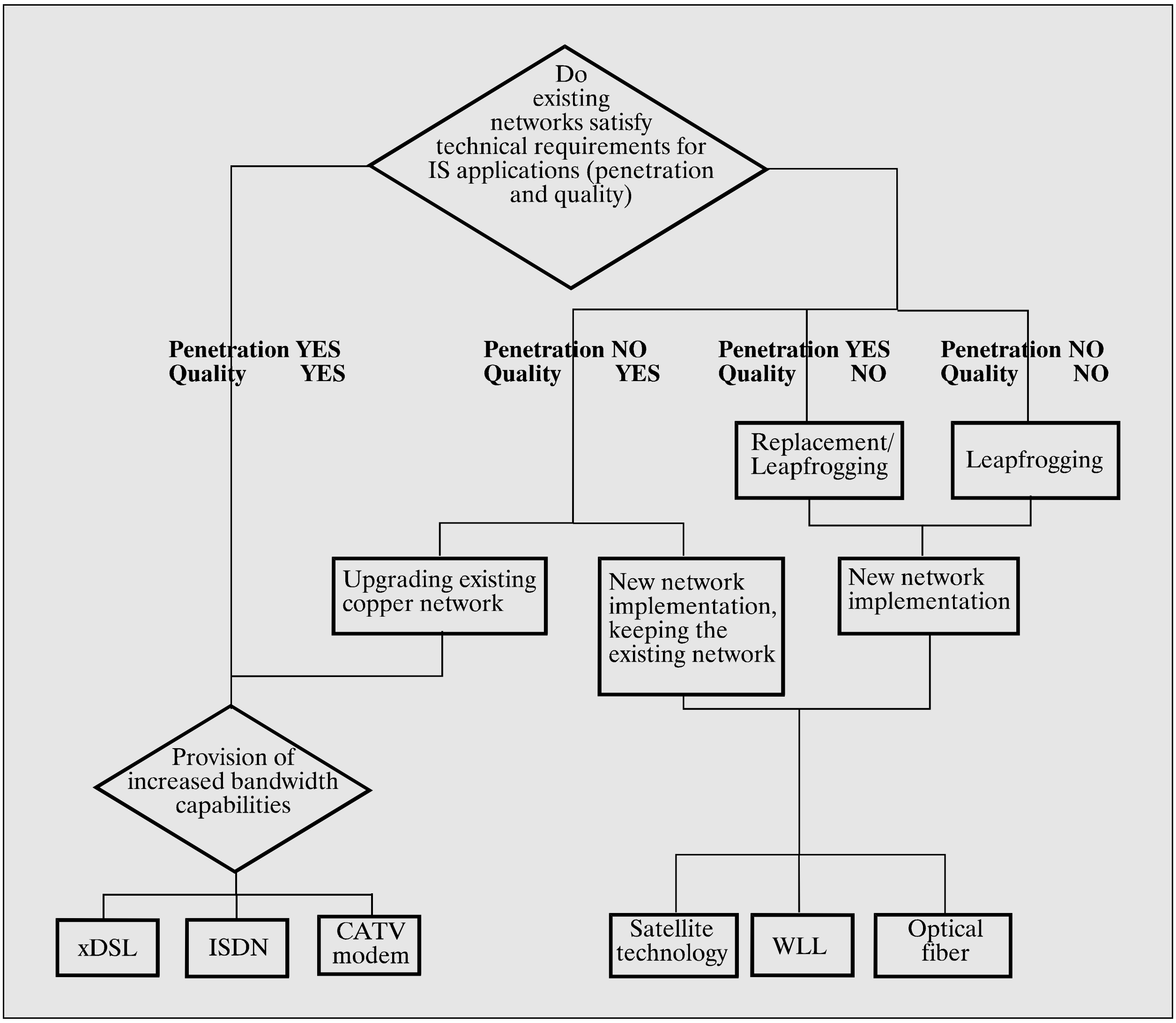
– broader range of architecture over single platform,

– faster deployment,

– better network flexibility.

Figure B2 illustrates an algorithm based on technical performance criteria that can be used in the process of identifying appropriate access technologies, taking into account that existing local networks are dominantly voice oriented. The proposed algorithm includes all possible scenarios and could be of significant help in finding an optimal choice and for managing the network modernization.

Figure B2 – Algorithm for identification of appropriate access technology



4 Financial techniques implementation

It is a fact that an unprecedented amount of capital investment will be necessary even for the first stage of IS deployment in developing countries. Although governments still have significant ownership of existing info-communications assets in developing countries, investments financed from that source are decreasing steadily. Therefore new techniques for obtaining the necessary capital must be identified. Basically, success of that process will depend firstly on business fundamentals and economic market conditions, and secondly on innovative financing techniques and structures. A number of techniques can be employed for project financing and they are mainly oriented towards private sector capital involvement. These are:

– joint ventures,

– blt (build-lease-transfer method), particularly applicable for projects which involve additions to existing networks,

– bot (build-operate-transfer method), with the possibilities to turn the ownership of the project to another local owner,

– vendor and supplier financing, used for equipment financing,

– high yield debt, suitable for institutional investors in high risk markets.

To create this shift from traditional public sector operators and government funds, the governments of developing countries have the responsibility for removing many present constraints that might limit the full benefit of these new financial arrangements. Therefore, to attract financing from the private sector the government has to ensure:

– an open and stable market economy,

– a regulatory framework that reduces unpredictability for investors,

– true competition at the local level as well as on higher network levels,

– a competitive procedure for licensing,

– an adequate tariff policy.

Thus, it is clear that this Segment of LII strategy strongly depends of government and regulatory actions taken in fostering is deployment. On the other hand, success in obtaining necessary capital will determine the possibilities for implementation of the access technology chosen on the basis of technical performance criteria.

Literature:

M. Pejanovic, N. Gospic "Strategy for implementation of Local Information Infrastructure", Development Summit, TELECOM 99, Geneva.

CHAPTER 7

7 Human resources aspects

7.1 Introduction

This chapter focuses on the main aspects of Human Resources Management (HRM) in terms of organization, staffing and training which are relevant to the introduction of new technologies and services and to set these issues in the wider context of overall structural reform in the telecommunications sector.

The main challenge for those responsible for human resources management is the fact that the modernization process, covering not only technological but also commercial, organizational and administrative, can give rise to changes at every level in the organization which have to be assimilated within time-frames that are very short in comparison with the existing level of organizational inertia.

7.2 Organization

In the context of overall organization, the management culture of the telecommunications entity and its legal status are important. Many developing countries are transforming their telecommunications sector from service driven utility monopolies to customer focused, commercially run organizations.

The pressure to undertake such structural reform increases with the introduction of new technologies and services. This is because flexibility in decision making and responsiveness to the market environment is required and these are comparatively rare in organizations run along traditional public sector utility lines.

7.2.1 Improving Market Orientation

Central to the successful introduction of new services is the recognition of the importance of proper market planning and implementation and the organizational consequence of this is the setting up of a marketing directorate or department. The marketing function seeks to ensure that customer’s needs are matched with available or planned services and the main responsibilities of the function are market research, new produce service development, pricing and promotion.

The concept of account management is important in improving market orientation. In the past the norm was to organize the sales force according to product or service. This approach had the perceived advantage of enabling the salesmen to become very knowledgeable about their product. However, the approach had distinct disadvantages from the customer's viewpoint. Multi-service customers had to deal with a number of different salesmen; salesmen could compete with each other in trying to meet the customer’s needs and nobody had an overview of the customer’s global needs.

The account management approach seeks to overcome these problems by designating an account manager as the primary point of contact for the customer. Account managers tend to be assigned according to market segment (banking, shipping, travel etc.) and become knowledgeable about the customer's business and overall communications needs. These account managers can form a close working relationship with customers and help them identify solutions to their telecommunications problems.

Other organizational units also require re-focusing in order to improve customer satisfaction. The operation and maintenance staff in contact with customers should be trained in customer awareness and recognize the importance of their interactions. Help desks and customer care centres further enhance the organizations ability to meet customer needs.

7.2.2 Sharpening the Business Focus

The concept of organizing the business management function along the lines of product management is being increasingly adopted by telecommunications administrations. Each product (service) is managed by an individual product manager who has responsibility for all aspects of the marketing mix. This approach is applied to both existing and new services and gives a clear business focus on each service. Clearly, if the sales force (and possibly customer installation and maintenance) is organized on the basis of market segmentation, a matrix management structure is required to accommodate both market and product orientations.

7.2.3 Gender Perspective

It is important to ensure that women's interests are included in preparations for the introduction of new services. Strategies for long-term market development should take into account women as a group of potential consumers of ICTs and that they have specific requirements. Organizations that succeed in responding to all consumers, men and women equally, will achieve commercial objectives and contribute to sustainable human development.

Recognizing that every policy, programme and project affects women and men differently, a gender analysis should be carried out at the earliest stages of project or programme cycle and the findings integrated into project or programme planning.

Using existing ICT applications and networks in new combinations provide women with affordable information and communication services. Telecentres, multipurpose community centres and kiosks are good examples that offer services through co-operative arrangements, micro credit or entrepreneurship programmes.

Special training initiatives and pro-active employment policies should be introduced to encourage and facilitate women's participation in the ICT sector and improve overall capacity to strengthen staff development of women and men equally.

7.3 The impact of new technologies on staff numbers

Technological modernization generally leads to a reduction in the number of staff required to operate and maintain telecommunications networks, whilst in terms of skill levels, these new technologies generally require a higher calibre of staff.

Traditionally external plant has been perhaps the most labour intensive of all activities within telecommunications organizations. However, the introduction of new technologies and associated work practices is having a major impact in this area. The introduction of Computer Aided Design (CAD) and computerized Line Management System (LMS) drastically reduce the staff required in the planning and line plant records functions. The maintenance organization can also be reduced in number as fibre optics trunk and junction cables and jelly filled primary and secondary cables are considerably more reliable than the technologies they replace.

In transmission and switching systems the introduction of Synchronous Digital Hierarchy (SDH) systems and the development of Telecommunications Management Network (TMN) technologies for the remote monitoring and supervision of network elements can greatly increase the effectiveness of the network. At the same time, the centralization of monitoring and control reduces the numbers of expert level staff required and this can be particularly important in situations where the high calibre engineers are in short supply.

At the basic level, the quantification of staff required for the operation and maintenance of the equipment used in new telecommunications services is determined on the basis of the planned methods of working, the experience of other administrations and/or the experience of the system supplier.

It is generally believed that the introduction of new technologies and services triggers labour cuts. This perception has often been the basis of labour and sometimes political resistance to these changes. It is interesting to note that a similar preconception exists when sector reforms that include liberalization are under consideration.

The reality, however, is that the relationship between these two variables (new technologies and services vs. level of employment) is complex and involves a series of factors that are either positively or negatively correlated. Since these factors generally occur more or less simultaneously, it becomes difficult to isolate their true impact. We are, only now, starting to obtain data and facts that help us understand this complex relationship and its implications.

On the one hand, some factors are clearly negatively correlated. Technological modernization generally leads to a reduction in the number of staff required to operate and maintain telecommunication networks, whilst these new technologies require new skills and a higher calibre of staff. New technologies also reduce the staff required in the planning and line plant record functions. New technologies that permit centralization of monitoring and control also reduce the level of staff required for these functions.

