ERICSSON REVIEW
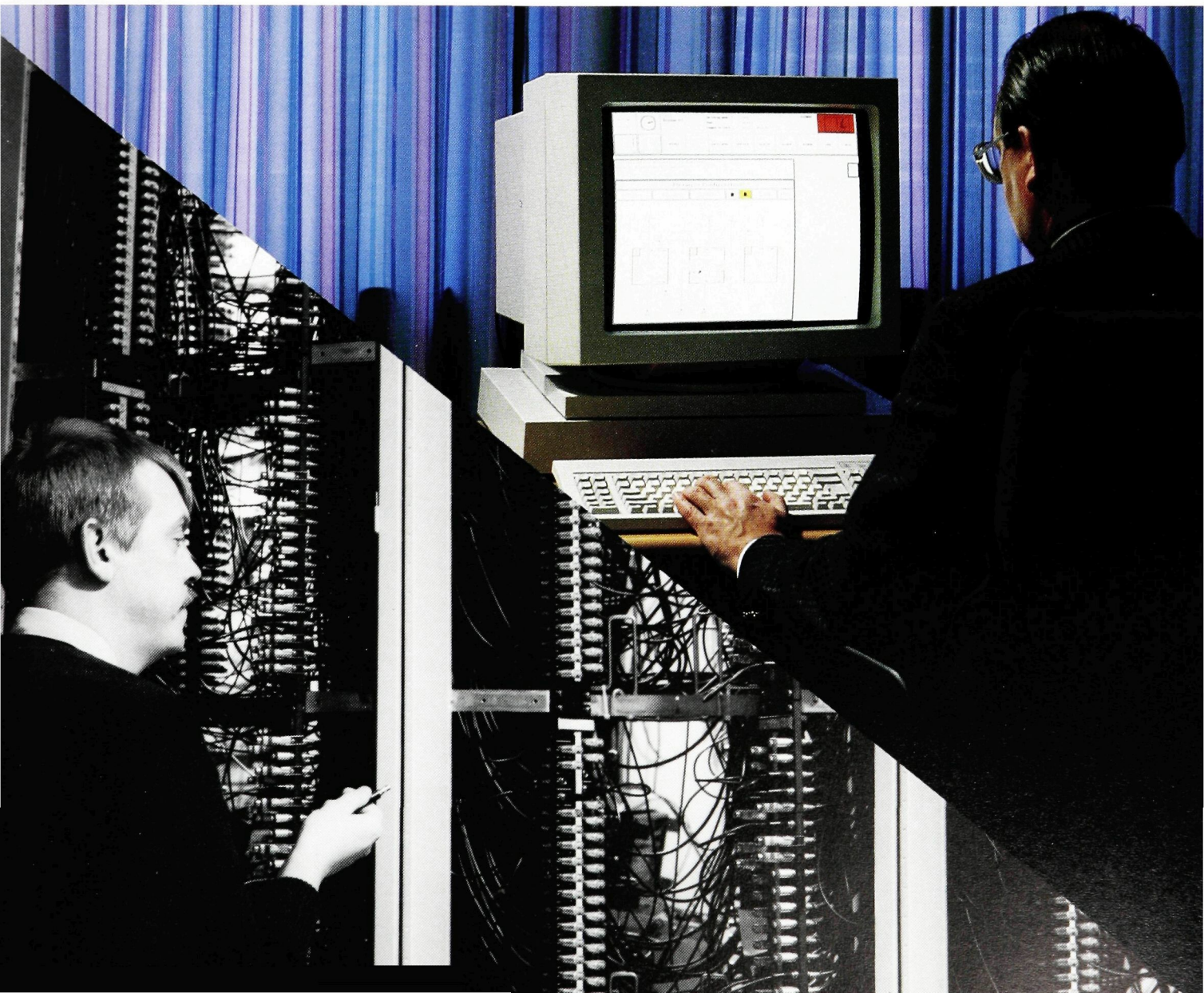
Telecommunications Network Architecture
FMAS – An Operations Support System for Transport Networks

4 1990

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Contents

Cover
The computerized operations support system
FMAS offers centralized supervision and control
of digital transport networks.
Traditionally, cross-connections between sets of
transmission equipment have been carried out
manually in coaxial distribution frames.
With FMAS, operators can order the
corresponding cross-connections from a terminal
at an operations centre. These connections are
effected by digital cross-connect systems located
in the transport network nodes.

Telecommunications Network Architecture

Walter Widl

The exchange of information between users of telecommunication services is based on the transport and transmission services supplied by the telecommunications networks. In future this exchange of information will also need the services provided by the Intelligent Network. To safeguard the functioning of the complex network configurations required, a separate telecommunications management network will have to be introduced.
The author focuses his description on the physical transmission network and the logical transport network. The operations support network will be described in an article in the next issue of Ericsson Review.

telecommunication networks
digital communication systems
telecommunication network management

The telecommunication process requires interaction between a number of different functions, which can be allocated to various networks
- the physical transmission network
- the logical transport network
- the intelligent services network (IN)
- the telecommunications management network (TMN)

as illustrated in fig. 1. This article describes in particular the architecture of the transmission and transport networks.

The *Transmission Network* contains the physical means for transfer of information, i.e. telecommunications equipment and connecting transmission media; typically switching matrices of switches and cross-connect systems, modems, muldexes and line systems. The signal generating and signal using functions of terminal equipment can be considered to be part of the transmission network. Fig. 1 a shows an example of a transmission network with digital exchanges (DE), digital cross-connect systems (DXC) and connecting line systems (LS). The transmission network connects the interfaces in the user terminals.

The *Transport Network* performs logical functions, such as network configuration and routing, and ensures reliable transfer of information between service users, regardless of the information content. Routing or configuration of the
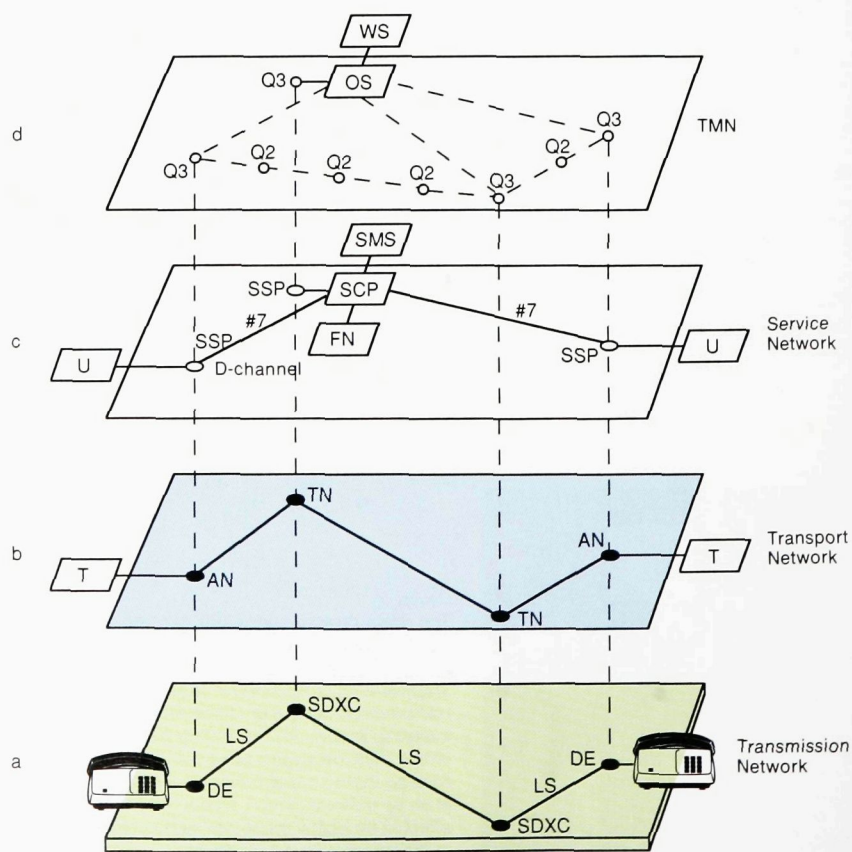

Fig. 1
The telecommunications network can be considered to be divided into
a the physical transmission network
b the logical transport network
c the intelligent services network
d the telecommunications management network (TMN)

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
SMS	Service Management System
U	User
WS	Workstation
OS	Operating system
Q	Interface between the Transmission Management Network and the managed objects

WALTER WIDL
Ericsson Telecom AB

bit streams are initiated either by the TMN – in case of failures – or by the service network if the traffic demands different bit rates. The transport network also connects the user terminals. In fig. 1 b, a logical end-to-end connection is established between terminals over Access Nodes (AN) and Transit Nodes (TN).

The purpose of the *Service Network* is to offer users a particular service. In the example in fig. 1 c, 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). SCP is updated – when new services are introduced or existing services changed – through the Service Management System (SMS) located in the network operator's administrative centre.

The *Telecommunications Management Network (TMN)* connects the network operators and administrators – via workstations (WS), operation systems (OS) and standardized Q-interfaces – to the managed telecommunication equipment, as shown in fig. 1 d. System management covers maintenance, performance monitoring, configuration, security and accounting. TMN serves as an overlay network using the facilities of the transmission network or the signalling channels provided by the service network. The relationship between TMN and IN is being studied by the CCITT and other standardization bodies.

