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Contents

Cover
Dehlfi is a computerised system for quality inspection in optical-fibre cable production. The Dehlfi system is available in three languages: English, Spanish and Swedish. The picture shows cable attenuation testing at Ericsson's Fibroco factory in Spain.

ERICSSON REVIEW

BO HEDFORS
Publisher 1992–

GÖSTA LINDBERG
Publisher 1979–1991

GÖRAN NORRMAN
Editor 1986–1991

EDITORIAL CHANGES

On March 1, 1992, Gösta Lindberg and Göran Norrman retired from their respective posts as publisher and editor of Ericsson Review. The new publisher is Bo Hedfors, senior vice president in Telefonaktiebolaget L M Ericsson and Director of Corporate Systems and Technology. Per-Olof Thyselius has been appointed as the new editor.

Gösta Lindberg succeeded Dr Christian Jacobaeus as publisher of Ericsson Review in 1979, following his appointment as Technical Director of Telefonaktiebolaget L M Ericsson. Gösta Lindberg has taken an active part in making Ericsson Review an objective and informative technical journal and has been a valuable support to the successive editors during his 13 years as publisher.

Göran Norrman leaves his position as editor of Ericsson Review with this issue. When he succeeded Gösta Neovius, in 1986, he had a long and successful service to the company behind him. His broad technical knowledge and interest in technology has been very valuable in his editorial work, which has been much appreciated by the publisher and management, and not least by the readers.

From the editor's desk

This, the first issue of Ericsson Review after my appointment as editor, is also the first issue to be published in English only. Subscribers who have previously received the French, Spanish or Swedish editions will from now on receive only the English edition. When the Board of Ericsson Review recently decided to stop publishing the non-English editions, their prime motive was the awkward delay between the first and last editions – even considering that Ericsson Review has never had the ambition to be a technical news magazine. Another basis for the decision was, of course, our firm belief that the majority of our French, Spanish and Swedish readers are familiar with English.

To avoid the situation of our English readers receiving the first issue of Ericsson Review 1992 prior to the last 1991 issue, we have chosen to publish a double-issue: 1–2, 1992.

Ericsson Review was first published in 1923, and as early as 1924 it became a five-language magazine. Since the discontinuance of the German edition, it has been issued in four languages. The ambition from the start was to publish a technical magazine to spread knowledge of Ericsson products and Ericsson technology to our customers' technical staffs and to the technical staffs within our own worldwide organisation. This objective has never been changed. The major content of Ericsson Review has always been descriptions of our different systems and products and outlines of our technical objectives. Occasionally, the magazine has also contained news from Ericsson's business operations, large telecom exhibitions and conferences.

Scientific material from our applied research activities had once an exclusive outlet in the form of Ericsson Technics. This magazine was integrated with Ericsson Review in 1978. Unfortunately, it turned out that scientific material met with difficulties in competing for space in Ericsson Review. The readers are the only ones who can change this situation, and we will certainly appreciate it if they inform us of their views on Ericsson Review and its contents.

During my 38 years of working with different parts of Ericsson, I have myself been a regular reader of Ericsson Review. Taking office as editor I will do my best to create a readable and informative magazine in the years to come.

PER-OLOF THYSELIUS
Editor 1992–

Frame Relay – for Faster and More Efficient Data Communications

Kajsa Lundfall

KAJSA LUNDFALL
Ericsson Business Communications

Today, workstations and personal computers have become everyday tools. This fact has radically changed the conditions for data communications networking. The processing power has moved from computer centres to users' desks. The communications pattern is also different: it is no longer a matter of exchanging transactions of the question/answer type, but of transferring large volumes of data in the form of "bursts". At the same time, technological improvements in the transport networks have resulted in better data transmission quality. This, in turn, reduces the need for error-correcting functions in the communication protocols; instead, efforts focus on the ever-growing need for higher transmission speed. Efficient handling of the new situation requires new protocols and new communications systems.
The author describes the way technological advances and a growing market demand contribute to the development of new communications protocols such as Frame Relay. The article compares Frame Relay to packet switching (X.25) and describes how Frame Relay works.

data communication systems
computer networks
packet switching
protocols

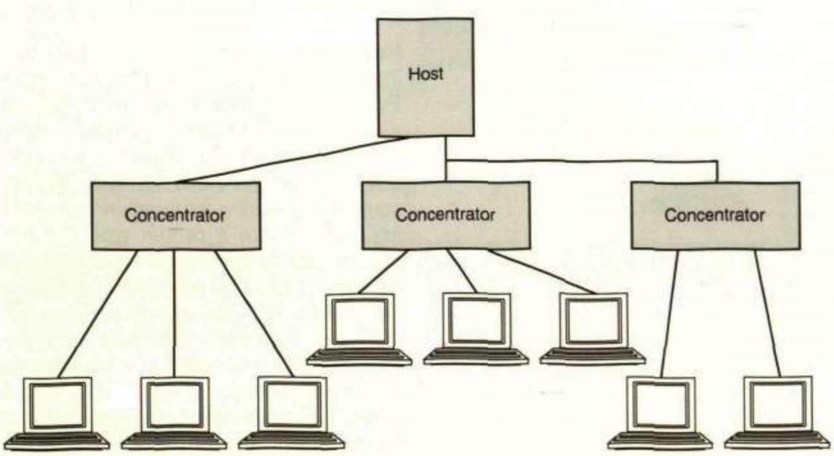
In the last few years we have been witnessing how developments in the data processing and data communication fields have changed the use of computers in many companies. Due to the low cost of personal computers and workstations, practically every desk is equipped with these tools today. The typical information system is no longer a centralised multi-user system, but a decentralised system made up of interacting Local Area Networks (LAN). These inter-networks (composed of various LANs) place new demands on the Wide Area Networks (WAN).

Centralised systems

The core of a typical transaction-oriented system is a central host computer which serves a large number of terminal users connected via concentrators and communication processors, Fig. 1. All exchange of information between a terminal and its environment takes place via the host computer, which also accommodates all processing power. Most of today's applications and communication networks have been designed for operation in this environment.

The typical transaction is a text string (a question) which is sent to the host computer, and a full screen (an answer) which is sent from the host computer to the terminal. Very little graphics – if any at all – is used, and the amount of information transferred is small. Moderate transmission speed can be used, even when the requirements for short response time are stringent.

Fig. 1
Traditional centralised multi-user system
The environment is primarily designed for moderate transmission speed



Distributed systems

The present development in computer technology is creating a new computer environment – based on Local Area Networks and distributed, interacting applications – which supplements the traditional host computer configuration. LANs use simple protocols and provide high transmission speed for data communications over short distances. Gone is the centralised arrangement, with a master-slave relationship between computer and terminal, in which all information must pass through a mainframe.

Local Area Networks and personal computers have developed along parallel lines.

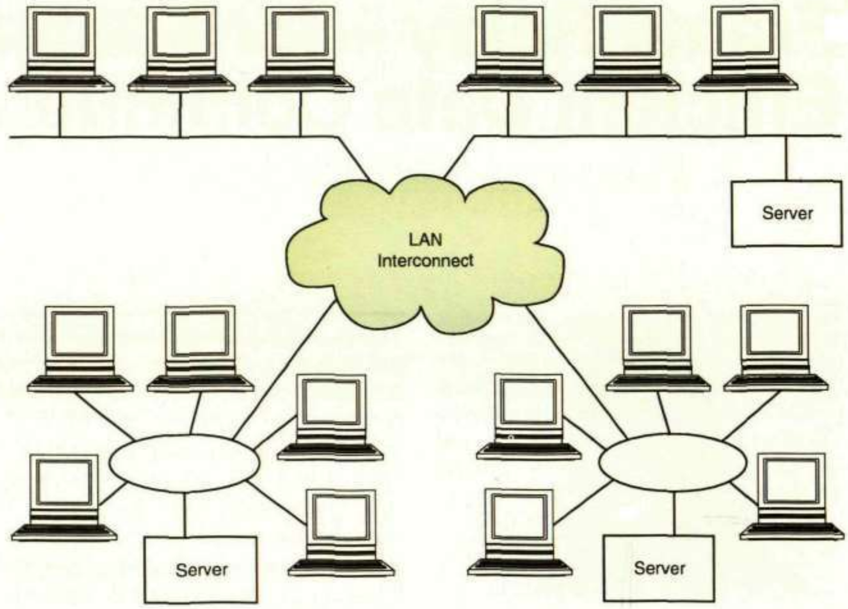


Fig. 2
Distributed computer environment based on Local Area Networks using internal transmission speeds of several Mbit/s. This places exacting demands on the datacom network, which is required to provide cost-effective LAN-to-LAN communications

Fig. 3
The transfer time varies with the link transmission speed, which in turn is dependent on the type of file transferred. When programs or files containing graphics are to be transferred, a link transmission speed of 64 kbit/s will result in unsatisfactory response time

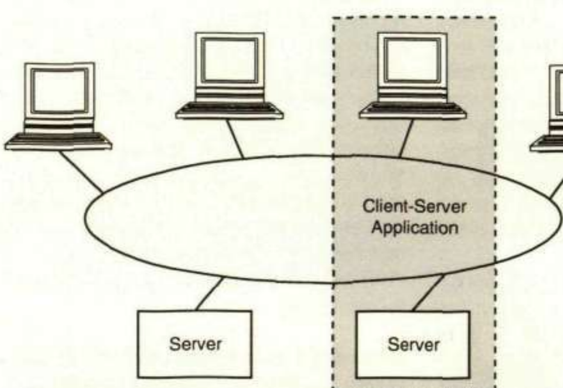
Type of file	64 kbit/s	2 Mbit/s
2 text pages	1/3 s	1/100 s
1 page of spreadsheet	6 s	1/5 s
1 drawing page	15 s	1/2 s
Large program file	1 min	2 s

The design of protocols for Local Area Networks has been based on the demand for these networks to be capable of handling short response times and transferring large amounts of data (file transfers, etc). This has been achieved by building LANs with internal cabling for data transmission at high speeds. The Wide Area Networks, on the other hand, use the existing transmission infrastructure, which is primarily designed for telephone traffic.

Increasingly, applications in the LAN environment are introducing more graphics, which accentuates the need for large file information transfer at high speed. An LAN can manage transmission speeds of 4, 10 or 16 Mbit/s, or even more. The transfer time is short even for large information volumes, and databases, program libraries and advanced I/O devices serving the entire network have become a reality. In a typical LAN, data is processed on the user's own personal computer or workstation. The user connects himself to the network only to print out files or to transfer files or programs to a server or retrieve them from that server. Information is transferred in the form of short bursts at a relatively low frequency.

The need for communications outside the local environment requires a distributed infrastructure, as exemplified in Fig. 2. But LAN-to-LAN traffic in Wide Area Networks is not altogether uncomplicated. Both technology and economy make the transmission speed on the links between local environments a restricting factor. Fig. 3 illustrates the differences in transfer time for different file types transferred on a link at 9.6 kbit/s, 64 kbit/s and 2 Mbit/s.

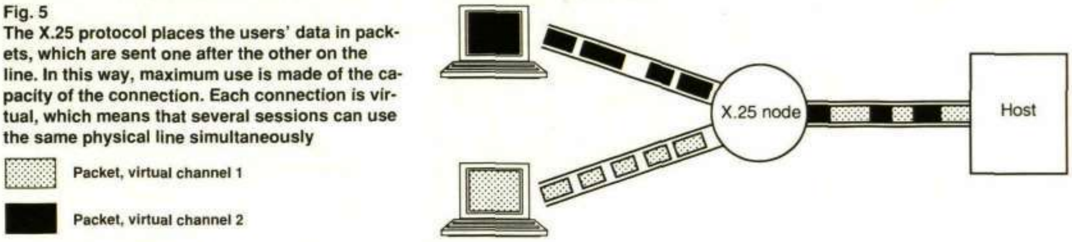
Fig. 4
A client-server application makes efficient use of the combined processing power provided by the host computer and the personal computer/workstation. This makes exacting demands on the network



New architectures

The processing power offered by today's PCs and workstations is sufficient for most applications. Databases, program libraries and many other applications are characterised by the need for common resources for storing information or for telling users where a certain type of information can be accessed. In LANs, these common resources are available in servers. In most PC networks, however, servers have so far been used only as an extra hard disk for storage and printout of data. All processing of data has taken place in the local workstation. In order to make more efficient use of the processing power

Fig. 5
The X.25 protocol places the users' data in packets, which are sent one after the other on the line. In this way, maximum use is made of the capacity of the connection. Each connection is virtual, which means that several sessions can use the same physical line simultaneously



provided by the server, a new type of application has emerged in which the server and the workstation share the processing work. This new way of designing applications is called the client-server model, Fig. 4.

In the future, the client-server concept may permit use of the network as an external data bus between workstation and server, a configuration which will place very high demands on fast and safe information transfer in the network.

The client-server model does not require that the user knows where the requested information is stored. It may be in a server in his own LAN or in another LAN that forms part of the network. The location of data is transparent to the user: he addresses the service he wants to use, leaving it to the network to keep track of where it is executed. These conditions set the requirements for LAN-to-LAN traffic that characterise future development of long-distance networks.

Improved transport networks

The ongoing modernisation of public telecom networks replaces analog transmission to a great extent with more robust digital technology, including extensive use of fibre optic cables that are immune to interference. The result is significantly decreased error rate and a dramatic reduction in the leasing cost of digital connections for transmission speeds of 64 kbit/s and upwards.

Planning for higher transmission speed

The Local Area Networks have the capacity required to meet the need for high-speed connections with very short delay, which is the result of increased workstation processing power and larger information volume in each transfer. The digitalisation of public networks makes it possible to meet this need in Wide Area Networks too. However, a traffic pattern characterised by short information bursts and high transmission speed means poor utilisation of point-to point connections between two Local Area Networks. Communication protocols which permit interleaving of traffic from a large number of users over a single communication line, are a prerequisite for cost-effective handling in Wide Area Networks.

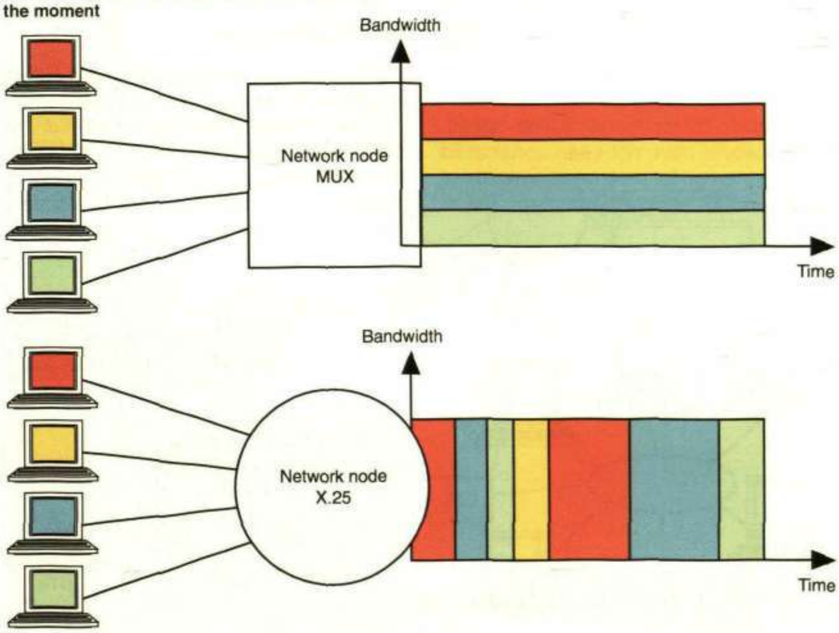
X.25

So far, X.25, or packet switching, has been the leading established communications protocol capable of interleaving data from many users over a single line. Packet switching is used both for public services and in private networks in order to ensure satisfactory economic utilisation of network trunks, Fig. 5.

X.25 is an effective method for meeting intermittent data communication needs, and today's X.25 networks have worldwide coverage. X.25 does not stipulate pre-allocation of a specific portion of the bit flow to a specific connection between two users. As opposed to time division multiplexing, this means that the whole bit flow is available to the user who has data to send at the moment, Fig. 6. This also means that several so-called "virtual connections" are set up in parallel over the same physical link. Each of these connections is allocated a logical channel: a unique identity indicated in the data packet header.

Two types of connection are defined in X.25: Permanent Virtual Connections

Fig. 6
X.25 switching permits maximum utilisation of the capacity of the connection, all of which is available for use by the party who needs it for the moment



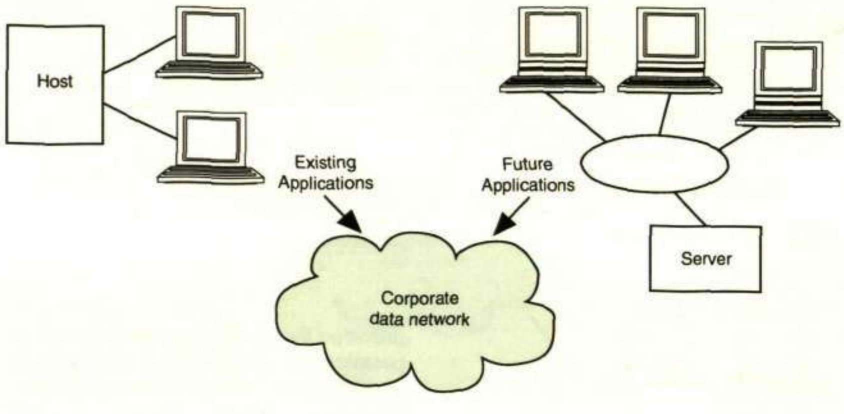


Fig. 7
A company's data network should be designed so as to permit both existing and future applications to use the same physical network

Box 1
Standardisation of Frame Relay

Frame Relay as a communications standard was first proposed by CCITT in the late 80's and then presented in Recommendation I.122. At that time, the US standardisation body ANSI had also began to take an interest in this field, but the result of both bodies' work was rather long in coming. Northern Telecom, DEC, CISCO, and Stratacom therefore took the matter in their own hands, submitting at the end of 1990 a proposal for a standard based on the existing – but still incomplete – proposals drawn up by CCITT and ANSI. This proposal also contained a "Local Management Interface", LMI, which describes the exchange of information on link status between the DTEs and the network. To complete the work and force the pace of standardisation, Frame Relay Forum was established in January, 1991.

More than 70 companies including Ericsson are now members of Frame Relay Forum, which does not do any standardisation work of its own but submits proposals to existing standardisation bodies such as CCITT, ANSI and ETSI. The formation of Frame Relay Forum speeded up the standardisation work, and the CCITT and ANSI standards have now reached an appreciable degree of development, including the specification of LMI functionality.

CCITT's recommendations include I.223 (which describes the service), Q.922 (describing the frame) and Q.933 (signalling). ANSI's versions of these standards, which are basically equivalent to those specified by CCITT, are called T1.606 (the service), T1.618 (frame) and T1.617 (signalling).

(PVC) and Virtual Connections (VC). The Permanent Virtual Connection is a network path which is predefined by the network operator. The procedure for setting up a Virtual Connection includes indication of the address by means of a Network Terminal Number, which is unique to each set of equipment connected. No network operator is involved in this set-up procedure, which results in the establishment of a network path that remains connected until the sender or receiver orders its release.

The X.25 protocol is based on the store-and-forward principle. Packets entering the network are stored in a buffer and passed on in the order of their arrival. The transfer over each individual link is monitored separately, and an error results in initiation of retransmission on the link. In this way, correct data transfer is possible even in networks with heavily disturbed connections. There is one disadvantage, however; the protocol handling requires much processing power, which causes delay and limits the available transfer speed. Today, a typical X.25 network cannot efficiently utilise link speeds above 64 kbit/s. But the development towards higher transmission speed is evident in the X.25 networks, too, and follows the development of microprocessor capacity.

Due to their limited transmission speed, X.25 networks have not been considered effective enough for the interconnection of LANs in a wide-area environment. Point-to-point connections have been preferred when high transmission speed has been the prime requirement. Although point-to-point configurations provide the required transmission speed, they are not usually cost-effective. The reason for this is that LAN interconnect applications generate data in the form of bursts; that is, they utilise the available capacity for very short periods only. In fact, the connections are passive most of the time, resulting in a low degree of utilisation.

Network solutions of today and tomorrow

The new and the traditional, centralised datacom environments usually coexist in a company's organisation. Today, many companies therefore have a datacom environment made up of separate infrastructures. A uniform communications environment must be able to meet the needs of both LAN-to-LAN connections and of the large number of terminals connected to host computers, Fig. 7.

Frame Relay – a new alternative in data communications

The purpose of introducing Frame Relay is to meet the new requirements, and mainly those resulting from the development of LAN-to-LAN communications. The standard defines a simplified packet switching service which meets the need for a simple

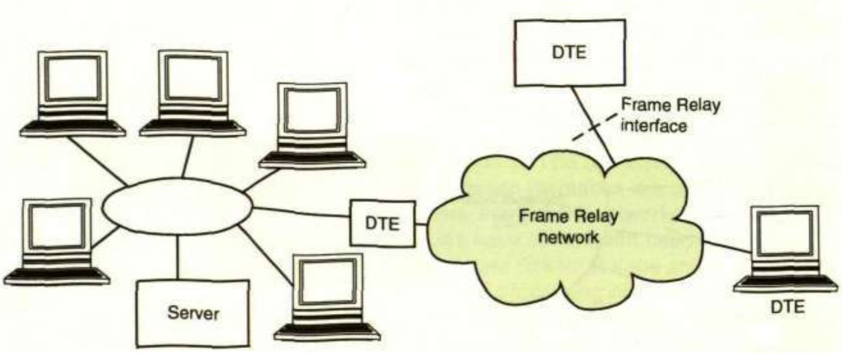


Fig. 8
The Frame Relay standard specifies an interface between a user and a Frame Relay network

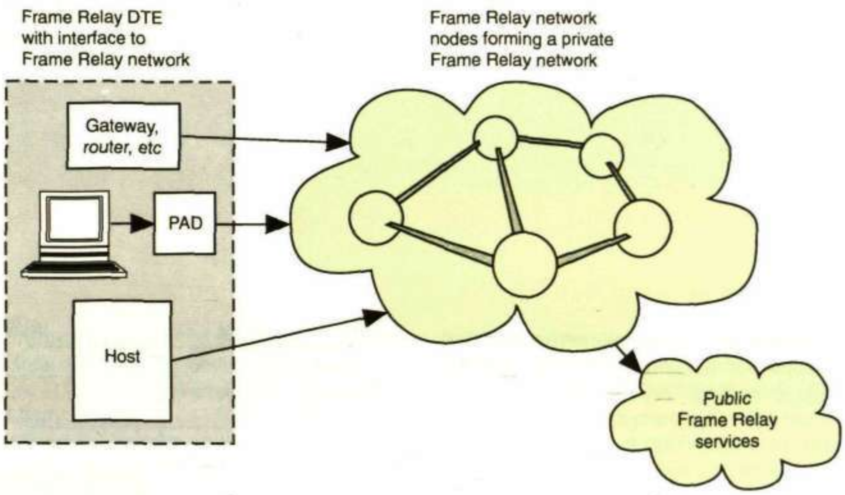


Fig. 9
A typical Frame Relay network with DTEs, network nodes and public Frame Relay services

data transmission protocol focusing on high speed and requiring a minimum of error-correcting and flow-controlling functions.

The standard, which is described in both CCITT and ANSI recommendations, defines signal and data transmission at link level, OSI level 2, in the interface between user equipment and network, Fig. 8. (Cf. X.25, which comprises the first three OSI levels and uses a frame at level 2 for the transmission of a packet at level 3.) The standardisation work is briefly described in Box 1.

How Frame Relay works

A Frame Relay network is made up of network nodes and user equipment, DTE:s (Date Terminal Equipment) connected to the network. The DTE, e.g., a personal computer, a gateway, a router or a host computer, is provided with the interface defined for Frame Relay, Fig. 9.

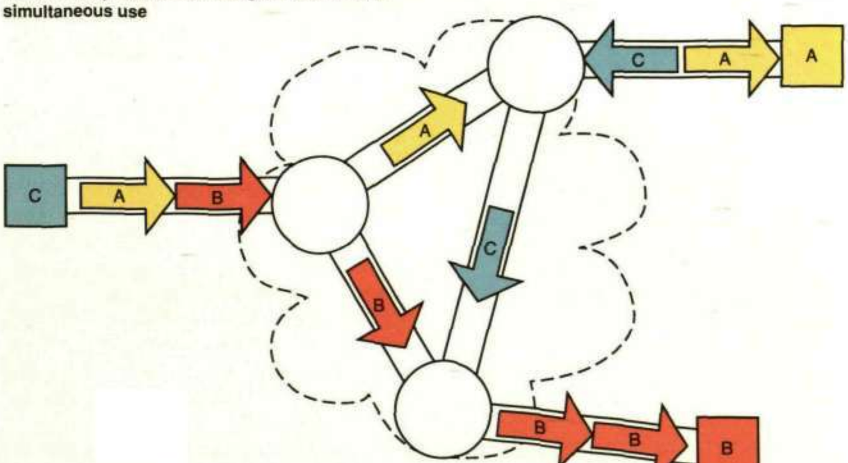
The sending DTE transmits frames to the network. Each of these frames contains an identification code (Data Link Connection Identifier, DLCI). All network nodes along the path to the final destination contain information indicating the outgoing channel to which a frame with a specific identification code is to be sent. The path between the sending and receiving DTEs has been predefined by the network operator. This type of connection – a Permanent Virtual Connection – is so far the only one defined in the standard. Virtual connections are not included in today's Frame Relay function, but future versions of the protocol are expected to allow such connections too.

The network node routes to the right destinations the frames sent from a DTE. The network node reads the identification code of the incoming frame and sends the frame (without changing it) on the outgoing channel indicated in the node's routing table. This outgoing channel can either be a connection to another network node (in which case the procedure described above is repeated) or a connection directly to the terminating DTE. However, the way the frames are handled internally in the network is not defined in the standard.

As in X.25 switching, the use of several identification codes permits several parallel sessions in different directions to coexist on one physical connection, Fig. 10. In this way, a DTE can communicate simultaneously with different destinations over the same physical connection to the network. This is necessary if the DTE is a communications port in an LAN, but it is also an attractive solution in cases where the DTE is a personal computer or workstation that uses several simultaneously active windows.

Handling is simple because the protocol does not include any error-correcting mechanism. Speeds of several Mbit/s can be used without requiring unreasonable processing capacity for link handling. Today's version of the standard stipulates a maximum link transmission speed of

Fig. 10
Frame Relay networks use permanent virtual connections, which means that a physical connection can provide several logical channels for simultaneous use



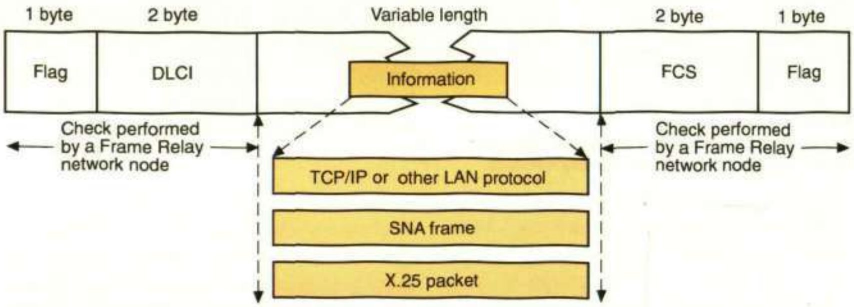


Fig. 11
The frame format used for Frame Relay

2 Mbit/s, but considerably higher speeds can be expected.

Frame Structure

The frame format used for Frame Relay is based on LAPD (Link Access Protocol D), which has been specified by CCITT (Q.922) and ANSI (T1.618). The frame, Fig. 11, is used to carry both user data and identification code (DLCI). The header of the LAPD frame consists of two byte and contains – in addition to the 10-bit DLCI – information bits for flow control (BECN, FECN and a DE bit; see below).

The length of the information field in the LAPD frame is adjustable to a maximum value defined for the service concerned. The length is normally set to a value at which the information from the application – a TCP/IP packet, an SDLC frame, an X.25 packet, etc – can be carried without having to be split.