Furthermore, many incumbent operators have used new technologies as one of the tools to reengineer their processes and remove tasks and activities that were not adding value in the eyes of the customers/users. These re-engineering activities, often occurring in parallel with those mentioned above, also clearly result in surplus staff.

In our parallel, when sector reforms that include liberalization were introduced, the level of employment of the incumbent operator generally decreased, at least initially, as it could only lose a part of its historical 100% market share.

On the other hand, other factors are clearly positively correlated. New technologies (e.g. cellular and PCS), insofar as they involve the design and construction of new networks, generate new employment in almost all operational departments.

In our parallel, when sector reforms that include liberalization are introduced, the new employment of new competitors is also, as facts demonstrate, a significant addition to the level of employment of the sector.

Furthermore, and this phenomenon is only in its infancy, the deployment of new technologies and services also generates additional employment in other sectors and components of society.

Data is now appearing, almost monthly, that demonstrates that overall the net impact of both negatively and positively correlated factors is that employment is growing in both developing (e.g. Chile, Philippines, China, Malaysia, Vietnam, Columbia etc.) and developed nations (e.g. Canada, U.S., Norway, Sweden, etc.) that pursue these policy and operational objectives.

As an example, the incumbent Canadian carrier (Bell Canada) has lowered its employment level, over the last few years, by almost 40%. These reductions, it should be noted, were the result of a series of voluntary termination packages (i.e. early retirement packages) that did not involve any lay offs of personnel. But new technologies and services, as well as the introduction of liberalization, resulted in additional net employment in the sector. Bell Canada has now over 150 competitors, who employ Canadians. Cellular companies generate significant employment. New PCS licenses were awarded that will result in the creation of 12,000 new jobs in Canada and as a result of these new technologies and services new jobs are being created in other sectors of the Canadian economy.

Facts and data now show that the net impact of the introduction of new technologies and services (as well as sector reform) is positive on the overall level of employment in an economy.

However, it also appears generally that the negatively correlated factors seem to precede the positively correlated factors in their impact. Smaller economies need to exercise greater care in determining the policy issues of timing. This phenomenon forces policy makers and operators to face important managerial challenges. For example, how to minimize the negative short-term impact while maximizing the positive benefits for the overall benefit of the Nation.

7.4 Training in new technologies

Training in new technologies and services is normally offered as part of the equipment supply contracts which procure the technology and the administration must ensure that it is appropriate for its needs and integrate the specific modules into the organization's staff development programs.

Whilst overseas training at the supplier's premises can be cost effective if the numbers to be trained are very small, on site training will normally be much more cost effective. Also on site training gives the organization the opportunity of ensuring more staff have access to training, as well as have more control over the entire process, ensuring that the training courses achieve their stated objectives. There may be "gaps" in the background knowledge of employees undergoing training and these can be more easily identified and remedied if the training is undertaken locally. Similarly any language problems can be minimized.

Investing in the training of in-house trainers and in dedicated training equipment (e.g. training exchange) should also be a priority as it ensures that the skills being taught are renewable and new technicians can be properly trained in future. Also this approach enables the administration to further tailor the training activity to meet its more general staff development needs by providing such possibilities as overview courses for technical managers and technical appreciation courses for non-technical staff. It may also be considered desirable to reduce the reliance on the equipment supplier in the medium to long term.

7.5 The management of change

Modernization continues to be a driving force in telecommunications organizations. But modernization alone is no longer sufficient to ensure the success of the organization unless coupled with changes aimed at improving customer satisfaction. Thus in today's telecommunications organizations, not only must systems and procedures be modernized in line with changing technology, but increasing emphasis must be placed on re-shaping systems and procedures relating to customer service, quality management, management control, etc. and which of necessity involve all areas of the organization.

The scale of change is such that the human resource can no longer be relegated to a secondary level, subordinated to financial, technical and operational issues. HRM must adopt a strategic approach to ensure the ongoing readaptation of the organization's skills base in line with the changing needs. This is an on-going activity, not just performed once during a reengineering exercise.

This in turn necessitates raising the level of the staff planning process. Starting with an inventory of the existing human resources and a vision of the target organization that meets the organization's new objectives, and factoring in such aspects as retirements, resignations, promotions etc., the aim is to plan the optimum reorientation of the human resource across the organization as a whole.

If proposed changes are to succeed, a way must be found for reconciling the corporate objectives with the individual achievement objectives of the workforce. The issues of redeployment and possible staff surpluses are obviously of immense importance to employees and skilful use of systems of communication are necessary so that staff feel fully informed of management's plans; this avoids rumours and misinformation. Emphasis must be placed on the positive aspects of personnel experiencing change and it must be clear that management will provide appropriate opportunities for preparing for change through training and development. In this context, the goals are:

– to encourage capable and motivated people to remain;

– to provide the necessary support, through training/retraining or development for people willing to work and adapt to change;

– to part with people who are proven to be a burden on the organization.

The mechanisms adopted for dealing with redeployable, retrainable and expendable staff will depend largely on the legal and contractual status of the employees and the cultural norms both within the organization and the wider community. What is important in all cases is that management is seen to be open in giving information and is consistent in the treatment of individuals; there should be a transparency in the handling of organizational change.

7.6 ITU activities related to human resources development

7.6.1 Introduction

The main ITU Objective in HRD is to assist developing countries in building institutional and organizational capacity through human resources management and development and organizational development activities. These activities will use and demonstrate modern techniques such as distance learning, computer-based training and teletraining so as to increase effectiveness, reduce cost and reflect developmental objectives related to access and gender.

Transfer of knowledge is planed through training, by strengthening national and regional centres to cope with new technologies, through centres of excellence (including broadcasting), partnerships with training institutions, emphasizing areas of interest such as spectrum management, modern management techniques and the training of managers and executives to adapt to the changing regulatory and commercial environment. This includes training for building business cases, managing the process of sector reform, and introducing new services and marketing.

Assistance to telecommunication and broadcasting organizations HRM/HRD, including the use of experts on short missions, the Virtual Training Centre, analysis of training needs, feasibility studies, design and preparation of project documents, models, guidelines and tools for practical applications, helps in financing and providing professional support for implementation.

Today the ITU is deeply involved in e-learning activities. An example is the World Symposium on Tele-Education for Developing Countries which was organized by ITU in Manaus, Brasil, Similar symposiums and other "e-HRD" related activities are expected to take place in the coming years.

7.6.2 Virtual Training Centre

The Human Resources Development Division (HRD) of the BDT started using distance-learning technologies as early as the end of the eighties. The Teleproject was born at the beginning of the nineties. At that time, the project was the focal point for using computer technology as well as communication networks in training courses in the field of telecommunications for the developing countries. Using a telephone line and a modem the Teleproject assisted face-to-face training sessions in the field from ITU headquarters in Geneva.

The positive experience of the Teleproject as well as the arrival of Internet led to the establishment of the ITU Virtual Training Centre in 1995. **This is now the platform for all e-learning activities at the BDT.** Other HRD activities and projects make use of the VTC platform for their distance learning actions.

The Virtual Training Centre (VTC) is conceptually a training centre offering its services on-line, or in other words **a training centre on the Information Highway**.

The paradigm of the VTC is on-line training, suitably complemented and reinforced by more traditional training delivery mechanisms, as needed. The decisions on the actual solutions to be implemented are based on factors such as the availability of material, the status of the infrastructures in the recipient organization and local cultural peculiarities.

Some of the VTC services are provided free-of-charge, for example the ITU training material and newsletters available in the Library, and the access to information on commercial training material and services available in the Resource-Store. Some services and material are provided to ITU Members free-of-charge under special agreements: among others, the CBT series "The Telecommunications Manager", a course on Spectrum Management and Frequency Planning for Broadcasting. Other services and material are provided on commercial bases by third-party partners of the VTC.

The VTC provides the following services:

– access to information (for example about material and courses available, links to service providers, etc.),
– access to training oriented material (via the library and the resource-store),
– distance tutoring and participation in virtual classes,
– distance consultancies services,
– administrative functions (registration, payment, etc.).

The main components of the VTC are the ***Library,*** the ***Resource Store*** and the ***Virtual Classes*** where the on-line training activities take place.

In the ***Virtual Library*** you can browse and download all the training-oriented material available for free from the VTC.

Currently, this includes:

The **Human Resources Development Quarterly**: a publication of the ITU Human Resource Development / Human Resource Management division.

A research and briefing service on advanced telecommunications technologies provided by the Ohio University Institute for Telecommunications Studies.

Web ProForums: a valuable collection of tutorials on advanced telecommunications technologies provided by the International Engineering Consortium, www.iec.org.

The International Training Resource Catalogue **published by ITU**, includes distance education courses, Technology-Based Training (TBT) courses, traditional training material and training opportunities (workshops, seminars...)

Training Centres World Wide Telecom Training Centres Directory **published by ITU**.

Please consult also the VTC Library, to find additional training material available free-of-charge.

In the VTC ***Resource-Store***, you can browse databases providing information about courses and course materials, traditional as well as technology-based, training centres and service providers.

At this stage, the Resource-Store only provides information about existing commercial material. In the future, users will have the possibility to order items directly from their desktops via the Resource Store.

Training material providers and course providers can advertise their products in the VTC Resource-Store free-of-charge, provided this information is of interest to the VTC intended users and it is submitted in the appropriate format.

The ***Virtual Classes*** are the actual environment where on-line training takes place. The delivery methods used in the virtual classes are very heterogeneous, ranging from standalone CBT, to the use of real time tele-conferencing, usually using inexpensive technological solutions.

The delivery method actually used in a given virtual class is chosen after analysing the available infrastructures in the target country, cost considerations, and appropriateness of the media to the specific training context.

Technologies utilized in the context of the VTC

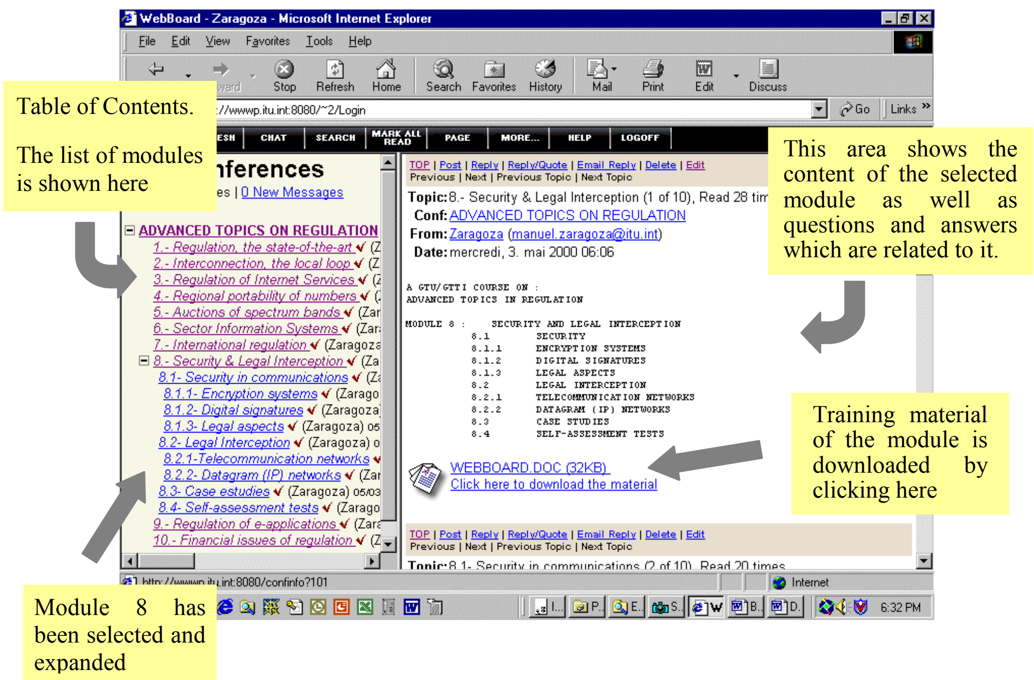
The VTC mainly targets developing countries, and tends to favour the use of already existing infrastructures, with a focus on affordable technologies. In order to cope with the most disparate situations and training requirements, the VTC makes use of a wide variety of technologies, even in specific training settings.