Among the driving forces behind the continuing evolution of telecommunications networks are the development of various technologies – miniaturization and the speeding up of processes at lower costs – and, last but not least, customer demands for new services and their quality. The concepts underlying the rapid evolution of the transmission and transport networks are
– the definition of the Synchronous Digital Hierarchy (SDH) by the CCITT, which is accepted worldwide, making an efficient transmission standard available[1]
– the introduction of new transmission equipment, such as synchronous dig-

ital cross-connects (SDXC), synchronous multiplexers (SMUX), fibre-optic synchronous line systems and flexible multiplexers, permitting new network configurations and flexibility[2]
– the application of Telecommunications Management Networks (TMN), leading to standardized and centralized management of telecommunications networks[3,4]
– the advent of Asynchronous Transfer Mode (ATM), which will be essential for flexible broadband switching and transmission.

Through synergistic effects, a combination of these concepts leads to the transmission and transport mechanisms that will be used in the intelligent networks of the future.[5]

Transmission Network

In the physical transfer of information over the transmission network, the digital information-carrying signals represent levels in digital hierarchies. The plesiochronous hierarchy uses individual timing in each level, whereas the synchronous hierarchy is based on synchronism between the various levels.

Plesiochronous digital hierarchies, as defined by the CCITT in 1972, led to different standards in Europe, North America and Japan (table 1). The multiplexing schemes chosen were based on bit interleaving and individual timing requirements for each level, which resulted in costly drop-insert arrangements. It was also found that the overhead information would be inadequate for extensive fault and performance management at all levels. In order to overcome these drawbacks, the CCITT defined the Synchronous Digital Hierarchy (SDH). The advantages of the SDH are
– one worldwide transmission standard
– byte interleaved structures for economical drop-insert
– ample overhead for network management
– compatibility of optical line interfaces.

The SDH uses a multiplexing scheme (fig. 2) which permits the transmission

Table 1
Bit rates used for signals in the Plesiochronous Digital Hierarchy (PDH)
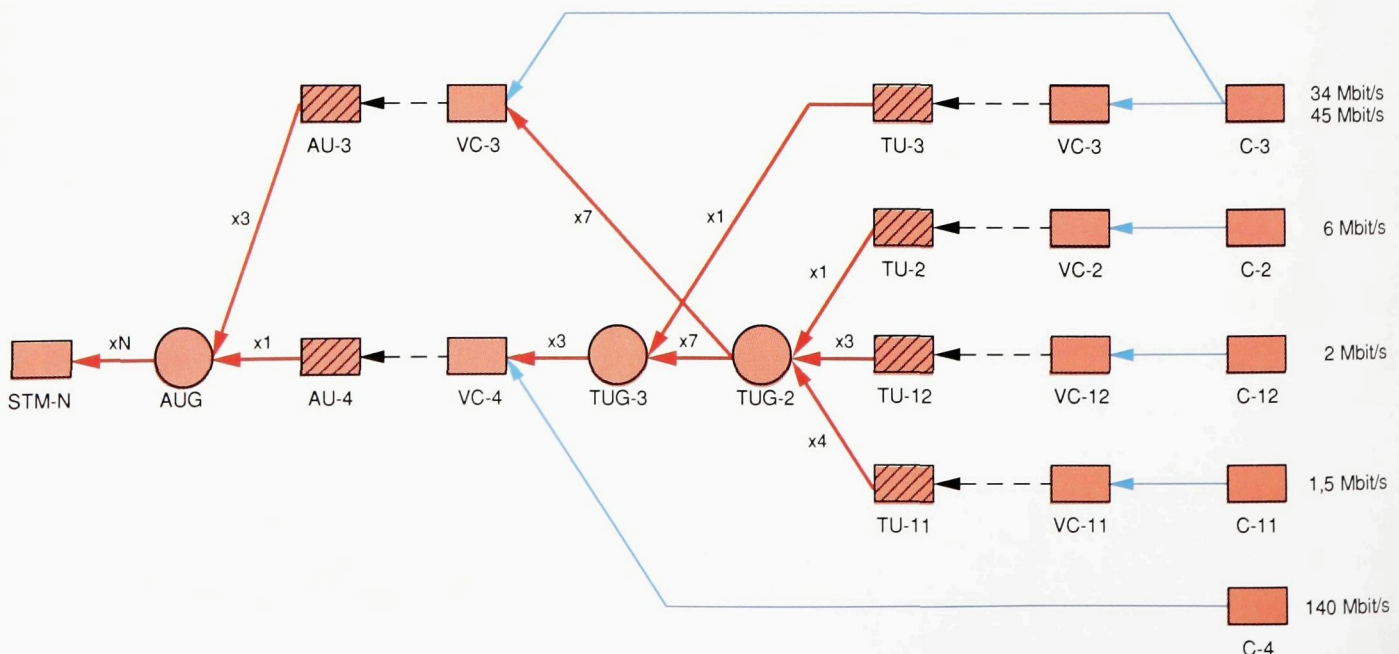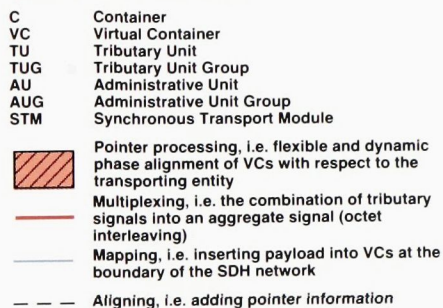
PDH level	Bit rate in both hierarchies (kbit/s) base 1,544		base 2,048
0	64		64
1	1,544		2,048
2	6,312		8,448
3	32,064	44,736	34,368
4	97,728		139,264

SDH level	SDH signal	Bit rate (kbit/s)
1	STM- 1	155,520
4	STM- 4	622,080
16	STM-16	2,488,320

STM Synchronous Transport Module

Table 2
Bit rates used for signals in the Synchronous Digital Hierarchy (SDH)

Fig. 2
The CCITT synchronous multiplexing structure. Each square and circle corresponds to a specific type of characteristic information

C	Container
VC	Virtual Container
TU	Tributary Unit
TUG	Tributary Unit Group
AU	Administrative Unit
AUG	Administrative Unit Group
STM	Synchronous Transport Module

Pointer processing, i.e. flexible and dynamic phase alignment of VCs with respect to the transporting entity

Multiplexing, i.e. the combination of tributary signals into an aggregate signal (octet interleaving)

Mapping, i.e. inserting payload into VCs at the boundary of the SDH network

— — — Aligning, i.e. adding pointer information

of both plesiochronous and synchronous bit rates over synchronous fibre-optical line systems and synchronous radio links. The designations used in fig. 2 are explained under the heading of *Synchronous transmission functions*. Each square and circle in fig. 2 corresponds to a signal with a defined combination of bit rate, coding and format, and each of these combinations constitute a specific type of *characteristic information*. Table 2 shows the bit rates used in the SDH line system. The SDH basic bit rate (155 Mbit/s) can be reached in many different ways with multiplexing stages arranged in tandem. Table 5 specifies the bit rate of all the *Virtual Containers (VC)*. The increase of the bit rate, through multiplexing, justification, payload adaptation and adding of overhead, is exemplified in the lower part of fig. 6.

The transmission network functions can be implemented in various ways in telecommunication equipment and maintenance equipment. Implementations of particular interest from the point of view of transmission networks are described below.

Typical equipments for implementation in Access Nodes are
– local exchanges

– remote subscriber switches/concentrators
– remote subscriber multiplexers
– flexible multiplexers
– digital multiplexers.

Typical equipments for implementation in Transit Nodes are
– transit exchanges
– digital multiplexers
– digital cross-connect systems.

The telecommunication equipment in Access or Transit Nodes is connected by plesiochronous transmission systems using
– line systems over paired, coaxial or fibre cables
– radio relay or satellite systems
and by synchronous transmission systems based on
– optical fibre cables using SDH principles
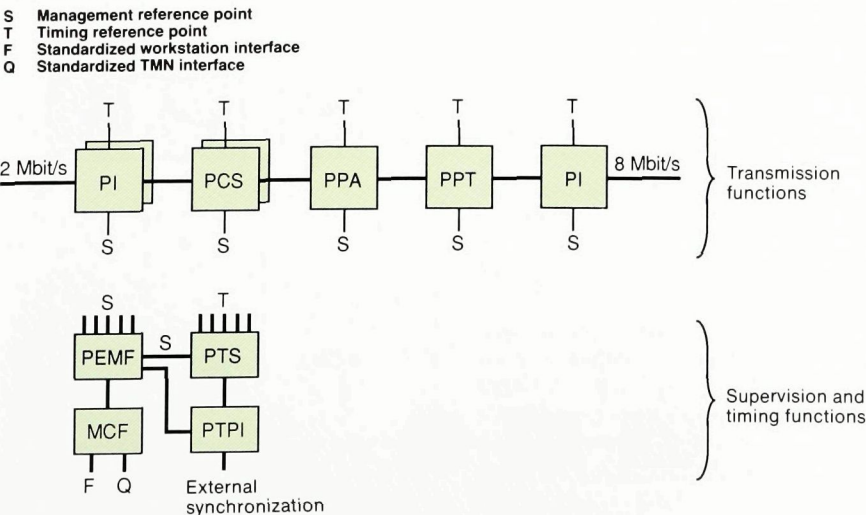– radio relay or satellite systems for SDH bit rates.

SDH systems, including synchronous digital multiplexers, synchronous digital cross-connects, synchronous digital line systems and PDH flexible multiplexers, are new elements of the physical network. They are expected to play an important role in the evolution of the transmission network.