The frame ends in a Frame Checking Sequence, FCS, which is used to check that the frame has been transferred correctly. As opposed to X.25, where an erroneous FCS triggers a retransmission procedure over the link, the network cannot guarantee that all frames will reach their destination. Frames indicated as erroneous by the FCS are discarded, but this does not necessarily mean that the user loses any data. Checking to ensure that the DTE-to-DTE transmission has been error-free is usually a mandatory function in the higher-level protocol used for information transfer in the application concerned. If an error occurs, data must be retransmitted through the entire network, and this obviously takes longer time than retransmission only over the link on which the error occurred. An approximate limit where Frame Relay is effective is a Bit Error Ratio (BER) of no more than 1/1,000,000 on individual links. This means that modern, digital transport networks are well suited for the simplified protocol, but if the chain contains an analog link, a short delay time for each link must be weighed against the expected frequency of end-to-end retransmission.

Flow control and handling of overload situations

The handling of an overload situation in a Frame Relay network demands less of the switching equipment than handling the same situation in an X.25 network. In the latter case, the flow is controlled by the network node sending confirmation messages in the backward direction to the DTE, to the effect that sending may go on. If no message is forthcoming, the DTE will stop sending new packets until it has received a confirmation. This rule ensures a controlled and stable system, at the cost of delayed transfer.

Fig. 12
The address field of the frame used for Frame Relay consists of a DLCI and control /check information for flow handling

C/R	Command/Response indication bit
EA	Extended Address bits
FECN	Forward Explicit Congestion Notification bit
BECN	Backward Explicit Congestion Notication bit
DE	Discard Eligibility bit

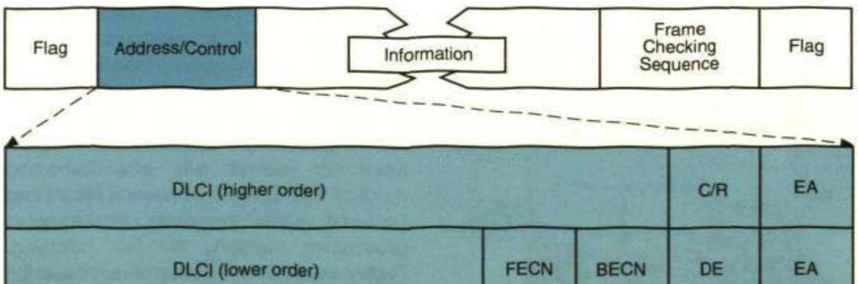
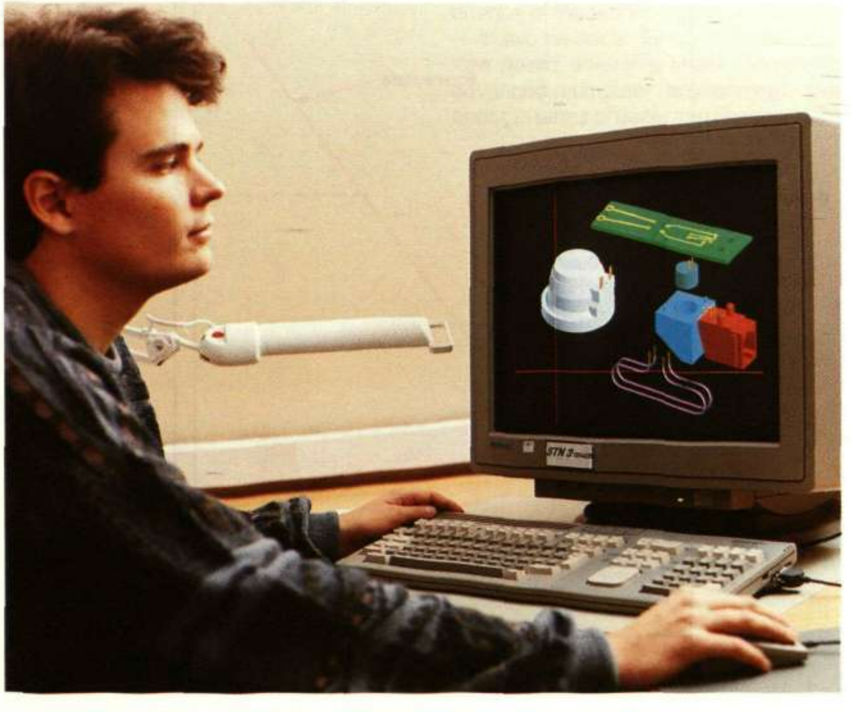


Fig. 13
Applications which use sophisticated graphics and therefore generate very large files are becoming more and more frequent. Transfer through the network requires a transmission speed of several Mbit/s to obtain a reasonable response time. Local networks are well adapted to this requirement, but in wide area network transfer there may be inconveniences, since these networks did not initially have the infrastructure required for high transmission speeds.

In pace with the digitalisation of the wide area networks, new communication protocols are now evolving, the development of them being to a large extent driven by the demand for efficient LAN-to-LAN communication. Frame Relay is one example of this trend



Frame Relay is based on the opposite principle: the network node sends signals to the DTE only in overload situations. This means simplified handling, and no delays will occur as long as the traffic is undisturbed. A Frame Relay network reacts to overload in two steps:

1 When the node registers a tendency towards overload, the network requests the DTE to reduce its data flow by sending a Forward/Backward Explicit Congestion Notification (FECN/BECN) consisting of the check bits of the frame header, Fig. 12. The network takes no action but leaves it to the DTE to decide on the best way of controlling its data flow.

2 If overload occurs, the network will discard frames.

The standard does not say how the network will define the concept "tendency towards overload". To exemplify, the node can count the number of frames queued for access to outgoing lines, or check the CPU load, and then send an FECN/BECN signal when a preset limit value is exceeded.

As has been mentioned already, a discarded frame in the network will not result in loss of information. The higher-level user application protocol checks that the terminating DTE sends a confirmation of data having arrived. If no such confirmation is received, retransmission through the entire network will be initiated, resulting in undesired delays, i.e. longer response time.

Transferring the flow control to the DTE clearly involves a risk, since most of today's frame-relay-compatible DTEs cannot handle FECN and BECN signals. Some suppliers of equipment capable of handling FECN/BECN signals recommend users to switch off the function in order to avoid falling behind when competing for transport capacity with equipment without that function.

For the simplified flow handling to function properly, each connection from a DTE is allocated a Committed Information Rate, CIR. This rate is affiliated to the virtual connection through the network, and the rate value determines how much data the DTE can send on this connection during a given period of time.

The standard does not give a strict definition of how to use the CIR value. It could, for example, be chosen so that each PVC would be guaranteed access to a given bit flow, which would basically be the same as using a leased line. A 2 Mbit/s connection would then be able to carry 32 PVCs of 64 kbit/s each. However, a more rational use will be ensured by starting from the stochastic traffic characteristics and interpreting CIR as a stochastic value of the average amount of data that a PVC is expected to carry during a given period of integration. Since the traffic is in the form of bursts, there is little probability of all sources sending at the same time. In other words, we can allow a PVC to momentarily utilise a relatively large portion of the available transmission capacity, provided the stipulated average value is kept. At an integration time of, say, 0.5 s, a CIR value of 256 kbit/s for a PVC will mean that the DTE can use this PVC for sending one or more bursts of altogether 128 kbit during each 500 ms interval.

Assigning CIR values will facilitate calculation of the traffic flow through the network. When the CIR value is exceeded, the Discard Eligibility bit in the frame header (DE, Fig. 12) should be set to 1. If this is not done in the DTE, it will be done by the access node of the network. If overload occurs, queued frames whose DE bit is set will be discarded before other, unmarked frames. The DTE is allowed to exceed the assigned CIR by a predetermined value, the Excess Burst Size. If larger amounts of data are being transmitted, all excess frames will be discarded, regardless of the load situation in the network, Fig. 14.

An overload situation may remain in the network even after all frames with set DE bits have been discarded. In order to further organise the continued discarding, it is also possible to establish an order of priority for the different virtual connections. This is up to the manufacturer or operator to decide, since the Frame Relay recommendation does not define any priorities.

Supervision of the interface
Supervisory frames with reserved DLCI addresses are used for two purposes: for supervision and for exchange of information between the network and the DTEs. The link status and the information indicating active or inactive link are transferred in these frames. Indication of the status of permanent virtual connections and execution of changes in the DLCIs used are other functions of these information frames.

Implementation of Frame Relay

Frame Relay can be implemented in different ways:

- As part of a private packet switching network that also supports other types of communication, such as X.25 and SNA.
- As a virtual private network consisting of an operator network section dedicated to use by a specific customer, a company or an organisation.
- As a public Frame Relay service provided by the PTT or some other operator.
- As a hybrid solution: a private network covering the primary geographical area of a company, and peripheral units connected via public Frame Relay services.

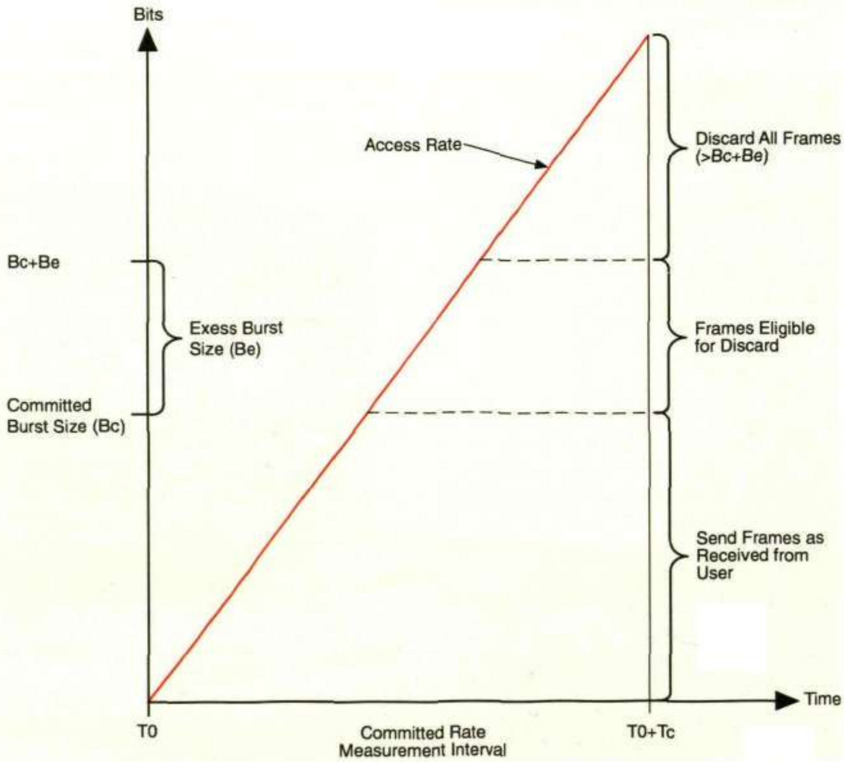


Fig. 14
Handling an overload situation in a Frame Relay network. Each Virtual Connection through the network is assigned a Committed Information Rate (CIR). The CIR value is generated by the network and indicates that the DTE on this connection is capable of sending a given amount (Committed Burst Size, Bc) of data during a given period of time (Tc), CIR=Bc/Tc. Provided the network is not overloaded, the DTE is allowed to send a somewhat larger amount of data (Excess Burst Size, Be) on the connection. But if an overload situation occurs, this extra amount will be cancelled and any frames above the CIR value discarded. If the DTE exceeds the maximum permissible quota (Bc + Be) for a given connection, the network will always discard the excess number of frames

Frame Relay in ERIPAX

Ericsson's packet switching system ERIPAX is continuosly improved to meet the emerging demands for an enhanced packet switching service. Frame Relay services is currently added to ERIPAX functionality.

The implementation of Frame Relay in ERIPAX conforms to applicable international standards but also includes additional services of value to the user. To follow and influence the Frame Relay standardisation process, Ericcson has been a member of the Frame Relay Forum since its founding in 1991.

Frame Relay will be offered as an integrated software function in the ERIPAX node, allowing packet switching and Frame Relay services to co-exist in the node. Packet-switched services, such as X.25 and SNA/SDLC, may use Frame Relay as a bearer service within the network and – without any additional investments – benefit by the higher speed and capacity of the Frame Relay service. If so required, certain parts of a network can be restricted for use of one of the services only.

Frame Relay services in ERIPAX will be described by Göran Ingemarsson and Bo Karlander in an article in the next issue of Ericsson Review.

A study of the 1000 largest companies in the USA, made by the Yankee Group and published in Data Communications International, January 1992, shows that 64 % of these companies were planning to install communications systems based on Frame Relay technology within the next two to five years. Western Europe is probably some years behind the development in the US, where deregulation has played an important role and where LANs are in more frequent use than in Europe.

Advantages of Frame Relay

Frame Relay is basically a simplified implementation of the X.25 protocol, aimed at facilitating a marked increase of the transmission speed on network links and DTE lines. The advantages of the X.25 protocol remain unchanged, i.e. efficient traffic interleaving and the possibility of establishing several connections over the same physical channel. The consequences of the removal of the error-correcting function and the greatly simplified flow control on individual network links are more than compensated for by the improved transmission quality obtained by extensive digitalisation of the public transmission facilities.

Frame Relay is therefore a logical consequence of the technological development — in two respects. Firstly, in terms of the new needs emerging in the increasingly advanced computer environment. Secondly, in terms of faster and cheaper transmission (characterised by a lower level of sensitivity to interference), which is the result of improved digital technology and which is probably also enhanced by the ongoing deregulation of public telecom operations.

Another important factor is the ease with which Frame Relay can be introduced in today's data communications environment. A PC, a workstation or a server becomes a Frame Relay DTE after adding software of low complexity. Frame Relay, just as X.25, is a specification of the interface between the DTE and the network, and many of the functions offered today by the X.25 networks (such as alternative routing and charging) can be directly applied when implementing Frame Relay functionality in an X.25 node.

No network-to-network interface is specified in the present version of the standard, but the standardisation work is in progress. The result of this work is likely to further strengthen the position of Frame Relay as an attractive public and private service.

Effective LAN-to-LAN communication is the driving force behind the introduction of Frame Relay, but once the Frame Relay networks have been implemented it will be possible to offer better solutions to other datacom needs too. Therefore, it is not surprising that Frame Relay has been widely accepted, both by operators and by suppliers of equipment for corporate datacom networks.

Computerised System for Quality Inspection in Optical-Fibre Cable Production

Göran Nilsson and Solweig Viklund

In order to meet the market's increasingly stringent quality requirements – those specified in SS-ISO 9001, for example – Ericsson Cables AB in Hudiksvall, Sweden, has developed a computerised system for quality inspection in optical-fibre cable production. The system, called Dehlfi, has been in operation at the Hudiksvall factory since 1988; another version has been used at Ericsson Cables' Spanish factory since its inauguration in July, 1991.

The authors describe the system's design, functions and field of application.

optical cables
optical fibres
quality control
inspection
statistical process control

Quality is a concept of vital importance to Ericsson Cables. For a product to be improved and optimised, its characteristics must be known. Knowledge of a product's quality is largely a matter of information – in design, sales and administration – and this information must be easy to understand and make use of.

A considerable number of parameters are needed in the design and manufacture of optical fibre and cable. Large amounts of measurement data have to be presented in an attractive and comprehensible way – even to our customers. To achieve our quality objectives we must have a system that can receive, store, process and present the necessary information. That is why Ericsson Cables has developed a computerised system called Dehlfi (Database at Ericsson Hudiksvall for optical Fibre and cable).

Some requirements have been given top priority in the development of the system:
- data must admit of being automatically entered and stored in the database
- the database must be user-friendly and easy to modify
- the database must allow the use of complex relations
- printouts – especially those in the form of customer documents – must be of high quality.

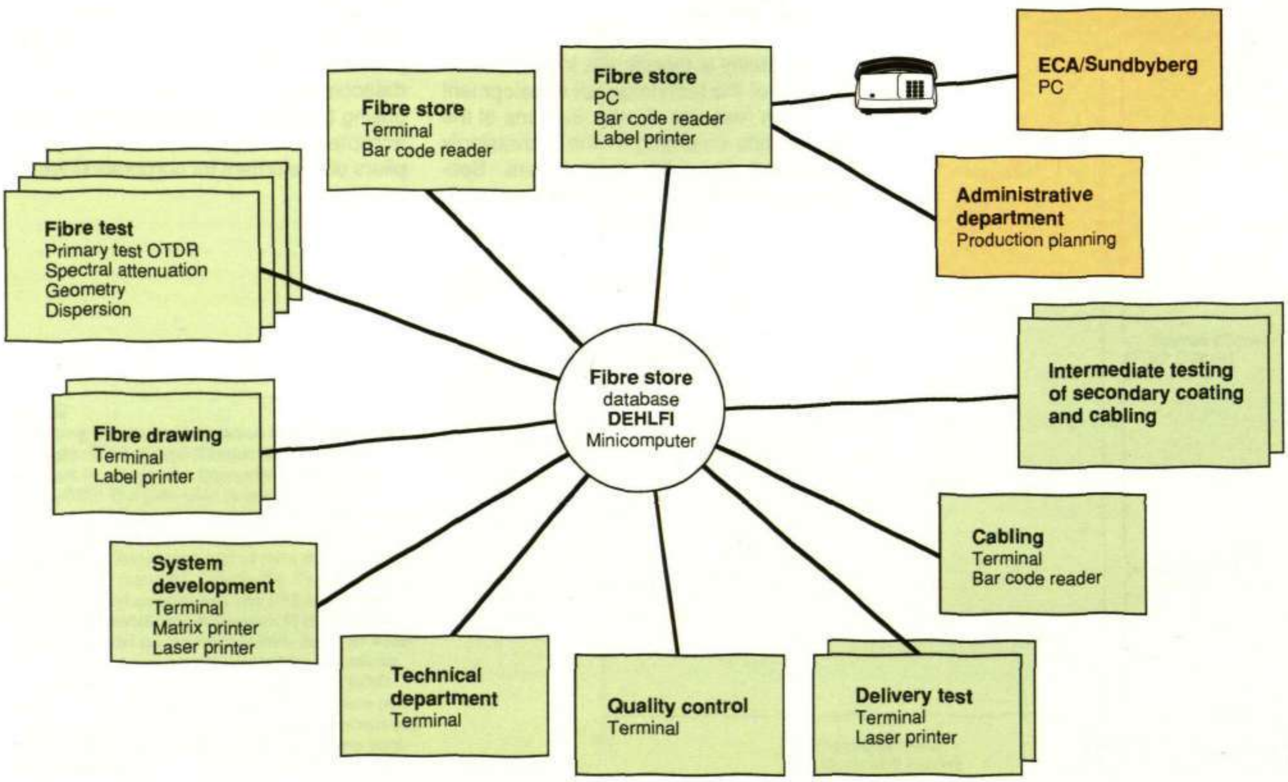
The manufacture of fibre and cable is described in References 1 and 2.

System description

Database

The core of Dehlfi is a minicomputer. It is an HP 9000/835S, with RISC architecture

Fig. 1
Workplaces, terminals and test stations in the Dehlfi system



GÖRAN NILSSON
SOLWEIG VIKLUND
Ericsson Cables AB

(Reduced Instruction Set Computing), capable of performing 14 million instructions per second (14 MIPS). It has an 8 Mbyte primary memory and uses two hard disks of 571 and 670 Mbyte respectively. Two magnetic tape stations are provided for backup copying.

The HP machine uses a UNIX operating system. The database is developed in HP Allbase/4GL, which is a special database language, and has ISAM data files (Index Sequential Access Method). A number of external routines are written in the two programming languages C and Pascal.

Fibre-optic network
A star-shaped network connects the minicomputer to terminals, test stations and other equipment, Fig. 1. Cable designers, system developers at the technical department and operators at the manufacturing and quality inspection departments can access the system via this network. In 1991, 12 test stations, 10 terminals and various PCs and printers were connected to the network.

The network is made up of fibre-optic modems and fibre-optic multimode cables, and designed according to EIA's standard RS 232 (CCITT V24/V28).

The units of a test station are interconnected via the instrument bus HP-IB (Hewlett-Packard Interface Bus), by other instrument manufacturers called GPIB (General Purpose Interface Bus). This is a standardised, general-purpose bus which connects one or more test instruments to a control unit, thus forming a computer-controlled test system.

The communication routines are written in HP Basic, and data is transferred in the form of text sequences in ASCII code (American National Standard Code for Information Interchange). This is not the fastest communication protocol available, but the transfer time is insignificant in comparison with the test time.

Test stations
A test station is equipped with a test instrument; for example, an OTDR (Optical Time Domain Reflectometer) and the associated computer HP 9000/332, a printer and a plotter, Fig. 2. Each test station has a specific test program in HP Basic. The menu-controlled test program instructs the operator and reads the instrument. A test station may either communicate directly with the database or operate in stand-alone mode.

User interfaces
The Dehlfi system has menu-based user interfaces. Each operator category has a separate, tailor-made set of menus, and each operator has a unique password. Personal computers have Windows user interfaces, Fig. 3.

The introduction of Dehlfi meant considerable saving of labour, for one thing because the system eliminates the time-consuming and monotonous manual recording of test data at terminals.

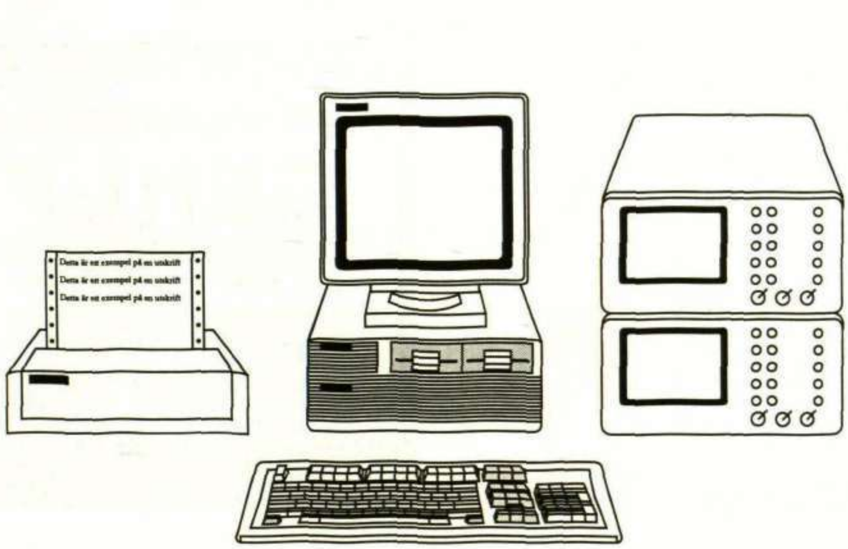


Fig. 2
Example of test station equipment

Printer	HP Thinkjet
Computer	HP 9000/332
Diskette drive	HP 9122
Test instrument	OTDR

Box 1

Code39, the first alphanumeric bar-code ever to be designed, is now the most frequent code in industrial applications. The code consists of 44 discrete, unique patterns. Each pattern is made up of 9 elements: 6 narrow and 3 wide; hence the name Code 3 of 9. Each sequence starts and ends with an asterisk, "*".

An enhanced version, Extended Code39, has been introduced to permit coding of all 128 characters in the ASCII table. Here, $, %, / and + are combined with other characters to form a complete ASCII table. Example: "a" is coded as "+A".

Data flow

Traceability is important when producing optical fibre and cable. The Dehlfi system provides an efficient tracing function: it can determine to which cables the fibres drawn from a given preform belong and, in the opposite direction, the original preforms used for a given cable, Fig. 4.

Preforms

Preforms delivered to the factory are registered on receipt, i.e. each preform is given a unique identification number – a preformid. This number, together with data on manufacture, supplier and type of fibre, is stored in the database. The number will then form part of the fibre identity.

Fibre drawing

When the fibre is drawn, a drawing record is prepared which contains run data and machine data. The finished fibre is then subjected to a strength test, and the fibre lengths obtained are registered in the database, which generates a unique identification number, a fiberid, for each fibre. The fiberid is printed – both in plain text and in bar-code – on a label printer and stuck on the fibre drum. All registration of preforms and fibres is done by staff serving at the drawing towers.

Fibre testing

The registration of the fibre is followed by quality inspection (primary testing) at four different test stations in the test room:
- Attenuation test, OTDR
- Spectral attenuation and mode field test, FOA (Fibre Optical Analyser)
- Dispersion test, CD3 (Chromatic Dispersion)
- Geometrical test, i.e. testing of the geometrical characteristics of the fibre.

The operator carries out the tests as prompted by the test program. Test data can be stored in three ways:
- Automatically in the database
- On diskettes
- In the form of printouts only.

A check is made to ascertain that the fibre has been registered, and then the test data is stored in the database. Storage on diskettes is primarily a backup routine to safeguard the system against faults, such as breaks in the communication between database and test station. A program routine is provided which automatically reads test data from diskettes to the database.

The system automatically compares the primary test results of each fibre with spec-

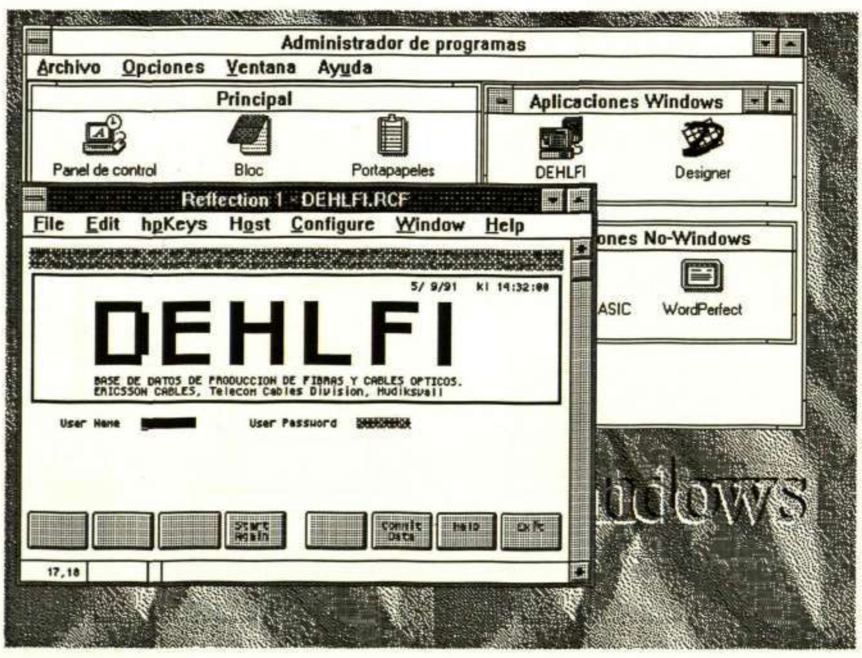


Fig. 3
Windows' Spanish user interface

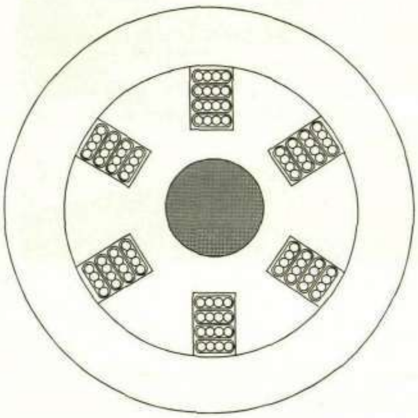


Fig. 5
96-fibre ribbon cable

ified values. Approved fibres are put in stock.

Purchased fibre
Purchased fibre is accompanied by test data stored on diskettes, whose contents are read to the database via a PC. At the same time, a cross-reference register is prepared which shows the supplier's and Ericsson's fiberids. A label showing fiberid, length and storage-location is printed on the label printer and stuck on the fibre drum.

All labels – Ericsson's as well as those of the fibre suppliers – have bar-code information which facilitates handling and minimises the risk of mistakes.

Code39 is the standard bar-code (symbology), and Extended Code39 is also used where required. See Box 1.

Ribbons
Ribbons are manufactured for use in ribbon cable. The ribbons are placed in the cable core, with up to four ribbons in each slot, which gives 96 fibres per cable, Fig. 5. In the manufacturing phase, each ribbon is given a unique identification number – a ribbonid. The quality of a ribbon is inspected by comparing its test data with the data of each fibre in the ribbon.

Storage management
The Dehlfi system also handles the storage of fibres. The database indicates the physical storage-location of each fibre. It only takes a couple of minutes to produce an inventory report showing the current quantity of each type of fibre. This information is sent once a week to the production planning department. The financial department also receives weekly reports on storage transactions, i.e. the amount of fibres received and withdrawn.

Secondary coating, stranding and jacketing
Fibres are withdrawn from store for secondary coating and stranding. For each cable, the fibres selected in the database tally exactly with the customer's specification. For this purpose, the system uses a search routine which selects fibres with the required properties and indicates their physical storage-location.