Standalone CBT (Computer-Based Training) packages, as well as more traditional paper-based and video material are used in combination with appropriate distance tutoring.

Concerning asynchronous communication, the Internet in particular has proved to be an extremely powerful environment.

The VTC uses a simple web conference system to deliver the distance learning courses. The platform is very intuitive and no special skills in computers or in Internet are required. A typical screen of a course is shown in Figure 7.1. The only requirement on the participant's side is a computer with access to Internet and a browser (typically Netscape or Explorer).

Figure 7.1 Example of screen of a typical distance-learning course



The methodology of the VTC for e-learning is also very simple. Most short term courses last for about eight weeks. Each week the participants work on a different module. They download the corresponding training material weekly. The tutor distributes tasks, coaches and is their mentor. The course administrator controls the level of activity of each participant. At the end of the course a certificate of participation is issued for those participants whose level of activity during the course was satisfactory.

All activities and communications are carried out through the Internet and the web. The participants, the tutor and the administrator remain at their place of work. Attending a distance-learning course is a part time activity and is very convenient for managers because they can follow the course and, simultaneously, attend to any most urgent matters. However, the VTC methodology recognizes the importance of traditional face-to-face seminars. Whenever possible the distance learning session is followed at the end by a short (2-3 day) face-to-face seminar.

Further information concerning the VTC may be found on the Web at http://www.itu.int/VTC/

7.6.3 MANDEVTEL (MANagement DEVelopment for TELecommuncations)

The mission statement of the MANDEVTEL project states that it "enhance through joint ventures with interested partners, the Management Development Project to develop and implement training for senior and top managers in modern management techniques".

MANDEVTEL focuses solely on the management skills required to run a telecommunication entity, for both operators and regulators. The project has built up its training modules, manuals, case studies in various areas of management, all supported by technology-based training. All materials are designed to be organized in workshops or to be studied individually with possible tutoring required. All MANDEVTEL products may be found in the Virtual Training Centre (restricted access).

Since 1993, MANDEVTEL quickly became a reality; and with the collaboration of valued partners, many workshops, TBT materials and case studies are now available in the Virtual Training Centre. Most workshops are available in a minimum of three working languages of the ITU, often five or more. Some of the workshops available are:

DDLM (Designing Distance Learning Materials	UIDL (Using Distance Learning Materials)
Business Planning	Activity Based Costing
Competitive Transformation of Entities	Competitive Transformation (distance learning)
Regulation of Telecommunications (distance learning)	Management for Senior Executives
Restructuring the Telecom Sector	Business Management and Planning
Strategic Management	Quality of Service
Total Quality Management	Nature and Purpose of HRM/HRD
A New Approach for Success	Corporate Planning
Marketing	Cost Management
Staff Planning	Organizational Development
Management of Training	Training Development
Instructor Training	Management and Leadership (distance learning)

It is recommended that interested persons access the MANDEVTEL website as new materials and courses are being added fairly regularly. http://www.itu.int/VTC/MANDEVTEL

7.6.4 Centres of Excellence

The increased use of new technologies, the move towards corporatisation and competition, and the separation of regulatory functions from operational services require advanced level policy, regulatory, managerial and technological expertise. In order to develop and strengthen the capability to generate this expertise in developing countries around the world, the Centre of Excellence concept was established. **It is primarily a virtual organization** with a physical office for the coordinator. All activities will be implemented in the different institutions that are partners of the organization.

Four Centres of Excellence projects are going-on:

1 – Centres of Excellence for Africa:

The Training activities are mainly supported by the existing Training Regional Organizations, AFRALTI (African Advanced Level Telecommunication Institute, Nairobi) for English speaking Countries, ESMT (Ecole Supérieur Multinationale des telecommunications, Dakar) for the French speaking ones. Since mid 1999, there is a strong will to expand the Centre of Excellence concept to other countries in the region, which are not necessarily AFRALTI or ESMT members.

In line with the increasing use of distance learning facilities, a networking process is being established. It should provide an opportunity to make the best use of the existing national training facilities available in the region, as well as to emphasise the value and the quality of the regional expertise. The offered programmes depend mainly on the initiatives, which are taken by the partners, with respect to the outcomes of recent regional training needs surveys. The same programmes apply to both sub-regions with specific case studies characterising each particular context.

a) Current partnerships

There are three major partners involved at present in the African Centres of Excellence activities : Nortel Networks, IDRC (through its specific ACACIA Program) and AGRA. They plan to implement 5 specific programmes as described in the table below, as well as an advanced laboratory on radiocommunication technology, in each sub-region.

A second partnership is being established with THOMSON and the French Government for African French-speaking Countries. It will also include the implementation of specific equipment.

b) Current challenges

The Centres of Excellence activities were launched by the end of 98 with a series of pilot activities and preliminary actions aiming at the future replacement of the current contribution-based membership by a pay-per-use system, both in AFRALTI and ESMT . The implementation of the new programmes needs to confirm the feasibility and long-term sustainability of this transformation. The partnership expertise will allow the benefit from the availability of a first set of advanced training resources to be tailored to the regional context throughout the networking process.

Appropriate Steering Committees still need to be established, and the networking process is still to be developed and rooted in the operational activity of each sub-region.

2 – Americas Centre of Excellence:

After consultation with countries in CITEL, the concept of a network of partners to create the virtual organization called "Americas Centre of Excellence" has been approved and the following activities have started.

AMERICAS C. of E. on-going development

- Implementation of a Co-ordination board, responsible for determining the activities and associated work plans. Appointment of a coordinator.
- Implementation of the network of nodes, with adequate configuration of the sub-regional focal points and definition of relevant tasks to be carried out.

AMERICAS C. of E. innovative training actions

- Implementation of a modular training program on regulatory issues (one expert recruited for 3 months to conduct training material development).
- Implementation of an advanced modular program on management issues (one expert being recruited for 3 months to conduct training material development).
- Implementation of a special training program for the Caribbean sub-region.

3 – Asia and the Pacific Centre of Excellence:

The ITU is currently establishing a Centre of Excellence in Telecommunications in the Asia and Pacific area. The Centre will bring together a network of research organizations, training and education centres, policy and economic study institutions, legal organizations, universities, etc.

This web site will play a major role in the ITU Centre of Excellence by drawing together the expertise in telecommunications in organizations within the Region and from outside the Region where there is something to offer. The present demonstration is a “proof-of-concept” demonstration that extends the depth of an earlier concept web site (http://www.aitec.edu.au/asian_itu_coe). This current web site is intended to explore ways in which the Internet might be used to support telecommunications growth and development in the Asia Pacific area and the development of the Asia Pacific Information Infrastructure.

4 – New Centre of Excellence for Arab states:

A new project on Centre of Excellence for Arab States was approved in February 2000.

Further information concerning the Valetta Action Plan mandate and subsequent reports related to the Centres of Excellence may be found on the Web at http://www.itu.int/ITU-D-HRD/cexcellence.

Each Centre of Excellence having its own program and time schedule. A further step will consist in establishing trans-regional links through the exchange of products, resources and experience.

7.6.5 Global Telecommunication University/Global Telecommunication Training Institute (GTU/GTTI)

The concept of the Global Telecommunication University and the Global Telecommunication Training Institute (GTU/GTTI) was launched at the Buenos Aires World Telecommunication Development Conference at the end of 1994. This project is the focal point for e-learning activities. It organizes e-learning courses using the VTC platform and assists other projects (MANDEVTEL, CoE – Centres of Excellence) in organizing e-learning activities.

Refining the concept of GTU/GTTI and analysing its feasibility took some time. In 1996, a team of experts carried out a feasibility study. The recommendations of this study have been guiding the activities and the evolution of the GTU/GTTI since then. The main conclusion of this study was that the GTU/GTTI could become a self-financed institution by charging very reasonable tuition fees. It was also recommended that the GTU/GTTI should establish partnerships with sponsors (financial partners) and course content providers (telecommunication training centres, technical universities, etc.). The long-term objective was to evolve toward a cost recovery and demand driven institution governed by a Board of Partners (Sponsors).

Potential participants in the GTU activities then proposed to change the name of GTU to GTTI, that is the Global Telecommunication Training Institute, so as to avoid the reference to the word “University” which was considered misleading. In the current understanding, the GTTI refers to distance learning activities targeting short training courses for technicians and supervisors, while the GTU refers to distance learning activities targeting higher-level professionals. It has nevertheless been agreed to use the combined GTU/GTTI acronym in order to reflect the interest of both populations.

At present the courses are offered free of charge and the project is looking for partners to sponsor these activities. Following the recommendations of the feasibility study, in the future, the GTU/GTTI will be funded by contributions of the sponsors as well as by charging reasonable tuition fees. The future structure of the GTU/GTTI is shown in Figure 7.2. As an ongoing activity, the GTU/GTTI is actively establishing links and contacts with potential partners (sponsors and course content providers) in order to enhance the programme of courses and to consolidate the achievements of the past. This will be the base of the future GTU/GTTI organization as a partnership venture.

The feasibility study also recommended to use the VTC as a platform and to initiate a Pilot Phase of the GTU/GTTI in order to test all the assumptions made by the team of experts. The VTC has been an essential instrument for the success of this Pilot Phase.

During the Pilot Phase, the GTU/GTTI has been offering short distance-learning courses (continuous education programme) through the VTC. During this period of time, other projects like the Centres of Excellence (CoE) have also organized distance-learning courses as a complement to their face-to-face courses and seminars. A sample of distance-learning courses is in Table 7.1. The course material can be in English, French and/or Spanish however not all the courses are available in the three languages.

The first accredited academic education course to be offered by the GTU/GTTI will be a Master's on Communication Management. It is being sponsored and prepared by Cable & Wireless. This 40 week programme is a mix of face-to-face and distance learning methods. The English edition will start in January 2001. It will be followed by the Spanish edition (2002) and the French edition (2003).