	Functional block	Function
PI	Physical Interface	Conversion from/to in-station, or inter-station signals (Rec. G.703)
PPA	Plesiochronous Path Adaptation	Provides digital multiplexer/demultiplexer functions
PPT	Plesiochronous Path Termination	Provides framing/deframing, adds/extracts path overhead information
PSA	Plesiochronous Section Adaptation	Provides line coding/decoding
PST	Plesiochronous Section Termination	Adds/extracts section overhead information
PRA	Plesiochronous Regenerator Section Adaptation	Provides facilities for regenerator section management
PRT	Plesiochronous Regenerator Section Termination	Adds/extracts regenerator section overhead
PCS	Plesiochronous Connection Supervision	Extracts alarm and performance monitoring values from each transmission direction
PEMF	Plesiochronous Equipment Management Function	Converts performance data and alarms into object oriented messages for transmission over a Q- or F-interface
MCF	Message Communication Function	Provides facilities for the transport of TMN messages to and from PEMF
PTS	Plesiochronous Timing Source	Provides timing to plesiochronous functional blocks
PTPI	Plesiochronous Timing Physical Interface	Provides interface for external synchronization signal

Table 3
Plesiochronous functional blocks

For many years to come, SDH systems will have to interwork with existing and new PDH systems. The functions of SDH and PDH systems should therefore be defined in a similar way, with a view to describing mixed SDH/PDH Transmission Networks. The method of defining functional blocks in the transmission network (a method that has been developed in the standardization of SDH equipment) could be applied to PDH

Fig. 3
Functional block diagram of plesiochronous digital 2/8 Mbit/s multiplexer. The functional blocks are defined in table 3

S Management reference point
T Timing reference point
F Standardized workstation interface
Q Standardized TMN interface

equipment too – as suggested in this article.

Plesiochronous transmission functions
The functions implemented in telecommunication equipment can be described by generalized functional blocks, i.e. a particular implementation of equipment is described by a unique set of functional blocks. Table 3 shows a list of functional blocks suitable for the description of plesiochronous networks. The definition of the blocks is analogous with that of the SDH blocks.

Three examples will explain the use of functional blocks.

Multiplexer 2/8 Mbit/s
The functional block diagram in fig. 3 shows the transmission functions of a 2/8 Mbit/s digital multiplexer with the associated supervisory and timing functions. An incoming 2 Mbit/s signal is checked in the Physical Interface, PI, (signal level) and in the Plesiochronous Connection Supervision, PCS, (alarm indication, loss of synchronization, excessive bit error rate, etc). Four 2 Mbit/s signals are multiplexed to a framed 8 Mbit/s signal in the Plesiochronous Path Adaptation, PPA, and overhead information is added in the Plesiochronous Path Termination, PPT. The Plesiochronous Equipment Management Function, PEMF, converts performance data and alarms received from the S-interfaces into messages for transfer to the Q- and F-interfaces in the TMN. Facilities for this transfer are provided by the Message Communication Function, MCF. Timing is generated in the Plesiochronous Timing Source, PTS, and synchronized with an external timing signal by the Plesiochronous Timing Physical Interface, PTPI.

Plesiochronous 2 Mbit/s line system
Fig. 4 shows the functional diagram of a 2 Mbit/s line system without functions for fault localization in regenerators. An incoming 2 Mbit/s signal is checked in the PI (signal level) and in the PCS (alarm indication). The Plesiochronous Section Adaptation, PSA, in the transmit Line Terminal, LT, converts the interface code to line code. The Plesiochronous Section Termination, PST, represents the redundancy added through the cod-

Fig. 4
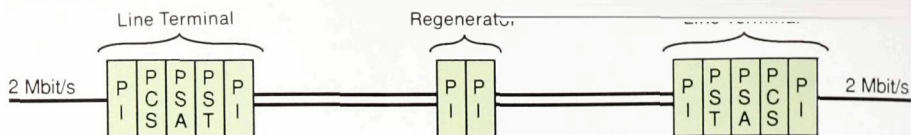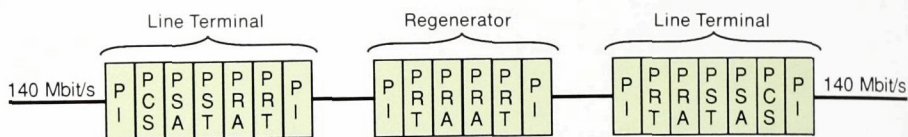Functional block diagram of plesiochronous
2 Mbit/s line system

Fig. 5
Functional block diagram of plesiochronous
140 Mbit/s line system with regenerator section
management

Fig. 6
Transmission functions and multiplexing when 63
plesiochronous 2 Mbit/s signals are transmitted
over a 155 Mbit/s signal in the SDH. The 2 Mbit/s
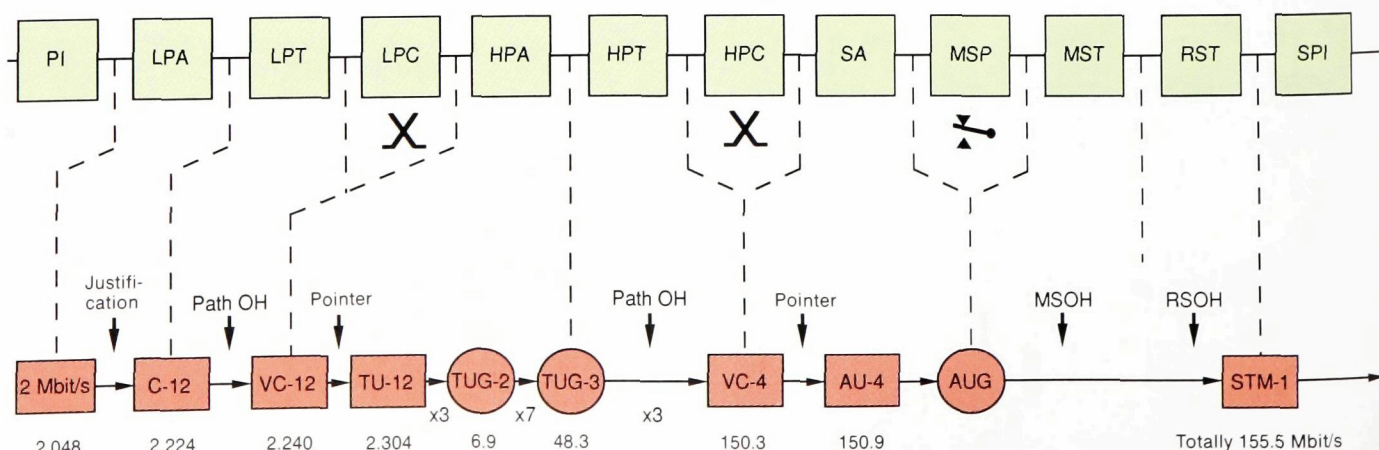signals are multiplexed in three stages (3x7x3)

OH   Overhead
MSOH   Multiplex Section Overhead
RSOH   Regenerator Section Overhead

X   Flexible switching of tributaries

   Choice of standby line (protection switching)

   Functional block

   Type of characteristic information

ing process. In the receive Line Terminal, the inverse process takes place. PST is also used to extract code violations, if any.

Plesiochronous 140 Mbit/s line system with fault localization functions
Fig. 5 shows the functional diagram of an optical 140 Mbit/s line system with functions for fault localization in regenerators. The Plesiochronous Regenerator section Adaptation, PRA, represents a modulation function that gives *the optical signal the redundancy required* for fault localization in the regenerator section. This fault localization is performed by the Plesiochronous Regenerator section Termination, PRT.

Flexible Multiplexer equipment
Flexible Multiplexer equipment in a PDH environment will be described with similar functional blocks.[10]

Synchronous transmission functions
The synchronous transmission functions are based on the SDH definitions of the data streams and formats (fig. 2 and the lower part of fig. 6).
– A Container (C1, C2, C3, C4) is the *transport mechanism for synchronous signals.* Plesiochronous signals are converted to synchronous signals by the adding of redundancy, justification and justification control information (mapping)

– A lower order Virtual Container (VC-1, VC-2, VC-3) results from adding overhead information (lower order path overhead) to a Container
– A Tributary Unit (TU) results from adding pointer information to a lower order Virtual Container. A Pointer is required in order to indicate the offset of the payload relative to the higher order Virtual Container (see below)
– A Tributary Unit Group (TUG) combines a number of Tributary Units
– A higher order Virtual Container (VC-3, VC-4) results from adding overhead information (higher order path overhead) to a Container or to an assembly of Tributary Unit Groups
– An Administrative Unit (AU-3, AU-4) results from adding pointer information to a higher order Virtual Container. A pointer is required in order to indicate the payload offset relative to the Synchronous Transport Module
– An Administrative Unit Group (AUG) consists of a homogeneous, byte-interleaved assembly of AU-3s, or an AU-4
– A Synchronous Transport Module (STM) consists of information payload and section overhead (SOH) organized in a frame which is repeated every 125 microseconds. The basic STM-1 comprises a single Administrative Unit Group and is transmitted at 155.520 Mbit/s.

	Functional block	Function
PI	Physical Interface	Conversion from/to in-station or inter-station signals (Rec. G.703)
LPA	Lower order Path Adaptation	Maps the payload into the container (Rec. G.709)
LPT	Lower order Path Termination	Adds VC Path overhead
LPC	Lower order Path Connection	Allows flexible assignment between lower and higher order VCs (bidirectional)
LPX	Lower order Path Cross Connection	Allows flexible cross-conections between lower and higher order VCs*
HPA	Higer 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	Higer order Path Connection	Allows flexible assignment between higher order VCs and STM-N (bidirectional)
HPX	Higher order Path Cross Connection	Allows flexible cross-connections between higher order VCs and STM-N*
SA	Section Adaptation	Processes pointer to indicate phase between higher order VCs and STM-N, assembles complete STM-MN
MSP	Multiplex Section Protection	Provides branching to other 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	Conversion to/from in-station or inter-station signals (Rec. G.707)
SEMF	Synchronous Equipment Management Function	Converts performance data and alarms into object oriented messages for transmission over DCCs (Data Communications Channels) or Q-Interface
MCF	Message Communication Function	Provides facilities for the transport of TMN messages to and from the SEMF
MTS	Multiplex Timing Source	Provides timing to synchronous functional blocks
MTPI	Multiplex Timing Physical Interface	Provides interface for external synchronization signal
LCS	Lower order Connection Supervision	Monitoring of VC overhead in signal towards cross-connected LPX/HPX. Termination of VC signal towards not connected LPX/HPX
HCS	Higer order Connection Supervision	Permits transparent transmission of signal from cross-connected LPX/HPX. Generation of replacement VC signal for not connected LPX/HPX

* types of cross-connect:
  – unidirectional
  – bidirectional
  – broadcast
  – loopback
  – monitoring
  – measurement

Table 4
Synchronous functional blocks

The various units, each of which carries a particular type of characteristic information, are combined in the multiplexing scheme defined by CCITT, fig 2.