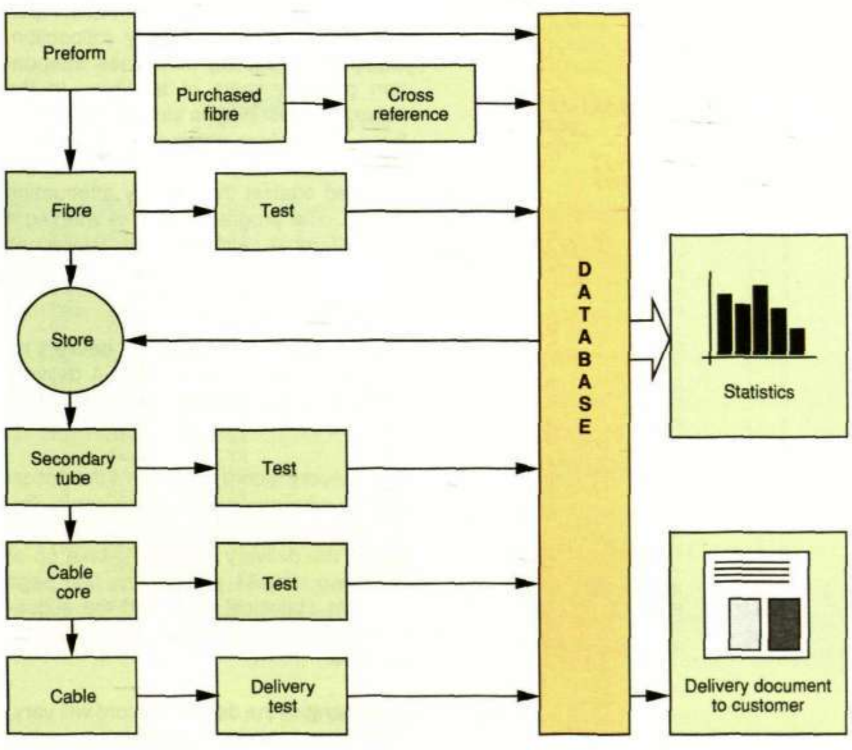


Fig. 4
Dehlfi data flow

Fig. 6
Cable attenuation test at Ericsson's Fibroco factory in Spain

After the secondary coating has been applied, the fibre is subjected to quality inspection (secondary testing). This test is carried out according to the same routines as those applied in the primary OTDR test. The test data is usually stored directly in the database.

Terminals at the stranding lines register the fibre contents of each cable, and the cable is given a unique identification number — a cableid. The cable line operators also handle the registration of cables. To facilitate work and minimise the risk of incorrect registration, all terminals have a bar code reader and a bar-code menu.

Stranding is followed by intermediate testing, jacketing and delivery inspection. Intermediate testing comprises attenuation measurements of all fibres in the cable. The test data is stored in the database. The values obtained in these tests and in secondary attenuation tests are checked against the primary attenuation values. The program issues a warning if the difference exceeds the tolerances specified.

Delivery inspection

A cable which has passed the delivery inspection is ready for delivery. A delivery record for the customer is printed on a laser printer.

The delivery record documents the optical and physical parameters of the cable, Fig. 7. Since a cable may contain hundreds of fibres, the delivery record will take up at least two size-A4 pages. The first page contains statistical data, and the subsequent pages give test data of each individual fibre.

The layout of the delivery record will vary, depending on the customer's requirements and on the type of cable delivered. To rationalise handling, customers may receive cable parameters stored on diskette.

Statistics

Two main system requirements were defined when Dehlfi was put into service in April, 1988: Automatic transfer of test data from test stations to the database, and printout of complete delivery records. During the subsequent development of the Dehlfi system, a large number of quality inspection parameters have been added, and the possibilities of using these parameters in quality work have also increased.

Three program categories are available for the processing of data extracted from the database:

- Search, processing and presentation
  Complete reports for recurrent follow-up are prepared
- Search and processing
  Data is prepared for presentation by means of a special graphics program, e.g. Graph-in-the-Box
- Search
  Routines which only locate predetermined data for processing and presentation later on by means of statistics software, e.g. Minitab.

Minitab is a software package for advanced statistical processing. EQFOS (Ericsson Quality, Design and Statistical Analysis of Experiments) is one of its users. Graph-in-the-Box is a very handy graphics program which also contains some statistics functions.

The software packages developed by Ericsson Cable's own specialists include one for collecting fibre data during a pre-

VK 1523-402033C

ERICSSON CABLES **RECORD OPTICAL CABLE**

Prepared		Date	Order no:
HL/ECA/T/VK Margit Dahlberg		17 Dec 91	29595-080
Approved	Checked	Manufacture no:	KB no:
		S40E00700	7779

Cable......: GNLWLV 24x10/125 EM

Fibre......: OVD/Q

Cable id...: 9035007

Drum no....: 3483

Length ordered..: 4000

tested...: 3978

shipped..: 3973

Customer........:

order..: KI 199-6755

spec no:

			SPECIFIED VALUES		TEST VALUES		
					mean	min	max
PHYSICAL PROPERTIES	FIBRE	Mode field diam PII	9.4 ± 0.8 μm			9.2	9.6
		Cladding diam	125 ± 3 μm			124	126
		Concentricity error	≤1.0 μm		0.32		
		Cladding non circ	≤2 %				0.90
		Cut-off wavelength	1.10 - 1.28 μm			1.18	1.27
		Sec coating diam	nom 2.4 mm			2.40	2.40
	CABLE	**Sheath 1**	**nom**	**min**			
		Diameter [mm]	10.3		10.3		
		Thickness [mm]	1.00	0.75		1.01	
		Sheath 2					
		Diameter [mm]	15.1		16.8		
		Thickness [mm]	1.50	1.13		1.40	
OPTICAL PROPERTIES		**ATTENUATION**	**mean**	**max**			
		1300 nm [dB/km]	0.40	0.50	0.34	0.33	0.35
		1550 nm [dB/km]	0.30	0.40	0.19	0.18	0.20
		DISPERSION	**min**	**max**			
		Zero disp [nm]	1295	1322	1315	1310	1319
		Slope [ps/(nm²·km)]		0.095	0.088	0.087	0.089
		1570 nm [ps/(nm·km)]		19			18.2

CABLE ID: 9035007

date:17 Dec 91
no of fibres: 24

tube:no	col	ATTENUATION 1300 [dB/km]	ATTENUATION 1550 [dB/km]	DISPERSION zero disp [nm]	DISPERSION slope [ps/(nm2 km)]	DISPERSION 1570 [ps/(nm km)]
1 :01	blu	00.34	00.19	1316	0.088	17.5
:02	org	00.34	00.20	1317	0.088	17.4
:03	gre	00.35	00.19	1319	0.087	17.2
:04	bro	00.34	00.19	1317	0.088	17.5
2 :05	blu	00.35	00.20	1314	0.088	17.8
:06	org	00.34	00.19	1313	0.088	17.8
:07	gre	00.34	00.20	1315	0.088	17.6
:08	bro	00.34	00.19	1316	0.088	17.5
3 :09	blu	00.35	00.20	1316	0.088	17.5
:10	org	00.34	00.19	1316	0.088	17.6
:11	gre	00.35	00.20	1315	0.088	17.6
:12	bro	00.35	00.20	1316	0.088	17.5
4 :13	blu	00.34	00.19	1316	0.088	17.6
:14	org	00.34	00.19	1314	0.088	17.7
:15	gre	00.33	00.18	1316	0.088	17.5
:16	bro	00.34	00.20	1314	0.088	17.8
5 :17	blu	00.34	00.19	1319	0.087	17.2
:18	org	00.34	00.19	1315	0.088	17.7
:19	gre	00.35	00.19	1312	0.089	17.9
:20	bro	00.35	00.20	1310	0.089	18.2
6 :21	blu	00.34	00.19	1314	0.088	17.7
:22	org	00.34	00.19	1312	0.089	18.0
:23	gre	00.34	00.19	1315	0.088	17.6
:24	bro	00.35	00.19	1310	0.089	18.1

..... **end of report** ....

Fig. 7
Example of delivery record

Fig. 9
Installing the Dehlfi system at Ericsson's Fibroco factory in Spain

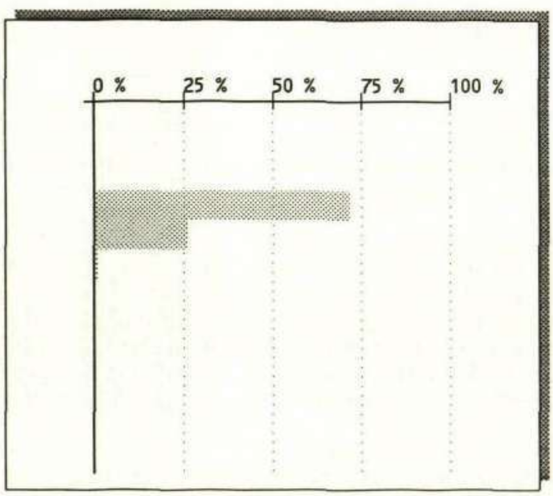
Fig. 8
Example of printout for monitoring fibre production. The program was developed by Ericsson Cable's own software specialists

ATTENUATION at 1310 nm
Week xx - yy, supplier AA.

File name......: er2
Date...........: 92-03-03

Mean value.........: 0.34
Standard deviation.: 0.007
Number of values...: 1732

class		part [%]
1	≤0.30 :	0.0
2	0.30- 0.32:	0.0
3	0.32- 0.34:	71.7
4	0.34- 0.36:	26.3
5	0.36- 0.38:	1.4
6	0.38- 0.40:	0.5
7	0.40- 0.42:	0.0
8	0.42- 0.44:	0.0
9	0.44- 0.46:	0.0
10	0.46- 0.48:	0.0
11	0.48- 0.50:	0.0
12	> 0.50 :	0.0



determined period, for presenting certain statistical information, and for showing (by means of histograms) how the data is distributed, Fig. 8. Quarterly reporting of fibre statistics is one application of this software.

A production report shows the output of the fibre manufacture at Ericsson Cable's own factories, both for defined periods of the year and on a per-year-basis. The figures show the approved amount of fibre, expressed either in number of metres or as a percentage of the total length of drawn fibre. Report items include the number of drawn preforms, the relation between actual and theoretical results, and the length of approved or rejected fibre.

Expected future development

Flexibility

Today, 30 peripheral units (terminals, test stations, etc) can be connected to the mini-computer of the Dehlfi system. Since the system would be useful to more technical, production and inspection staff, an extension is being planned according to two main options:

- Extension of the present star-shaped network by adding serial ports on the mini-computer. This will permit connection of 80 users
- Installation of an LAN (Local Area Network). The advantage of this option is twofold: a larger number of users can be connected, and the LAN can be connected to the existing PC network.

Both options require extension of the primary memory to 16 Mbyte.

A result of the in-house development of the software is high flexibility. Programs in the database and in the test stations can easily be modified in step with the introduction of changes to design and production procedures.

International application

The Dehlfi system is available in three languages: English, Spanish and Swedish. In addition to the Swedish Hudiksvall factory, the system has been in operation at Ericsson's new Fibroco factory in Spain since that factory was inaugurated in July, 1991. The English version is used when guiding visitors from abroad and as a platform for translations into other languages (only Spanish, so far).

All further Dehlfi development work is done at Hudiksvall. The English and Spanish versions are updated in parallel with the development of the Swedish software. Our objective is to be able to provide three mutually compatible versions.

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Human Factors – A Key to Improved Quality

Thomas Backström and Nigel Claridge

Telecom services are being developed rapidly, and introduced at an alarming pace. Both end-users and telecom network operators will soon experience how these services and other emerging possibilities place new and greater demands on their communication with the telecom system. Technical solutions must take human issues into account – technology is used by people in their daily lives. As the number of services offered increases, it will become more and more important to provide efficient interaction between the individual and the technology.
Internationally, the art of creating an integrated man-machine system is known as Human Factors Engineering, or Human Factors for short.
The authors describe what Human Factors is, Ericsson's corporate policy within the area, and the process required to create good and usable products from the human viewpoint.

human factors
telecommunication services
standardisation

Ericsson manufactures and supplies products within a wide variety of areas – from specialised and complex products, such as information systems used in fighter aircraft, to public and private telephone exchanges and consumer products such as telephone sets. Each product has its own set of specific design requirements and conditions, based on the characteristics and limitations of the intended users.

Although there are few similarities between the design specifications for the cockpit of a modern fighter and those for a desk-top telephone set, all products – irrespective of the level of technology – have one basic demand in common: they must be designed so as to perform well in the environment for which they are intended. Clearly, a fighter cockpit or air traffic control centre requires significantly more development resources than a simpler product, but how many of us have been frustrated, if not injured, when using a can opener. After several unsuccessful attempts we have probably thrown it away. To avoid these problems, the way a product will be used – and by whom – must be thoroughly analysed and the results integrated early into relevant product specifications.

Fig. 1
In a changing world, where telecommunications is becoming a part of everyday life of the individual, variations in culture, traditions and language place demands on the design of telecom products and services. Human Factors increases the degree of usability and acceptability by making products simple and easy to use

In principle, there is little difference between the Human Factors methods applied when designing a cockpit and those applied in the design of a telephone set. The variation lies in the number and complexity of relevant factors, resulting in cockpit design being significantly more difficult and more extensive.

Historical background

The need for new specialist knowledge arose because both users and manufacturers became more and more specialised in their activities, and because demands for safety and efficiency increased. This knowledge identified demands to be included in product design – demands that were based on the users' (operators') cognitive and physical limitations and the work situation. It also formulated these demands so that they were understood and usable by the systems engineer.

The need for Human Factors knowledge was accentuated during the Second World War. Technical developments advanced to such a degree that individuals operating systems and vehicles experienced serious difficulties and were exposed to personal danger. It became necessary to design control systems and to present information in a way that permitted efficient operation, yet avoided overstressing the individual and eliminated the risk of accidents.

This development has continued, and Human Factors knowledge is now applied not only to complex and sophisticated products but also to a wide range of everyday products, such as cars, computers, tools and machinery and consumables. Aids for the elderly and the handicapped is another area where Human Factors knowledge is applied.

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Box 1

Definition of Human Factors

Human Factors is defined as "The study of the relation between man and his occupation, equipment and environment, and particularly the application of anatomical, physiological and psychological knowledge to problems arising therefrom".
Therefore, "Human Factors in Information Technology" (IT) is considered to be the study of, and application of Human Factors knowledge to, all aspects of the relation between the human, the machine and the environment which directly influence the safe, efficient, acceptable and satisfying usage of the IT system.

Box 2

HUMAN FACTORS ENGINEERING
Ericsson's Policy

Purpose	To ensure high Human Factors' quality in all Ericsson products
Policy	Human Factors Engineering should be applied to all product design, thus making the products professional also from the individual user's and handler's point of view
Responsibility	Business Area and/or Local Company management is responsible for the issuance of application rules for Human Factors Engineering. Corporate Systems and Technology is responsible for coordination activities

Guiding Principles
- Products and systems to be used in similar user environments should be given uniform ergonomic or Human Factors properties
- In product design work, great attention should be paid to the concepts "user-friendliness" and "suitability for purpose"
- Our professional knowledge in Human Factors Engineering should be utilised in our marketing
- Qualified application of Human Factors Engineering should be emphasised as important quality improvements
- Existing standards in the Human Factors field must be followed and measures must be taken to further develop such standards

What is Human Factors

As defined in Box 1, Human Factors is an interdisciplinary science. The terms Human Factors and Ergonomics are often used synonymously when defining both the applied area of research and the method used to create products. In Scandinavia, the term Ergonomics has been strongly identified with the physical design of products and workplaces, i.e. associated with man's physical characteristics relevant in this context: anthropometry, stress, vision and hearing. The term Human Factors is used to encompass these aspects – and also the cognitive aspects – in the design process, such as man's ability to process, interpret and act upon information. Cognitive issues have grown in importance as information technology has broken into more and more areas of application.

The changing world of Telecommunications

As a result of increased competition through deregulation, network operators' cost situation has become strained at the same time as subscriber demand for service has increased. Subscribers have become increasingly dependent on the telecom services they use. Individuals and companies are emphasising the need for mobility; yet demanding access to the same functions and services irrespective of location. Many of these demands are now fulfilled by both public and private exchanges and by fixed and mobile services.

Common to all these changes is the demand for simplified methods of handling an increased range of complex services. Services must be easy to learn and easy to use for end-users, subscribers and network operator service staff. Handling procedures for a given service should be the same irrespective of the application, which means that efficient, uniform handling characteristics will become one of the most important competitive edges in the future. This applies both to products which are part of the network and to products used by subscribers when utilising network services. Efficient handling characteristics are a result of products that are well adapted to user requirements and the intended task.

There are further advantages to be gained through the application of Human Factors. Variations in culture, tradition and language are taken into account, which results in products becoming accessible to a wider range of end-users. The application of Human Factors will reduce training time, lead to more reliable data input and higher productivity, and ensure that products will be better adapted to the environments in which they will be used. Faced with the trend (noticeable in many countries) of increased supplier responsibility for product safety, the need to design good, safe products supported by usability testing becomes paramount. Human Factors input in product development will become more and more essential.

Ericsson's Policy

Ericsson's goal as regards Human Factors is that all Ericsson products should meet user requirements for comfort and safety, and at the same time promote user and system performance efficiency. The Ericsson view of Human Factors is summarised in a corporate policy which has been approved by the Corporate Executive Committee, Box 2. The policy emphasises the need for all Ericsson products to have a professional design with regard to user requirements. It also expresses the need for co-ordination in these issues between the different corporate units.

A principal criteria put into practice is that specifications about usability and functionality are integrated, at an early stage, into the development process of completely new or existing products.

The Technical Committee for Human Factors

Ericsson Technology Council (ETC) coordinates the follow-up of technical developments in general, and also the provision of new technology within Ericsson. This task is performed via a number of research centres, application labs and a series of specialised technical committees. The Technical Committee for Human Factors (TUHF) is one of these committees.

TUHF's task is to strengthen Ericsson's competence within the area of Human Factors and to ensure a uniform corporate profile.

TUHF, through a network of contacts, both within Ericsson and with external institu-

1 Use the user's model
2 Introduce through experience
3 Design the product to be user-centred
4 Allow the user to observe and control the system
5 Log activities during testing
6 Ensure consistency and uniformity
7 Provide immediate feedback
8 Avoid the unexpected
9 Validate entered data where possible
10 Provide selected help information

Fig. 3
Ten fundamental principles to keep the user friendly! (British Telecom, 1990)

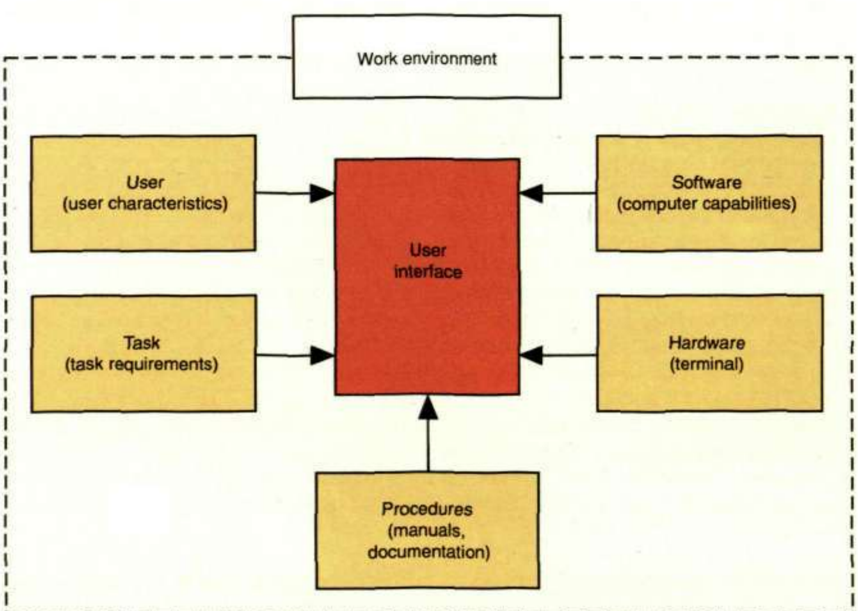
tions, organisations and specialists, receives vital input for its development programme and in this way ensures increased Human Factors knowledge about new technology and market demands. Ericsson cooperates with Nomos Management AB, which provides access to current specialist knowledge in the Human Factors area.

Human Factors and Industrial Design have many areas of mutual interest. Although Industrial Design tends to work with the physical characteristics of products, emphasising aesthetic values, more and more work is being done on the graphical design of user interfaces, notably the design of symbols, pictograms and icons. TUHF, therefore, works in close cooperation with The Technical Committee for Design.[4]

International Cooperation

Cooperation has been established with British Telecom's Human Factors Division in England. The purpose of this cooperation is – through exchange of knowledge and experience – to strengthen Human Factors know-how in both companies and to ensure that Ericsson products fulfil British Telecom's usability requirements. It also aims at developing a broader base for usability testing, involving end-users from several markets.

Fig. 2
The main elements in the computer system
It is important to view the system not merely as a set of technological items, but as the totality of people at work with equipment in a working environment. The challenge is to provide sufficient flexibility and variety of interfaces to suit the wide range of users and task situations



Working with Human Factors

The user, the task, the system and the software are the main elements which, together with procedures and decision rules, form an efficient system, Fig. 2. The user interface, where a given task is to be performed, is the common boundary between the user and the technical system. The primary goal of Human Factors is to specify and design the interface so that the user will be given the best possible environment to carry out his task safely and efficiently (Box 3).

The general approach is the same when designing all types of interfaces, although methods and the amount of input data in the different project phases may vary. Like all other development work, Human Factors is an iterative process. The design principles presented in Fig. 3 should be followed throughout the development of user interfaces.

Start with the users

The end-user determines how a system is used in day-to-day operation and, hence, the design of the interface. The initial stage is to identify the users and describe their knowledge, skills and experience. It is important to note the differences and extremes here, and design the interface accordingly. More complex products and systems require an understanding of the way users process information, interpret displays and make decisions. Faulty assumptions about user needs can have a negative effect on usability. If the interface is not designed to meet user requirements, it is unlikely that the product will be used efficiently, if at all.

Identify the task to be performed

A task analysis is made to describe user tasks in detail and to collect information about working environments. This provides fundamental information about user needs. Several task analysis methods are available for making the process of collecting and abstracting information about users more systematic. They range from "macro" methods – the whole system is analysed in terms of organizational, social and environmental issues – to "micro" methods, through which sub-tasks are reduced into small cognitive units.

Box 3
User interfaces

User interfaces can be defined as the boundary between the user and the system and where some task is performed. Interfaces can be
- dialogues with computers and other products
- presentation of information on a display and/or other medium
- entry of data/commands from keyboard or other input device
- physical design of products and workplaces
- sight and sound characteristics
- procedures, rules and routines
- icons, symbols and pictograms
- systems for marking cables and connectors
- instructions, manuals and training material

Fig. 4
Two generations of Ericsson mobile telephones
Mobile telephony will be a major part of future telecom services. Human Factors will play an integral role in designing services based on user requirements and interfaces with regard to cognitive and physical issues

Examples of task factors are
- ease
- complexity
- novelty
- time limits
- whether tasks are repetitive, overlapping, monitoring
- what skills a task requires
- whether a task is performed by a group or by an individual.

Define evaluation criteria
When usability testing is integrated into the design cycle, it should be quantitatively specified in advance. Performance goals for usability should be measurable. Key factors in usability testing are
- *learnability* – or ease of learning – is the time and effort required to reach a predefined level of user performance
- *performance* – or ease of use – is the number of tasks accomplished by experienced users, the speed of task execution and the number of mistakes made
- *flexibility*, the extent to which users can adapt a system to new ways of interaction as they become more experienced
- *attitude*, subjective assessment engendered in users by the system and the interface.

Test and evaluate
Testing and evaluation should be carried out with users early in the design process to ensure that products and interfaces are designed to meet user needs and requirements.

The conceptual design of an interface may start with the creation of sketches of the interface which demonstrate surface features. These can be tested for appropriateness; for example, the design of a metaphor or symbol can be checked with respect to how well it is understood by users.

As design develops it will be transformed through simple models and simulations to prototypes, full-scale models and, eventually, the final product (implementation).

There are many computer-based design tools which permit quick and easy evaluation of user-interface options. Application of these tools is essential if interface design is to be cost-effective. Well conducted trials ensure that the design matches the users' mental model of the system and the tasks.

Trials should be conducted in environments which are as realistic as possible; preferably the real situation. It is important to establish whether the product is really usable or not. The principle rule is to design iteratively, with many cycles of "design – test with users – redesign". The aim is not to produce one correct solution which is subsequently not changed, but an evolving system which – with each iteration – is further tailored to users' needs.

Experience gained from evaluating the products, especially in the real situation, will provide input when planning future generations of the product, or completely new products. "Future-proofness" is of key importance, and interface design guidelines provide a consistent approach to product and system uppgrades.

Variation in the development process
The development process is seldom simple and regular. The process rarely starts from square one, i.e. the development of a completely new product or system. There is invariably some form of history from existing products which must be taken into account. This means that Human Factors efforts in each phase will vary from product to product.

When a new product is created, based on new technology, it is important to identify user attitudes and requirements so that the product is used, understood and accepted by users once the novelty value wears off.

When combining products from several vendors into a new and unique configuration, qualities such as homogeneity and continuity in use are important. In general, the primary Human Factors consideration is consistency of operation of all components rather than optimisation of a single component.

Manufacturers sometimes buy products from another vendor. Human Factors effort will depend on several factors, such as the quantity purchased, the importance of the product to the corporate strategy, and the ease with which usability can be improved.

There is a golden opportunity to improve usability when redesigning an existing product: by obtaining usability data from the users of the existing product. Features and functions that have been well received

Fig. 5
Advanced Human Factors design – JAS cockpit
The cockpit of JAS 39 is designed to provide the pilot with maximum support during flying, navigation and tactical applications. Displayed information is either presented automatically or can be selected by the pilot.
The display in the centre is an electronic map providing navigational information. Human Factors specified the quantity of information presented and designed and tested symbols. Simplicity is the key. All information must be easily understood under the most difficult conditions possible

may be retained, while the redesign effort focuses on solutions to problems that users have identified as being the most serious.

Standardisation

Current standardisation activities in the area of Human Factors are directed mainly towards the *user interface* and *software*. A number of relatively similar de-facto standards for information display (CUA, OPEN LOOK, Motif, Apple) are used by manufacturers when they design their applications. This illustrates the difficulties in establishing a uniform standard during rapid technical developments. A user interface standard must be verified in a wide range of applications before it can be generally accepted. During this time, further developments occur and the conditions change. No quick breakthrough resulting in one particular standard dominating over the others is therefore expected.

In the telecommunications area, where the large network operators have a significant influence in the standardisation bodies, standards for completely new services are being worked out. The European Telecommunications Standards Institute (ETSI) has twelve committees, one of which deals with Human Factors. Issues dealt with concern usability in telecommunications, such as Universal Personal Telephony (UPT) and video telephony. The procedures, symbols and icons used in these applications are studied. Other issues concern telecommunications for people with special needs, including the handicapped; the objective being to ascertain that public telephone services are available to these groups. ETSI also produces manuals, handbooks and check-lists for the design of services and products.

Current Human Factors projects

Telecom services

The total number of telecom services is expanding rapidly and each user is going to be confronted with many more services than today. Services are going to be broad in nature and not, as today, mainly of telephony character. Thus, the demand for simple, intuitive and reliable use of services will become more and more important. There must be a significant degree of uniformity between closely related services, and a clear and consistent difference between different groups of services so that users understand the distinctions. To achieve this is no easy task, especially when cultural variations in the interpretation of concepts and use of telephony must be considered.

Human Factors is intensively engaged in *designing new services for public, private and mobile telephony*. Examples of current activities are

- Development of system-independent methods of specifying and describing services based on user perspectives of the services. (The design of services in current networks is determined by the way in which the telecom system is constructed)
- Studies of the use of current services with detailed analysis of motivation and justification for each service
- Evaluation of prototypes of new services within different user groups
- Test and evaluation of symbols and icons for services.

Presentation of information in advanced vehicles

One of the most stressful workplaces imaginable is the cockpit of a modern fighter aircraft. Pilots must interpret situations quickly and accurately and act accordingly. They are often exposed to a combination of mental and physical stress, typically g-forces. To support the decision-making process, the pilot receives information – from several different sources – which is continuously adapted and combined in a suitable way before being presented. The visual display unit is the most efficient and suitable means of presenting this information.