Table 7.1 – Sample of distance learning courses and their status

Course	Status
National Frequency Management	Available (1998)
Quality Management	Available (1998)
Frequency Planning for Broadcasters	Available (1999)
Marketing	Available (1999)
Designing Distance Learning Material	Available (1999)
Fix Wireless Access	Available (1999)
Business Planning (CoE Project)	Available (2000)
Regulation of Telecommunications (CoE AMS Project)	Available (2000)
Management with Leadership (CoE AMS Project)	Available (2000)
Designing Training for Internet	In preparation (2000)
Use of Technology in Training	In preparation (2000)
Negotiations on Telecom Service Commerce at the WTO	In preparation (2000)
Telecom Security, Electronic Signatures and Certification	Under consideration (2000)
Implementation and Management of National IP Networks	Under consideration (2000)

The target population of the GTU/GTTI are decision makers of the telecom sector, who can introduce changes to speed up the development of the sector in their countries. This includes top managers as well as senior professionals from telecom entities such as operators, regulators, policy makers, training and research centres, etc.

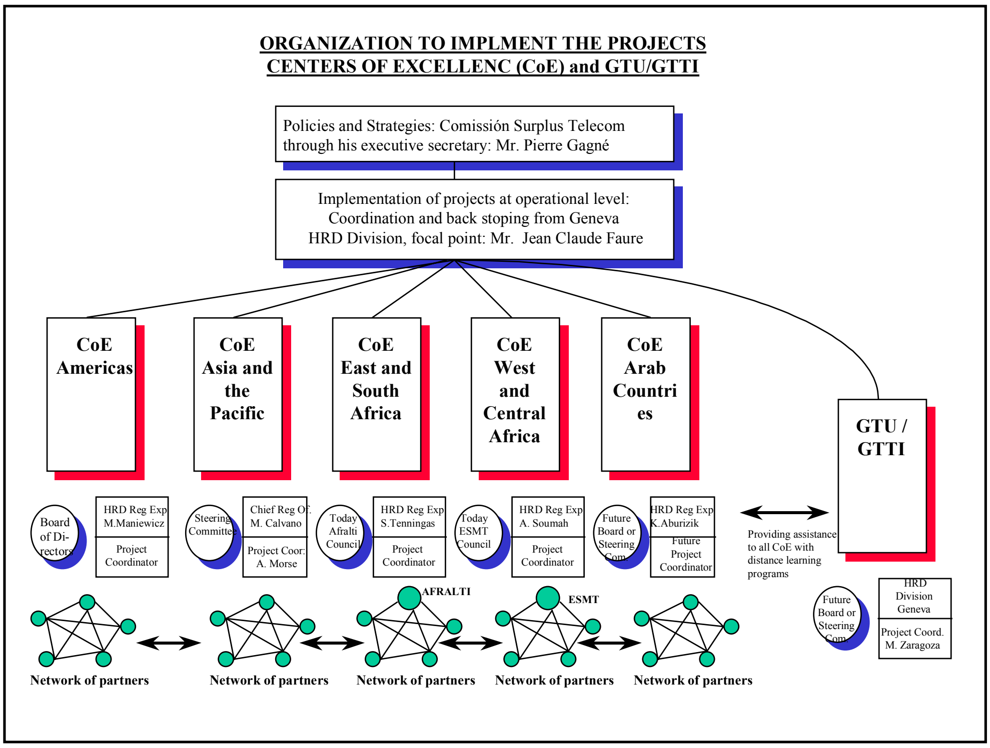
The mission of the GTU is to contribute to the development of human resources in the telecommunication sector. A special emphasis is placed on engineering and management training needs, arising from the changing environment in developing countries, as a result of privatisation, competition, the opening to the market economy, the digitalisation of networks and the introduction of new technologies and services. The purpose of the GTU/GTTI is to train for specific telecommunications needs and not to re-educate towards obtaining an academic degree.

Further information concerning the GTU/GTTI project may be found on the Web at http://www.itu.int/ITU-D-HRD/gtugtti.

7.6.6 HRD project management

As the activities on HRD are growing fast, because the very large demand of assistance from developing countries and countries of emerging economies, special measures are being taken to be able to manage all the mentioned projects.

The following graph shows the distribution of responsibilities in order to implement the five Centres of Excellence projects, the GTU/GTTI project as well as the rest of HRD actions required by the customers. The graph shows the need for regional BDT staff to work in close cooperation with the customers and users of the services to be provided by the different projects.



In addition to all the above mentioned projects and actions, the HRD Division organizes many other complementary activities in order to fulfil the objectives mentioned at the beginning of this section. These include:

- Assistance to countries/organizations in the areas of HRD, management development, organization development and transformation. This is done through short missions sending experts to the countries (by request)

- Organization of workshops. In order to fulfil the different needs, the MANDEVTEL project was organized. Within this project the HRD Division developed and produced the training material required for the different workshops. Additional information on MANDEVTEL is provided in section 7.6.3.
- Publication of guidelines, manuals, reports, case studies, and especially the prestigious Human Resource Development Quarterly (in the 3 working languages: English, French and Spanish).
- Managing data bases on training opportunities and the directory of training centres and making them, as well as all publications and training material, available on the web.

Several additional activities are carried-out in the BDT related with the development of human resources. The principal ones are:

1) Training and transfer of know-how: All the programs included in the Chapter 2 of the Valletta Action Plan, additional to the program 6 on HRD, also organization of workshops, seminars and symposiums in the fields of the programs (Policies and strategies, new technologies, finance and costs, private sector relations, tele-centres and rural telephony, etc.)

2) In Study Group 2, the Question 15/2 is dealing with the impact of the Telecommunications Reform on HRD.

3) Also in the Study Groups, one special group on Human Resources has been created to provide guidance through the TDAG (Telecommunication Development Advisory Board) to the Director of BDT.

7.7 Knowledge transfer

An example of knowledge transfer is shown in Annex 7A.

7.8 ITU publications

The following ITU issued publications can lead the reader in HRD:

1) *Competitive Transformation of Telecommunication Organizations* – MANDEVTEL, 1997, Separate editions in E, F, S.
2) *The Virtual Training Centre*, 1998.
3) *Designing Distance Learning Material*.
4) *Using the Internet for Distance Learning.*
5) *Manual on Mobile Communications Development*, 1997.
6) Reference Manual – *Guide for the Production of a Diagnosis-Evaluation and Plan for Establishing or Improving a Telecommunication Training System*, 1997.
7) Useful Reading for Directors and Managers – *General Principles of Telecommunication Management* (Volume I), 1993.
8) Useful Reading for Directors and Managers – *General Principles of Telecommunication Management* (Volume II), 1996.
9) *Directory of Training Centres,* 5th edition – January 1998.
10) *Training Development Guidelines*, 1994.
11) *Training Handbook on Rural Telecommunications (first part)*, Separate edition.

ANNEX 7A

Innovative knowledge transfer example

(as offered by Alcatel)

1 Introduction

The liberalization and deregulation of the telecomms markets in numerous countries has provided opportunities for competition among telecomms operators. As a result a variety of new entrants are showing up in those markets.

In view of the fierce competition with its effect of significantly shrinking tariff levels (and margins) there is wide awareness between the new operators that concentrating on the core business of a telecom service provider – service innovation and successful marketing – will decisively strengthen an operator's competitive position.

It is generally accepted that the "Cost-of-Ownership" – a catch phrase that encompasses all economical aspects of a network ownership from procurement to operating and continuous optimization – is a key factor in achieving this goal.

Network Operator Services (NOS) helps operators to reduce time to market, cut costs, provide efficient customer care and gain increased revenues.

A totally new approach is needed to cope with these challenges. To be innovative, support service offerings must be based on thoroughly tested, state of the art design, but nonetheless, on tailored concepts addressing principle return-on-investment concerns of telecom operators.

New, more stringent operational relations between the network operator and supplier are based on remote access/online procedures utilizing the telecom infrastructure of public networks with ISDN subscriber lines, corporate networks and the Internet as a platform.

A typical example of these Network Operator Service solutions is the Operator Information Centre (OIC).

2 The OIC concept

The Operator Information Centre is an integrated documentation transfer and training service to assure instant availability of information and know-how at any time at every workplace for the optimum qualification of the operator's personnel. This fully integrated concept amalgamates know-how transfer by electronic documentation, correlated computer-based-training and virtual classroom training, backed-up by online tutorial support.

The OIC services can be grouped into four categories:

– Documentation Database

– Interactive Training

– Customer Support

– Helpdesk.

Figure A1

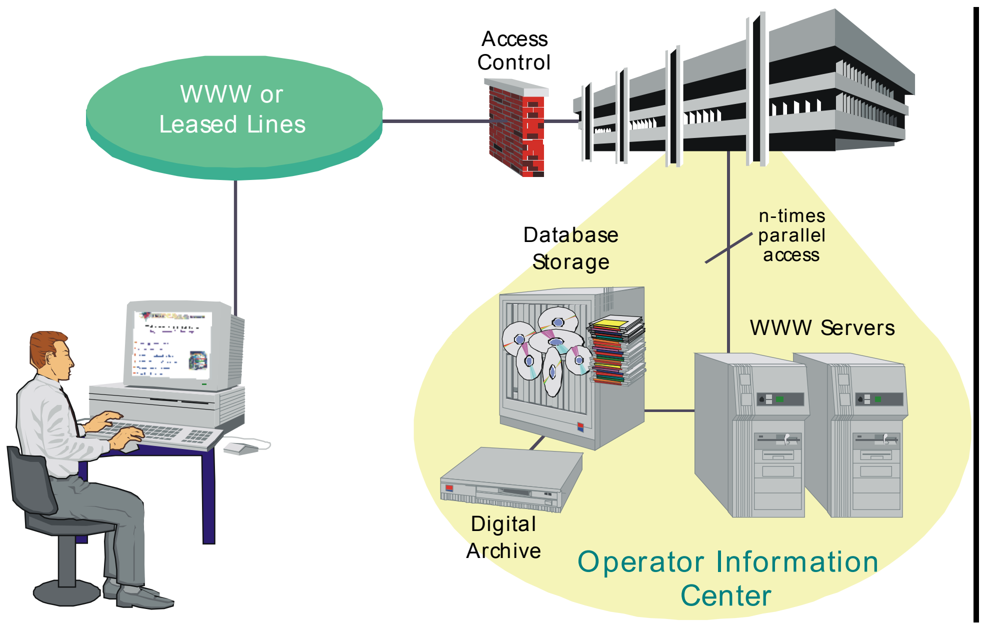
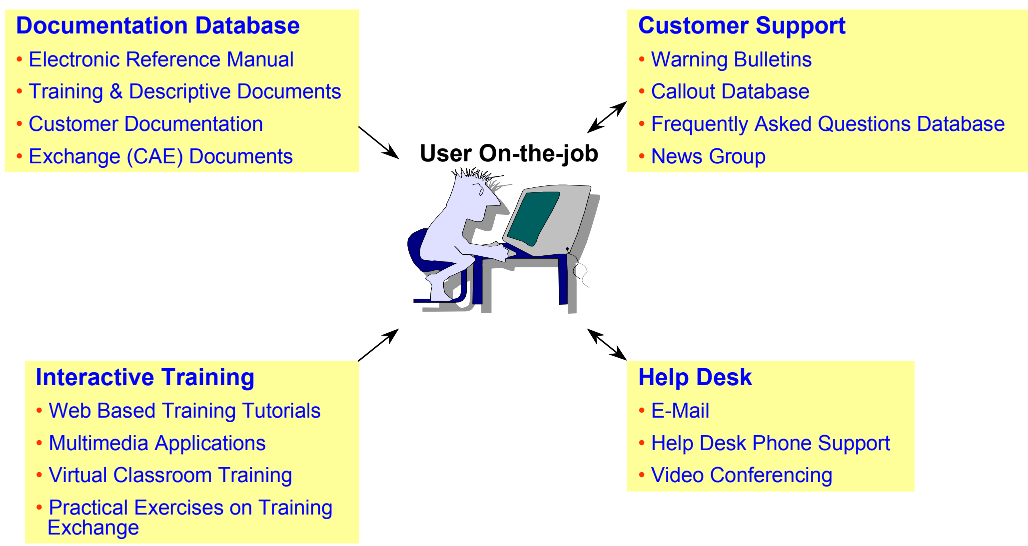


Figure A2



3 The OIC services

- OFFERING TELE-TEACHING ON DEMAND

Tele-Teaching sessions are the method of choice for cost efficient and flexible training courses. The Tele-teaching application is based on standard Internet techniques.