The complete function of synchronous digital transmission equipment can be described by means of a set of functional blocks similar to those used for plesiochronous transmission functions. The synchronous functional blocks are listed in table 4.

Specific implementations of SDH equipment, such as digital multiplexers[6] (SMUX), cross-connect systems[7] (SDXC) and digital line systems[8], are described by means of defined combinations of functional blocks as exemplified below.

Multiplexing and synchronous transmission of plesiochronous tributaries

Fig. 6 illustrates the transmission of 63 plesiochronous 2 Mbit/s signals over an STM-1 section. The relationships between the SDH elements of the multiplexing scheme and the involved functional blocks are also shown. In the first functional block (LPA) after the physical interface (PI), the plesiochronous tributaries are mapped into a container in the SDH.

Synchronous multiplexer, SMUX

Fig. 7 shows a generalized functional block diagram of Synchronous Digital Multiplexers (SMUX). The function of a specific SMUX, type 1, is built up of the shaded blocks. This SMUX converts a number of plesiochronous digital tributary signals of a lower bit rate to an aggregate synchronous signal of a higher bit rate, and vice versa. In addition to these basic functions, features such as flexible assignment of information, drop-insert and protection switching can be included in the general version of an SMUX. The SPI (Synchronous Physical Interface) can be either electric or optical in exchanges; between exchanges it is normally optical.

Synchronous cross-connects, SDXC

Synchronous digital cross-connect equipment is capable of switching and multiplexing a variety of PDH and SDH signals. Characteristic SDXC features are

– cross-connection of different bit-rates, e.g. 64 kbit/s to 155 Mbit/s
– holding times equivalent to hours, days or longer periods
– switch control and management via TMN management interface.

The signals belong to certain levels in the transport network depending on their bit rates and formats. At the input and output ports of the SDXC the signals appear at port level, whereas they are cross-connected at what is called cross-connect levels. Tables 1 and 2 show typical port levels; table 5 typical cross-connect levels. The combinations of port and cross-connect levels that can be handled by an SDXC determine its function and designation. For a detailed description of the functions of different equipments in the SDXC family – see ref. 2.

Cross-connect level	base 1,544	base 2,048
1	VC-11 1,664	VC-12 2,240
2		VC-2 6,848
3		VC-3 48,960
4		VC-4 150,336

VC   *Virtual Container*

Port level	Cross-connect level
STM-1	VC-4
140 Mbit/s	VC-4 and VC-12
34 Mbit/s	VC-3 and VC-12
2 Mbit/s	VC-12

Table 5 (left)
Cross-connect levels (kbit/s) for synchronous digital cross-connect (SDXC)

Table 6 (right)
SDXC functions

Topology Transport Function
LN   Layer Network
L   Link
SN   Subnetwork
DSN   Degenerate Subnetwork

Association Transport Function
A   Client-to-server Adaptation
Trail   Trail
T   Trail Termination
LC   Link Connection
SNC   Subnetwork Connection
DSNC Degenerate Subnetwork Connection
TLC   Tandem Link Connection
NC   Network Connection

Transport Reference Points
AP   Access Points to the Server Layer Network
CP   Connection Point
TCP   Termination Connection Point

Table 7
Transport Functions and Transport Reference Points

Fig. 7
Generalized functional block diagram of synchronous multiplexers (SMUX). Type 1 SMUXes multiplex a number of plesiochronous lower bit rate tributaries into an aggregate synchronous signal with higher bit rate

▢ Functional blocks included in a Type 1 SMUX

Fig. 8 shows a generalized block diagram of synchronous digital cross-connect equipment for the 2 Mbit/s digital hierarchy. The functional blocks are defined in table 4. Table 6 shows the functionality of the equipment.

Transport Network

The described architecture of the transport network can be applied to PDH, SDH and ATM networks. The transport network model considered is based on the concepts of *layering* and *partitioning* — concepts which allow a high degree of recursion. The transport of information is described by means of Transport Functions separated by Transport Reference Points. Each Transport Function for one-way transport is characterized by an input and an output. The Transport Reference Point combines the output and input of consecutive Transport Functions in a binding relationship. Inputs and outputs of two-way Transport Functions are combined in pairing relationships.

Transport Functions can be divided into Topology Transport Functions, describing the capability to provide transport, and Association Transport Functions, which describe the particular instance of transport, table 7. Transport Functions can also be divided according to their ability to be configured. Static Transport Functions are configured pri-

or to a demand for transport; basically, they provide inflexible connectivity. Dynamic Transport Functions are configured in response to a demand for transport; they provide flexible connectivity. A number of Association Transport Functions can be assembled into an Abstract Transport Function.

Table 8 shows different types of Transport Function, and table 9 shows Transport Reference Points binding particular Association Transport Functions.

Typical examples of Topology Transport Functions are

Layer Network	International 140 Mbit/s network
Link	A number of parallel 140 Mbit/s fibre optical line systems between two cross-connects
Subnetwork	Digital Cross-connect equipment
Degenerate Subnetwork	Digital Distribution Frame

Typical examples of Association Transport Functions are

Client-to-server adaptation (A)	Analog-digital conversion in *PCM* terminals, bit rate conversion in PDH digital multiplexers, framing and frame alignment functions
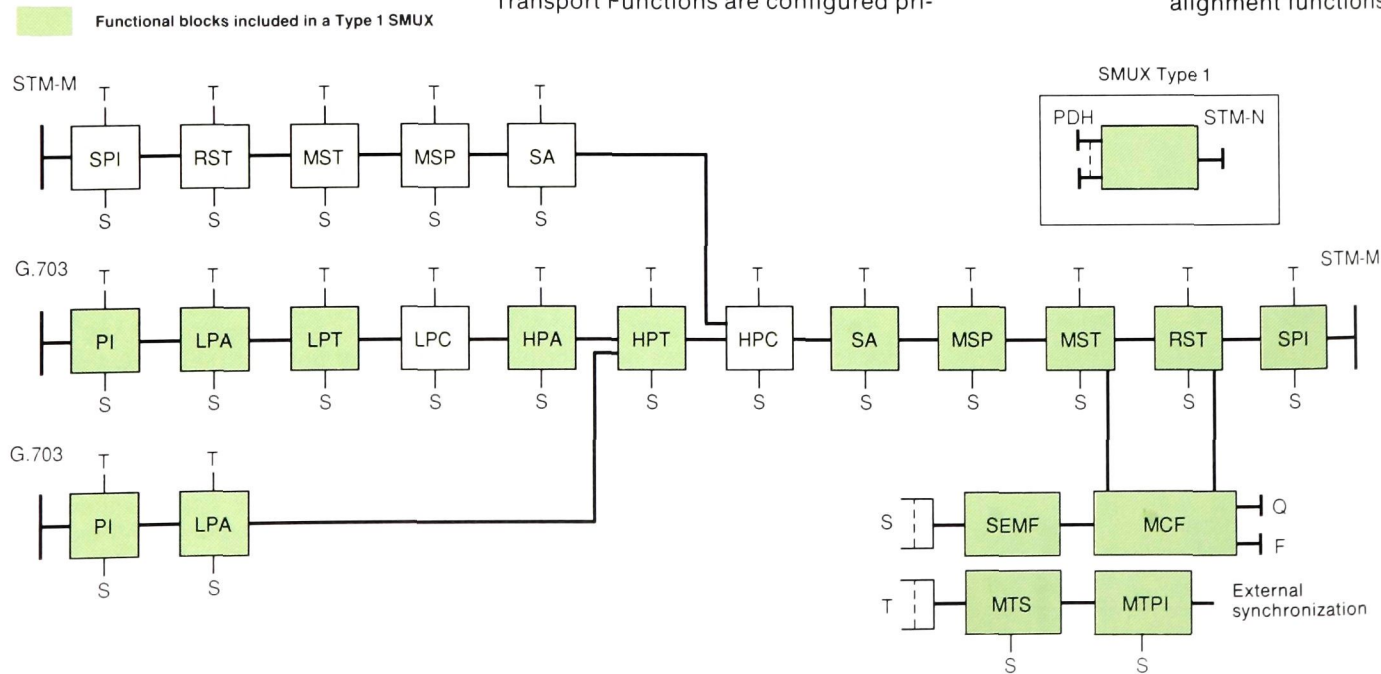
Table 8 (right)
Transport Functions

Transport Function	Static (inflexible connectivity)	Dynamic (flexible connectivity)
Topology	LN, L, DSN	SN
Association	A, T, LC, DSNC	SNC
Abstract Association	LC, TLC	TRAIL, NC

Association Transport Function	A	T	LC, SNC DSNC TLC
A	AP	AP	CP
T	AP	TCP	TCP
LC, SNC DSNC, TLC	CP	TCP	CP

Table 9
Transport Reference Points

Trail Termination (T) Error detection, sending and reception of alarms related to a characteristic signal