Ericsson has designed the information system for the Swedish Airforce's new fighter, JAS 39 Gripen (Fig. 5). The cockpit of JAS has been the subject of Human Factors effort in four major areas: presentation of information, design of controls, workstation design and environmental adaptation. The pilots' physical characteristics, capabilities and limitations have been analysed in detail, as have the type and amount of information they need. Tests with mock-ups and various forms of prototypes have been used to increase knowledge. The establishment of the final design of the cockpit, with information systems and controls, has been based on results from simulation and full-scale trials. Only then has the system been installed in its correct environment.

Telecommunications Management and Operation Support-TMOS

TMOS is a family of systems whose different products together offer operative support for the whole telephone network and its services. Based on TMOS, Ericsson has developed a series of products:

NMAS Network Management System for the switched telecommunications network

SMAS Service Management System for intelligent networks

CMAS Cellular Management System for mobile telephone networks

FMAS Facility Management System for transport networks

BMAS Business Management System for Centrex and Virtual Private Networks

In a family of systems, characteristics and configurations should be based on a uniform basic structure, partly to illustrate the relationship but mainly so that users recognise situations and procedures. This is of particular importance for the user interface. TMOS is based on workstation technology that provides products with powerful graphical user interfaces, Fig. 6. In order to create a homogeneous interface, Ericsson has developed a standard for TMOS "look and feel" – TMOS User Inter-

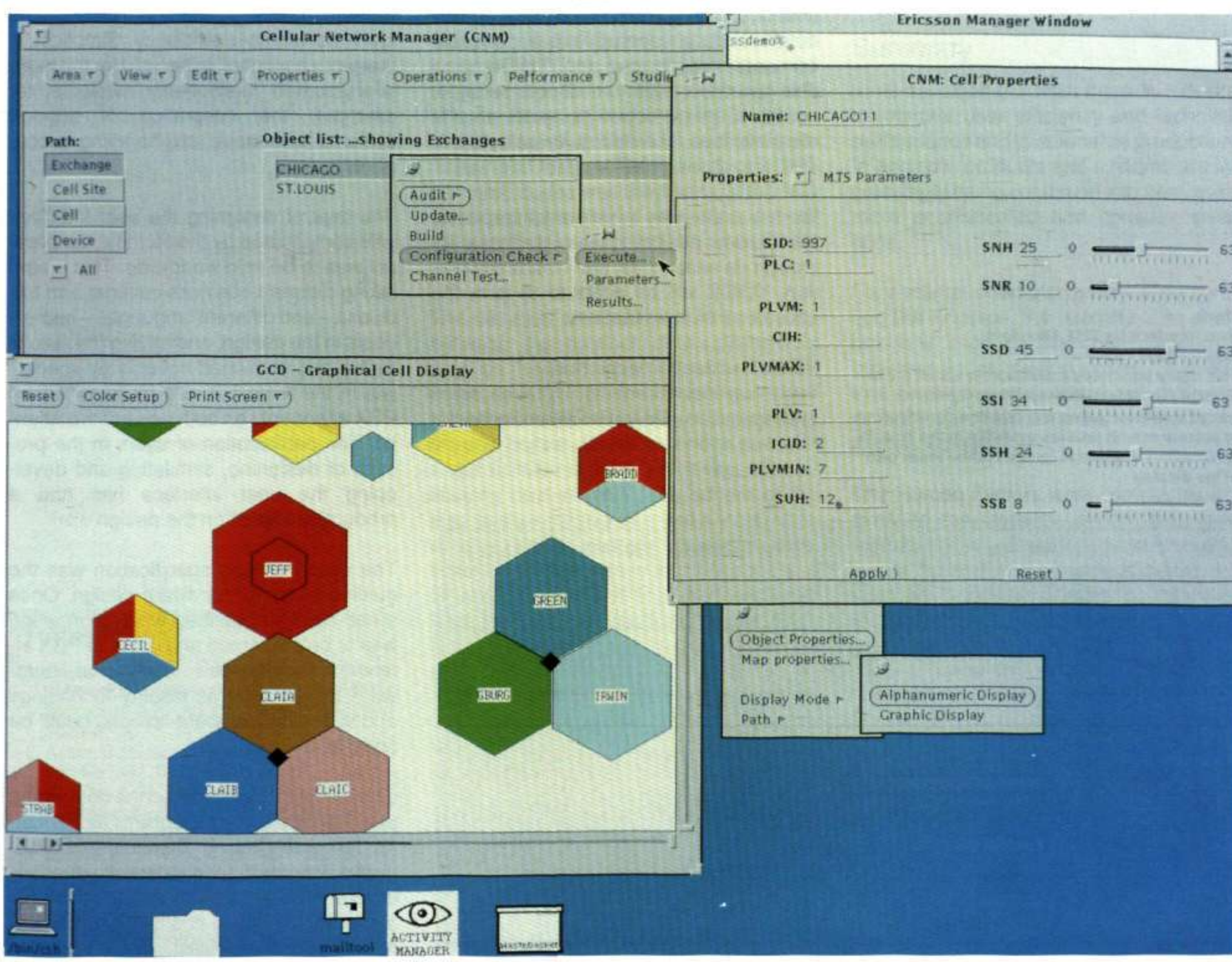


Fig. 6
Cellular network configurations
It is essential to see information about all or part of a cellular network in order to manage it efficiently. TMOS User Interface Design Standards (TUIDS) have been applied to interface design and have specified rules for the selection and use of colour, for example

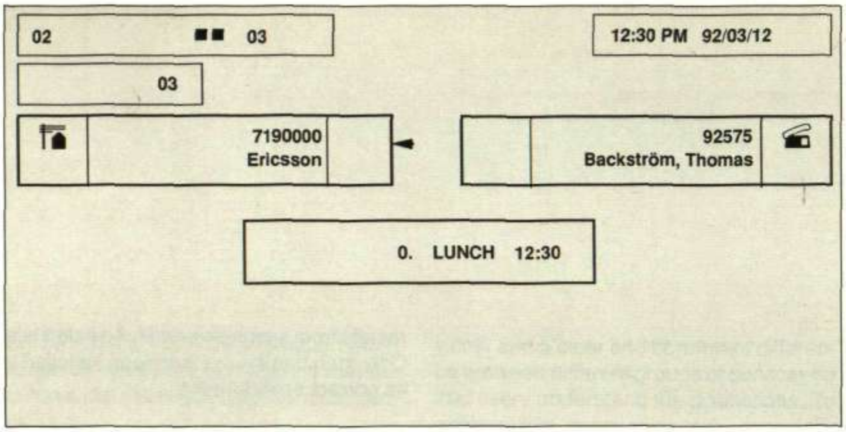


Fig. 7
User interface for PBX attendant workstations
Human Factors has been involved in the analysis and simulation of new PBX workstations. This figure illustrates a normal traffic situation. Incoming calls are presented in the left-hand field; outgoing calls in the right-hand field. The arrow in the centre indicates voice contact. The display is void of redundant information making the required information easy to find and select

face Design Standards, TUIDS. TUIDS consists of two equally important parts:
- Part 1, which describes the method of integrating Human Factors into the specification and design process
- Part 2, which provides general and specific rules for the design of TMOS user interfaces

When designing interfaces, trade-offs between conflicting demands must be made. TUIDS provides information which eases this situation. It is designed to work together with commercially available user interface style guides, where all interface details are described (windows, window frames, buttons, menus, etc). TUIDS specifies how these elements should be used, combined and grouped to create an efficient interface. The style guide selected for TMOS is Open Look.

Work is under way to present a corporate standard for designing user interfaces. Although developed for the TMOS application, TUIDS will be adapted to form the back-bone of this standard.

PBX attendant workstations

Technical developments have changed the application of Human Factors in the design of attendant workstations: the emphasis has shifted from physical issues to cognitive ones. Prime requirements in the development of Ericsson Business Communications' future workstation for MD 110 were increased user efficiency, availability and flexibility. The functionality within the PBX has become more complex and more sophisticated, accentuating the need for easy and logical access to the different features.

If basic and frequent tasks are awkward to perform and less frequent tasks difficult to remember, then system credibility will be low – as will user efficiency. Simplicity is therefore essential, especially for the more sophisticated functionality available; for example, the integration of support systems with basic call-handling procedures.

The task of designing the user interface was complicated by the fact that the product was to be sold worldwide. This meant taking different business cultures and traditions – and different languages – into account in the design, and having the results tested and evaluated not only by specialists in the team but also by experienced PBX attendants on both sides of the Atlantic. The participation of users in the process of designing, simulating and developing the user interface has had a productive impact on the design work.

The user interface specification was the guiding factor for hardware design. Once it had been established what information was to be presented and how the PBX attendant handled this information, hardware issues such as display technology and size, and keyboard layouts, could be specified.

One specific area has been the design and test of symbols and pictograms for PBX attendant workstations. Symbols and pictograms are interpreted differently in different countries and also by individuals within a country. This is a challenge to the Human Factors specialist, since the user

Fig. 8
User interface for PBX attendant workstations
This figure illustrates a situation in which the attendant can obtain information about the required extension using any one or a combination of several search profiles available in the directory. Directory support is located in the lower part of the display

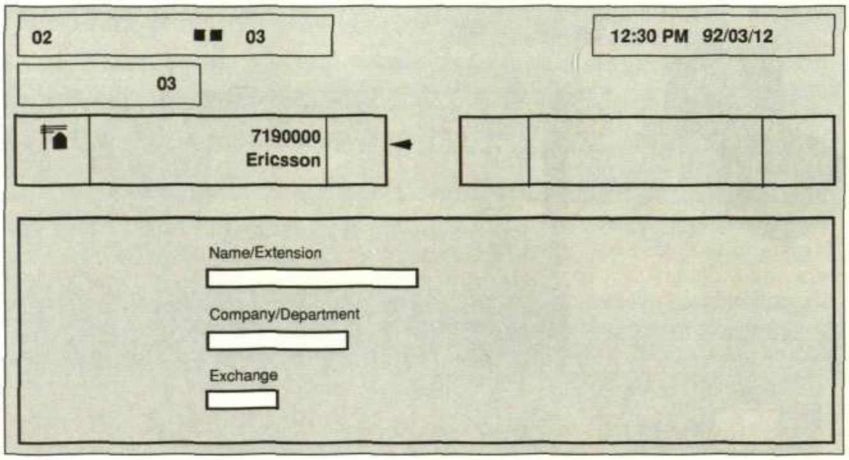


Fig. 9
User interface for desk-top telephone sets
The advent of the display in desk-top telephones has solved many Human Factors problems and, at the same time, has created new ones. Initially, the type and quantity of information displayed was specified and the way in which users accessed the various functions and features were identified.
Fig 9a illustrates the "Idle Mode" with information such as time and date, subscribers' extension number and subscriber name. The third row is reserved for menu selection only. A maximum of four alternatives are presented, each corresponding to a menu key located directly underneath.
Figure 9b represents the "Message Mode". The user is informed that there are messages and can either call a person direct, leaf through other messages or delete messages

a

```
1:03pm  Thursday 4th Jun 1992          24112
Kuna Rafal
Recall        Directory Absence     "More"
```

b

```
1:05pm  Thursday 4th Jun 1992          24112
Diverted to: Birgitta Allerberg        24472
Recall        Directory I-am-back "More"
```

interface must work efficiently and be understood irrespective of whether it is used by a Russian or an Australian operator.

Design of desk-top telephone sets
The desk-top telephone set has always been the subject for Human Factors application. Traditionally, Human Factors has addressed the physical issues, such as numeric keyboard layout, keytop shape and size, receiver weight, size and balance.

With the advent of digital phones, the emphasis has shifted from these physical issues over to the analysis of procedures required to obtain the wide variety of functions and features now available.

The procedures required to obtain these features/functions have been none too user-friendly. The everyday user has had to enter long unfamiliar codes, such as *21* number #, in order to use the simple "follow-me" feature. The net result of these awkward codes was that many of the features/functions offered were not used because procedures were long and difficult to remember.

The situation was partly remedied by increasing the number of programmable keys on the telephone set. Instead of the complicated codes, the user only needed to press one key. This was convenient for the user but resulted in telephone sets with a vast number of keys, which was not particularly cost-efficient. The advent of the display in the telephone set eased many of the Human Factors problems mentioned. The aim was to minimise the use of long codes and reduce the number of keys. But the display created new problems. Human Factors work addressed user-interface design, in particular the type and quantity of information displayed and the way in which the user accessed the various features/functions available. On the basis of this analysis, then and only then, could the size of the display be established.

Figs 9a and 9b illustrate the information content in the telephone display. The exemplified display is made up of three rows with 40 characters in each row.

The analysis of the user interface is followed by a visualisation process where end users participate in the simulation and evaluation of traffic situations. User participation and feedback is an integral part of this design and development work.

Summary

In all development work there is a desire to improve user efficiency and technical performance and to rationalise production. In addition, products and systems are increasingly being combined into new, even more sophisticated and complex creations.

For a market-orientated technical corporation like Ericsson, the usability of its products is an important part of the company's business and marketing strategy. It is vital that products and systems are designed so that they meet customers' requirements and expectations.

The Human Factors work contributes actively to the usability, acceptability and learnability of Ericsson products and systems, and to the application of the company's Human Factors policy within the scope of the Ericsson Human Factors programme.

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Cell-voltage Equalisers Series BMP 160

Johan Frändfors

In telecom installations, batteries are used to guarantee uninterrupted service in the event of a power outage. The dimensioning of battery capacity is based on estimates of the frequency and duration of outages and other disturbances. The condition of the batteries is also an essential parameter. Inadequate charge of individual battery cells will reduce the time electronic equipment can be powered by batteries. In 1982, Ericsson Components AB introduced cell-voltage equalisers as a means of securing full charge of all cells in a battery.
The author describes Ericsson Components' new cell-voltage equalisers BMP 160 003, BMP 160 004 and BMP 160 005 and how they can be employed to secure proper charging and increase battery service life.

equalisers
cells (electric)
power supplies to apparatus

The principle of cell-voltage equalisers

A 48 V battery contains 23 or 24 cells connected in series. Each cell is subjected to a self-discharge process, the intensity of which depends on manufacturing tolerances and the battery's age. Float-charging of the battery, in normal operation, is one way to compensate for this self-discharge. If no cell-voltage equalisers are used, all battery cells are supplied with the same floating current, which means that for some of the cells the floating current is lower than the self-discharge current and, as a consequence, that these cells will be discharged. Other cells are supplied with a current in excess of their need and are overcharged. To improve the condition of the first-mentioned cells, the battery must be subjected to equalising charge at regular intervals, with a current that is capable of recharging those cells which have not been compensated for their self-discharge. Other cells will inevitably be overcharged, which has a negative effect on their service life.

The cell-voltage equaliser is a current/voltage regulator (Fig. 2), which is connected across each single battery cell. The rectifier that feeds the battery is set at an output voltage equal to the nominal cell floating voltage multiplied by the number of series-connected cells in the chain. If all the cells were identical, all of them would have the nominal voltage and, as appears from Fig. 3, an additional current of 200 mA would pass through the shunt regulator in each cell-voltage equaliser. If a cell has a voltage below the nominal value, the cell-voltage equaliser will reduce the current through the shunt regulator, and the corresponding higher current will pass through the cell. If the cell voltage exceeds the nominal value, the equaliser will increase the current through the shunt reg-

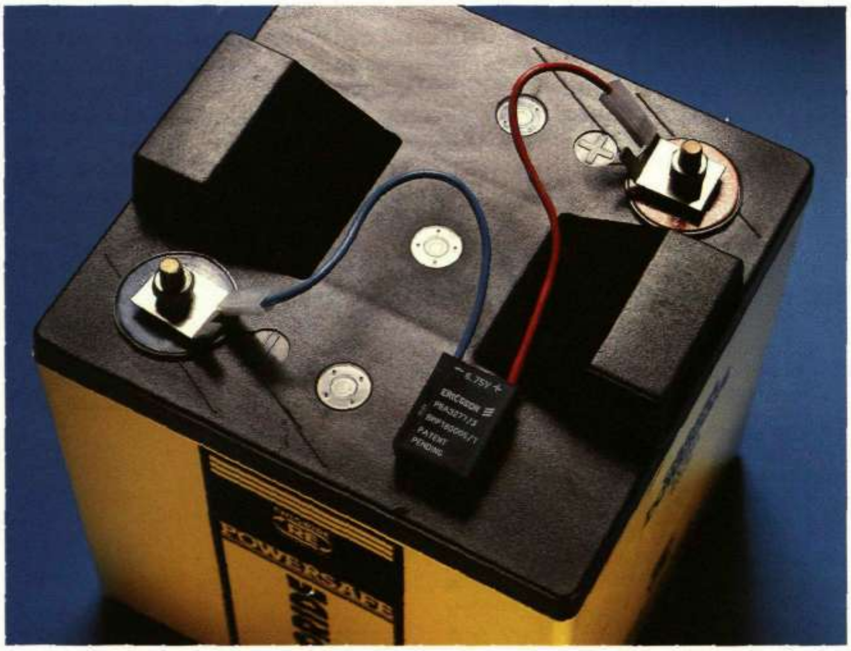


Fig. 1
Cell-voltage equaliser BMP 160 005/1, connected to a battery cell

JOHAN FRÄNDFORS
Ericsson Components AB

ulator and so reduce the current through the cell. In this way, each individual cell will have a current whose value is determined by the deviation of the cell voltage from the nominal value. This means that, in a fully charged battery, each individual cell will be supplied with the floating current needed to compensate for its self-discharge.

Cell-voltage equaliser BMP 160

Fig. 1 shows a BMP 160 cell-voltage equaliser connected to a battery cell. The equaliser weighs 40 g and its dimensions are 30×23×9 (H×W×D). It is connected directly to the cell poles by means of one red and one blue 270 mm cable provided with a blade-type contact. BMP 160 comes in three mechanically identical designs which are in different colours: BMP 160 003/1 for 2.25 V is red, BMP 160 004/1 for 2.23 V is blue, and BMP 160 005/1 for 6.75 V is black. The equalisers for 2.25 V and 2.23 V are intended for individual cells; the one for 6.75 V is intended for three-cell batteries. The design is simple and rugged. The regulating capacity, 0–350 mA, is sufficient for batteries with a nominal floating current of up to 200 mA. If greater capacity is needed, several equalisers can be connected in parallel across the cell.

Technical data of the three versions are given in Box 1.

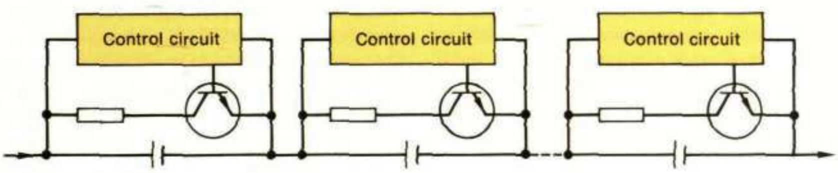


Fig. 2
The battery floating current is regulated in each individual cell and is not affected by the condition of other cells

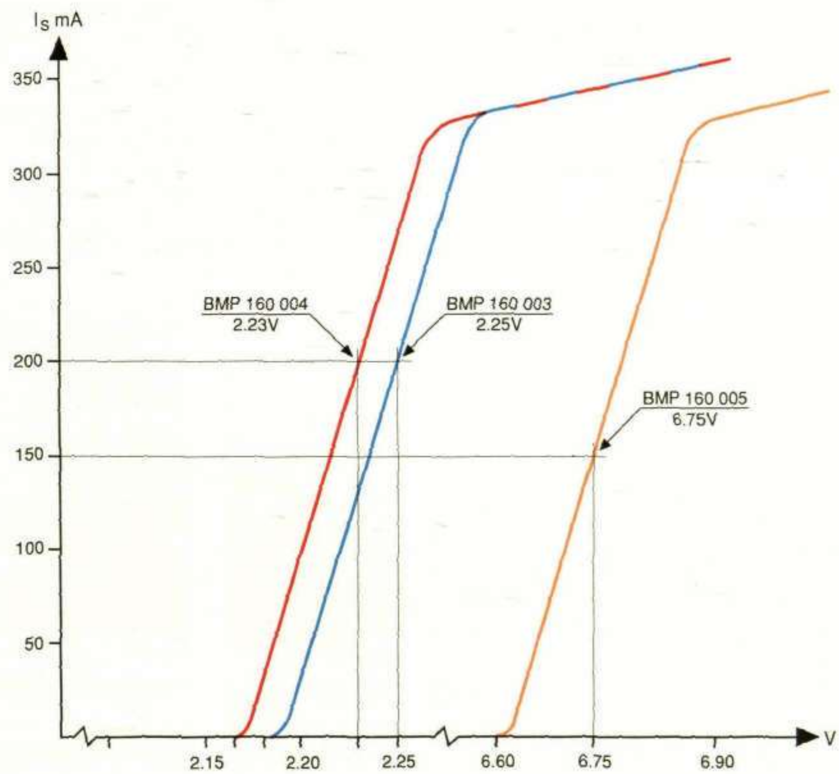


Fig. 3
Current I_s through shunt regulator for cell-voltage equaliser BMP 160

BMP 160 004, 2.23 V

BMP 160 003, 2.25 V

BMP 160 005, 6.75 V

Box 1

CELL-VOLTAGE EQUALISER BMP 160 – TECHNICAL DATA

Dimensions	30×23×9 mm	(1.2"×0.9"×0.4")	
Weight	40 g	(1.4 oz)	
Connection	6 mm blade		
Connecting cable	270 mm		
Max voltage without destruction	2.9 V		
Temperature range	0 to +55°C	(32 to 131F)	
Model	BMP 160 004/1	BMP 160 003/1	BMP 160 005/1
Trimming level	2.23 ±0.007	2.25 ±0.007	6.75 ±0.015
Colour	Blue	Red	Black
Shunt current at trimming level	200 mA	200 mA	150 mA

Experiences of cell-voltage equalisers

Backup time

Fig. 4 shows the distribution of cell-voltage values measured in a large-size battery which has been used in a plant, under observance of normal maintenance routines but without cell-voltage equalisers. Fig. 5 shows the corresponding values when the battery has been provided with cell-voltage equalisers for a short period. The distribution between the cells has decreased from the order of ±200 mV to about ±20 mV; that is, by a factor of 10. This means a marked improvement of the condition of the battery.

The proper charging of a battery cell can only be checked through several hours of loading tests and voltage measurements. The fact that the voltage across a cell in normal float-charging is close to the nominal voltage does not guarantee a satisfactory condition of this cell. Nor is the opposite self-evident: if the voltage across a cell in a battery without equaliser is up to 50 mV below the nominal voltage, this does not necessarily mean that the cell is in a bad condition. The latter, on the other hand, is an indication that the cell may have a higher self-discharge than other cells in the battery and that the floating current therefore has not been sufficient to keep the cell fully charged. If the worst comes to the worst, the charging of such a cell may be only 50–60 % of the capacity of a fully loaded one. In an eight-hour test, the battery capacity would drop to the lower voltage limit after less than five hours. This means a 50 % reduction of the battery backup time in spite of the fact that all the cells are fully capable of functioning.

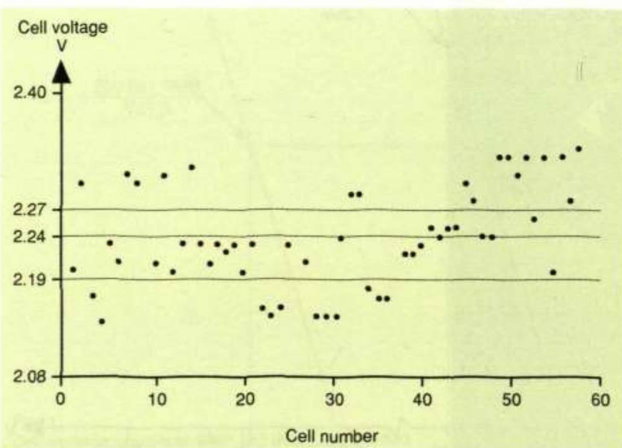
Economy

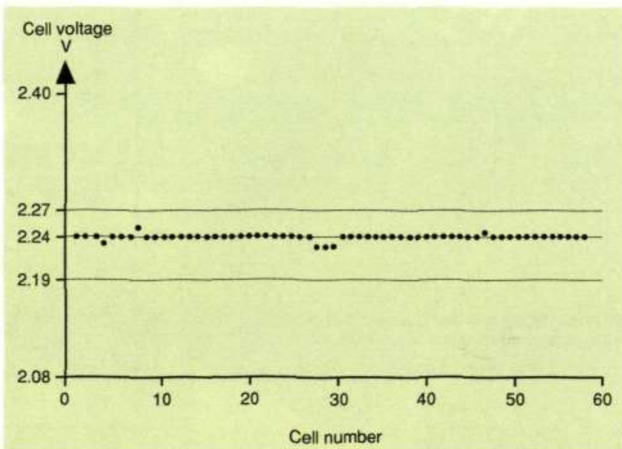
The above example may seem somewhat drastic, but low cell voltages caused by insufficient float-charging occasionally appear even in relatively new batteries. The empty circles in Fig. 6 show the cell voltages in a 48 V, 3,000 Ah battery that has been in operation for four years. The values for about one third of the cells are 35 mV or more below the nominal voltage. Unfortunately, this battery was not tested with respect to capacity when the voltages were measured, and its real condition is therefore not known. However, plant management considered boost charging necessary in order to restore the condition of the battery but decided to choose the alternative solution: cell-voltage equalisers.

Fig. 6 shows the voltages measured before the cell-voltage equalisers were installed and the corresponding values after six weeks. An eight-hour discharging test, in conformity with US standards, was made after another three months. The bat-

Fig. 4, below left
Cell voltages measured in a large-size battery without cell-voltage equalisers (ICE)

Fig. 5, below right
Cell voltages measured in the same battery when it has been provided with cell-voltage equalisers for a short period





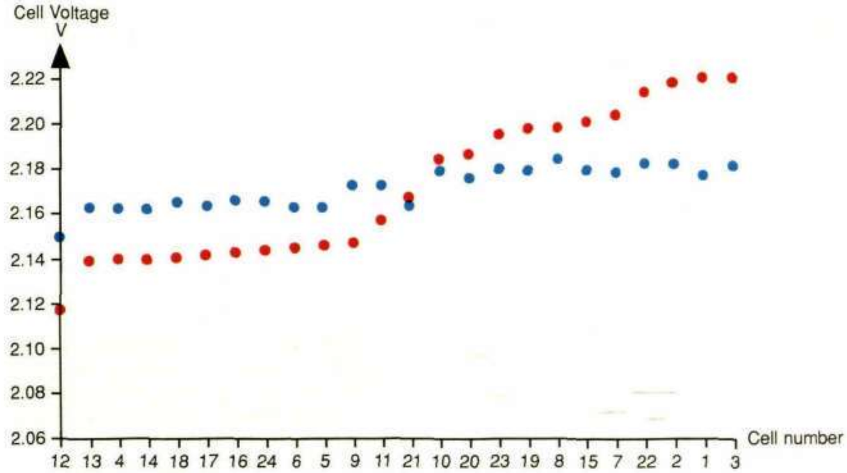


Fig. 6
Cell voltages measured in a 3,000 Ah battery after four years' operation without cell-voltage equalisers, and six weeks after equalisers have been installed. The cells in the diagram are arranged according to the values recorded in the first measurement

- Initial reading
- Reading after 6 weeks

tery voltage was measured every fifteen minutes; the results are shown in Fig. 7. As is evident from the power drawn from the battery – 104 % of the nominal eight-hour capacity – it had been restored to perfect condition.

In a battery without cell-voltage equalisers, the balance between the cells is restored through periodic equalising charges. Since the battery backup time in practice is determined by that battery cell which is in the worst state of charge, the battery will not – in the intervals between the additional charges – meet the backup-time requirements calculated on the basis of nominal battery data. Correct dimensioning, therefore, requires that a battery without cell-voltage equalisers should have somewhat greater capacity than a battery provided with such equalisers. It is difficult to quantify the need for overcapacity: it depends very much on the maintenance of batteries at each specific plant. But a plausible estimate is that the cost price of batteries with cell-voltage equalisers is roughly the same as that of batteries without equalisers. The two alternatives – greater battery capacity or automatic control – are in all probability equally good. On the other hand, cell-voltage equalisers make the battery more resistant to insufficient maintenance and in this way help to assure that it is in good condition when its capacity is needed.

This means that battery maintenance can be made easier. Experience has shown that the number of voltage readings can be halved, and substantial reductions of costs have been demonstrated in many cases. Relatively large cost savings can also be made when new batteries are installed and when battery cells have to be exchanged.