- OFFERING REMOTE ACCESS TO TRAINING HARDWARE

The OIC enables your staff to have remote access to the hardware equipment located at the Training Centres at any time. To access these devices, you simply have to dial a pre-assigned phone number.

- OFFERING HELPDESK FUNCTIONALITY

In addition to the pure on-line training session, a helpdesk function is offered as well. Here the trainee can get in direct contact with the trainer and have his questions answered in an interactive mode.

There are different levels of this helpdesk functionality available:

– via phone

– via e-mail

– via videoconference.

- OFFERING ON-LINE ACCESS TO DOCUMENTS

Starting from the OIC home page located on a central web server, you can click on links to move to different sources of information. An efficient information structure ensures easy and fast navigation.

The OIC server contains on the one hand all documentation related to the offered training courses, that is, all the charts shown during the courses, glossaries and additional sources of information (books, Computer Based Training sessions, standards, etc.). On the other hand, the entire product and network documentation is available on the same server as well.

4 The OIC benefits

- UP-TO-DATE INFORMATION

OIC provides staff with the information they need. The ideal combination of training, documentation and operational data enables one to work in an adequate way. It is very easy to be trained on new features of the network, to look up some information in a computer-based training or to exchange experiences with other experts in the User Forum of the OIC server. Everything is just one mouse click away from your desk. Always the latest set of documents is available on the OIC server. The documentation system automatically indicates, if there is a new version of documents available on the central server. This ensures that the staff at all your sites will have the latest information on hand.

- EASY ACCESS

The OIC server is just one mouse click away from the desk. Standard browser technology and a database structured to ones needs provide exactly with the information needed. Integrated search mechanisms and hyperlinks make it easy to navigate within the provided information.

- DISTRIBUTION

As the OIC solution is based on electronic documents stored on a central server, distribution of documents within a company is no longer an issue. There is no longer the need to handle large sets of paper documentation or exchange pages for updated documents with all the administrative burdens behind it. As soon as the information is on the server, staff can access it from anywhere.

- EFFICIENCY

OIC is designed to assist staff in their day-to-day job. Access to a user forum containing News Groups and answers to Frequently Asked Questions provides an operational environment that enables staff to handle their tasks quickly and efficiently by having all the information at hand, with links to related documents and tools, makes it easy to keep the network up and running.

- TIME SAVINGS

Embedded search mechanisms make it very easy to find specific information in the electronic documentation. Normally a user will not read the documentation page by page like a book, but will jump between different chapters and even folders to find useful information. This is very easy with an electronic system in contrast to paper-based documentation.

- INCREASED FLEXIBILITY

Using Tele-teaching methods increases the flexibility of training sessions. As soon as new features or services are implemented in the network a training session can be held to keep staff updated. With the remote access to the training hardware devices, immediate hands-on experience can be gained. Whenever there is the need to refresh know-how, the direct access to the training documents and the computer based training sessions on the centre OIC server offer a time and location independent solution.

- LOWER TRAINING EXPENSES

Offering training sessions via videoconference relieves the problem of staff being unavailable during training sessions. It is no longer necessary to have expensive trips for training purposes. All necessary know-how can be transferred within ones premises.

ANNEX 7B

ITU-D/Cable & Wireless Training Scheme

Background information[1]

Since the creation of the development sector within the ITU, BDT has established an excellent relationship with Cable & Wireless which builds upon the 'ITU and Cable & Wireless Training Scheme' that began during Telecom91.

There is a series of programmes developed by Cable & Wireless that is a route to the ITU Global Telecommunication University. BDT contributed to the development of the Masters Degree in Communications Management, which will commence in 2001.

MASTER OF COMMUNICATIONS MANAGEMENT

(as offered by ITU/Cable & Wireless)

Offers the opportunity for Communications professionals to participate in the Master of Communications Management programme.

The purpose of this course is to equip participants with the sophisticated management skills required to address critical strategic issues within the rapidly changing communications environment.

What the course will cover

- The Communications Environment and Markets
- Strategic Business Planning in Communications
- Organizational Change and Technology in a Competitive Environment
- The Principles and Practice of Communications Policy
- Communications Management
- E-Commerce and its Impact
- Communications Law
- International Joint Ventures and Strategic Alliances
- Customer-focused Management in Communications
- Risk and Project Management of Projects in Communications
- Management of Employee Relations in Communications

Participants will normally be managers who have been identified as having the potential to achieve senior positions within their organizations.

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[1] From BDT Secretariat.

An appropriate Bachelor's degree and a good command of the English Language are pre-requisites for this programme.

For further information please contact:

Telephone: +44 24 76292029

Fax: +44 24 76868657

E-mail: ir.admin@cwplc.com

CHAPTER 8

8 Financial and economic aspects

8.1 General

8.1.1 The importance of economic planning

On both a national and corporate level the concepts and tools for economic evaluation are important means of ensuring that limited capital and expensive resources are applied over time to the most productive investments in the advancement of telephone networks.

The list of projects in an administration construction programme will contain not only projects of a "must" nature, consisting of growth jobs and public requirement projects, but also projects of a discretionary nature such as those providing for the modernization of existing equipment and for certain marketing programmes. The entire construction program needs to be evaluated on the basis of economics and the financial well being of the administration. In general, only those discretionary projects that will meet market needs, return income and generate funds for business development should be included in a construction programme. In addition, because of the public responsibility of the telecommunication provider in a country, the projects undertaken must include those that are needed and benefit the social welfare of the citizens.

For the purposes of the chapter, reference to the GAS 11 Handbook will be essential. Many of the project evaluation procedures include elements that are discussed in Chapter VII of the GAS 11 Handbook.

8.1.2 Purpose of this Chapter

This chapter will cover the overall guidelines for the selection of projects that will provide new technologies and new services using economic evaluation of project alternatives. This chapter will also cover sources for capital, risk analysis, profitability, and tariff considerations.

8.1.3 Advantage of exact analysis of new services

The introduction of any new service into a public telephone network is a challenging task because of the unknowns in the marketplace not only in terms of estimating market demand and price characteristics of the new service, but also in estimating equipment costs and ongoing operational expenses. Care must be taken ahead of time to prepare for any contingencies in the marketplace or in the administration. Managing the financial risks of a new service can be done by minimizing initial investments; by initially limiting the scope of new service offering by establishing a market trial; or by sharing the initial investment requirements with private investors, prospective customers, or local and regional governments.

8.2 Methods of economic analysis

8.2.1 Evaluation criteria

The methodology for analysing the selection of projects to be implemented can be found in the GAS 11 Handbook, Chapter VII. This chapter explains in detail the approach and tools used in evaluating alternative plans for investment using discounted cash flow analysis, profitability analysis, sensitivity studies and tariff designs. Since there are many potential new services to choose from, the selection process has to be an interactive process of researching customers needs and their willingness to pay for the service and alternative service/network investment plans.

Projects should be evaluated first by their long-term benefits and the discounted cumulative cash flow is used for this. The resultant Net Present Value (NPV) of a project is compared to other programmes with similar topics. Sensitivity studies are important to determine how sensitive the plan is to changes in costs or actual revenue. The intent is to estimate the return on the investment and expenses of a project over its expected life.

In addition to NPV, a project must have a reasonable payback or break-even period, which is usually 3 to 5 years, although one or two programmes which involve major modernization plans and mass marketed programmes may have an extended payback. This is where an administrator must be cognizant of the total portfolio of investment plans with the objectives of maximizing profitability of the business, offering a return to investors, and advancing the economic strength of the country. Advanced communication services have the potential to meet all of these economic requirements.

Once the long-term, economic benefits of an investment are identified, the annual profitability of the programme must next be evaluated. Administrators may chose projects with high short-term profitability for the sake of cash flow but must not overlook longer term profitability projects for the sake of near term gain.

In addition, an analysis of what a company can afford to invest over time should be performed. This includes the administration's corporate sources of funds as well as new sources from world development funds or private investment.

Finally, the strategies and objectives of the organization as a whole, whether it is a commercial or government owned operator, will need to be used as a benchmark for all decision making. There are occasions where the local social obligations require the provision of certain potentially loss making, new services (for example a domestic satellite system in rural areas). The rules of economic analysis remain unchanged, with the overall objective of assessing and subsequently managing the project in an appropriate way still being of prime importance.

8.2.2 Life cycle analysis

As with all evaluation criteria, analysis is required of the cost versus benefits of a project over its expected duration, which could be as long as 20 years, not just the first few years of the plan. An analysis of the first few years will bias a plan to the lowest initial cost and fail to anticipate future operational costs, including maintenance and upgrade expenses. The duration of the study must cover the payback period, which is the period over which the capital investment is expected to be recovered.

8.2.3 Accounting methods

Even though a project appears to be profitable over the long term, it may not be viable if the administration is unable to afford the initial investment.

A financial analysis can be performed on the investment requirements by determining how the capital investment will be financed, given the current financial condition of the administration. The current financial statements are found in the income statement and balance sheet of the administration. In summary, the business financial statements include the current income and expenses of the administration's transactions, along with its debt-to-equity ratio. Using accounting models of income statements and funds flows for a five-year period the financial officers of the administration can assess the affordability of the project and the feasibility of a financial plan to repay the investment.

If an administration cannot afford a project which appears however to be profitable in the long term, it can decide to:

– defer the investment until it can afford to pursue project;

– scale down the project; or

– look for more affordable capital financing alternatives.

8.3 Policy considerations

8.3.1 Profitability requirements

Two measures of profitability are firstly the long-term contribution of an investment alternative, and secondly the measure of the annual profits obtained from the new service.

If we assume that the operation of the basic service for an administration is earning an acceptable average rate of return, then it is wise to require a higher rate of return for the new service to cover the associated risks. This will give some assurances compensating for the lack of exact data on the costs and benefits of the investment. The rate of return here refers to the long-term rate of return on investment in a specific project. Any project with a positive NPV will earn more than the cost of money (discount rate for the cash flow analysis) and the higher the NPV, the more favourable the plan.

Sometimes a modernization/development programme will prepare a telephone network for more than one new service, with the contribution from each of those services being an integral part of the overall decision making process.

After the long-term profitability of a plan on a cash flow basis is known, then the annual costs and revenues are analysed. Chapter VII of the GAS 11 Handbook describes the methodology and rationale for measuring the profitability of each project on an annual basis. This is required to ensure short-term viability of the project and to establish price levels for the new services.