Subnetwork Connection (SNC) Process of switching and cross-connection. Subnetwork connections are configured in the management process, i.e. the configuration of network resources during network operation (allocation, routing)

Degenerate Subnetwork Connection (Deg SNC) Connection in a Digital Distribution Frame. Degenerate subnetwork connections cannot be configured; they

result from functional partitioning for the purpose of management (e.g. monitoring of parts of tandem link connections)

Link Connection (LC) Connection offered by fibre optical line systems. Link Connections are configured in the commissioning process, i.e. the configuration of network resources prior to start of network operation

Tandem Link Connection (TLC) Connection offered by a number of line systems in tandem transporting the same characteristic

Fig. 8
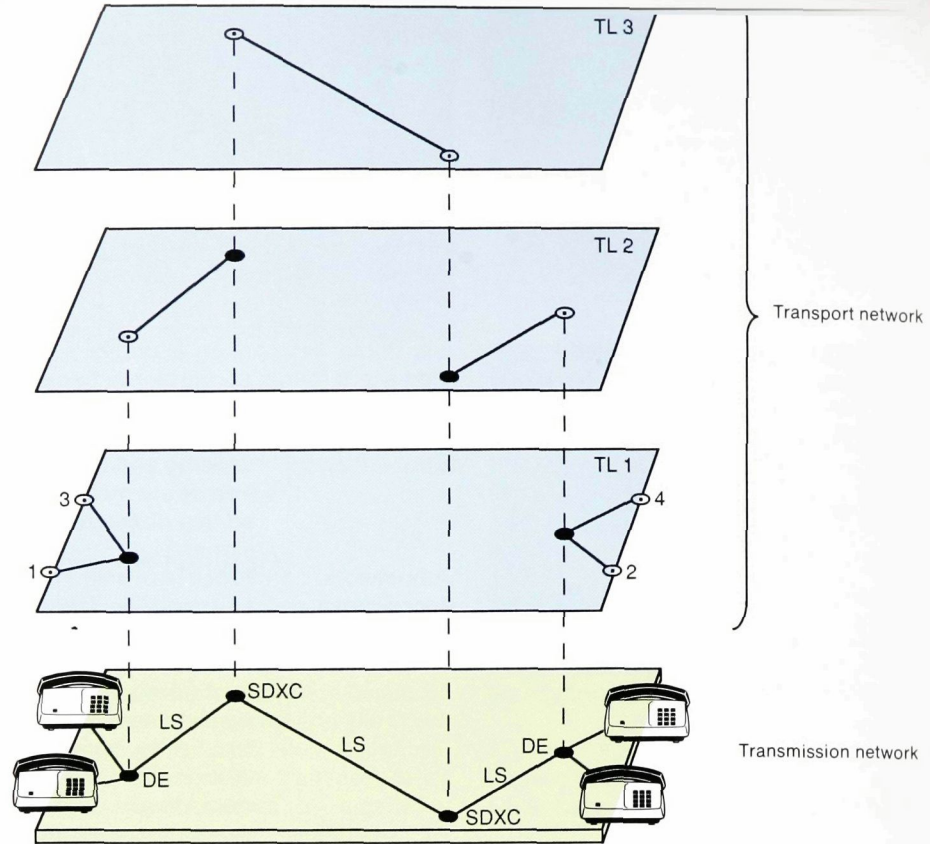**Generalized functional block diagram of synchronous digital cross-connect equipment (SDXC)**
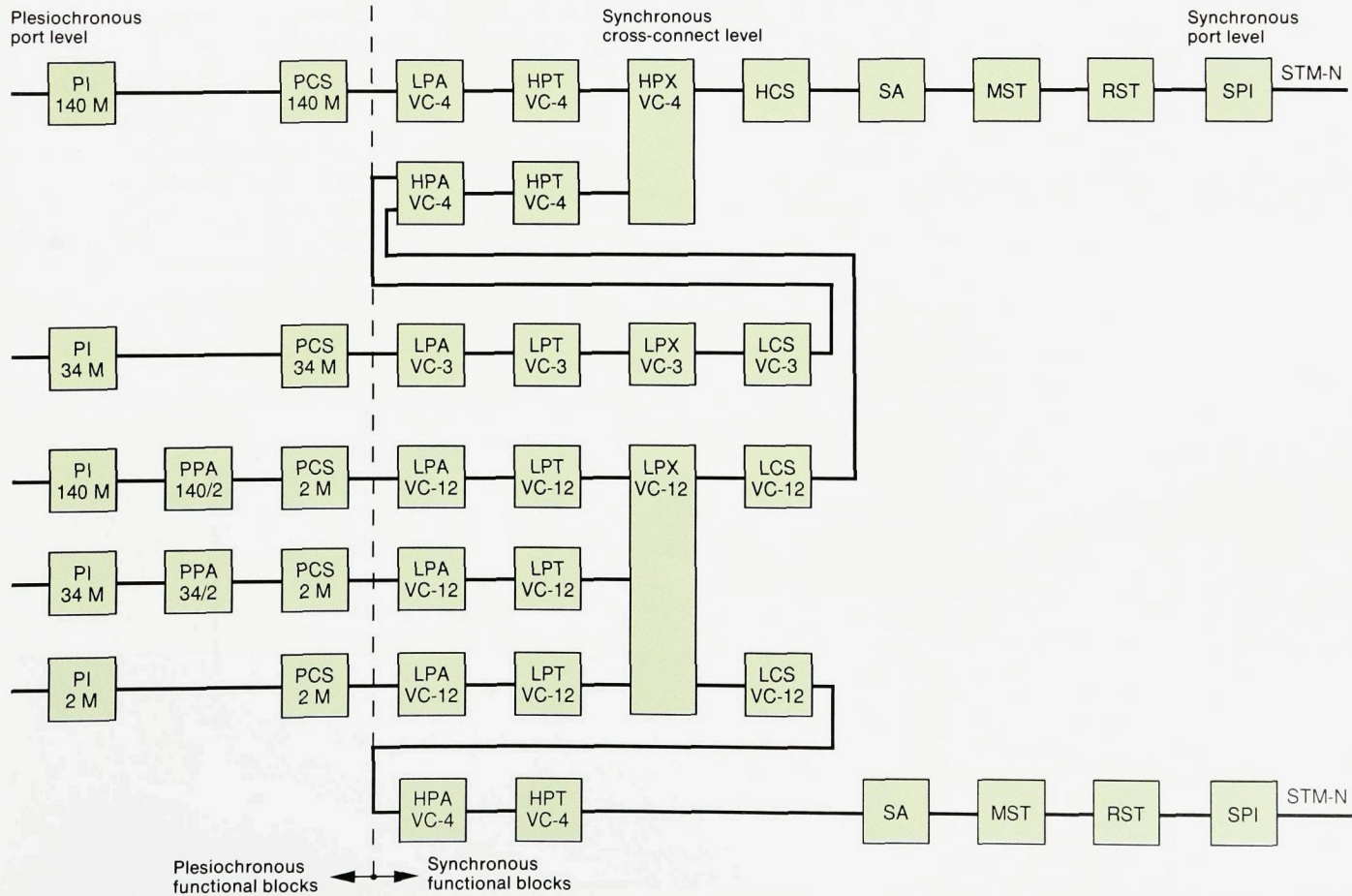
Fig. 9
The pinciple of transport network layering. Two calls in progress: one between telephone sets 1 and 2, and another between telephone sets 3 and 4

TL   Transport network Layer

⊙   Layer Access Point

●   Node

signal and interconnected through distribution frames

Trail
(T)

A particular instance of a connection through a layer network – see examples in fig. 11.

An additional Transport Function – Connection Supervision – is being studied. It will be used for trail monitoring and generation of output signals in a digital cross-connect if the incoming signal is lost.
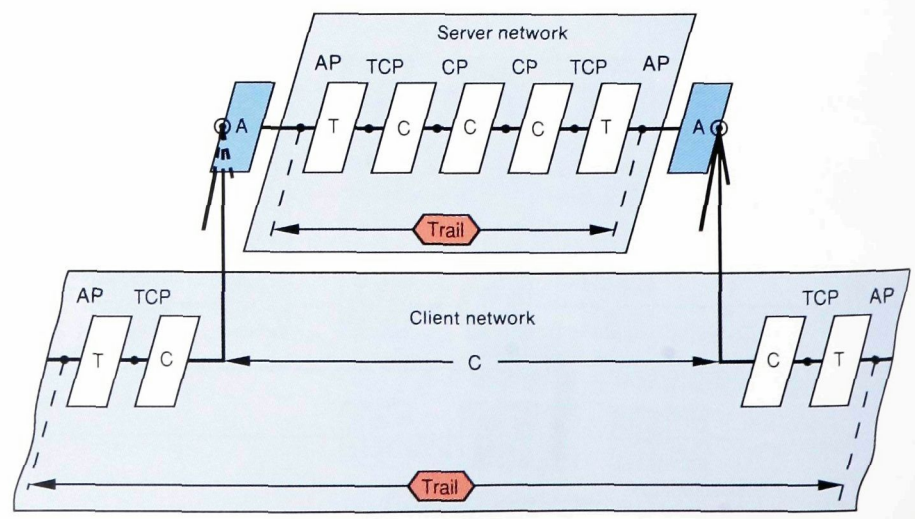
Network layering
The Transport Network is divided into a number of Transport network Layers (TL). Each layer carries one type of characteristic information and has its own management capability and managed objects. Characteristic information is distinguished by bit rates, coding, and frame formats. Examples of types of characteristic information are 2 Mbit/s information flows framed according to Rec. G.704 and VC-4 signals according to Rec. G.708. Each layer of the transport network is independent and can be changed without affecting the architecture of other layers. Normally, an end-to-end connection between users employs

Fig. 10
Generic network layering model showing the interworking between two adjacent transport network layers