When a new battery is installed, it is normally cycled three or four times, in order for all its cells to be in the same condition. In this procedure, which takes three to four days, the battery is measured each hour. It has turned out, though, that a battery provided with cell-voltage equalisers seldom requires this cycling and measurement procedure. Such a battery is in perfect condition after six weeks of normal float-charging. When the equipment to be powered is installed and tested, the battery is well balanced and in good condition.

If the capacity of a cell in an installed battery has been considerably reduced, due to premature ageing or some kind of dam-

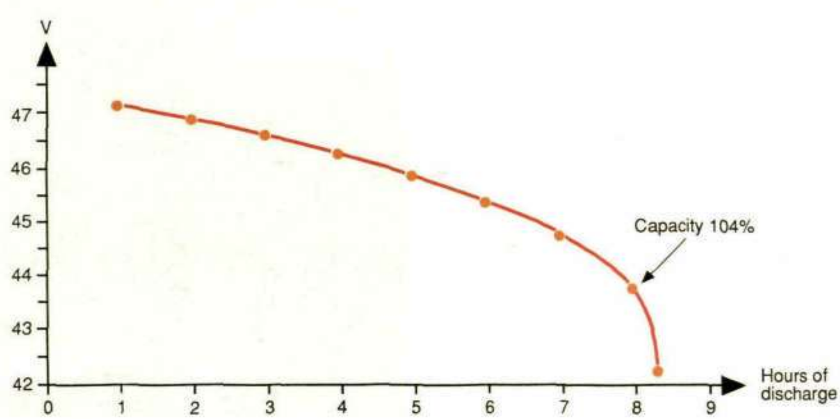


Fig. 7
Capacity test of the battery shown in Fig. 4, three months after installation of cell-voltage equalisers

age, the faulty cell or the entire battery must be exchanged. In most cases, a new cell has much lower self-discharge than the ordinary battery cells. Replacement of individual cells in a battery therefore causes balance problems and is not recommended in industry standards. In a battery provided with cell-voltage equalisers, the imbalances between the cells are automatically compensated for, which means that individual cells can be replaced without any risk of complications.

An interesting alternative, when replacing a cell in a battery without cell-voltage equaliser, is to provide only the new cell with an equaliser. This is one way of avoiding both overcharge of the new cell and voltage drops in other cells in the series-connected floating-current chain. But if a battery cell needs to be replaced, it is likely that other cells too are in a bad condition and that the battery backup time has been reduced to a value well under what was projected. If an assessment of the battery's condition indicates that satisfactory backup time can be achieved by providing all the cells with equalisers, then this solution is often preferable to scrapping the battery. When it is eventually scrapped, after having served its time, the cell-voltage equalisers can be shifted on to the new battery.

Fig. 8
Measurement of cell voltages in batteries installed vertically

Thermal run-away

Placing batteries in cramped spaces involves a risk of thermal run-away. When the temperature in a battery rises, the self-discharge process is intensified, which will raise the floating current. The power generation in the battery increases and causes the temperature to rise further. The cells in the centre of a battery as a rule cannot carry off heat to the same extent as the outer cells and will therefore have a higher temperature. The cell voltage rises with increased temperature, which means that the hottest cells account for a greater portion of the total power generated in the battery. The temperature in these cells rises even more. If a cell cannot carry off enough heat, the process will get out of control, causing the electrolyte to boil away and destroying the overheated cell. The plant will no longer have any standby power.

If the battery is provided with cell-voltage equalisers, even a slight voltage increase leads to a substantial reduction of the current through the cell. The feedback is negative. The risk of thermal run-away – and thus a potential source of trouble – has been eliminated.

Valve-regulated batteries – in theory and in practice

Cell-voltage equalisers have been successfully used in valve-regulated batteries also. However, some experts – basing their arguments on theoretical models of the chemical processes involved – claim that cell-voltage equalisers should not be used in this type of battery. If low cell voltages are caused by sulphation in the cells, the increase of the floating current achieved by means of cell-voltage equalisers clearly has a positive effect. If, on the other hand, the low cell voltages are due to the fact that cells have dried out, and that a recombination process is going on, then increased floating current will have a negative effect. Correspondingly, high cell voltages may indicate that the recombination process is incomplete, in which case the floating current should be kept at a high value.

In the operational data of valve-regulated batteries that Ericsson Components AB has access to, there are no indications that cell-voltage equalisers have any negative effects, even though batteries from different manufacturers might possibly have different characteristics in this respect.

Summary

In a power supply system, the battery is that component which has the shortest life and needs most maintenance. This not-too-glamorous maintenance also requires that the applicable instructions are followed in every detail.

When the primary power supply fails, the proper functioning of a fully charged battery suddenly becomes vitally important. The cell-voltage equaliser has been developed to assure that the battery is always in the best possible condition and to reduce the consequences of temporary deviations from stipulated maintenance routines.

The costs of cell-voltage equalisers are compensated for by cost savings. Firstly, maintenance routines can be simplified, and, secondly, a battery with cell-voltage equalisers need not be cycled when it is installed. In a longer perspective, the battery economy will be improved thanks to ideal float-charging conditions, which increase the life of the battery cells, and thanks to the possibility of replacing damaged or prematurely aged battery cells without having to include any additional maintenance measures.

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In Search of Managed Objects

Walter Widl and Kidane Woldegiorgis

Management of the telecommunication network across standardised interfaces requires that the necessary resources – in the form of Managed Objects – should also be standardised. A methodology for describing tools and processes is needed to define the Managed Objects that represent the manageable resources of the telecommunication network.
The derivation of the Managed Objects for the transport network is the main focus of this article.

telecommunication networks
telecommunication network management
standardisation

Introduction

Efficient management of new and existing telecommunication networks is one of the main concerns of administrations, manufacturers and standardisation bodies. Intensive studies during the last few years seem to have finally resulted in workable tools for the description of networks and their management, as appears from the relations between CCITT's TMN Recommendations, Fig. 3. The methodology and the driving forces behind the definition of the standardised interfaces (both communication protocols and information model) are laid out in Recommendation M.3010. M.3020 identifies the management services that represent the management tasks and describes the methodology to be used in the specification of the interfaces. M.3400 contains the list of TMN management functions for the different TMN functional areas. Two recommendations that provide information models are in the final process of approval. M.3100 provides a generic network information model, and G.744 is the information model for SDH-based transport networks.

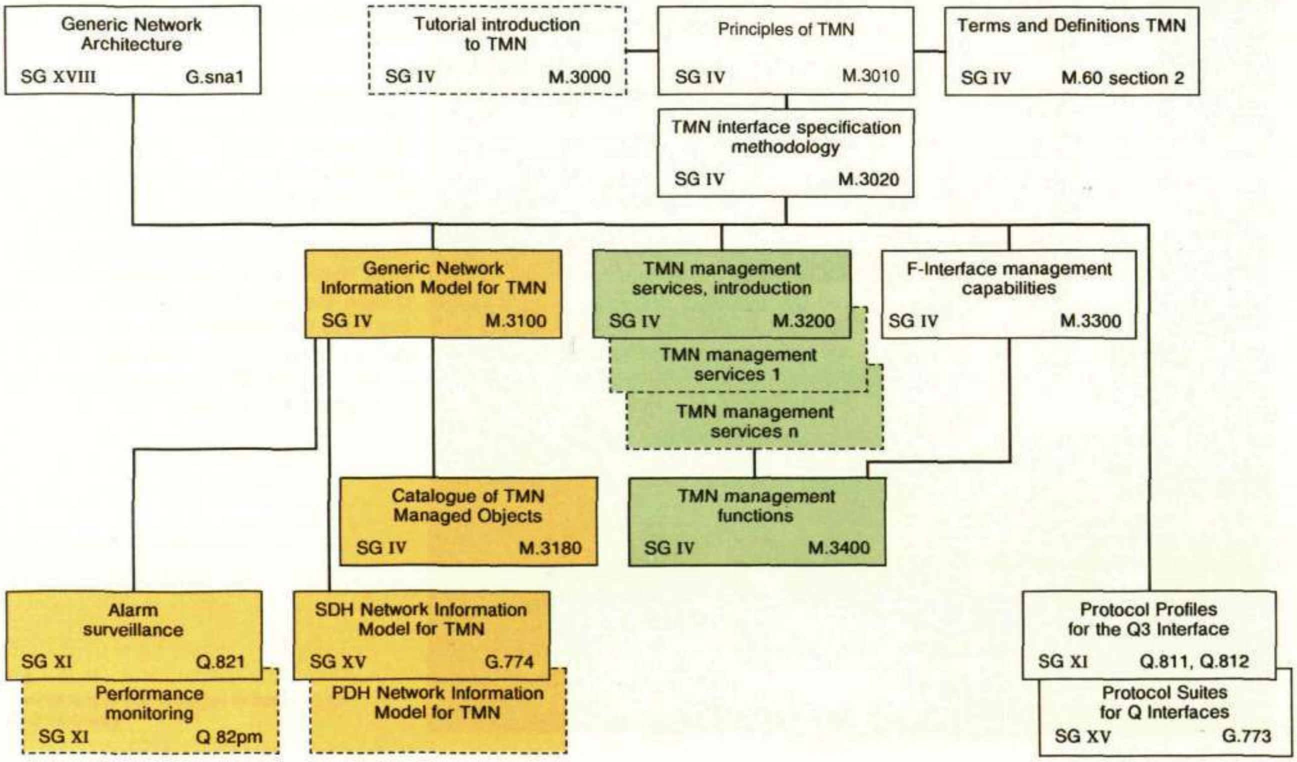
Figs. 1 and 2 show an overview of the methodology and the processes involved in deriving the Managed Objects. Fig. 1 shows the associated tasks, which – in a broad sense – are seen as the functional and information modelling processes.

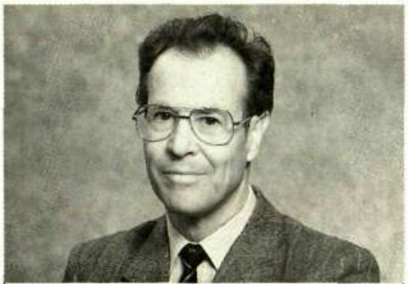
A number of TMN Management Services are defined by CCITT. "Management of transport networks" is an example of such a service. The functional modelling of the transport network consists of a process, Fig. 2, in which – for each transport network layer or sublayer – Trails and Con-

Fig. 3
Relations between CCITT's TMN Recommendations

Recommendation for approval 1992

Recommendation under study





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nections are identified, along with the corresponding Termination Points (Connection Points and Termination Connection Points).[2] In this process, Manageable Resources in the vicinity of the Termination Points are derived.

In the information modelling, the Resources are combined into Managed Objects. This article demonstrates these processes for the Termination Point and cross-connection aspects of the transport network.

Fig. 1
Development of transport network Managed Objects

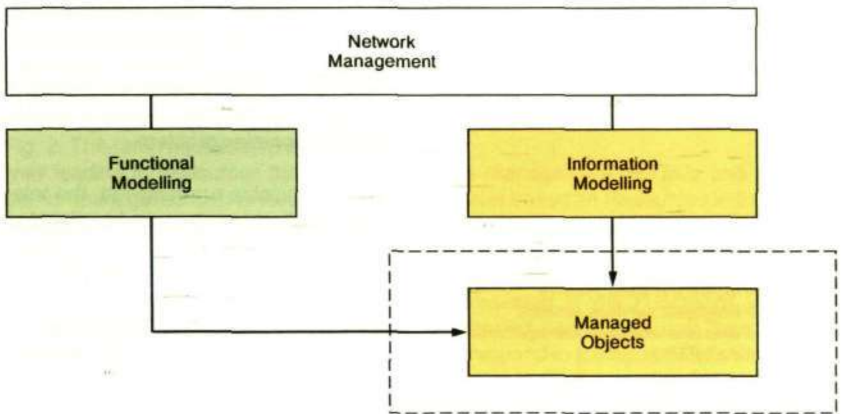
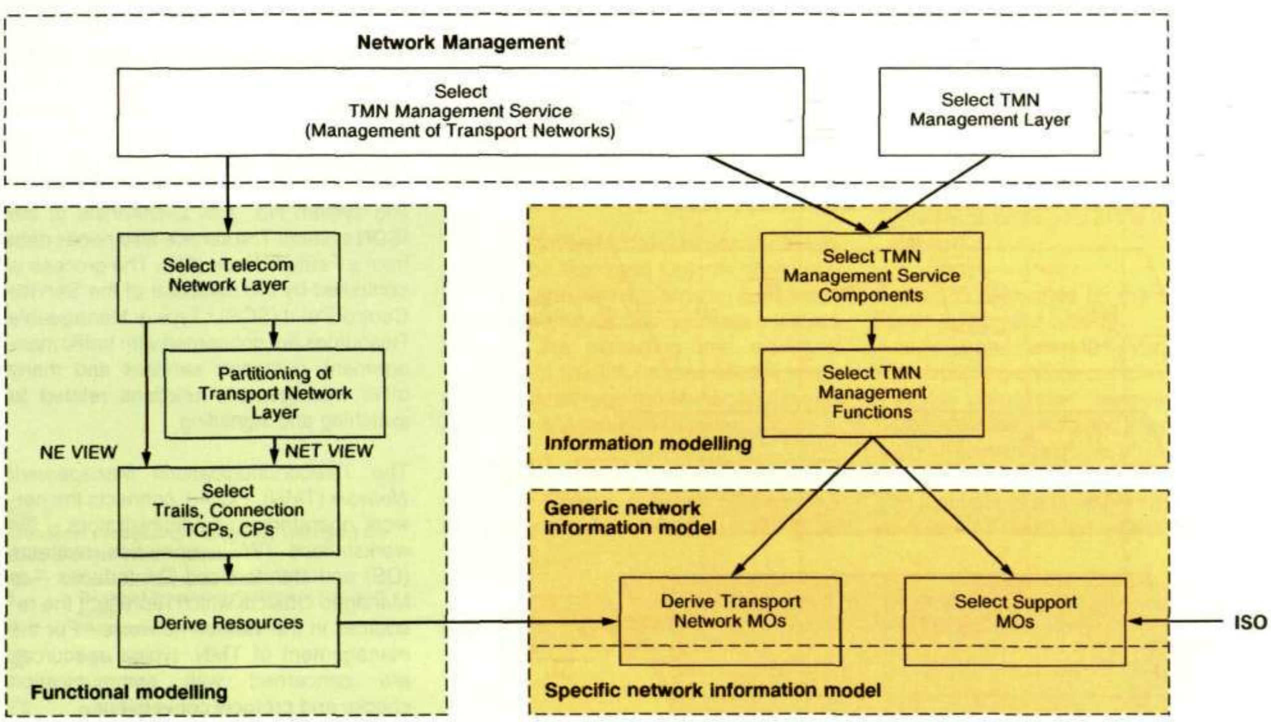


Fig. 2
Development process for transport network Managed Objects

NE	Network Element
TCP	Termination Connection Point
CP	Connection Point
MO	Managed Object



In a follow-up article, the derivation of Managed Objects for other aspects will be presented. No attempt is made in this article to define the Managed Objects in detail, since the standards referred to give complete definitions of the objects in question.

A layered view of the telecommunication network

Basically, networks and their management are described according to the principle of dividing complex problems into less complex ones, which can be solved independently of each other. Partial solutions can contribute in an iterative manner to the solution of a complex problem.

If these principles are followed, the telecommunication process can be allocated to various networks, Fig. 4,
- the physical transmission network
- the logical transport network
- the intelligent services network (IN)
- the telecommunications management network (TMN).

In addition to the telecommunication functions, each of the networks also contains functions for network management. Manageable Resources are represented by Managed Objects in the Information Model.

The *Transmission Network*, Fig. 4a, contains the physical means of transfer of information, i.e. telecommunications equipment and connecting transmission media: typically, switching matrices of switches and cross-connect systems, modems, muldexes, line systems and cables. The transmission network contains various transmission network layers, as specified in Recommendations G.702 and G.707, for example.[5] Typical physical management resources that are part of the transmission network are: signal level detectors, error counters and error information storage.

The *Transport network*, Fig. 4b, performs logical functions related to transmission, such as network configuration and protection switching, and ensures reliable transfer of information between service users, regardless of the information content. The transport network contains various Transport Network Layers, each of which carries a distinct characteristic signal, i.e. a signal with a particular data rate and format.[2] Manageable Resources are the functional representations of the physical resources implemented in the transmission network.

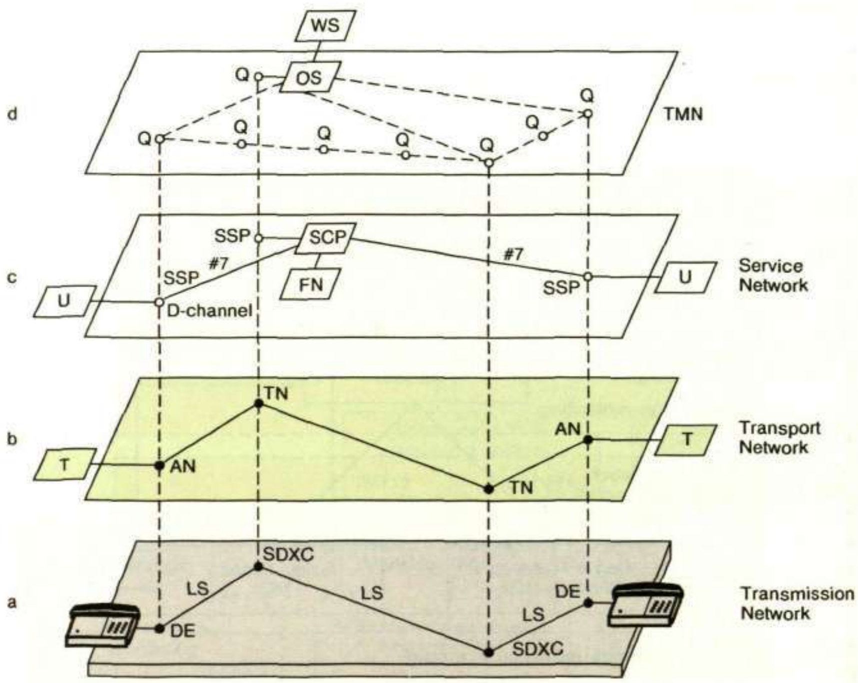
The *Service network*, Fig. 4c, performs functions related to switching and signalling. The purpose of the intelligent Service Network is to offer users a particular service. The user initiates a service via a Service Switching Point (SSP) using signalling system No. 7 or D-channels of the ISDN system. The service also needs data from a Feature Node (FN). The process is controlled by the database of the Service Control Point (SCP).[6] Typical Manageable Resources are concerned with traffic management, customer services and many other management functions related to switching and signalling.

The *Telecommunications Management Network* (TMN), Fig. 4d, connects the network operators and administrators – via workstations (WS), operation systems (OS) and standardised Q-interfaces – to Managed Objects which represent the resources in the various networks.[3] For the management of TMN, typical resources are concerned with communication checks and protocol conversions.

Fig. 4
The telecommunication network can be considered to be divided into

a	the physical transmission network
b	the logical transport network
c	the intelligent services network
d	the telecommunication management network (TMN)

DE	Digital Exchange
SDXC	Synchronous digital cross-connect equipment
LS	Line System
T	Terminal
AN	Access Node
TN	Transit Node
SSP	Service Switching Point
SCP	Service Control Point
FN	Feature Node
U	User
WS	Workstation
OS	Operating System
Q	Interface between the Transmission Management Network and the Managed Objects



Telecommunication network functions and resources appear in all the networks shown in Fig. 4. Each network can consist of several layers, each of which can be managed individually by a Manager-Agent Process.[3] The resources and their properties are represented in a standardised way as Managed Objects in databases.

Management methodology
Network management requires the selection of a TMN Management Service – i.e. a distinct task for an operator – which involves several TMN Management Layers – i.e. the area of application of the task, Fig. 2. The task requires a functional analysis leading to Resources that are suitable for management. The Resources are described in the functional modelling process.

The information modelling process is based on the management tasks and organisation of the management provider. The selection of a particular TMN Management Service and related TMN Management Layers leads to the selection of TMN Management Service Components and TMN Management Functions. TMN Management Functions are performed on Managed Objects.[3]

The information modelling process specifies which Managed Objects are needed to perform the desired management tasks. The functional modelling process leads to the Manageable Recources offered by the network. Harmonisation of these requirements normally leads to iterative processes.

The Information Model contains all data related to the Managed Objects, their relationships and naming structure, as seen across a particular management interface between the managing and managed systems. In the Information Model, when completed, all required Managed Objects appear in a standardised form.

The process of deriving transport network Managed Objects consists of functional modelling and information modelling. In these analyses, a given physical transmission network supports a transport network. Each transport network contains layers defined by a characteristic signal.[2] Connections and Connection Points carrying the characteristic signal are determined for each transport network layer. This process leads to a detailed specification of management aspects of the Network Elements forming the transport network (Network Element View). Each transport network layer can be partitioned into various geographical and administrative regions, which offers various degrees of detail in the network views.

The management of Trails and Connections is based on Resources in the vicinity of the end points of Trails and Connections. The anomaly detectors and controllable devices in the telecom equipment are represented in the Functional Model as properties and Resources; these in turn correspond to transport network Managed Objects in the Information Model. The following chapters go into more detail concerning functional modelling and information modelling for transport network-related TMN Management Services.

Functional modelling

The physical implementation of digital telecommunication networks comprises equipment such as
- switching matrices
- modems and muldexes
- line, radio and satellite systems
- transmission media for line systems and interfaces belonging to the transmission network.

Functions performed by the above-mentioned equipment include
- cross connection and switching
- multiplexing and demultiplexing
- signal conversion between physical transmission media and interface cables
- signal transmission via physical media.

The functions of a telecommunication network can be modelled with the aid of the

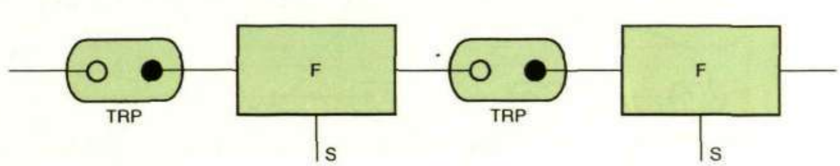


Fig. 5
Transport Processing Functions, Transport Entities and Reference Points

TRP Transport Reference Point
F Transport Processing Function or Transport Entity
S Management Reference Point
● Input to F
○ Output from F

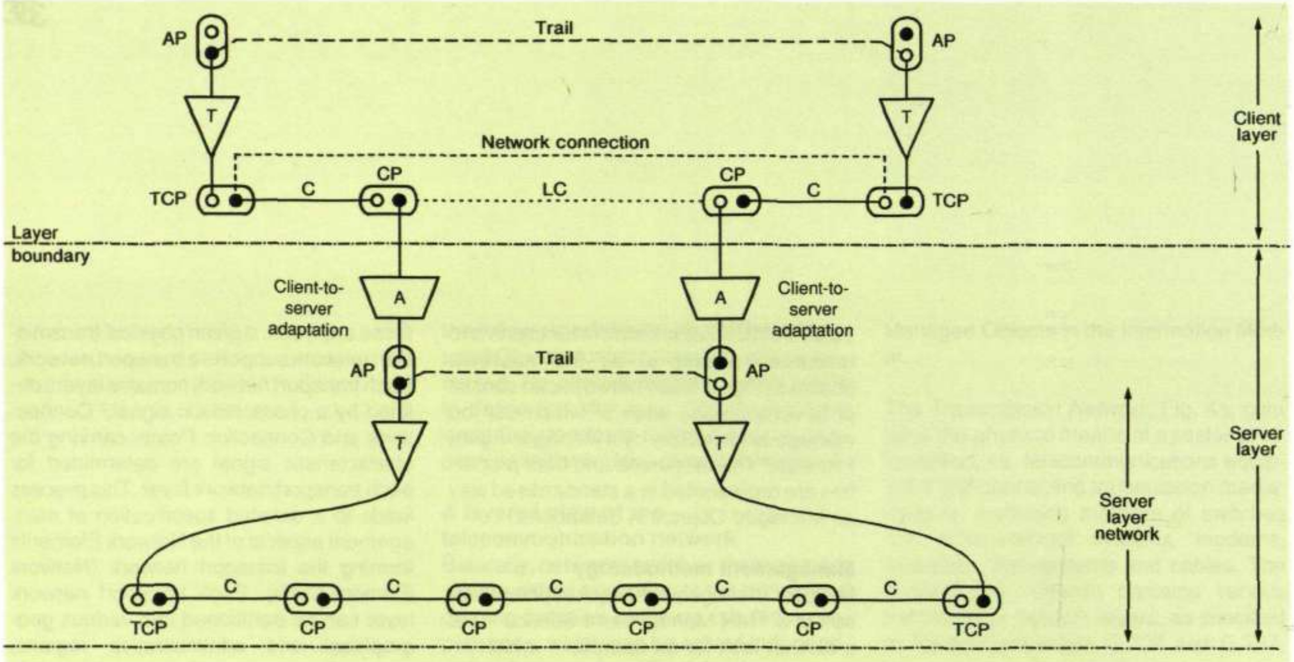


Fig. 6
Functional Model illustrating the use of Transport Functions
A Connection can be a Link Connection, a Sub-Network Connection or a Matrix connection

A	Client-to-server adaptation
T	Trail Termination
C	Connection
LC	Link Connection
AP	Access Point
CP	Connection Point
TCP	Termination Connection Point

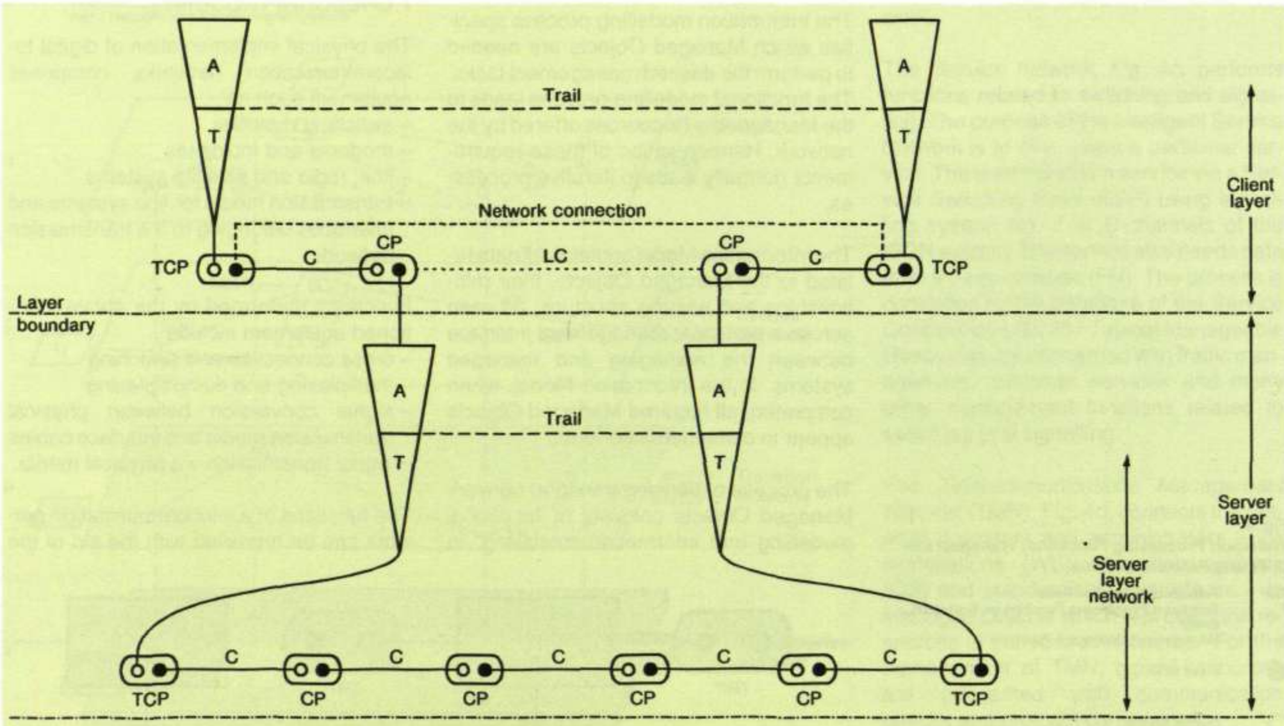
Fig 7
Simplified Functional Model illustrating the use of Transport Functions

Generic Transport Network Architecture.[4] The basic elements of this model are

- Transport Entities, such as Link Connection (LC), Sub-Network Connection (SNC) and Trail. Transport Entities transfer information transparently
- Transport Processing Functions, such as Adaptation (A) and Trail Termination (T). Transport Processing Functions process the transferred information
- Transport Reference Points, such as Connection Points (CP), Termination Connection Points (TCP) and Access Points (AP).