8.3.2 Overall benefit to national telecommunications or the national economy

From the onset of the economic analysis, the selection of which new technologies and services to target will include a consideration of national economic needs. There are direct and indirect benefits of adding new services. The direct benefits are revenue growth for the administration, operational benefits, advanced training and viable employment for telephone workers, and increased use of the public network by businesses. Indirectly, the new services can stimulate growth in the national economy by increasing for example the effectiveness of business customers, will spawn related service providers, which will in turn provide a source of new skills.

8.3.3 Goal of time required to achieve profitability; effect on network implementation

Each project should attain the required profitability that meets administration objectives. Some projects may be accepted at an extended payback period for the sake of long-term profits but a few should return a profit to the administration in the short term.

Once a project, or a set of projects, are selected it is crucial to implement the plan in the most effective and efficient manner as possible. Each administration needs to review its procurement, engineering, installation, marketing service, provisioning, and maintenance policies and capabilities to maximize its ability to carry out the plan. The risks are to miss the market window for the services resulting in customers finding alternative means to satisfy their needs, or to delay installation and market introduction after shipment and payment, thereby incurring the capital burden without coincident income to cover the investment. It is very important to install the network equipment and provide the services as soon as possible after the implementation of the equipment.

8.4 Capital considerations

8.4.1 Estimation of required capital

Chapter VII of the GAS 11 Manual describes investment costs that are referred to as capital expenditures. Along with the material costs in the construction of the plant, the estimate of capital should include installation, engineering and costs incurred during construction, e.g. interest expense, insurance, taxes.

8.4.2 Financing of customer premises equipment

Some services will require new terminal equipment at the customer premises. In order to stimulate the use of the new service, it may be necessary to provide the Customer Premises Equipment (CPE) in a convenient and inexpensive way. The costs of this CPE should be determined, then a price should be set, allowing for appropriate margins. Administrations can then provide options for the acquisition of the CPE by:

– providing the equipment for sale at market price,

– leasing the equipment,

– selling the equipment at a lower, introductory price to stimulate demand, or

– offering the equipment at no charge.

The costs of the latter two options can be covered by service revenues or underwritten by other investors in the services that have related products/services that would benefit from this new service offering.

8.4.3 Investment financing

There are several options that can be used to finance a new service, including:

– using internal corporate funding (e.g. depreciation reserve), or retained earnings with increased future profits being possible through operating efficiencies and business growth,

– using external funds obtained from the world bank (see below) or regional development organizations/banks,

– private investment, using loans (possibly with debt conversion) or the issue of equity commonly through joint venture agreements,

– supplier financing and advanced payments,

– budget allocations received from the government,

– deposits for the services from prospective users.

{For reference, the World Bank is made up of five organizations:

1. International Bank for Reconstruction and Development (IBRD) – lending to developing countries with high per capita income for structural development projects.
2. International Development Association (IDA) – provides loans to the poorest developing countries (per capita income of less than US$ 905 – 1995) who cannot afford to borrow from the IBRD.
3. International Finance Corporation (IFC) – lends to the private sector only (IBRD and IDA lend to Government sector). Support also includes project underwriting and risk management.
4. Multi-lateral Investment Guarantee Agency (MIGA) – helps attract foreign investment in developing countries by providing to investors guarantees against non-commercial risk.
5. International Centre for the Settlement of Investment Disputes (ICSID) – for conciliation and arbitration of disputes.}

In the case of private investment, a large user of the new services may directly pay for the construction of portions of the network required for their access. Another alternative would be for a private company or set of companies to offer to build, operate, and transfer (BOT) the network required for the new services. There are advantages to the BOT approach. The most significant advantage is that the risk of the new venture will be shared among a set of financial entities. A second possible advantage occurs when one of the companies is an equipment provider; this company may then remain involved for the duration of the contract (say 10 to 5 years), and thereby has a particular incentive to deliver an operational system at a cost that allows the administration to better achieve its financial objectives.

An even more far-reaching alternative is to sell shares in the administration to large interested private companies who will pay a good price for the shares and invest additional funds for the expansion of the business.

Supplier financing is offered by many equipment suppliers. If desirable, the need for supplier financing should be stipulated in the request for quotation, and should be evaluated along with the capital cost of the equipment. The economic studies will reflect a range of costs for debt, since competition may encourage wide variation in the rates for the initial financing.

Given the complexity of the funding options available it is advisable to carefully review the options and where necessary to seek expert guidance, for example from a representative from the local Central Bank.

In all cases the local government regulations and political opinions will place constraints upon the options available and selected.

As a final note it is essential that a comprehensive business plan is produced, including all the economic justifications for the introduction of the new service/technology, and the risks associated with it. Investors are likely to be much more responsive to a well thought out investment project, which carefully considers all of the risks and downsides and the plans to manage them, than they are to a plan which lacks depth and tries to hide potential problems.

8.5 Study parameters

8.5.1 Economic parameters

The economic parameters of the cash flow analysis of a prospective project should include the length of the study, tax rates, inflation, and cost of money (discount rate). On a set of projects it is also necessary to determine overall resources available to invest over time, and the most economic approaches to business long-term growth and short-term gain.

The following gives some considerations to be followed in choosing the economic parameters:

Length of study

The cash flow analysis of costs and benefits should cover the total life cycle of the capital investments. For example, for a local area network using a data switch, a period of approximately 5 to 7 years in length could be appropriate, however a cable expansion might be expected to last for 20 years and therefore the study length should be at least 20 years. Given that cost and revenue estimates are difficult to estimate over the long term, the study could be designed for 10 to 15 years without significantly reducing the quality.

Tax rates

In order to compute taxes paid, the national and local government rates, where applicable, need to be applied to the revenues less expenses. There may be opportunities to discuss with the local tax authorities the use of accelerated depreciation rates for specific projects, for the purpose of calculating charges against profit. This acceleration will reduce tax in the early years and improve the cash flow profile.

Inflation

Capital and labour inflation rates need to be estimated and applied to the material and labour costs each year for the plan. This is done in order to compute the actual cash flow each year of the study in that year.

Discount rate

The discount rate (cost of money) is used to convert after-tax cash flows to their present worth. The cost of money relates to the required return on investment to cover debt issue and return on equity to investors in simple terms will be:

Discount rate = (Debt ratio) × (Incremental cost of debt) + (1 Debt ratio) × (Cost of equity)

Where the incremental cost of debt will be the interest paid, after the deduction of tax.

The Figure to be used for the rate of return required to cover the cost of capital depends on the method of financing the project. If the project is financed by borrowed capital, then the rate should be as close to the borrowing interest rate as possible. If the project is financed out of reserves, then the rate should equal the rate of return earned by investing the money in a risk free investment (e.g., government bonds), or a rate of return which is close to the rate of return expected by investor in the company (i.e. including a reward for accepting a degree of risk associated with the company, and with this project).

An alternative to identifying how this "specific" project is to be financed (debt or equity) is to use a weighted for all planned projects, within an overall development programme. In both cases however the key requirement is still to look at the future cost of financing and not to past costs.

8.5.2 Economic life

The economic life of equipment will be the expected length of time that the equipment will remain in service. It is called the economic life because this is the number of years that original capital investment and subsequent equipment additions will be useful in providing income to the administration as a return on those investments.

At the end of the economic life of the equipment, a net salvage value is estimated and accounted for as a cash flow. The net salvage value is the fair market value of the item less cost of removal, which includes disconnecting, dismantling and removing the item.

8.5.3 Estimation of uncertain parameters

Of the study parameters mentioned, the inflation rate will be the most uncertain and the most difficult to estimate because it is the most volatile aspect in a national economy and least controllable from the perspective of an individual company. For this reason, a life cycle cost/benefit, analysis is very important. If sensitivity studies are performed using different inflation rates, a course of action can be devised which will minimize the risks of inflation increases. For example it might be advantageous to schedule the purchase of the initial equipment in advance and for an extended period, for example 3 to 5 years. The initial price could then be lower, and an inflation factor could be agreed with the supplier at the outset. This would remove the uncertainty due to inflation in the price of the equipment. Another method of minimizing risks would be to design the tariffs with inflation in mind.

8.5.4 Effect on existing services

A review of all of the new technologies/services will reveal whether customers are able to satisfy their needs with existing capabilities, or whether new capabilities are required. The newer services usually offer feature or price advantages over existing services. The decline of existing services must also be managed within the financial portfolio of the administration and will need to be taken into account when assessing the impact of the new service. On the other hand, some new services may increase the usage of existing services and the resulting capacity required must be anticipated.

8.6 Risk analysis

8.6.1 Identification of risk factors

The expected return on an investment in a new service/technology is a function of the expected revenues and expected costs of those new services. There is an inherent risk in any forecasting exercise. The market size may not be as large as anticipated, the marketing programs of price, promotion, delivery and performance may not attract a high volume of users or operating costs may be higher than expected.

Before a project is implemented risk analysis should be undertaken on the cash flows of a project. This is accomplished by altering the parameters and cash flows to reflect hypothetical risk conditions. If possible, the worst case situation should be determined, so that all measures can be taken by the administration to assure achieving the required return on the investment, or at least mitigating the risks beforehand.

8.6.2 Quantification of risks

For all inputs into a cash flow analysis a sensitivity study should be designed using a variation (+ or – x%) about the nominal inputs in order to determine the sensitivity of the NPV values to variations in the inputs, such as benefit and cost assumptions. For example, 85% could be used as a variation for certain inputs. The original study, with nominal values would then be recalculated with the inputs (singly or multiple) multiplied by 85%. The reasons for using particular multipliers should be clearly stated.

Another method for quantifying risks is to establish a set of benefit and cost values that result in an acceptable (perhaps not optimum) NPV. This may be called the "baseline" case. Any variation in inputs, which yield an increase in NPV over the "baseline" case, is an improvement; this will provide the administration with guidelines for choosing the optimum case, and for avoiding undue risk.

The input elements which need to be subjected to sensitivity analysis include market size, market share, price or tariff for the services, capital costs, operating costs, number of users, usage of the service, inflation rate, timing of the investment, and timing of tile penetration of the market.

8.7 Economic analysis

8.7.1 Costs

All costs that can be identified should be included in the study once a network and operations plan is determined. In comparing alternatives, an incremental cost approach is preferable. The incremental approach considers only costs which are required for the new services, and which did not exist prior to the new service introduction. Once a final decision among the alternatives is taken, the fully allocated cost of the network can be used for profitability and tariff analysis. Care must be taken to identify interrelationships when considering a number of potential new service offerings (for example where certain costs may be shared).

The overall goal of the analysis is to optimize the use of available resources for new investments.

8.7.2 Revenues

The market demand projections for any new services/technologies should be based on:

– the identification of the target market;

– a profile of usage of the new service for the target market;

– identification of potential customers from the target market for the features of the service.

A price for the service and usage is computed, based on projected costs and price/demand relationships, and then market penetration over time is estimated. Revenue forecasts are then derived from the market forecasts.

8.7.3 Cash flow

In organizing data for making project evaluation decisions the emphasis should be on cash flows and not on accounting net income. The reason is that accounting net income is based on actual concepts that ignore the timing of cash flows into and out of an organization.

8.7.4 Profitability

After a project is selected based on long-term economic benefit or NPV, profitability measures should be examined for viability to the business.