A   Client-to-server adaptation
T   Trail termination
C   Connection
AP   Access Point to the Server Layer Network
TCP Termination Connection Point
CP   Connection Point

⊙   Client Layer Access Point
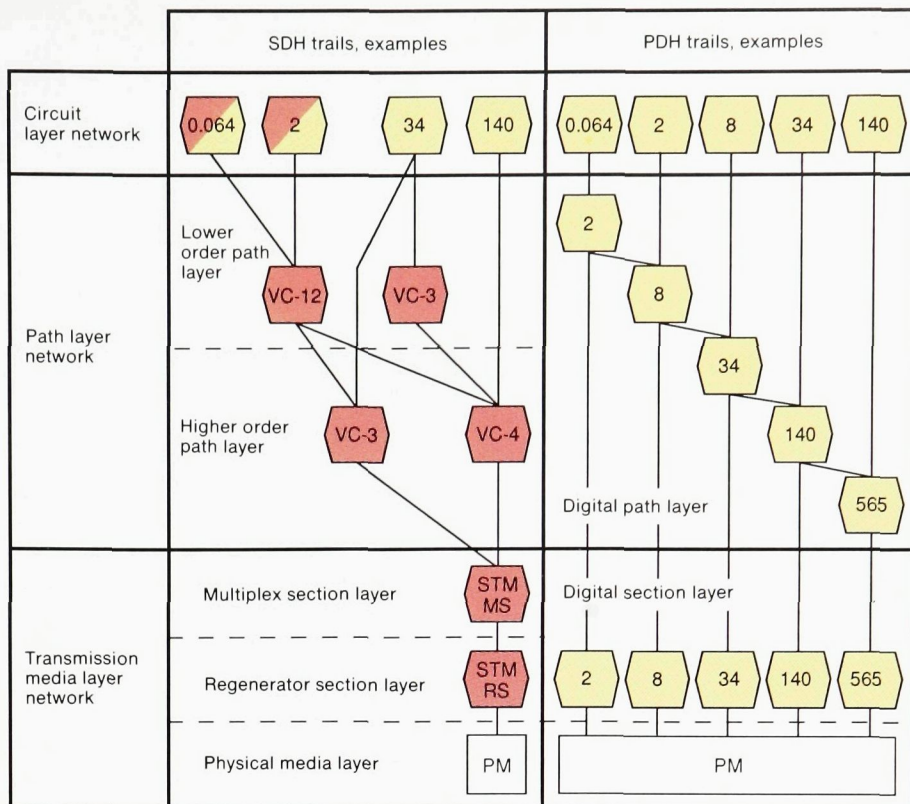
	SDH trails, examples	PDH trails, examples
Circuit layer network	0.064 2 34 140	0.064 2 8 34 140
Path layer network — Lower order path layer	VC-12 VC-3	2 8
Path layer network — Higher order path layer	VC-3 VC-4	34 140 565 — Digital path layer
Transmission media layer network — Multiplex section layer	STM MS	Digital section layer
Transmission media layer network — Regenerator section layer	STM RS	2 8 34 140 565
Physical media layer	PM	PM

Fig. 11
Examples of SDH and PDH trails

- Synchronous trail
- Plesiochronous trail

various types of characteristic information, which means that the information flow must be supported by several transport network layers. The principle of network layering is exemplified in fig. 9, which shows a transport network with three layers.

The Transmission Network contains
- 64 kbit/s digital telephones and local exchanges
- 2 Mbit/s line systems and synchronous digital cross-connect equipment
- 140 Mbit/s line systems.

The corresponding network layers are
- TL1, for the sourcing, sinking, transmitting and switching of 64 kbit/s signals
- TL2, for the transmitting and cross-connecting of 2 Mbit/s signals
- TL3, for the transmitting of 140 Mbit/s signals.

Two telephone services are shown in the example: between subscribers 1-2 and between subscribers 3-4.

Fig. 10 shows, as an example, the Association Transport Functions involved in two-layer signal transport. Basically, the client-to-server adaptation occurs between the client and server layers. To illustrate the principles of the transport network, the adaptation has been included in the server network and only the access point to the client layer is shown in the figure (Client Layer Access Point).

A transport layer may contain several trails, each carrying the same type of characteristic information. TL1 in fig. 9 contains two 64 kbit/s trails (64 kbit/s circuits).

According to definitions used for the SDH, trails exist in three groups of layers forming circuit, path and transmission media layer networks, fig. 11. A circuit is a trail in the circuit layer network, a path is a trail in the path layer network, and a section is a trail in the transmission media layer network.

A circuit layer network provides telecommunication services to users, e.g. circuit-switched, packet-switched and leased-line services. A path layer network is used by the circuit layer networks. A transmission media layer network is used by the path layer network. It is dependent on the transmission media (e.g. optical fibre, radio) and can be divided into a Section Layer and a Physical Media Layer, fig. 11.

The information in a layer is carried by a *trail* consisting of trail terminations (T) and connections (C). A trail is terminated by a Trail Termination Point (TTP). Network connections are terminated by Termination Connection Points (TCP). A Connection Point (CP) marks the boundary between connections. TTP, TCP and CP are reference points consisting of an output port for functions performed (source) and an input port for functions to be performed (sink). The input and output ports of a reference

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point are connected in a binding relationship.

Each transport layer may contain several trails. For example, TL1 in fig. 9 has two 64 kbit/s trails. A network layer is defined by the type of characteristic information transferred over its trails. In a multilayer configuration, client-to-server relationships exist in an iterative manner between adjacent layers.

Some of the existing definitions for the PDH have to be changed or new definitions have to be adopted to permit the use of the generic network layering model for mixed SDH-PDH networks. However, the described principles can be applied to all types of network, such as SDH, PDH and ATM (Asynchronous Transfer Mode).

Fig. 11 shows some examples of trails in the three layers (circuit, path and transmission media) of the SDH and the 2 Mbit/s based PDH. Three of the examples are explained in more detail. Iterative client-server relationships between trails, according to fig. 10, are used to describe the signal transport.

Plesiochronous signal transport
A plesiochronous 34 Mbit/s circuit between two data terminals is carried by a

140 Mbit/s digital path and a 140 Mbit/s digital section using a coaxial cable. The plesiochronous network used is shown in fig. 15.
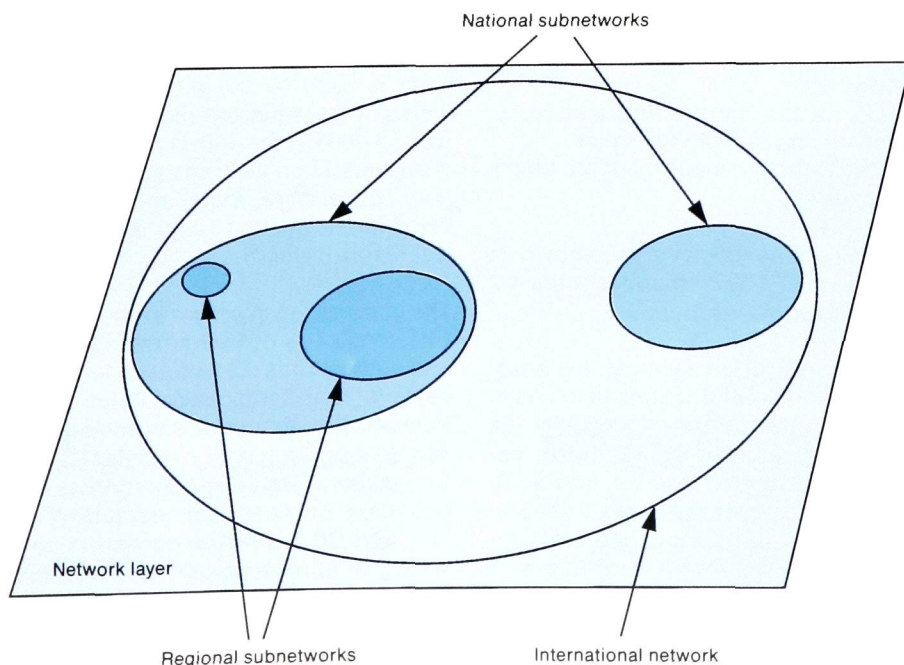
Synchronous signal transport
A synchronous 2 Mbit/s circuit between ISDN terminals is carried by a lower order VC-12 path, a higher order VC-4 path, an STM-1 Multiplex Section, and an STM-1 Regenerator Section which uses an optical cable in the Physical Media Layer. This example is identical with the one shown in fig. 6. It corresponds to the following of a horizontal line from 2 Mbit/s to STM-N in fig. 2. The synchronous network used is shown in fig. 16.

Mixed SDH-PDH signal transport
A plesiochronous 64 kbit/s circuit between digital telephones is multiplexed to a 140 Mbit/s path (plesiochronous trails). The plesiochronous 140 Mbit/s signal is mapped into a higher order VC-4 path and transmitted over an optical cable (synchronous trails). This case corresponds to the plesiochronous 140 Mbit/s signal being mapped into container C-4 in fig. 2. The mixed network used is shown in fig. 17.

In fig. 11, which does not show all the existing signal transport cases, a line between a 140 Mbit/s plesiochronous trail and a synchronous VC-4 trail would be needed to illustrate the case in point.

Network Partitioning
Partitioning of a layer network can be described by means of Topology Transport Functions, i.e. a layer network consists of subnetworks connected by links. Each subnetwork, in turn, may be divided into new subnetworks and linked through an iterative process. The division is normally based on routing and management demands. Fig. 12 shows a transport network layer representing regional subdivisions. Transfer of information through a subnetwork is by means of a subnetwork or degenerate subnetwork connection. Subnetwork connections are interconnected through link connections.