Some of the Transport Processing Functions and Transport Entities are defined as follows:

- The Transport Entity "Trail" is responsible for the transfer of characteristic information (signals with specified data rates and formats) between the Access Points to a layer (AP). A Trail contains near-end and far-end Trail Terminations and one or several Network Connections
- The Transport Entity "Network Connection" is responsible for the transfer of information between Termination Connec-



tion Points (TCP). A Network Connection contains either Link Connections (LC) or Sub-Network Connections (SNC), or both

- *The Transport Entity "Connection" is responsible* for the transfer of information between Connection Points (CP). A Connection can be a Sub-Network Connection or a Link Connection
- The Sub-Network Connection transfers information transparently across a subnetwork. The connectivity of a Sub-Network Connection can be controlled by a management process
- The Link Connection transfers information transparently across a link between two subnetworks. The connectivity of a Link Connection cannot be changed by a management process.

Fig. 5 shows that Transport Functions, i.e. Transport Processing Functions and Transport Entities, are separated by one Transport Reference Point. In addition, a management reference point S is provided for management information to and from each Transport Function. The input/output concept is related to Transport Functions and should not be interpreted as indicating signal directions. "Input" represents the input, "output" the output part of the function.

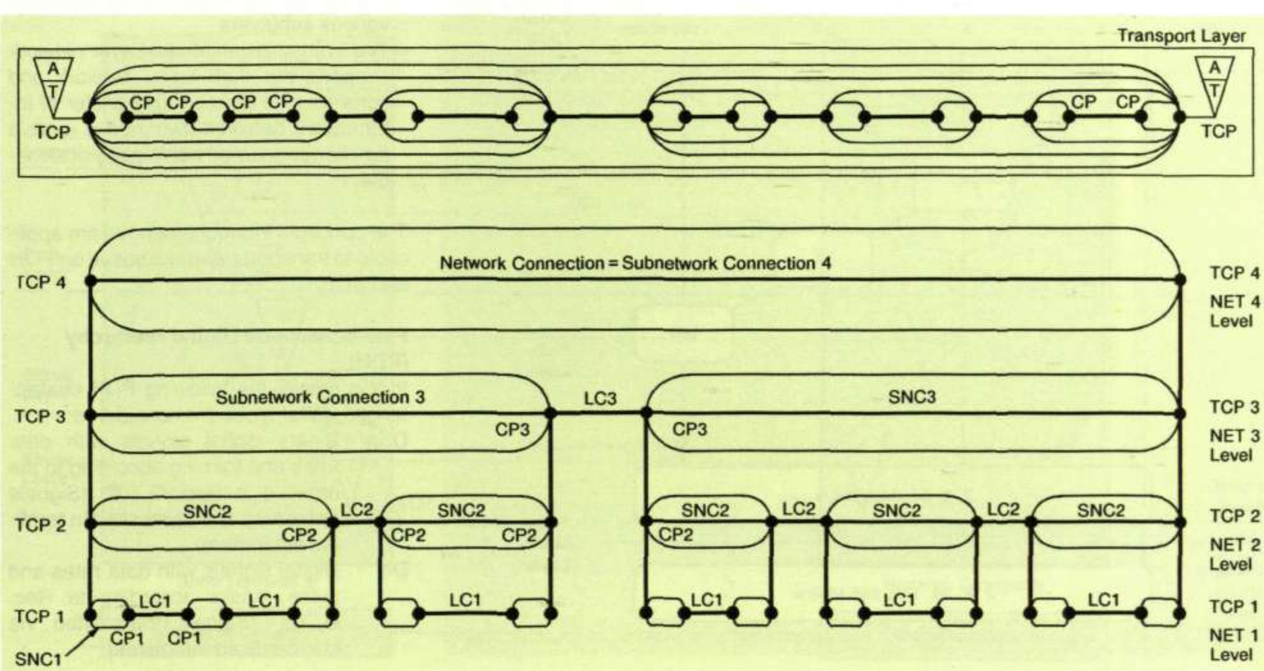
The use of the Transport Functions is illustrated in Fig. 6.[4] Fig. 7 is a simplified version of Fig. 6 and does not show the Access Points (AP) explicitly.

The Functional Model can be used to model the telecommunication network to the desired degree of detail. For example, Network Elements and parts of Network Elements can be represented. Fig. 8 shows Sub-Network Connections and Link Connections which belong to the same transport layer, and which in turn can be partitioned into subnetworks showing various degrees of detail.

The NET 1 level shows SNC1s, LC1s, CP1s and TCP1s, i.e. the greatest degree of detail. The NET 2 level – less detailed – shows SNC2s, LC2s, CP2s and TCP2s. In this way various degrees of detail (levels of abstraction) can be chosen, depending on the purpose of the Functional Model. The network connection in the NET 4 level is that of a single SNC4 between two TCPs. From a management point of view, NET 1 provides the details required at the

Fig. 8
Levels of abstraction in a Layered Network; example

Subnetwork
SNC Sub-Network Connection
Node with cross connection (Matrix)
LC = Link Connection
CP = Connection Point
TCP = Termination Connection Point



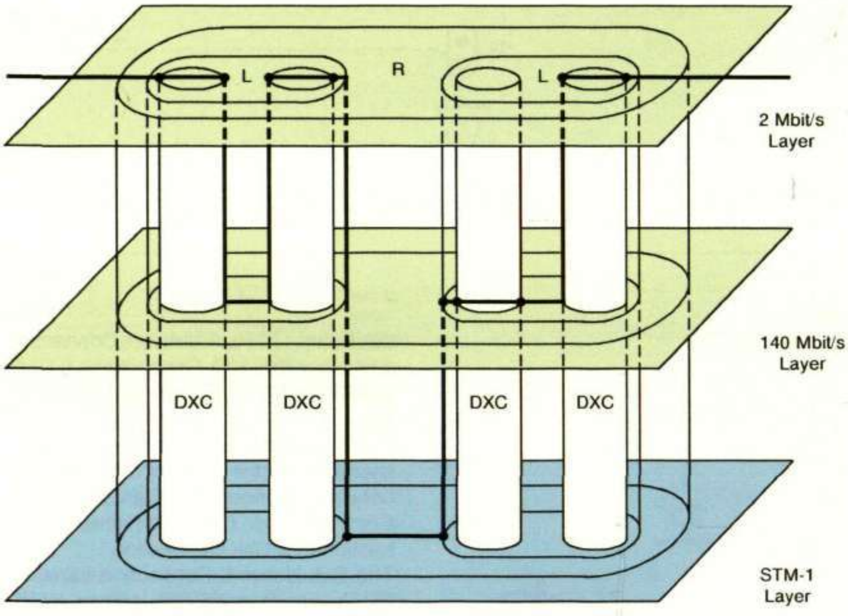


Fig. 9
Combination of layering and partitioning; example

L	Local network
R	Regional network
DXC	Digital cross connect

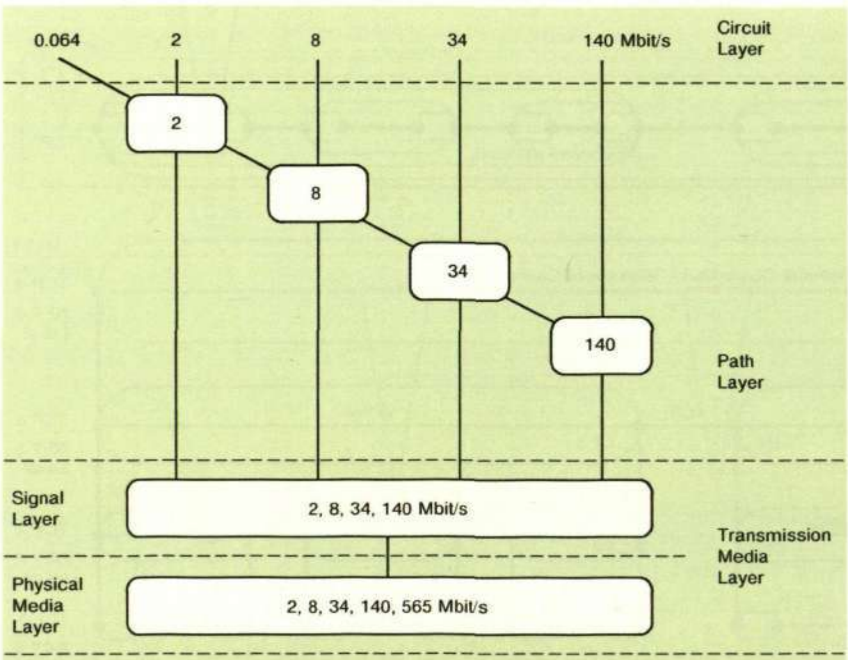
local level, NET 2 at the district, NET 3 at the regional and NET 4 at the national level.

Signal transport in real networks leads to a combination of layering and partitioning, Fig. 9. A 2 Mbit/s signal passes through digital cross connects (DXC) located in a local network, is transmitted via a 140 Mbit/s line between the cross connects and via an STM-1 system between the local networks, and then passes again through DXCs in a local region. Three of the DXCs use the 2 Mbit/s and one of them the 140 Mbit/s switching level. The example shows that all Reference Points and Transport Processing Functions involved in the transport of information can be identified as belonging to a certain layer of the transport network and a certain level of abstraction.

In CCITT draft Recommendation G.sna1, the transport network is divided into three layers, which in turn can be divided into sublayers. The layers are as follows:
- The Circuit Layer network is concerned with the transfer of information between users, in direct support of telecommunication services. This circuit definition is specifically used to describe network architecture and differs from CCITT circuit definitions used for other purposes
- The Path Layer network supports the Circuit Layer network and may consist of various sublayers
- The Transmission Media Layer network supports the Path Layer network and consists of a function for transfer of information between two nodes and a function concerned with the physical media.

The concepts introduced above are applicable to transport networks based on PDH and SDH.

Fig. 10
PDH-based Transport Network Layered Model (CEPT hierarchy)



Plesiochronous Digital Hierarchy (PDH)

In this article, the following PDH characteristic signal types are considered:

DSn	Binary digital signals with data rates and framing according to the order *n* in Rec. G.702. (Signals generated and processed in terminal equipment)
Dn	Digital signals with data rates and pulse masks according to Rec. G.703. (Signals transmitted via standardised interfaces).

In PDH, the following transport network layers are defined:

- The Path Layer network consists of sublayers for various data rates (e.g. DSn = 2, 8, 34 and 140 Mbit/s sublayers)
- The Transmission Media Layer network consists of a Signal Layer (e.g. Dn = 2, 8, 34, and 140 Mbit/s) and a media-dependent Physical Media Layer (for the transmission of non-standardised 2, 8, 34, 140 and 565 Mbit/s line signals).

The use of the Functional Model will be illustrated by a number of examples based on the Transport Network Layered model for PDH, Fig. 10. The lines between the blocks represent different alternatives for transporting information. The Physical Media Layer belonging to the transport network represents the physical media appearing in the transmission network.

Plesiochronous digital networks contain the following Transport Processing Functions:

PPA Plesiochronous Path Adaptation for the client-server relationships DSn-1/DSn required for multiplexing/demultiplexing and framing

PPT Plesiochronous Trail Terminations for the DSn Trails required for overhead insertion and extraction

SLA Signal Layer Adaptation for the client-server relationships DSn-1/Dn required for line coding/decoding

SLT Signal Layer Trail Terminations for the Dn Trails required for line code checking

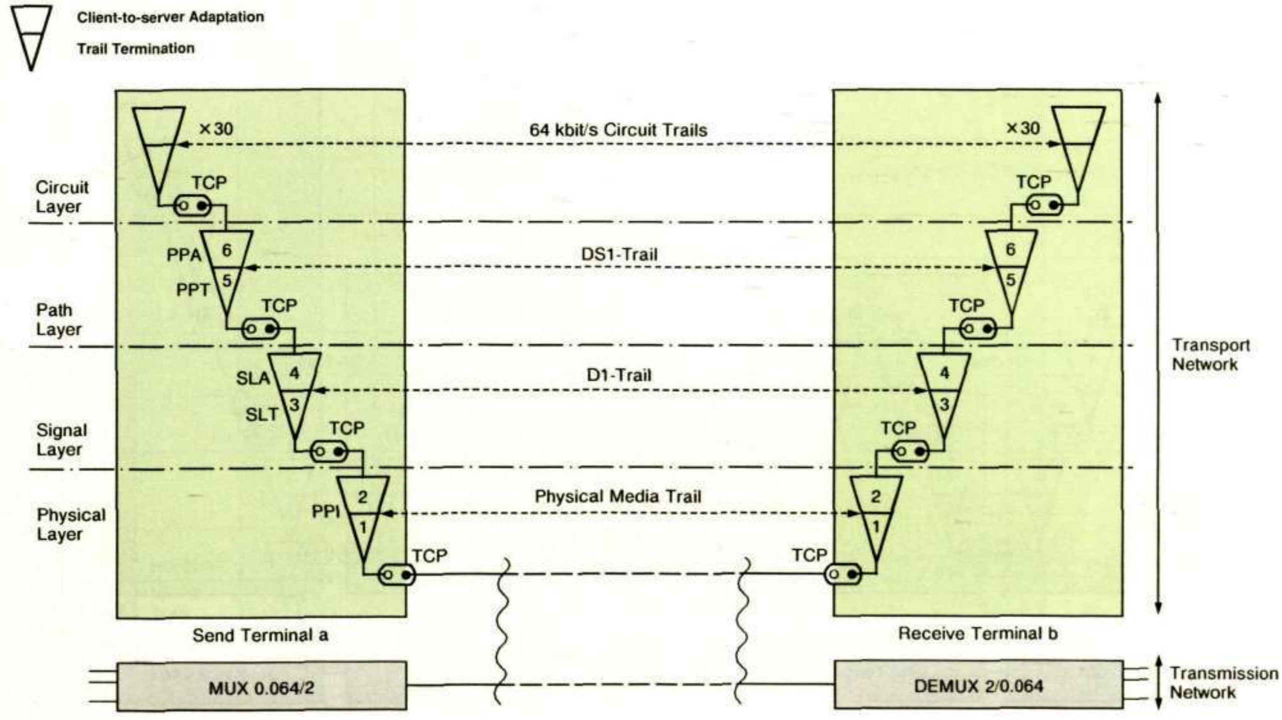
PPI Plesiochronous Physical Interfaces required for the adaptation of signals to cables, and vice versa.

Fig. 11 shows in detail the unidirectional signal transport of 30x64 kbit/s circuits between a multiplexer and a demultiplexer. The lower part of the figure shows the physical representation in the transmission network; the upper part the functional representation in various layers of the transport network. The send terminal contains the multiplexing function, generates the 2 Mbit/s framed signal, and contains functions for signal conversion to HDB-3 coding and for connection of the interface cable. The receive terminal contains the corresponding functions. The Transport Functions appear in various transport

Fig. 11
Functional Model of PDH multiplexer

DS1 Framed 2 Mbit/s signal
D1 HDB-3 coded 2 Mbit/s signal

Client-to-server Adaptation
Trail Termination



Layer	Transport Function	Send side	Receive side
Physical Layer	1 PPI	No function	No function
	2 PPI	Adaptation to transmission media	Adaptation to equipment
Signal Layer	3 SLT	No function	Loss of signal check
	4 SLA	Binary to HDB-3 code conversion	HDB-3 to binary code conversion HDB-3 violation check
Path Layer	5 PPT	2 Mbit/s overhead insertion	2 Mbit/s frame alignment 2 Mbit/s overhead extraction
	6 PPA	0,064/2 Mbit/s multiplexing 2 Mbit/s frame generation	2/0,064 Mbit/s demultiplexing

Table 1
Functions in the PDH transmission system, shown in Fig. 11

HDB-3 **High-Density Binary Code**

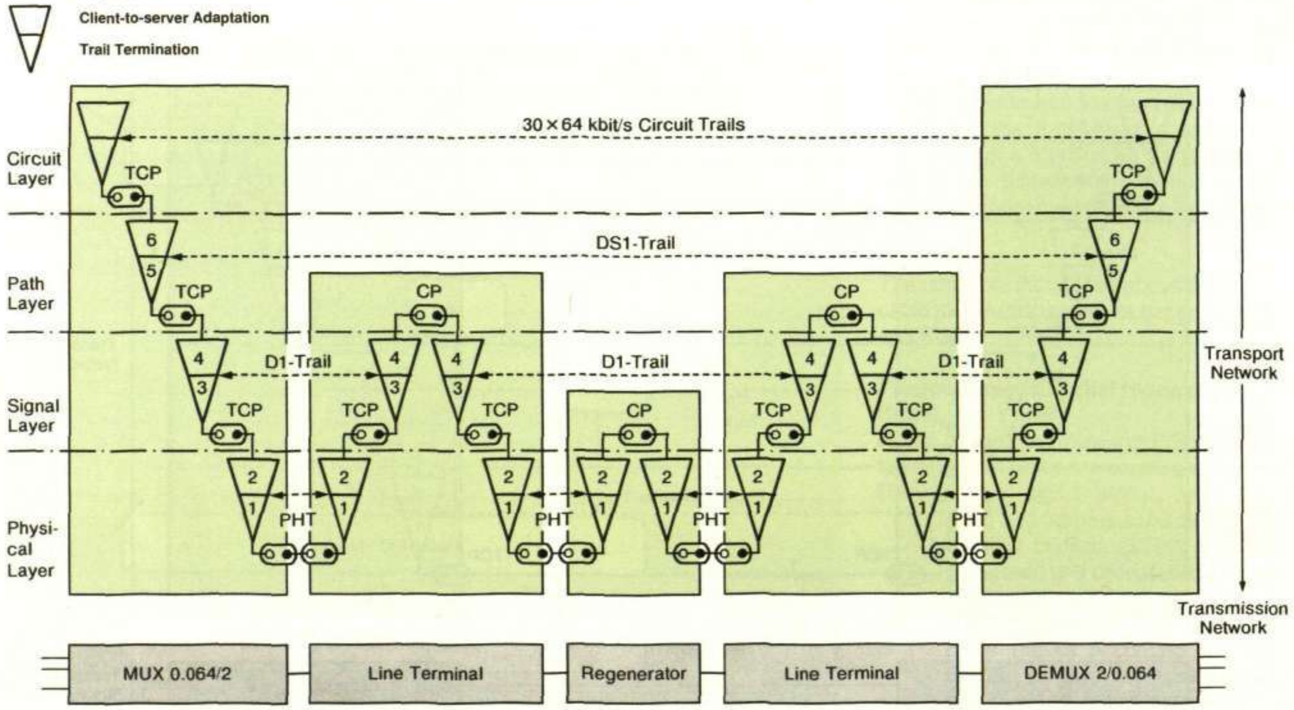
Table 2
Relationship between Functional and Information Model

	Functional Model, see Fig. 6	Managed Objects in Information Model, see Fig. 18
Transport Function	Trail Connection	Trail (Managed Object) Connection (Managed Object)
Transport Reference Points	End point of trail AP End point of a connection CP or network connection TCP	Trail Termination Point TTP (Managed Object) Connection Termination Point CTP (Managed Object)
Relationships between Transport Reference Points and related Managed Objects	One-to-one relationship between AP and CP One-to-one relationship between CP/TCP and CP One-to-n relationship between AP in a server layer and CP in a client layer	One-to-one relationship between TTP and CTP expressed by connectivity pointers One-to-one relationship between CTP and CTP expressed by connectivity pointers One-to-n relationship between TTP in a server layer and CTP in a client layer expressed by naming

Fig. 12
Functional Model of PDH muldex and line system

DS1 Framed 2 Mbit/s signal
D1 HDB-3 coded 2 Mbit/s signal
PHT Physical Media Trail

Client-to-server Adaptation
Trail Termination



layers, Table 1. Each function is characterised by a number, which appears in tables and figures in a consistent way. (The same number is used for the send and receive parts).

The example in Fig. 12 is based on the example in Fig. 11 and shows the connection of the terminals via a line system consisting of line terminals and one regenerator. Thirty 64 kbit/s Circuit Trails are transmitted via a DS1 Trail which consists of Trail Terminations, two Sub-Network Connections (TCP-CP) and one Link Connection (CP-CP) in the Path Layer network.

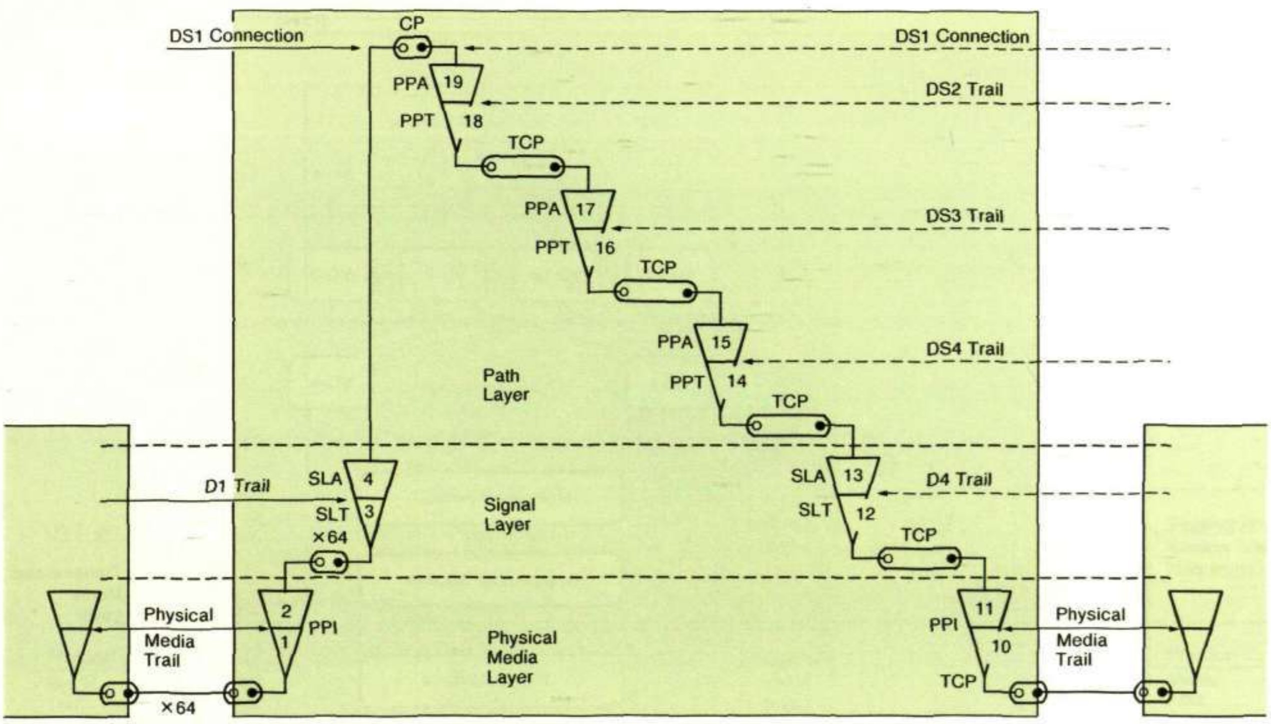
These Sub-Network and Link Connections are served by three D1 Trails in the Signal Layer network. The D1 Trail in the middle consists of Trail Terminations and two Link Connections.

The D1 Trail is served by two Physical Trails, i.e. two cable sections separated by a regenerator in the physical layer.

Fig. 13 shows the Functional Model of a digital multiplexer converting 64x2 Mbit/s signals into one 140 Mbit/s signal. Terminal *a* is connected to a digital multiplexer *a*, and the multiplexer is connected to a 140 Mbit/s line terminal *a*. Similarly, the corresponding b-side contains line terminal *b*, digital multiplexer *b* and terminal *b*. The multiplexers and line terminals contain resources for management. Transport Functions 1 to 4 are explained in Table 1 and functions 10 to 19 in Table 3.

Synchronous Digital Hierarchy (SDH)
The functions of SDH systems, as defined in CCITT Recommendations G.781, 782 and 783 for digital multiplexers and for digital cross connects, are much more complicated than PDH systems that conform to existing Series G Recommendations (-Blue Book). This is compensated by the increased flexibility and manageability of SDH systems, however. Ample overhead information, the corresponding resources and management interfaces suitable for

Fig. 13
Functional Model of PDH multiplexer (64x2 Mbit/s to 140 Mbit/s)



No	Transport Function (sending)	R	MO	Transport Function (receiving)	R	MO
1 PPI	No function	–	–	No function	–	–
2 PPI	Adaptation to transmission media	–	–	Adaptation to equipment	–	–
3 SLT	No function	–	–	Loss of signal check	LOS	D1 TTP
4 SLA	Binary to HDB-3 conversion	–	–	HDB-3 to binary code conversion HDB-3 violation check	– BER	SINK
5 PPT	2 Mbit/s overhead insertion	–	–	2 Mbit/s frame alignment 2 Mbit/s overhead extraction	LOF, AIS, BER RAI	DS1 TTP
6 PPA	0.064/2 Mbit/s multiplexing	–	–	2/0.064 Mbit/s demultiplexing	–	SINK
10 PPI	No function	–	–	No function	–	–
11 PPI	Adaptation to cable	–	–	Adaptation to equipment	–	–
12 SLT	No function	–	–	Loss of signal check	LOS	D4 TTP
13 SLA	Binary to CMI code conversion	–	–	CMI to binary code conversion CMI code violation check	– BER	SINK
14 PPT	140 Mbit/s de-framing 140 Mbit/s overhead insertion	–	–	140 Mbit/s frame alignment 140 Mbit/s overhead extraction	LOF, AIS, BER RAI	DS4 TTP
15 PPA	34/140 Mbit/s multiplexing	–	–	140/34 Mbit/s demultiplexing	–	SINK
16 PPT	34 Mbit/s deframing 34 Mbit/s overhead insertion	–	–	34 Mbit/s frame alignment 34 Mbit/s overhead extraction	LOF, AIS, BER RAI	DS3 TTP
17 PPA	8/34 Mbit/s multiplexing	–	–	34/8 Mbit/s demultiplexing	–	SINK
18 PPT	8 Mbit/s deframing 8 Mbit/s overhead insertion	–	–	8 Mbit/s frame alignment 8 MBit/s overhead extraction	LOF, AIS, BER RAI	DS2 TTP
19 PPA	2/8 Mbit/s multiplexing	–	–	8/2 Mbit/s demultiplexing	–	SINK

Table 3
PDH Functions, Resources and Managed Objects

LOS	Loss Of Signal
LOF	Loss Of Frame
BER	Bit Error Ratio
AIS	Alarm Indication Signal
RAI	Remote Alarm Indication
R	Resource
MO	Managed Object