Profitability, as well as the above three study areas on costs, revenues, and cash flows are covered in Chapter VII of the GAS 11 manual.

8.8 Tariff considerations

8.8.1 Introduction

Fixing tariffs is a complex exercise that takes experience, an understanding of the principles involved, and an understanding of the specific circumstances facing the operator. Chapter VII of GAS 11 considers the structure of tariff, tariff levels, and gives some examples.

8.8.2 Key issues

Given the need to ensure that all operational elements are commonly focused on the achievement of the administration's overall business objectives, the complex inter-relationships that exist between the various elements of total revenue and the need to ensure that prices appear rational to the consumer, etc., a tariff structure/strategy is required that encompasses all products and services offered.

Decisions on prices to be charged for individual products/services must therefore not be taken in isolation, but must fit within this overall structure/strategy.

This section contains a checklist of the key factors that need to be considered and built into the administration's tariff model.

1. Business objectives. The tariff structure will be an integral part of the overall strategy targeted at achieving the administration's business objectives. These business objectives (all with specific time-scales) could include for example some of the following:

   Financial:

   - target or maximized profits
   - target turnover
   - target R.O.C.E.
   - early pay-back of outstanding debts

   Non-financial:

   - specific increases in numbers of customers/lines (perhaps driven by Government targets)
   - geographical coverage.

   If the prime objective for example was to increase the numbers of lines in service the installation price charged would probably be lower than if the objective was to maximize total financial returns in the short term.

2. Cost of service provision. This will include a review of:

   - the cost structure, in terms of fixed and marginal costs, and the cost drivers.
   - the cost of operating the national network (labour, depreciation. maintenance etc.).
   - the additional costs of providing international services, for example inter-administration traffic charges, overseas capacity rental (satellite/cable).
   - the standard and non-standard costs associated with installations.

- the inclusive cost of CPE.
- an appropriate basis for the allocation and apportionment of costs to the various products and services.
- current and future costs.

An assessment of the costs is required to evaluate the relative profitability of the different products and services delivered under various tariff strategies. It would be expected that the profit derived from each service achieves a specific financial target.

3. Scarcity of resources: Where financial or labour resources are scarce within the administration, a premium may need to be charged to cover the additional costs associated with the provision of a particular service, over and above the prices normally charged for a particular type of service.
4. Consumer demand: A structured approach to the assessment of demand in a particular market is an essential part of the pricing exercise, with demand being influenced by numerous factors in addition to the price being charged, for example quality, consumer disposable income, other competitive offerings, etc.
5. Competition: There are expected to be significant differences between the prices charged in an open competitive market with those charged in a monopolistic environment, with competition normally forcing down prices, reducing costs, and increasing the quality of service overall.

   A careful assessment must be made of all the available strategies that could be implemented, and the expected competitor reaction. In today's international telecommunications market, even where there are no locally licensed competitors, the use of call-back, re-file, etc., effectively creates competition for international services (traditionally the most profitable part of any state-owned telecommunications administration).
6. National economy: The impact of the local economy needs to be considered, for example national economic growth, inflation rates, and currency exchange rates (current and projected).

   The growth in the economy will impact upon the demand for telecommunications services, however the development in the telecommunications infrastructure has been found to be a prime driver of total economic growth in developing countries. The assessment of the local economy, and the tariff structure to be adopted, must therefore take into account this relationship.
7. Political/legal restrictions: These could include restrictions on price rises, the imposition of price reductions, service availability, or required pay-back for government loans.
8. Financial exposure: As an administration emerges from a monopolistic business to become a more competitive service provider it should attempt to reduce its debt financing and increase its equity financing. The reduction of a company's debt ratio will lower its costs over time and, thereby, mitigate financial risks. It will also raise tile standing of the company's position in the financial and lending sectors.

8.9 Review based on experience

8.9.1 Recalculation of profitability

The profitability of a service should be reviewed on a regular basis, preferably at the executive level within the administration.

As each project is implemented and the services are offered, the administration needs to monitor both internal and external factors to see if the business is proceeding as planned. The trends which should be monitored include sales volume and profit by service and by market segment or customer, fixed costs, break-even points, operating income, and income before taxes. Key external measures considered should be customer needs and values, market size and growth, market share, business conditions, competitor activities and government regulatory actions. Administrations can study the situation against the economic analysis of each plan to make decisions that will improve profits.

8.9.2 Reconsideration of tariffs

The initial tariffs for a new service can be reviewed along with the profits from a service. If the rates are not returning sufficient income to cover capital or operating costs, or if the rates are too high to attract sufficient utilization, then they need to be adjusted.

8.10 A transitional mechanism to cost oriented settlement rates

The World Telecommunication Policy Forum on the trade in telecommunication services (WTPF, Geneva 1998) recommended the creation, within the ITU-T Study Group 3, of a Focus Group in order to define a transitional mechanism to cost orientated settlement rates. The outcome of the work of that group is a proposal to add an Annex E to the Recommendation D.140. The Draft annex E (see Annex 8A) has received a lot of support from Administrations and is to be included in the report of Study Group 3 to the WTSA (Montreal, October 2000) for final approval. It has been noted that although the annex E has not been officially adopted yet, many operators from developing and developed countries are already using it as a basis of their negotiations.

8.11 ITU publications and reports

The text of this Chapter is based substantially on ITU GAS 12 Handbook, Chapter 5, Economic aspects of the introduction of new non-voice telecommunication services in developing countries. Other relevant ITU publications related to financial issues are listed below. Also, abstracts from recently prepared reports from important events are listed.

1) Telecommunications and Economic Growth – Seminars Jointly Organized by ITU/Webster University, 1999.
2) Collection of General Trends in Telecommunication Reform, 1st edition, 1998.
3) Telecommunication Policy on CD-ROM, 1999.
4) World Telecommunication Development Report – Mobile Cellular – World Telecommunication Indicators, 5th edition, 1999.
5) World Telecommunication Development Report: Universal Access, 4th edition, 1998.
6) World Telecommunication Development Report: Trade in Telecommunications, 3rd edition, 1996/97.
7) World Telecommunication Indicators Database, 5th edition, 1999.
8) Direction of Traffic: Trading Telecom Minutes – Report, 3rd edition, 1999.
9) Direction of Traffic: Trading Telecom Minutes, 3rd edition, 1999.
10) Direction of Traffic: 3rd edition, 1999.
11) ITU Yearbook of Statistics – Telecommunication Services 1989-1998, 26th edition, 2000.
12) ITU Statistical Yearbook (Chronological Series 1987-1994), 1994.
13) ITU-D Question 1/1 – Role of Telecommunications in Economic, Social and Cultural Development, 1998 – (SG1) Final Report, Separate editions in E, F, S.

14) ITU-D Question 2/2 – Preparation of Handbooks for Developing Countries: Economic, Organizational and Regulatory Aspects of National Spectrum Management, 1999 – (SG2) Final Report.
15) ITU-D Question 4/1 – Policies and Ways for Financing Telecommunication Infrastructures in Developing Countries.
16) Manual on Tendering and Procurement of Broadcasting Systems and Equipment, Separate editions in E, F.
17) Competitive Transformation of Telecommunication Organizations – MANDEVTEL, 1997, Separate editions in E, F, S.
18) Useful Reading for Directors and Managers – General Principles of Telecommunication Management (Volume I) 1993.
19) Useful Reading for Directors and Managers – General Principles of Telecommunication Management (Volume II) 1996.
20) Partners in Development: Telecommunications – The First Link, 1994.

Abstracts:

- *Final Report and Proceedings of the Seminar on Partnerships and Rural Telecommunication Development Kampala (Uganda), 3-5 November 1999*

The final report contains the statements at the opening and closing sessions as well the main conclusions on the presentations and discussions on each working session. The Proceedings contain the full papers presented during the sessions, covering various aspects of rural telecommunications such as financing regulatory issues and technologies.

- *Addendum Issues in Telecommunications Development Volume II: Reforming the international accounting rate system*

During 1999, the ITU's Telecommunications Development Bureau continued to support the efforts of developing countries to review telecommunications costs and tariff reform. The addendum of the 1998 Review of "**Reforming the international account rate system**" contains the reports of the 1999 series of seminars and contributions from developing countries to the work of the Regional Tariff Groups and the Study Group 3. These reports are complemented by three additional case studies.

The 1998 series of BDT seminars and workshops highlighted the importance for developing countries to examine the underlying cost elements of telecommunications in order to contribute to the reform of the accounting rate system. At the request of participants in those seminars and workshops, the BDT continued to support meetings at which developing country representatives applied the various methodologies for calculating tariffs to real situations. Part 3 contains reports of these meetings, as well as recommendations to Study Group 3's on-going deliberations on tariff reform. In addition, Regional Tariff Groups met to review cost models for use in calculating more precisely actual costs. A number of additional papers give overviews of tariff-related questions, of significant interest to developing countries. Three more country case studies – Barbados, Trinidad & Tobago and Ukraine – are also contained in this volume, as a complement to the 11 published in 1998.

- *Financial Institutions Offering Resources for Telecommunications Projectsand Technical Assistance in Developing Countries (as verified by Financial Institutions) Fourth Edition July 1999*

This publication, divided into three categories (multilateral agencies, bilateral agencies and funds), aims at providing easy reference to institutions that provide resources for telecommunication projects and technical assistance in developing countries. It acts as a guide to the main sources of financing for development for governments, regulators and public telecommunication entities, as well as private institutions and enterprises. In addition to providing addresses, telephone and fax numbers, email addresses, contact persons, each entry gives factual information (verified by each institution) on the purpose for which the institution was established, its activities, its objectives, broader knowledge about its policies, lending criteria, awareness of terms and conditions for project financing with respect to geographical coverage.

- *Issues in Telecommunications Development Volume II: Reforming the international accounting rate system – 1998 Review, First edition, May 1999*

On behalf of the ITU, the Bureau of Telecommunications Development has taken on the responsibility of guiding, assisting and encouraging developing countries as they restructure their telecommunications sectors to meet the challenges of globalisation and liberalization.

This volume contains the reports from Validation Seminars and Workshops at which developing country representatives reviewed the moves towards international accounting rate reform and a number of papers dealing with cost calculation methodologies. They also provided useful contributions and recommendations for consideration by Study Group 3's Focus Group.

- *Issues in Telecommunications Development: Finance and Trade – 1998 Review, First edition, June 1999*

This publication is intended to provide an annual review of various key issues in international telecommunications as examined by the International Telecommunication Union/Telecommunication Development Bureau – ITU/BDT.

This year's authors have focused on trade, partnership and financing within the context of restructuring and globalisation. Papers have been selected to reflect a balance amongst the main stakeholders in telecommunications: governments, regulators, the private sector, telecommunications operators and the financial sector, as well as amongst the various regions. The case studies further illustrate the diversity of restructuring and the privatisation processes, as well as their impact on different stages of a country's development.

Detailed proceedings and reports have been produced separately. The Annexes comprise an inventory of financial institutions, and a comprehensive list of authors and papers presented at the Colloquia. All of these publications are available on request from the ITU/BDT.

- *Final Reports of the Telecommunication Trade and Finance Colloquia*

The six Final Reports (Volumes 1 and 2) are the resume of the six regional Trade and Finance Colloquia organized by the Telecommunications Development Bureau, during 1996 to 1998, in all the world.