Fig. 13 illustrates the connection options in a layer as a consequence of network subdivision. The end-to-end connection through a network has been
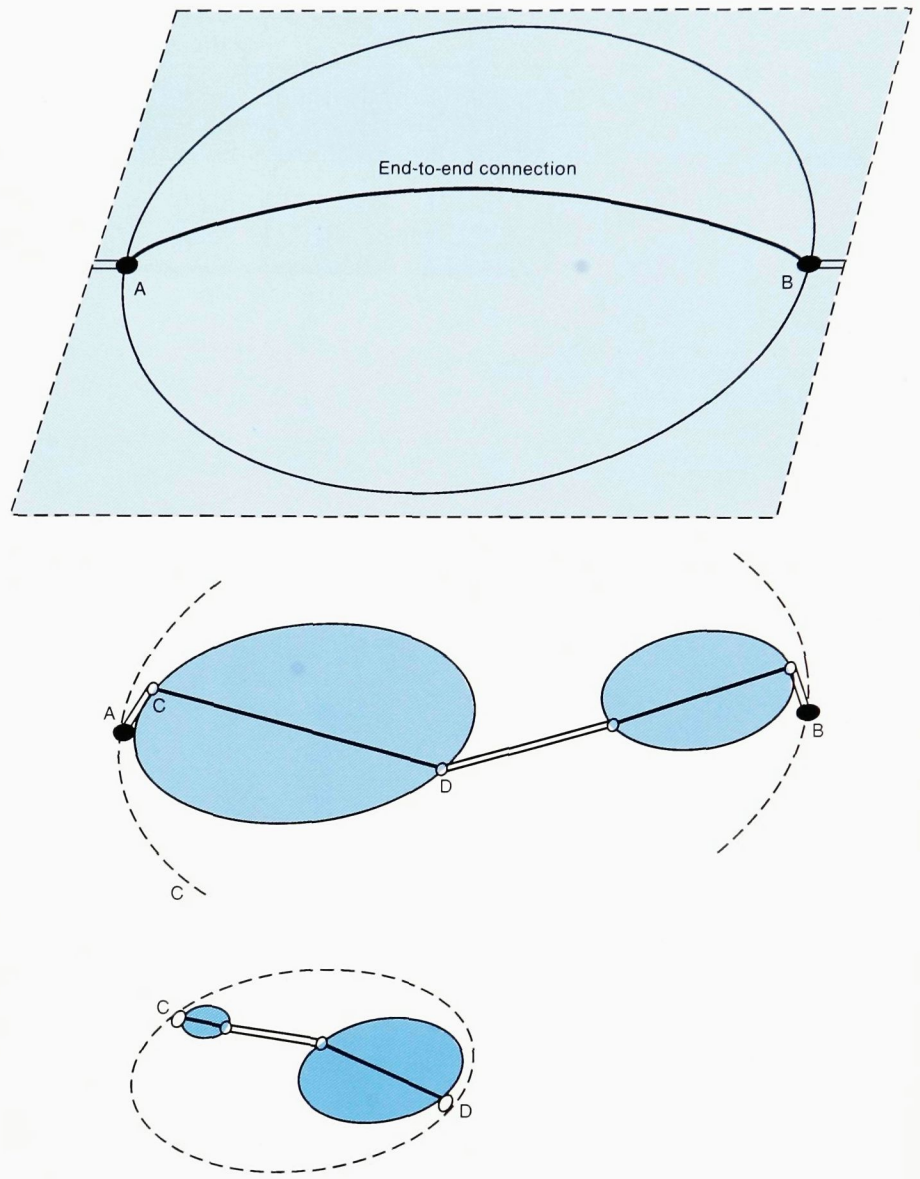
Fig. 12
Partitioning of a network into subnetworks

National subnetworks

Network layer

Regional subnetworks

International network

End-to-end connection

A

B

A

C

B

D

C

C

D

Fig. 13
Link and network connections in the subnetworks shown in fig. 12

—— Subnetwork connection

══ Link connection

TLC

LC

Deg.
SNC

LC

SNC

SNC

SNC

Transport
network

Digital
section

Digital
section

SDXC | LT

LT

LT

LT | SDXC

Transmission
network

Monitoring point
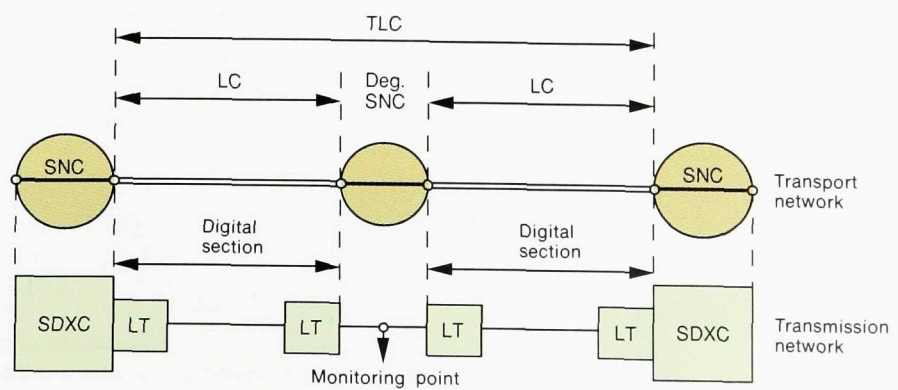
Fig. 14
Example of a degenerate subnetwork with line terminals connected "back-to-back"

TLC   *Tandem Link Connection*
SNC   Subnetwork Connection
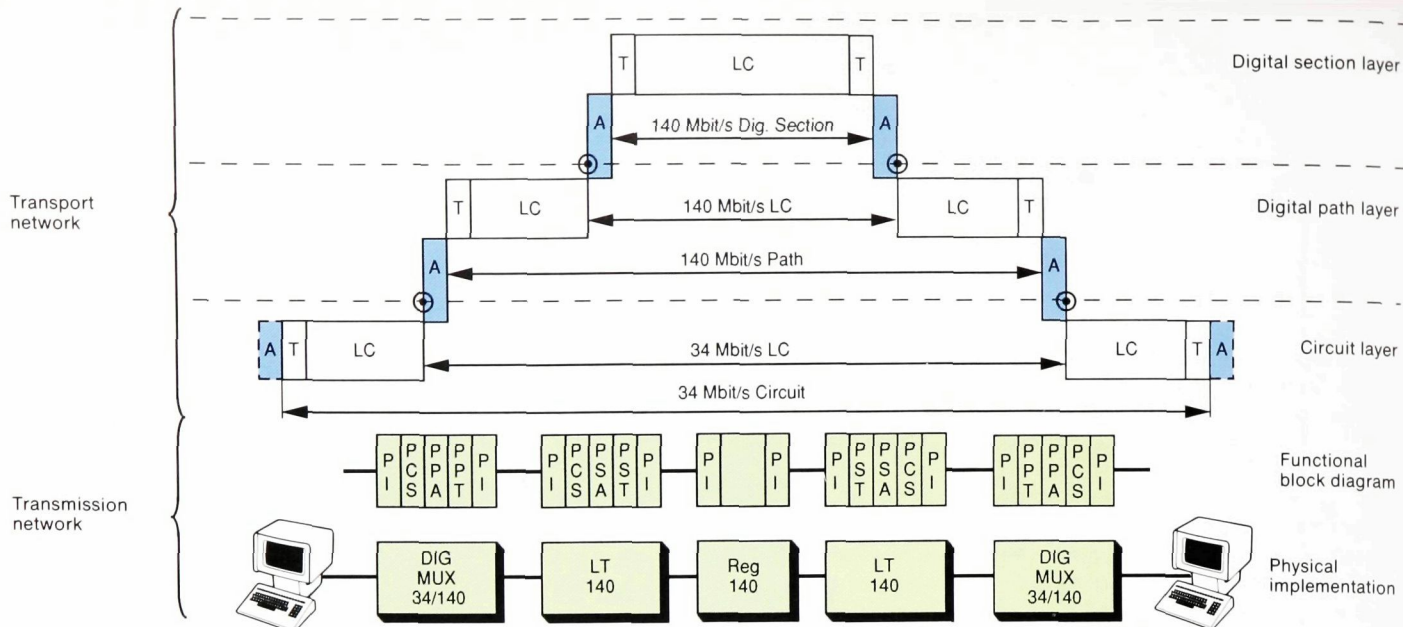LC   Link Connection
Deg SNC   Degenerate Subnetwork Connection

Fig. 15 (above)
Transmission of a plesiochronous 34 Mbit/s signal between two data terminals over multiplexers and a 140 Mbit/s line system

LT	Line Terminal
Reg	Regenerator
A	Client-to-server adaptation
T	Trail termination

Fig. 16 (below)
Example of an SDH network transmitting 2 Mbit/s signals over an STM-1 line system. The degenerate adaptation between the regenerator and multiplex sections is not shown