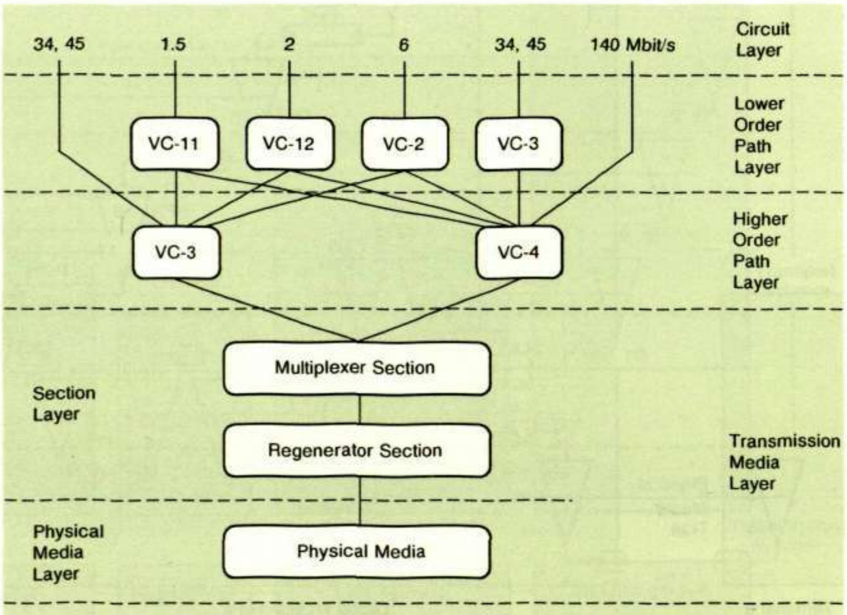


Fig. 14
SDH-based Transport Network Layered Model

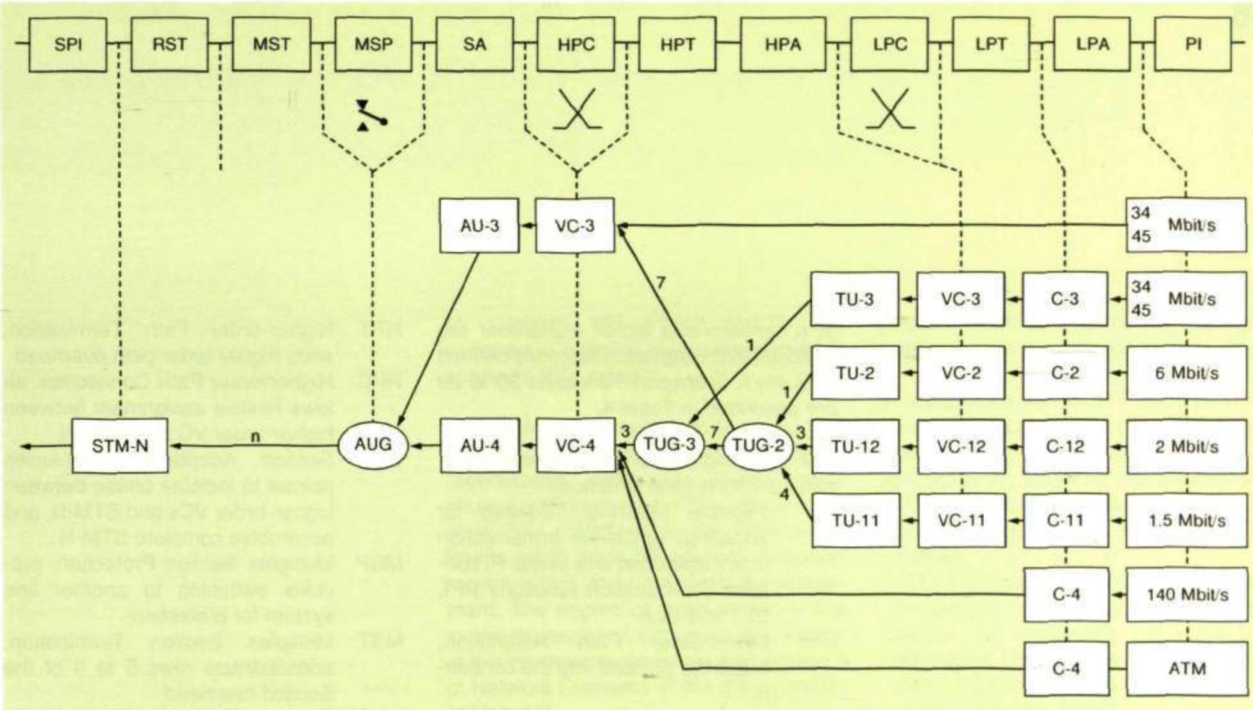
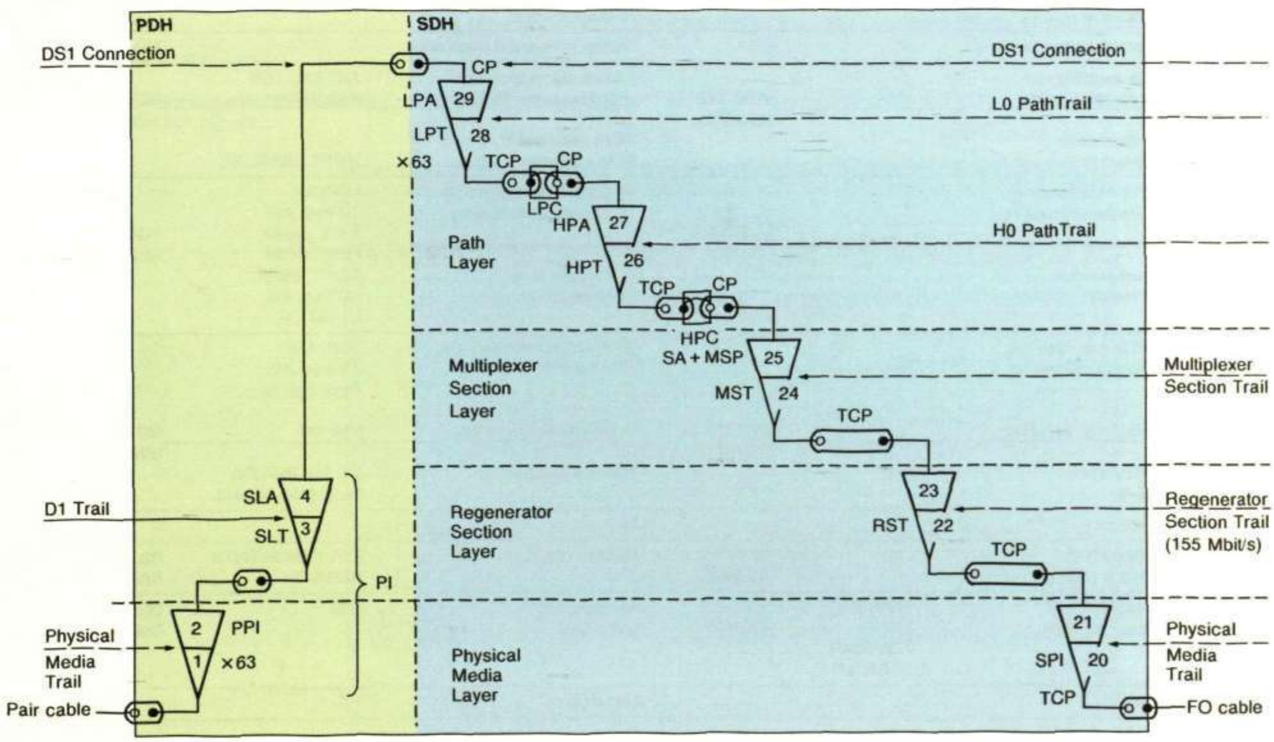


Fig. 15
SDH Transport Functions and Signals

TMN will permit SDH-based telecommunication networks to be monitored and controlled. Fig. 14 shows the Transport Network Layered Model based on the SDH multiplexing rules, and Fig. 15 shows the Transport Functions (as defined in G.783) and related signals.[2]

Fig. 16 shows the Layered Functional Model of a synchronous digital multiplexer converting 63x2 Mbit/s framed signals – connected via pair cables – into one 155 Mbit/s signal transmitted via a fibre-optical cable. The figure shows the way in which the functional blocks (as defined in G.783)

Fig. 16
Functional Model of SDH multiplexer (63x2 Mbit/s to 155 Mbit/s)



of a synchronous digital multiplexer are matched to the transport functions defined in G.sna1. Transport Functions 20 to 29 are described in Table 4.

SDH networks contain the following Transport Functions (one direction):

- PI Physical Interface, required for adapting signals for transmission over cables and vice versa. PI contains the transport functions PPI, SLT and SLA
- LPA Lower-order Path Adaptation, maps the payload into the container
- LPT Lower-order Path Termination, adds VC Path overhead
- LPC Lower-order Path Connection, allows flexible assignment between lower- and higher-order VCs
- HPA Higher-order Path Adaptation, processes pointer to indicate phase between lower- and higher-order VCs, assembles complete higher-order VC
- HPT Higher-order Path Termination, adds higher-order path overhead
- HPC Higher-order Path Connection, allows flexible assignment between higher-order VC and STM-N
- SA Section Adaptation, processes pointer to indicate phase between higher-order VCs and STM-N, and assembles complete STM-N
- MSP Multiplex Section Protection, provides switching to another line system for protection
- MST Multiplex Section Termination, adds/extracts rows 5 to 9 of the Section overhead
- RST Regenerator Section Termination, adds/extracts rows 1 to 3 of the Section overhead
- SPI Synchronous Physical Interface, converts to/from in-station or inter-station signals.

Networks with digital cross-connection equipment can be modelled in a similar way. As shown in Fig. 17, N incoming and

Table 4
SDH functions, Resources and Managed Objects

FAL	Frame Alignment Loss
FEBE	Far End Block Error
FERF	Far End Remote Failure
BE	Block Error
LOP	Loss of Pointer
LOS	Loss of Signal
MMPT	MisMatch, Path Trace
MMSL	MisMatch, Signal Label
MMSRK	MisMatch between Sent and Received K-bytes
OOF	Out Of Frame
LTUMF	Loss of TU Multiframe
SF	Signal Fail
SD	Signal Degrade
R	Resource
MO	Managed Object

	Send terminal			Receive terminal		
No	Transport Function (sending)	R	MO	Transport Function (receiving)	R	MO
29 LPA	2 Mbit/s mapping into virtual container VC12	–	VC12 TTP SOURCE	2 Mbit/s demapping from virtual container VC12	AIS, FAL, LOS Path AIS	VC12 TTP SINK
28 LPT	VC12 lower order POH insertion	–		VC12 lower order POH extraction	MMPT, MMSL, BE	
27 HPA	VC12/VC4 multiplexing TU12 Pointer processing	–	VC4 TTP SOURCE	VC4/VC12 demultiplexing TU12 pointer processing	LOP(TU), TU Path AIS Point. just.ev	VC4 TTP SINK
26 HPT	VC4 Higher order POH insertion			VC4 Higher order POH extraction	FERF, FEBE MMPT, MMSL AU Path AIS LT UMF, BE	
25 SA	VC4/STM-1 multiplexing AU4 Pointer processing	–		STM-1/VC4 demultiplexing AU4 Pointer processing	LOP (AU) AU Path AIS Point. just. ev	
MSP	Line protection switching		MS TTP SOURCE	Line protection switching	MMSRK	MS TTP SINK
24 MST	MSOH insertion, rows 5–9	–		MSOH extraction	SF, SD, BER(B2) FERF(M5), MS AIS	
23	No function	–	–	No function	–	–
22 RST	RSOH insertion, rows 1–3	–	RS TTP SOURCE	RSOH extraction	LSF, OOF EVENTS BER(B1)	RS TTP SINK
21 SPI	Adaptation to transmission media	TRANSMIT FAIL TRANSMIT DEGRADE	OSPI TTP SOURCE	Adaptation to equipment	LOS	OSPI TTP SINK
20	No function	–	–	No function	–	–

M outgoing 155 Mbit/s signals are switched in a digital cross connect which connects VC4 signals.

The examples show that every detail of a network – such as cables, line terminals, regenerators, distribution frames, multiplexers and cross connects – can be modelled. The model shows the Connection Points which might be required for performance, alarm and configuration management. The degree of detail shown in the model depends on its purpose, e.g. whether it is intended to model the management of Network Elements or the management of Networks.

Information modelling

Managed Object definitions

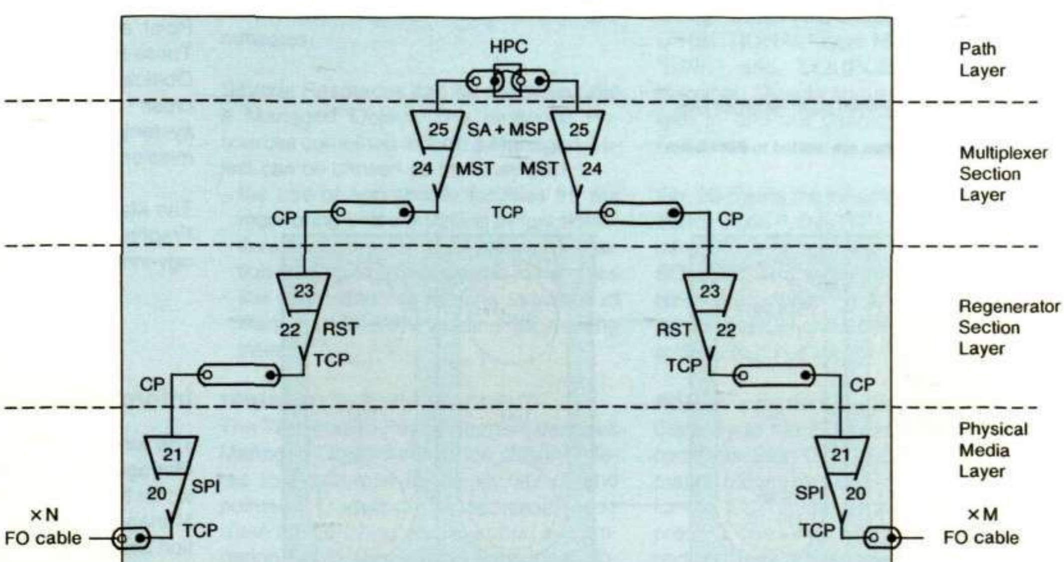
The execution of a management task (a TMN Management service) in a certain area of application (Management Layer) requires communication between the managing system (the Operation System) and the managed system (Networks or Network Elements) across management interfaces. The Information Model defines the types and contents of messages across the interface which are suitable for managing a given Managed Object. A Managed Object is the data representation of a physical or logical Resource in the managed system as seen by the managing system across the management interface.

In accordance with CCITT Recommendation X.722 (Guidelines for the definition of Managed Objects), a Managed Object is defined by the following characteristics:

- The attributes visible at its boundary. Attributes have one or more associated values
- The management operations that may be applied to a Managed Object. Operations can manipulate the value of a Managed Object attribute (GET, SET, ADD, REMOVE) or the Managed Object itself (CREATE, DELETE)
- The notifications emitted by the Managed Object
- The behaviour exhibited by a Managed Object in response to management operations
- The Conditional Packages that can be encapsulated in the Managed Object. A Conditional Package is a collection of optional attributes, notifications, operations and behaviours which are either all present or all absent in a Managed Object.

Managed Objects with similar attributes and behaviours may be grouped into a specific object class. An object is characterised by its object class and object in-

Fig. 17
Functional model of digital cross connect
Digital cross connect between 155 Mbit/s signals, switching of VC4 signals



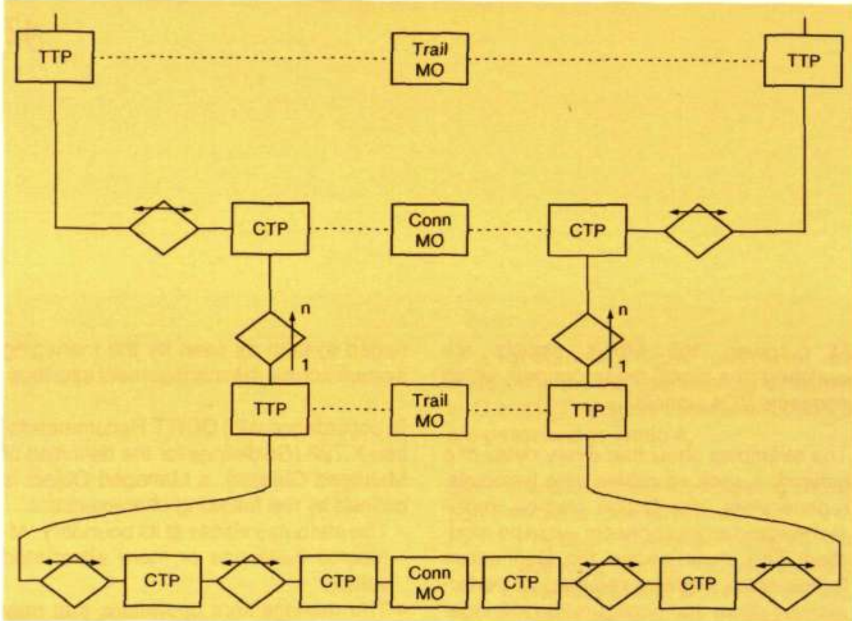
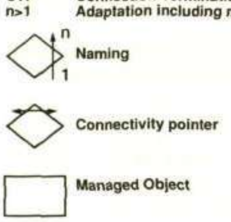


Fig. 18
Entity Relationship diagram derived from the Transport Functions in Fig. 6

TTP Trail Termination Point MO
CTP Connection Termination Point MO
n>1 Adaptation including multiplexing



stance and may possess multiple attribute types and associated values. An object class may be a subclass from another object class. A subclass inherits attribute types and behaviours of its superclass, in addition to possessing its own specific attributes and properties. Each object instance is identified by a unique name. Such a unique name is composed hierarchically and the most common way of organising a naming hierarchy is through a containment relationship. The relationship between Managed Object classes can be expressed with Entity-Relationship diagrams. Inheritance hierarchy diagrams show the subclassing of Managed Objects.[3]

The Managed Objects and their properties are contained in Network Information Models. The Generic Network Information Model defines Managed Objects that are common to many different technologies. Specific Network Information Models have been developed – or are being developed – for SDH, PDH and ATM networks.

Generic and specific Managed Objects are listed in a standardised form in Management Information Bases (MIB). The process of defining "all" new Managed Objects for the existing telecommunication networks will take many years, and new Managed Objects have to be foreseen as new technologies are introduced.

Use of Fragments

A number of views, referred to as Fragments, are used as a practical means of dividing the Information Model into well defined parts. These Fragments can be applied to modelling – according to the relevant purpose – more or less independently of each other. A Fragment can be illustrated by means of Entity-Relationship diagrams.

The following Fragments are derived from Functional Models:
- Network Fragment
- Managed Element Fragment
- Termination Point Fragment
- Transmission Fragment
- Cross-connection Fragment.

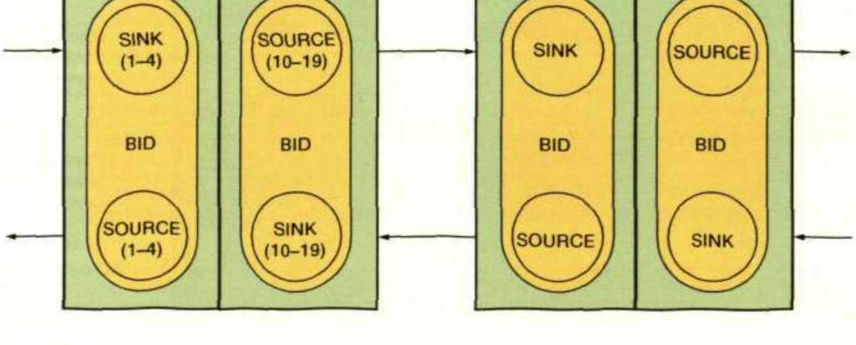
This article focuses on the Termination Point and Cross-connection Fragments. These Fragments assemble the Managed Objects required for the management of cross connects, muldexes and line systems, i.e the main components of transmission networks.

The Managed Objects for the three other Fragments will be described on a technology-independent basis in a future article.

Information Model

The functional modelling, which identifies Manageable Resources, provides the basis for the information modelling leading to Managed Objects. The various Information Models are introduced with reference to the relevant Functional Models.

Fig. 19
Identification of termination point Managed Objects
Numbers in parentheses are related to PDH functions in Fig. 13
BID Bidirectional



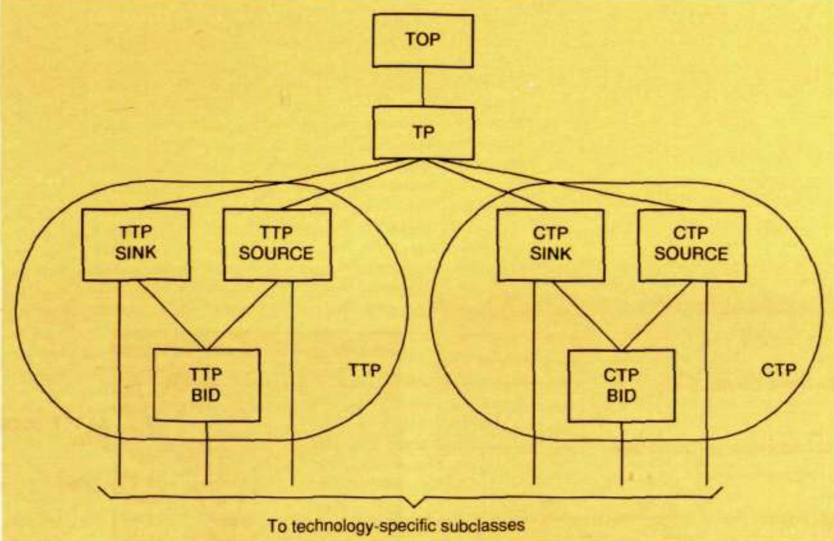


Fig. 20
Inheritance Hierarchy for Generic Termination Points
SINK, SOURCE and BIDIRECTIONAL

TP Termination Point
TTP Trail Termination Point
CTP Connection Termination Point

The process that leads from the Functional Model of the transport network, Fig. 6, to the corresponding Information Model is described below. The Functional Model of the transport network describes Connection Points that are related to accessible or non-accessible points in transmission network implementations. It also describes Transport Functions performed by these implementations, in which the Resources required for management are found too.

The Network Element aspect provides a detailed description of the NEs, while the Network aspect uses only those details that are required for network management. The Functional Model provides an abstract view of telecommunications equipment, based on the essential functions that such equipment must perform. These functional components are modelled by Managed Objects in the Information Model. Managed Objects represent implementation-independent aspects of equipment and networks.

Several Resources can be combined into a Managed Object. The particular Resources combined to form a Managed Object can be chosen so that they permit
- the use of appropriate facilities for the monitoring and controlling of functions
- iterative usage of management information leading to subclasses in hierarchies
- the name and the naming structure of Managed Objects leading to naming trees.

TERMINATION POINT FRAGMENT
The Termination Point Fragment decribes Managed Objects which are closely related to Resources in the vicinity of end points of Trails and Connections. These close relationships are illustrated by comparing Fig. 6, showing the Functional Model, with Fig. 18, showing the Entity Relationship diagram of the corresponding Information Model. Table 2 lists Transport Functions, Transport Reference Points, and relationships between Transport Reference Points and related Managed Objects.

A relationship between Managed Objects can be expressed either as a Managed Object or as an attribute of one or both of the Managed Objects associated by the relationship. In Fig. 18 two types of relationship are shown:
- Connectivity Pointer relationship, defining the one-to-one association between Termination Points, appears as attributes in both Termination Points
- Naming (containing) relationship, defining the association between *n* Termination Points in the client layer and one Termination Point in the server layer, appears as an attribute in the Termination Point of the server layer.

Fig. 19 illustrates signal transport to and from functional units in a network. Resources involved in signal receiving lead to "SINK" type Managed Objects. Resources involved in signal sending lead to "SOURCE" type Managed Objects. For signal transmission 2 to 140 Mbit/s across the PDH multiplexer shown in Fig. 13, Functions 1–4 lead to "SINK" type and Functions 10–19 to "SOURCE" type Managed Objects. In the reverse direction, Functions 10–19 are related to "SINK" and Functions 1–4 to "SOURCE". Resources for signal receiving and sending lead to "BIDIRECTIONAL" type Managed Objects. "SINK" and "SOURCE" characterising Managed Objects should not be confused with "in" and "out" characterising Transport Functions.

Fig. 20 shows the Inheritance Hierarchy of Termination Points (TP). Bidirectional TPs inherit the properties from SINK and SOURCE TPs through a multiple inheritance mechanism. This is valid, in principle, for all PDH and SDH Inheritance Hierarchies (but not shown in all the figures).

PDH Information model
Contrary to the SDH case, for which Recommendation G.774 specifies the Information Model, no CCITT recommendation for the PDH Information Model exists at present. The Model described below is based on the principles used in the SDH case.

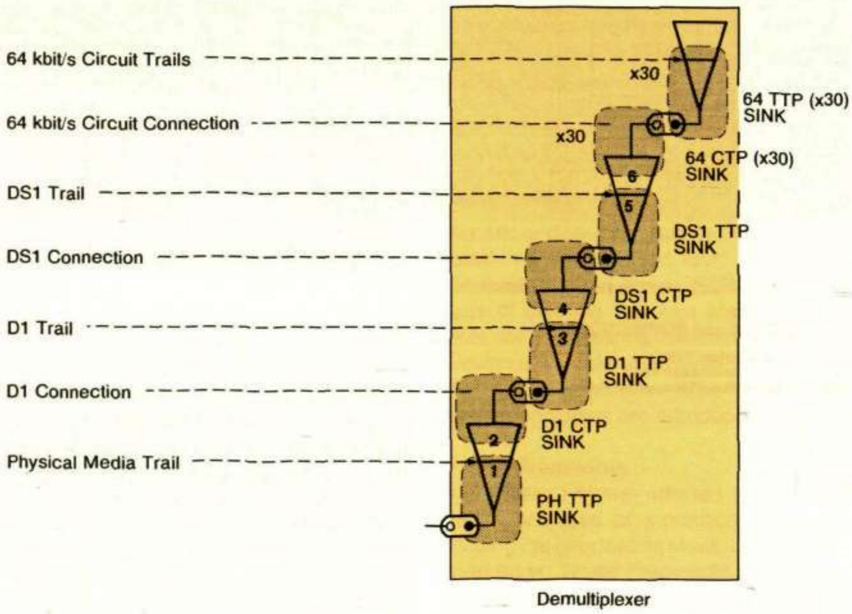


Fig. 21
Information Model of PDH demultiplexer
All Managed Objects in the figure are of SINK type

TCP

Managed Object

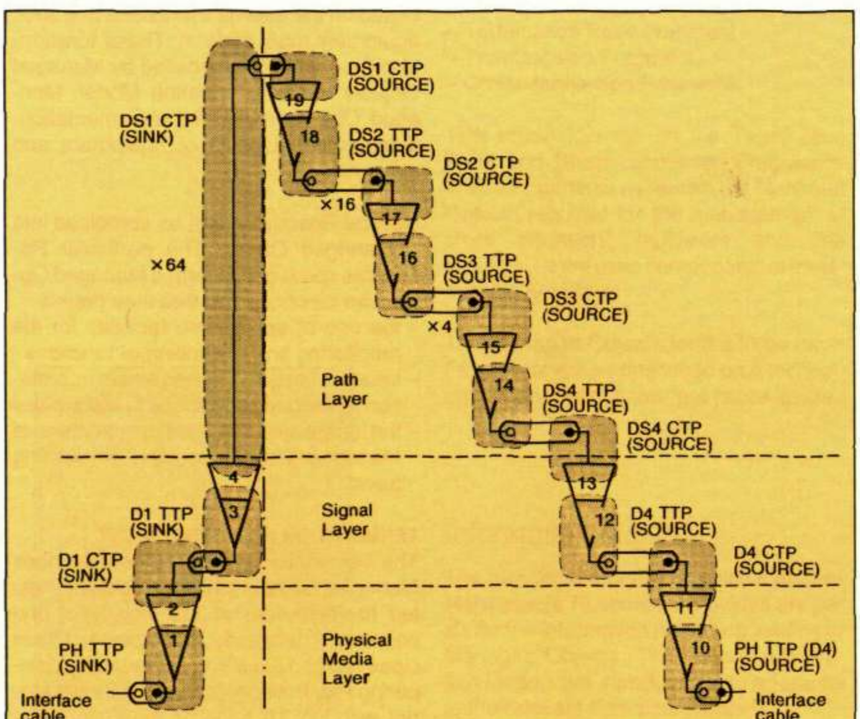


Fig. 22
Information Model of PDH multiplexer
64x2 Mbit/s signals transmitted via a 140 Mbit/s signal and vice versa

Managed Object

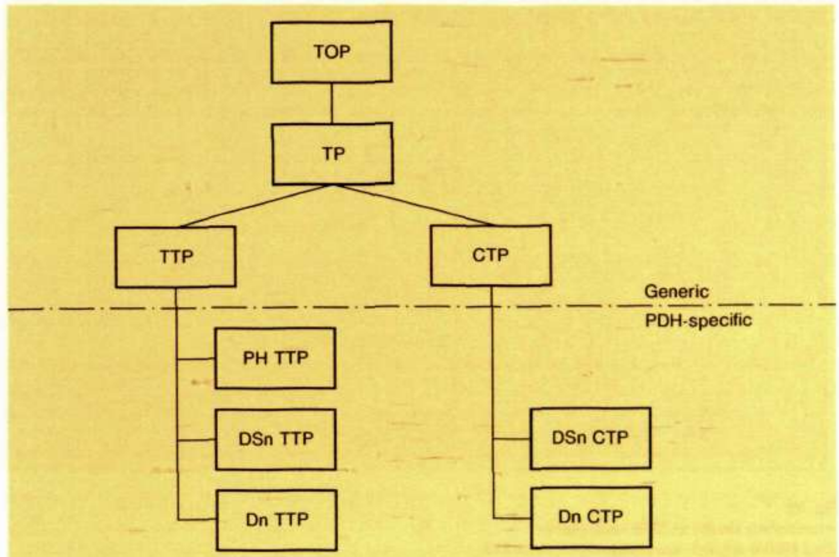


Fig. 23
Inheritance hierarchy for PDH Termination Points

TTP Trail Termination Point
CTP Connection Termination Point

The choice of transport Managed Objects is illustrated in Fig. 21, which shows the Information Model of a PDH 2/0.064 Mbit/s demultiplexer. The figure is based on the receive side of Fig. 11 and shows how Managed Objects and their possible locations are derived from Transport Functions. The Resources in the vicinity of an end point of a Trail or a Connection can be assembled into a Managed Object. The name of the Managed Object is related to this end point.