Taking into account the significance of financing problems and global developments in the trade in telecommunication services in the word, the objectives of these six regional Colloquia were: to encourage and stimulate new sources and innovative modalities of financing; to facilitate partnership through bilateral and private meetings between the private and public sector; to foster telecommunication sector liberalization so as to facilitate the entry of new telecommunication operators.

- *Africa Telecommunication Finance Colloquium Abidjan, Côte d'Ivoire, 25-29 March 1996, Final Report (Vol. I and Vol. II)*

The Final Report (Volumes 1 and 2) is the resume of the Africa Telecommunication Finance Colloquium organized by the Telecommunication Development Bureau, 25-29 March 1996, took place in Abidjan, Côte d'Ivoire. It was provided appropriate, well-consolidated and innovative framework of action on financing and resource mobilisation strategies in the context of new technologies, changing regulatory environment for trade and investment in telecommunication.

- *Arab States Telecommunication Finance Colloquium Amman, Jordan, 1-4 September 1996, Final Report (Vol. I and Vol. II)*

The Final Report (Volumes 1 and 2) is the resume of the Arab States Telecommunication Finance Colloquium organized by the Telecommunication Development Bureau, 1-4 September 1996, took place in Amman, Jordan. The findings of the Colloquium provide a better understanding of the necessary conditions for attracting investment and for emphasising the importance of the investment required for the development of the telecommunication sector.

- *Telecommunication Trade and Finance Colloquium for Latin America and Caribbean Brasilia (Brazil), 14-16 July 1997, Final Report (Vol. I and Vol. II)*

The Final Report (Volumes 1 and 2) is the resume of the Latin America and Caribbean Telecommunication Finance and Trade Colloquium organized by the Telecommunications Development Bureau, 14-16 July 1997, took place in Brasilia, Brazil with the participation of 120 delegates from 33 countries. The objectives were: to encourage and stimulate new sources and innovative modalities of financing; to facilitate partnership through bilateral and private meetings between the private and public sector; and to foster telecommunication sector liberalization.

- *Telecommunication Trade and Finance Colloquium for Asia and Pacific, New Delhi (India), 3-5 November 1997, Final Report (Vol. I and Vol. II)*

The Final Report (Volume 1 and 2) is the resume of the Asia Pacific Telecommunication Trade and Finance Colloquium organized by the Telecommunication Development Bureau, 3-5 November 1997, it took place in New Delhi, India with the participation of 275 delegates from 28 countries. Its purpose was to address on a regional basis with all potential partners the critical issue of financing telecommunication development in each region, and related aspects of telecommunications.

- *Telecommunication Trade and Finance Colloquium for Europe, Geneva (Switzerland), 15-17 December 1997, Final Report (Vol. I and Vol. II)*

The Final Report (Volumes 1 and 2) is the resume of the Telecommunication Trade and Finance Colloquium for Europe organized by the Telecommunication Development Bureau, 15-17 December 1997, took place in Geneva, Switzerland. It was provided appropriate, well-consolidated and innovative framework of action on financing and resource mobilisation strategies in the context of new technologies, changing regulatory environment for trade and investment in telecommunication and specific requirements of different countries.

- *Telecommunication Trade and Finance Colloquium for CIS, St. Petersburg (Russia), 2-3 February 1998, Final Report (Vol. I and Vol. II)*

The Final Report (Volumes 1 and 2) is the resume of the Telecommunication Trade and Finance Colloquium for CIS Countries, organized by the Telecommunication Development Bureau, 2-3 February 1998, took place in St Petersburg, Russia with the participation of 113 delegates from 26 countries.

The findings of the Colloquium provide a better understanding of the necessary conditions for attracting investment and for emphasising the importance of the investment required for the development of the sector, as well as for setting up specific agreements between participants.

ANNEX 8A

Guidelines for bilateral negotiations of transitional arrangements towards cost-orientation, 1999 to 2001[1]

E.1 Introduction

This Annex contains the multilaterally-agreed guidelines to be used in bilateral negotiations to establish and revise accounting rates, accounting rate shares and transit shares during the transition to cost-orientation, in cases where it has not proved possible to apply Approach 1 in Annex C of this Recommendation, to the satisfaction of all parties in a correspondent relationship. When implementing these guidelines, the ITRs, Recommendations D.150, D.155 and other relevant D-series Recommendations should also be taken into account.

E.2 General

Recognizing the change in the international telecommunications environment and the agreement to expand the menu of remuneration arrangements to be incorporated into D.150, it is recommended that Administrations take into account the transitional arrangements towards cost-orientation, detailed below.

E.3 Indicative target rates for direct relations[2]

E.3.1 As a transitional measure pending the application of approach 1 in Annex C, it is recommended that Administrations progressively move towards and attain the indicative target rates set out in Table A1 in their bilateral negotiations. The target rates are shown in SDRs per minute, for countries / territories grouped according to their level of teledensity (telephone lines per 100 inhabitants) at 1st January 1998. Administrations which have already attained these indicative target rates should continue to take positive steps to reduce their accounting rates to cost orientated levels. When after 1 January 1999, a country or territory moves from one teledensity group to the next owing to an increase in the number of subscribers, the applicable indicative target rate should be adjusted accordingly and achieved within the same period as previously, subject to E.5.

Table A1 – Indicative target rates for direct relations (settlement rates)
Based on the average of the lowest 20 per cent of current published settlement rates in each teledensity group, and measured in SDRs per minute (T = telephone lines per 100 inhabitants)

Teledensity $T \leq 1$	$1 < T \leq 5$	$5 < T \leq 10$	$10 < T \leq 20$	$20 < T \leq 35$	$35 < T \leq 50$	$T > 50$
0.327 SDR	0.251 SDR	0.210 SDR	0.162 SDR	0.118 SDR	0.088 SDR	0.043 SDR

E.3.2 The indicative target rates in Table A1 show upper limits and should not be interpreted as providing any guidance for establishing lower limits for direct relations, nor should they be taken as cost-orientated levels.

1 Note: This period may be extended, subject to the provisions in paragraphs E.5.3.

2 The direct and transit target rates are not applicable between competitive markets.

E.3.3 For small island states, which are defined as having a population of less than 300'000 inhabitants, distant from a continental mainland, off the main cable routes and therefore reliant on satellite communications, the indicative target rate of 0.266 SDR per minute may be used. The countries/territories within this category (see Appendix) may choose to adhere to this target or the one relevant to its teledensity.

E.3.4 For the Least Developed Countries, which are recognized by the United Nations, the indicative target rate of 0.312 SDR per minute may be used. The 48 LDCs, plus the 3 "as if" LDCs, eligible within category (see Appendix) may choose to adhere to this target or the one relevant to its teledensity.

E.3.5 The transitional rates under Table A1 are not applicable to those Administrations who have calculated their costs according to a mutually agreed costing approach and are aware that their cost is different for terminating an international call on their network than that identified for them under Table A1.

E.3.6 Where the indicative target rates proposed in Table A1 differ from the results obtained by applying a regional cost model which has been recognized by ITU-T Study Group 3, the results of the cost model could be applied, by bilateral agreement, within the region and in relations with Administrations outside the region, as described in Approach 1 of Annex C of this Recommendation. It is recognized that where this is not possible, the indicative target rates proposed in Table A1 could be used as the basis for the cost and/or accounting rate trends described in Approach 2 of Annex C of this Recommendation.

E.3.7 It is recommended that Administrations should utilize an appropriate costing methodology as soon as possible to determine their relevant costs.

E.3.8 Where the indicative target rates proposed in Table A1 differ from the cost elements identified in a country case study, which has been validated by the region concerned and endorsed by ITU-T Study Group 3, the cost elements from the case study could be applied, by bilateral agreement, within the region and in relations with Administrations outside the region.

E.4 Indicative target rate for indirect relation (transit share)[3]

E.4.1 In order to provide guidance on transit shares, on routes where an origin Administration lacks choice[4] among transit routes and service providers, it is recommended that transit Administrations move towards the indicative target rate (upper limit) of 0.05 SDRs per minute.

E.4.2 The indicative target rate of 0.05 SDR (upper limit) should not be interpreted as providing any guidance for establishing lower limit for transit shares, nor should it be taken as cost-orientated levels. It is recognized that, on competitive routes, transit shares may be considerably below that target rate.

E.5 Transition period

E.5.1 The starting point for the transition would be the current settlement rate level and transit share level.

E.5.2 The transitional arrangements towards cost-orientation should be negotiated through bilateral agreement, for instance in the following ways:

a) On the principle of a 50/50 division of accounting revenue from traffic exchanged (symmetry), with both Administrations applying the same rate (settlement rate) to attain a level at or below the

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[3] The direct and transit target rates are not applicable between competitive markets.

[4] Only has access to three or less independent and comparable transit providers.

indicative target rate of the Administration in the lower teledensity category by or before the end of the transition period.

b) In an asymmetric manner, with both Administrations applying different rates for call termination, in the context of an agreement to move to below the indicative target rate of the Administration in the lower teledensity category. In this case the Administration in the higher teledensity category would apply a lower rate for call termination than the Administration in the lower teledensity category.

c) In order to enhance Universal Access to telecommunications in developing countries, Administrations in developed countries may give consideration to terminating incoming calls at their own cost-orientated rate without requiring reciprocal treatment. Such consideration would be voluntary and based on bilateral agreement.

E.5.3 It is recommended that the indicative target rates for direct relations in Table A1 be attained by staged reductions over a three year period (i.e., by year-end 2001). However, for those Administrations in LDCs plus the 3 "as if" LDCs, a longer transition period is recommended, as a function of the level of dependency of the country on net settlement payments, as proposed in Table A2.

The level of dependence on net settlement payments as shown in Table A2 should be calculated on the basis of the moving average of the last three years. It shall be recalculated each year. If an administration's level of dependence moves, from one year to the next, from one category to another, the target year will be adjusted accordingly but not beyond 2004.

Where circumstances are identified, through a transparent process, of the significant difficulties other Administrations may have in coping with the reduction, the target date may be deferred by bilateral agreement. Similarly Administrations that have identified through a transparent process, serious difficulties in meeting the target rates proposed in Table A1 may apply, by bilateral agreement a program of regular/annual reductions.

E.5.4 It is recommended that the transit shares be reduced progressively in order to arrive at the indicative target rate of 0.05 SDR (upper limit) by the end of year 2000.

Table A2: Transition period as a function of dependence on net settlement payments (NSP)

Net settlement payments (NSP) as a percentage of total telecommunication revenue (TTR)	Target year for achieving target rate
NSP < 10 per cent of TTR	year-end 2001
10 < NSP < 20 per cent of TTR	year-end 2002
20 < NSP < 30 per cent of TTR	year-end 2003
NSP > 30 per cent of TTR	year-end 2004

Note: 1. Calculations should be based on published data, from company accounts, on net settlement payments and total telecommunication revenue, valid for 1997 or most recent.

2. Data for net settlement payments and total telecommunication revenue should be valid for the country/territory as a whole,not just an individual Administration.

E.6 Universal Service Obligations

Any Member State has the right to define the kind of Universal Service Obligation it wishes to maintain. However, such Obligations should be administered in a transparent, non-discriminatory and competitively neutral manner which is not more burdensome than necessary for the kind of universal service defined by the Member.