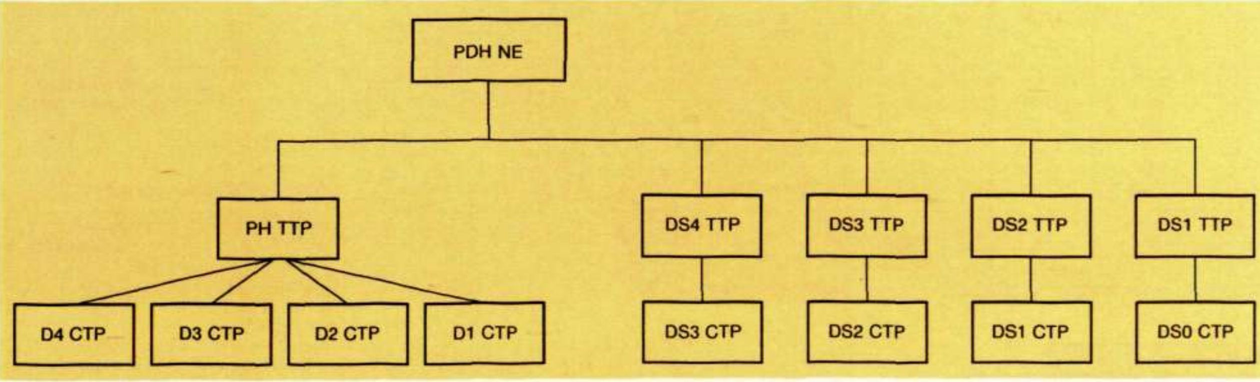
Fig. 22, which is based on Fig. 13, shows the Information Model of a PDH 2/140 Mbit/s multiplexer, multiplexing 64 separate 2 Mbit/s signals into a 140 Mbit/s signal and vice versa. The multiplexer is connected to adjacent equipment by means of interface cables.

However, only those Managed Objects which are based on Resources are usable for management. Table 3 lists Functions, Resources and Managed Objects related to the examples in Figs. 21 and 22. The table takes into account both transmission directions, whereas the figures are concerned with only one direction.

In PDH equipment, Resources normally appear only in the receive side, leading to "SINK" type Managed Objects.

The PDH Information Model can be used to model, in a general way, all the different kinds of PDH networks. This leads to the inheritance hierarchy shown in Fig. 23 and to the Naming Tree shown in Fig. 24. The inheritance hierarchy consists of a generic part and a PDH-specific part. Each

Fig. 24
PDH naming tree



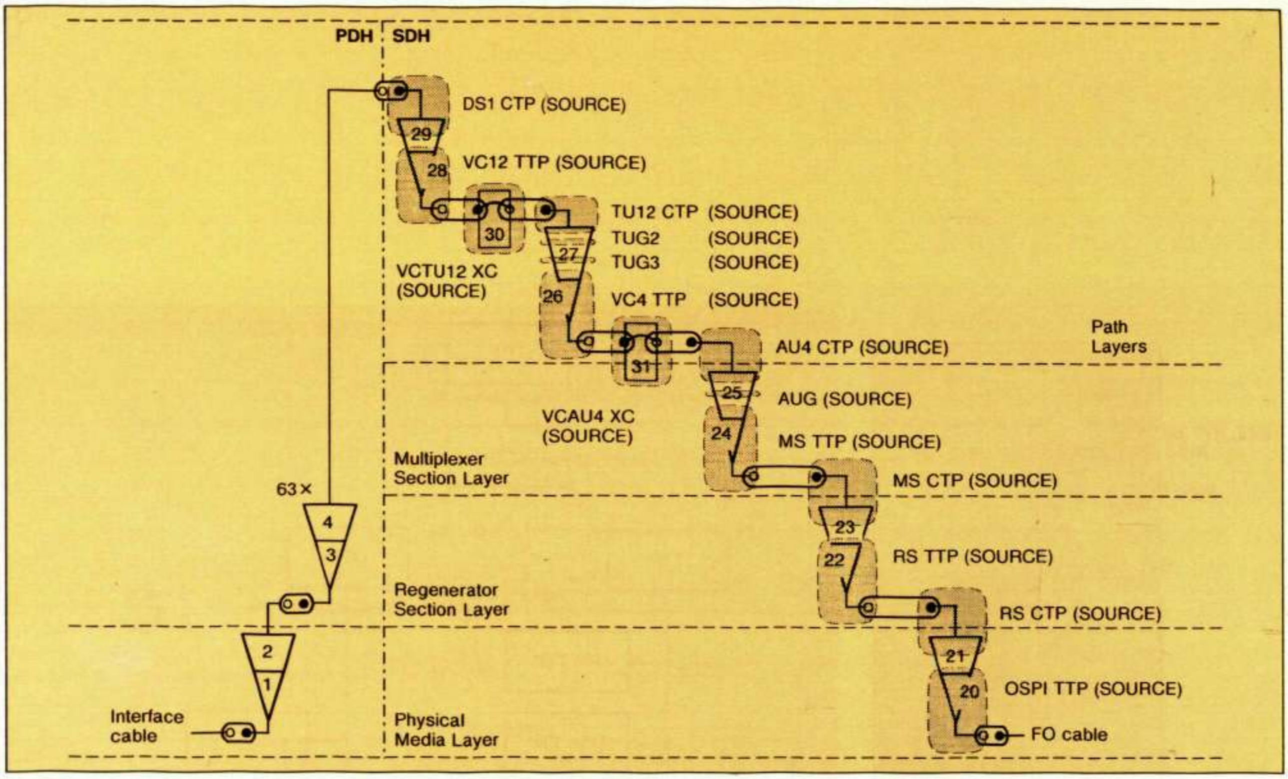


Fig. 25
Information Model of SDH multiplexer 63x2 Mbit/s signals are transmitted via a 155 Mbit/s signal

Managed Object

Adaptation Function

Trail Termination Function

Sub-Network Connection Function

of the managed TPs may be either SOURCE, SINK or BIDIRECTIONAL.

SDH Information Model

The SDH Information Model is based on the Functional Model already presented. Fig. 15 shows the SDH multiplexing structure with Transport Functions and related signals. Fig. 25 exemplifies the derivation of Managed Objects related to the multiplexing of 63x2 Mbit/s signals into an STM-1 signal. Fig. 26 shows a corresponding example of an SDH Regenerator. Table 4 lists functions, Resources and those Managed Objects which are based on Resources for the send and receive parts involved in multiplexing and demultiplexing. SDH multiplexers offer – in addition to the multiplexing function – cross-connect functions, which are treated in detail in the next chapter. (See also Table 5.) The comparison of SDH and PDH multiplexers clearly shows the increased management capabilities of the SDH concept.

The SDH Information Model can be used to represent, in a general way, all the different kinds of SDH networks. The corresponding inheritance hierarchy is shown in Fig. 27 and the naming tree in Fig. 28.

As a general principle, the containment relationship between TTPs and CTPs (TTP contains CTP) is used for naming. The associations between CTPs and TTPs are either fixed links represented by Connec-

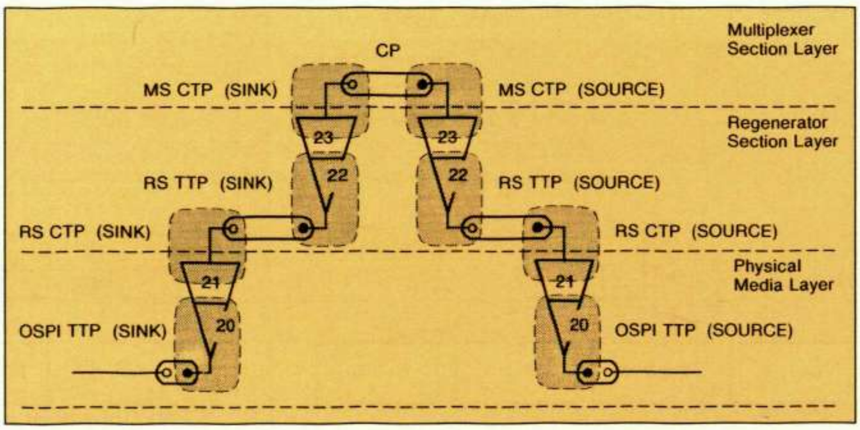


Fig. 26
Information Model of SDH regenerator

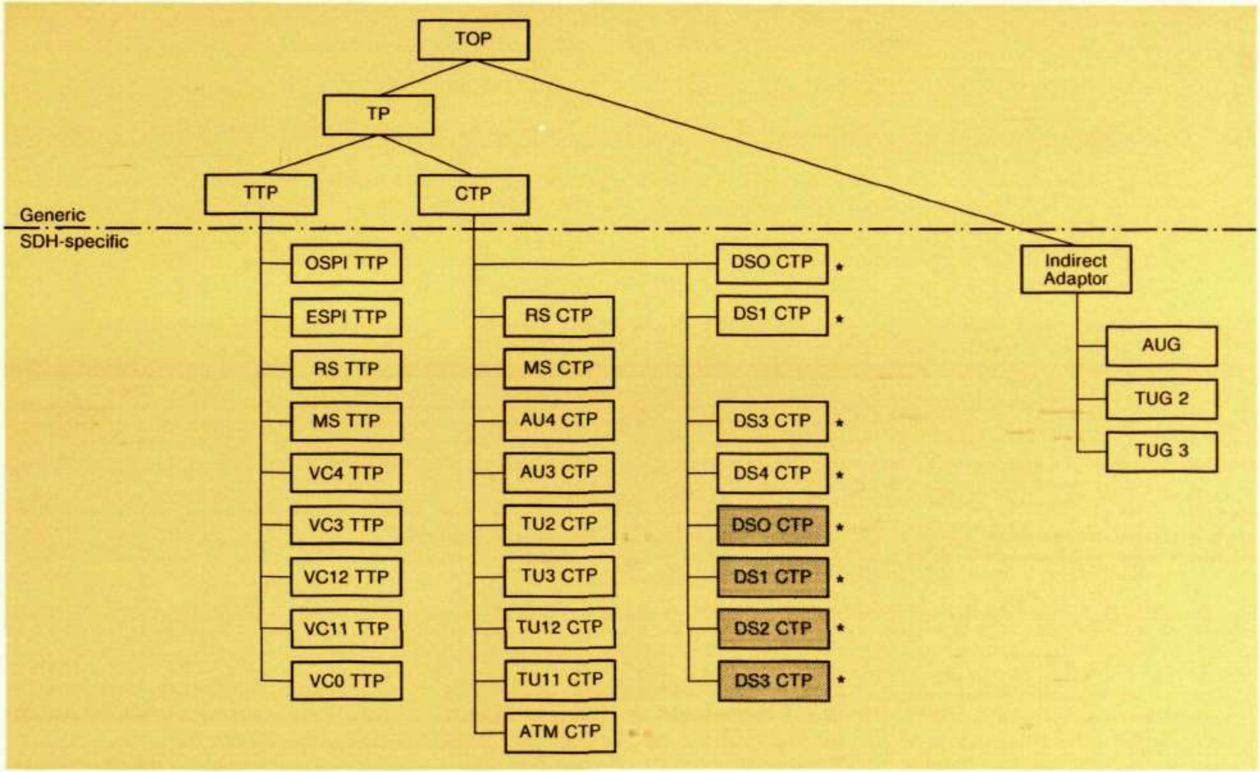


Fig. 27, above
SDH Termination Point inheritance hierarchy
*** The name of this MO is not included in Rec G.774**
ANSI standard

Fig. 28, below
SDH naming tree
Indirect Adaptor
Connection Termination Point
Trail Termination Point
Containment/naming relationship
ANSI standard

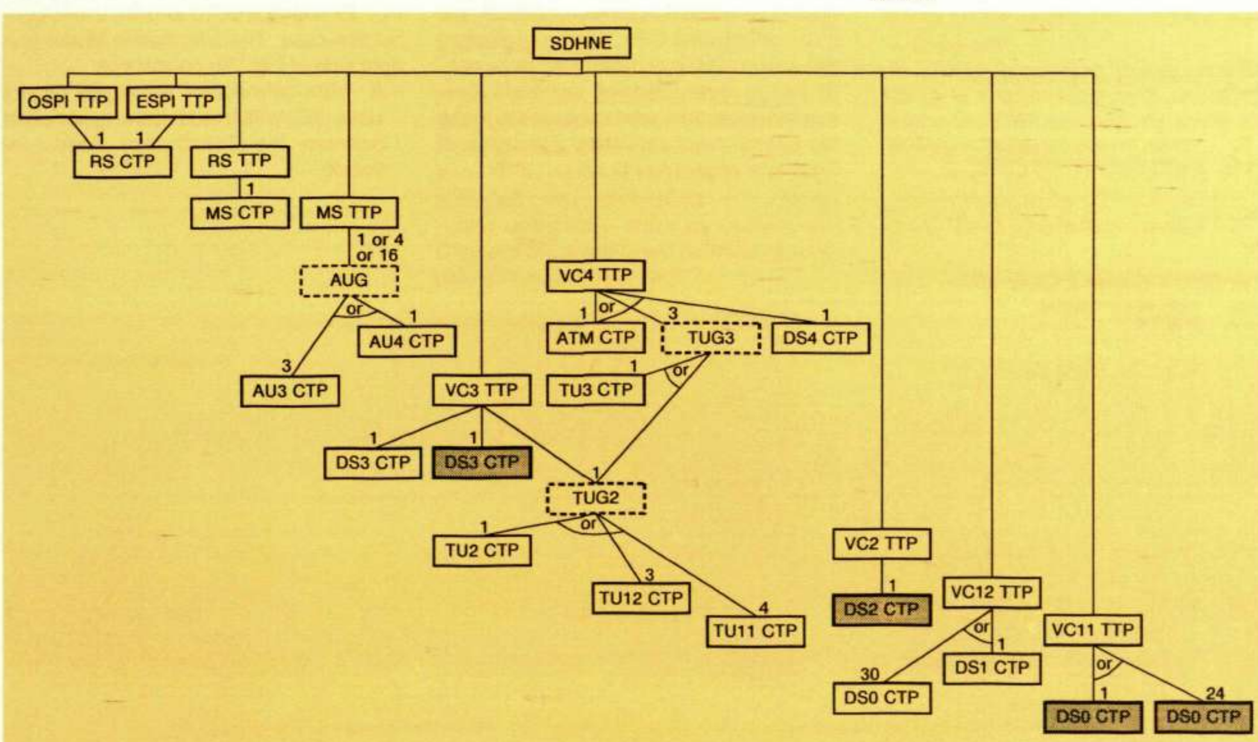


Table 5
Cross-connect functions, Resources and Managed Objects related to the example in Fig. 25

No	Function (sending, receiving)	Resource	Managed Object *
30 LPC	Assignment of VC12s within VC4	Cross-connection capability	VC12 TTP – TU12 CTP VCTU12XC
31 HPC	Assignment of VC4s within STM-1 (STN-N in general case)	Cross-connection capability	VC4 TTP – AU4 CTP VCAU4XC

* The name of this Managed Object is not included in Rec. G.774

tivity pointers (see Table 2) or flexibility points represented by Managed Objects belonging to the cross-connection Fragment (see below).

Cross connection

The cross-connection capability referred to in Table 5 deals with the possibility (within the equipment) of freely assigning VCs to available VC-n capacity in a higher order Path (LPC) or in a multiplex section (HPC). The association can either be an assignment (preparation) or an actual cross connection.

In the Functional Model (the left side of figures 29, 30 and 31) cross connection is the possible association between a TCP and a CP or between CPs. It is by controlling this association that networks can be configured to meet changing demands. Certain requirements have to be met to make the control function easier. Examples of functional requirements are:

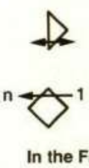
- It should be possible only to assign (prepare) a cross connection without activating it (Figs. 29 and 30)
- It should be possible to perform point-to-point and point-to-multipoint (broadcast) cross connections (Figs. 29 and 31)
- It should be possible to cross-connect several Termination/Connection Points as a single unit without the need to make individual cross connections (Fig. 30)
- It should be possible to group Termination/Connection Points for management purposes like routing, etc.

Figs. 29, 30 and 31 illustrate how the functional requirements listed above are used to derive both the Functional and Information Models.

Fig. 29 shows a point-to-point cross-connection case. The Information Model (the right side of Fig. 29) consists of:

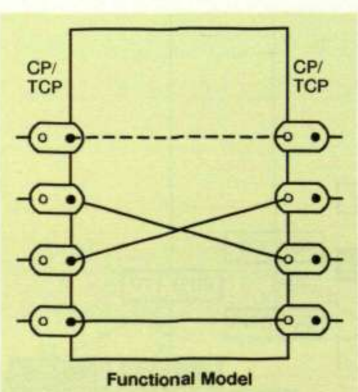
- A cross-connection Managed Object class (XC) which models the association between the Termination Points involved

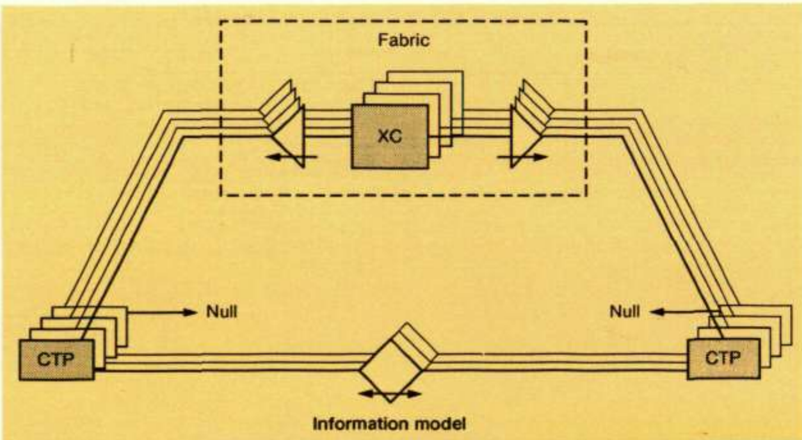
Fig. 29
Point-to-Point cross connections
In the Information Model (Figs. 29–31)
Cross Connection Pointers pointing from CTP to CX are not shown



Managed Object
To/from TP pointer between a CTP and an XC
Connectivity pointer between CTPs
To/From TP pointer between a GTP and an XC + Cross Connection object pointer
n — 1 Naming

In the Functional Model (Figs. 29–31)
—— Assigned and activated
– – – Assigned





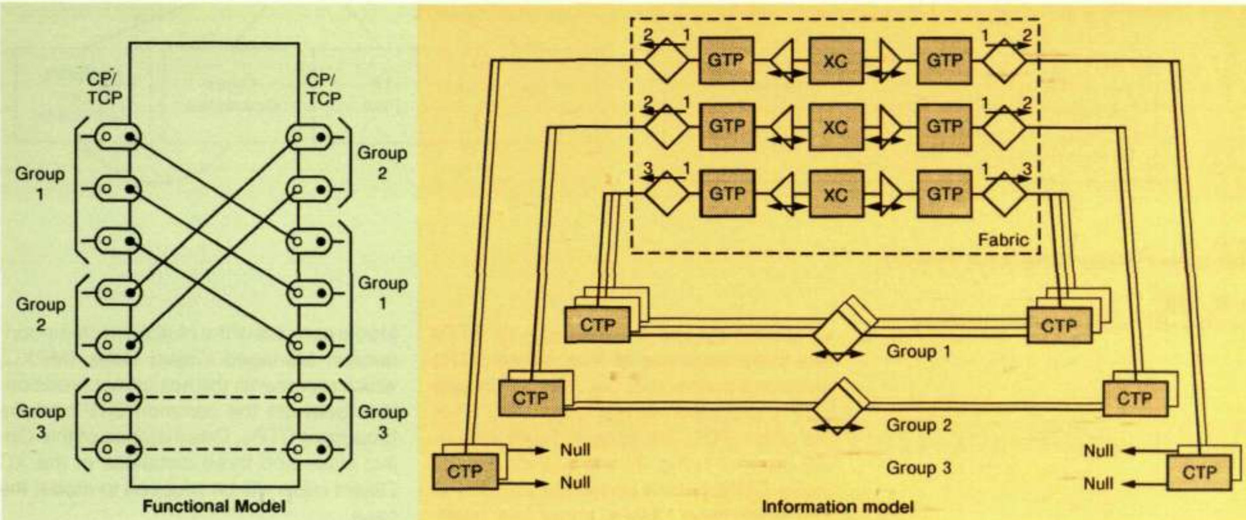


Fig. 30
Group Termination Point cross connection

- To/from TP pointers, which are relationship attributes belonging to the XC Managed Object and pointing at the CTPs (or GTPs)
- Connectivity pointers, which are relationship attributes belonging to the CTPs and indicating which CTP is connected to which CTP.

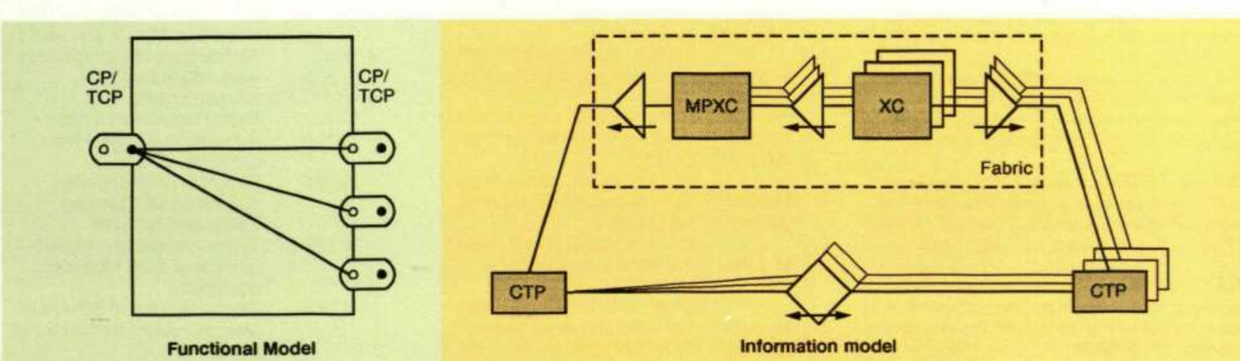
In the example, four instances of this Object class represent the four point-to-point cross connections. Three of the four to/-from TP pointers correspond to the three activated cross connections. In the fourth – only assigned – cross connection, the Connectivity pointers will be NULL to indicate a non-activated state.

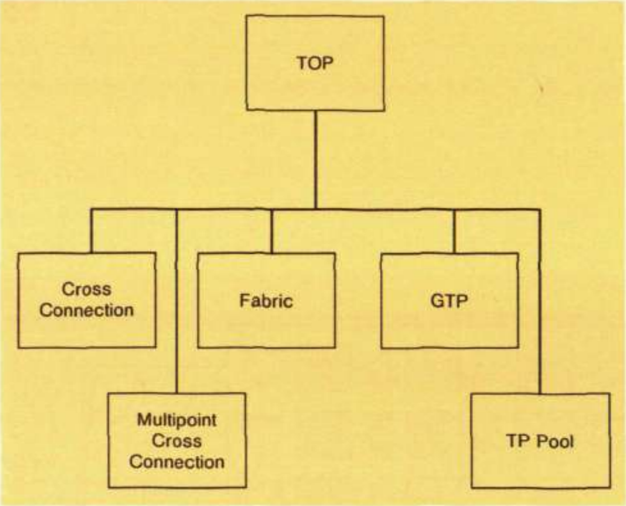
Fig. 30 shows cross connections between different groups of Termination/Connection Points. In addition to the point-to-point case, the Information Model consists of:

- A Group Termination Point Managed Object class (GTP) which represents a group of CTPs to be cross-connected as a single unit
- A Cross Connection object pointer, which is a relationship attribute belonging to the GTP and pointing at the XC Managed Object
- A "naming", which is a relationship attribute belonging to the GTP and pointing at the CTPs that constitute the GTP.

In the example, the three cross-connect-

Fig. 31
Broadcast cross connection





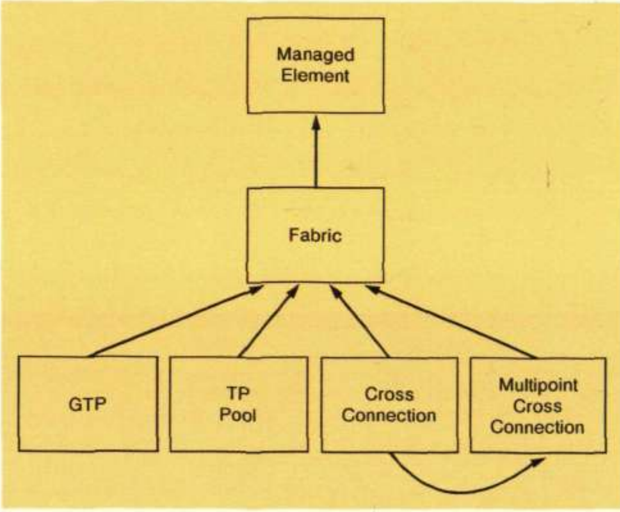


Fig. 32, left
Cross-connect Fragment, Inheritance hierarchy

Fig. 33, right
Cross-connect Fragment, Naming hierarchy

ed groups require six instances of GTPs and three instances of XCs. When GTPs are cross-connected, the *n*th CTP of one GTP is cross-connected to the *n*th CTP of the other GTP. The assigned (not activated) group 3 in Fig. 30 will be indicated by those CTPs (which constitute the GTPs) and which have NULL Connectivity pointers.

Fig. 31 shows a broadcast (point-to-multipoint) cross-connection case. In addition to the point-to-point case, the Information Model consists of the Multipoint cross-connection Managed Object class (MPXC) which represents the assignment relationship between the common CTP and the broadcast CTPs. One instance of this Object class and three instances of the XC Object class will be required to model the case.

The Managed Objects for the cross-connection Fragment are defined in Box 1. The inheritance hierarchy and naming tree are shown in Figs. 32 and 33 respectively.

Box 1
Object definitions for cross-connect Fragment

The Fabric Object class represents the set of logical matrices that are co-ordinated to provide connectivity of a range of characteristic information types. It manages the establishment and release of cross connections. It also manages the assignment of Termination Points to TP pools and GTPs

The Group Termination Point Managed Object class (GTP) represents a group of Termination Points that can be treated as a single unit for cross connection and other administration purposes

"TP pool" represents a set of Termination Points or GTPs that are equally handled in a number of management applications, e.g. routing. All the TPs in a TP pool have the same signal type

The "Multipoint cross-connection" Managed Object class (MPXC) represents an assignment relationship between a TP or GTP and the corresponding TPs or GTPs.

Reference

1 CCITT Recommendations
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M3010 (M30) Principles for a Telecommunications Management Network (TMN) COM IV-R28E, part 2, 991
M.3020 (M.meth) TMN interface specification methodology COM IV-R28E, part 2, 1991
M.3100 (M.gnm) Generic Network Information Model COM IV-R28E, part 2, 1991
M.3180 (M.cat) Catalogue of TMN Managed Objects COM IV-R28E, part 2, 1991
M.3200 (M.app) TMN management services, introduction COM IV-R28E, part 2, 1991
M.3300 (M.f) F-Interface management capabilities COM IV-R28E, part 2, 1991
M.3400 (M.func) TMN management functions COM IV-R28E, part 2, 1991
G.773 Protocol profiles for the Qx-Interfaces for management of transmission systems
G.774 SDH Network Information Model for TMN
Q.811 Lower Layer Protocol Profile for the Q3-Interface
Q.812 Upper Layer Protocol Profile for the Q3-Interface

2 Widl, W.: *Telecommunications Network Architecture*. Ericsson Review *67* (1990):4, pp. 148–162.

3 Widl, W.: *CCITT standardisation of TMN.* Ericsson Review *68* (1991):2, pp. 34–51.

4 Rec. G.803 Architecture of transport networks based on SDH

5 CCITT Recommendations
G.702 Digital hierarchy bit rates
G.707 Synchronous Digital Hierarchy bit rates
G.781 Structure of Recommendations on Multiplexing Equipment for SDH
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