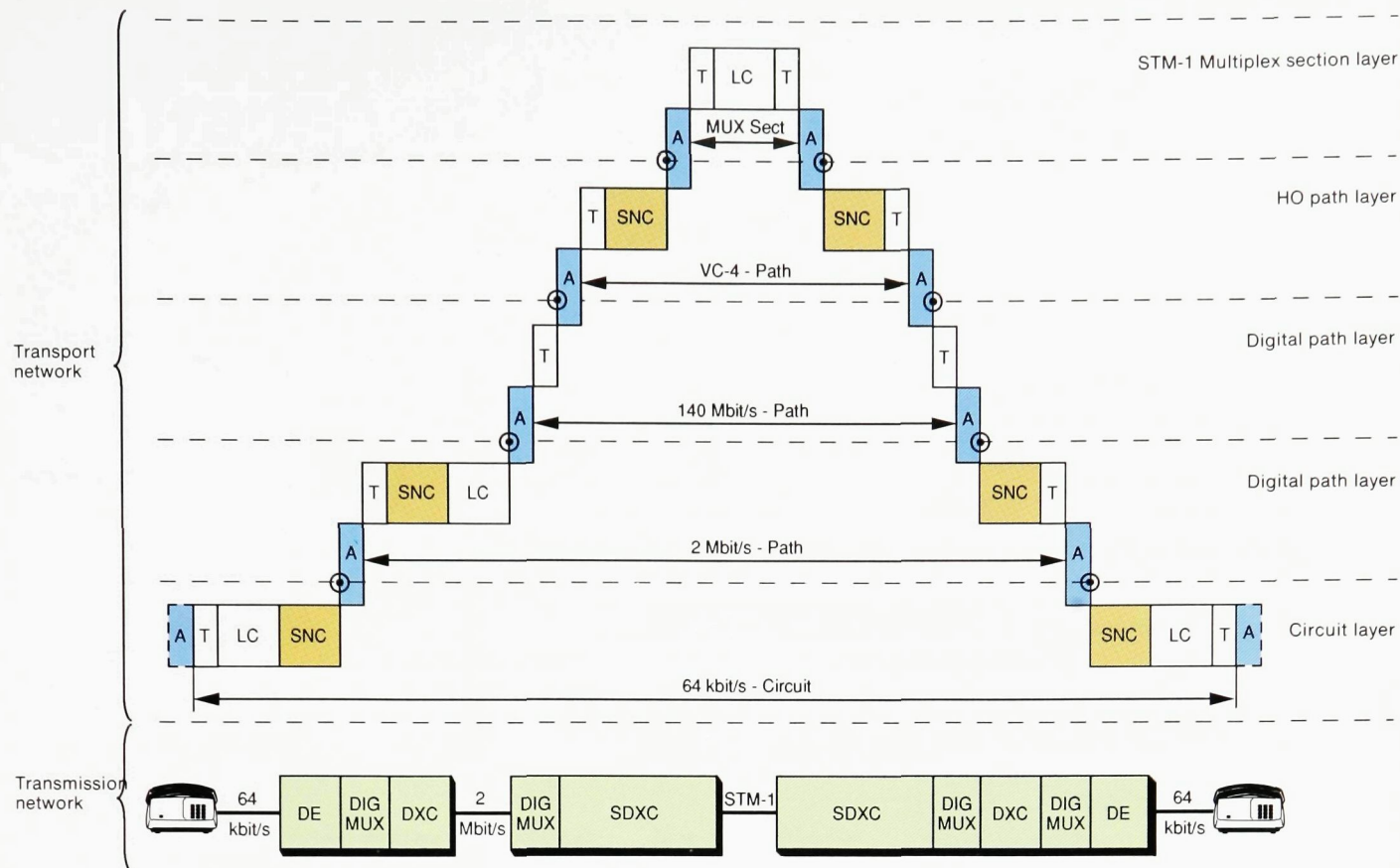|	
LO	Lower order
HO	Higher order
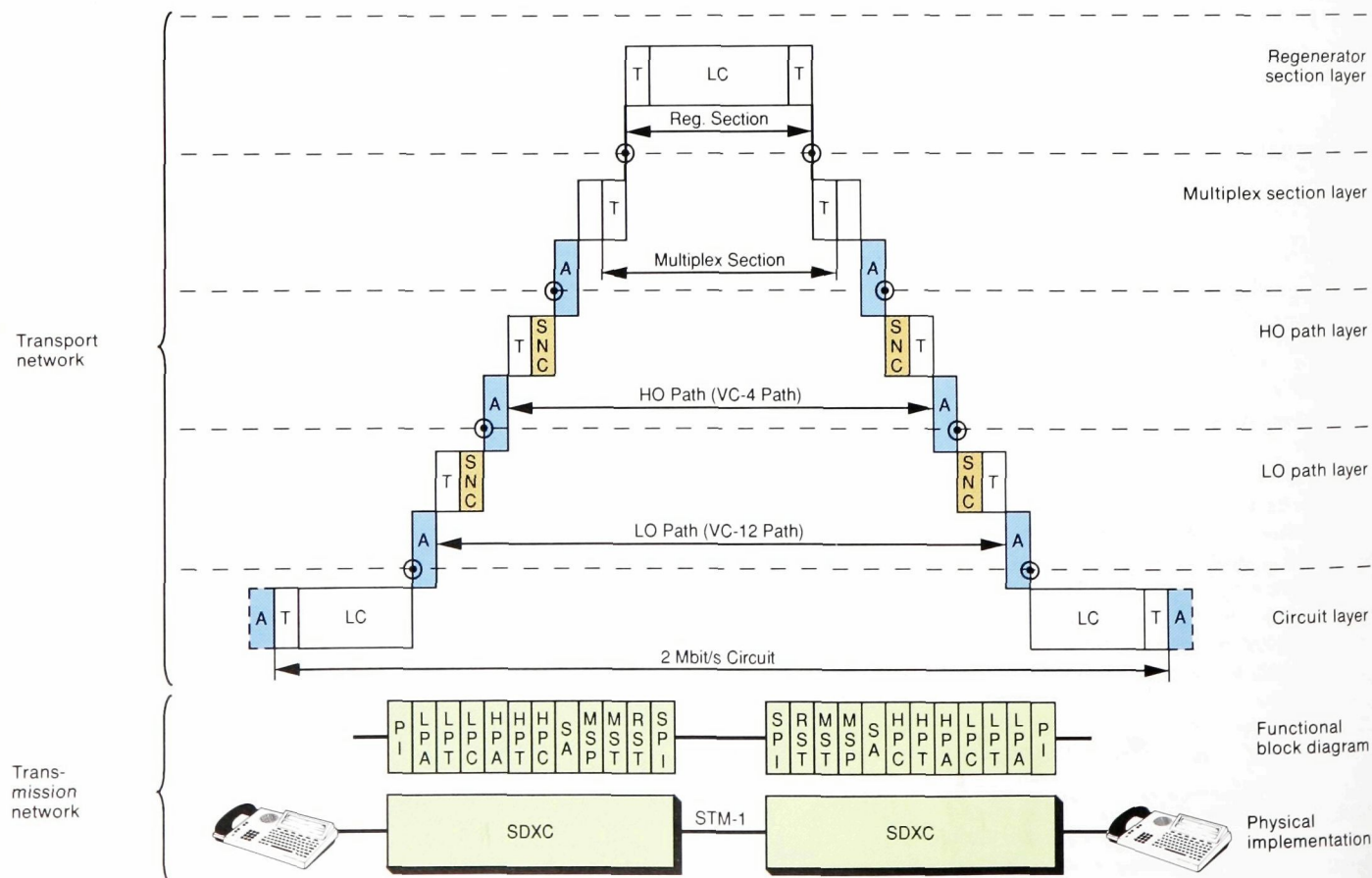
Fig. 17
Transmission of a plesiochronous 64 kbit/s signal over a mixed plesiochronous/synchronous network. Functional description of the transmission network. The regenerator section and physical media layers are not shown

DE   Local exchange
DXC   Digital cross-connect equipment

split up into a number of link and subnetwork connections according to the division into subnetworks.

Examples of transport networks
A number of network examples are given in order to illustrate the use of the transmission and transport network concepts. For the sake of clarity, the physical media layer − e.g. cable − has been omitted.

Fig. 14 illustrates the degenerate subnetwork concept. A degenerate subnetwork connection is created when line terminals are connected "back-to-back". A monitoring point for line systems in the transmission network is obtained. Command-controlled switching is not possible, however.

Fig. 15 shows the transmission of a plesiochronous 2 Mbit/s signal between two data terminals over a transmission network consisting of digital multiplexers and a 140 Mbit/s line system over coaxial cable. The transport network comprises three layers: a 34 Mbit/s cir-

cuit layer, a 140 Mbit/s path layer, and a 140 Mbit/s digital section layer. The layers are separated by Layer Access Points. Connections can be supervised at the access points for the different trails.

Fig. 15 also shows the relationship between
− the physical implementation, with the associated functional blocks in the transmission network
− trails (circuit, path, section) with the associated functional blocks in the transport network.

Fig. 16 shows the transmission of 2 Mbit/s signals in an SDH network over an STM-1 line system. Each SDH multiplexer contains the functional blocks shown in fig. 6.

Figs. 17 and 18 show the transmission of a plesiochronous 64 kbit/s signal over a mixed plesiochronous/synchronous network, consisting of telephones, local exchanges, digital multiplexers, and cross-connects. A functional representation of the transmission network can be obtained according to the principles described earlier.

Fig. 17 shows a simplified network model, indicating adaptations, terminations and trails. This model can be used for fault management.

Fig. 18 shows the subnetworks involved in the example; the model outlined is

required for configuration management.

Table 10 illustrates − for the network in fig. 18 − the topology in the VC-4 layer, which uses link relations over the STM-1 layer. The topology of the complete network requires the corresponding analyses of all network layers involved.

The management of the telecom network is based on TMN Application Functions, such as Fault Management, Performance Management and Configuration Management, which treat the various atomic parts of the network as managed objects. Transport Functions and Transport Reference Points are those network resources which lead to Termination-Point managed objects in an information model. (Termination Points which are managed objects should not be mistaken for Connection Points which are Reference points in a functional model of the network).

Termination Points of trails (paths and sections) can be used for fault and performance management. Linking of Trail Termination Points is also necessary for configuration management. Termination Points are treated as managed objects with manager-agent properties, their link and list relations being specified by the information model of the network. The details of the managed objects, their attributes and values, notifications and names are stored and handled by the TMN.
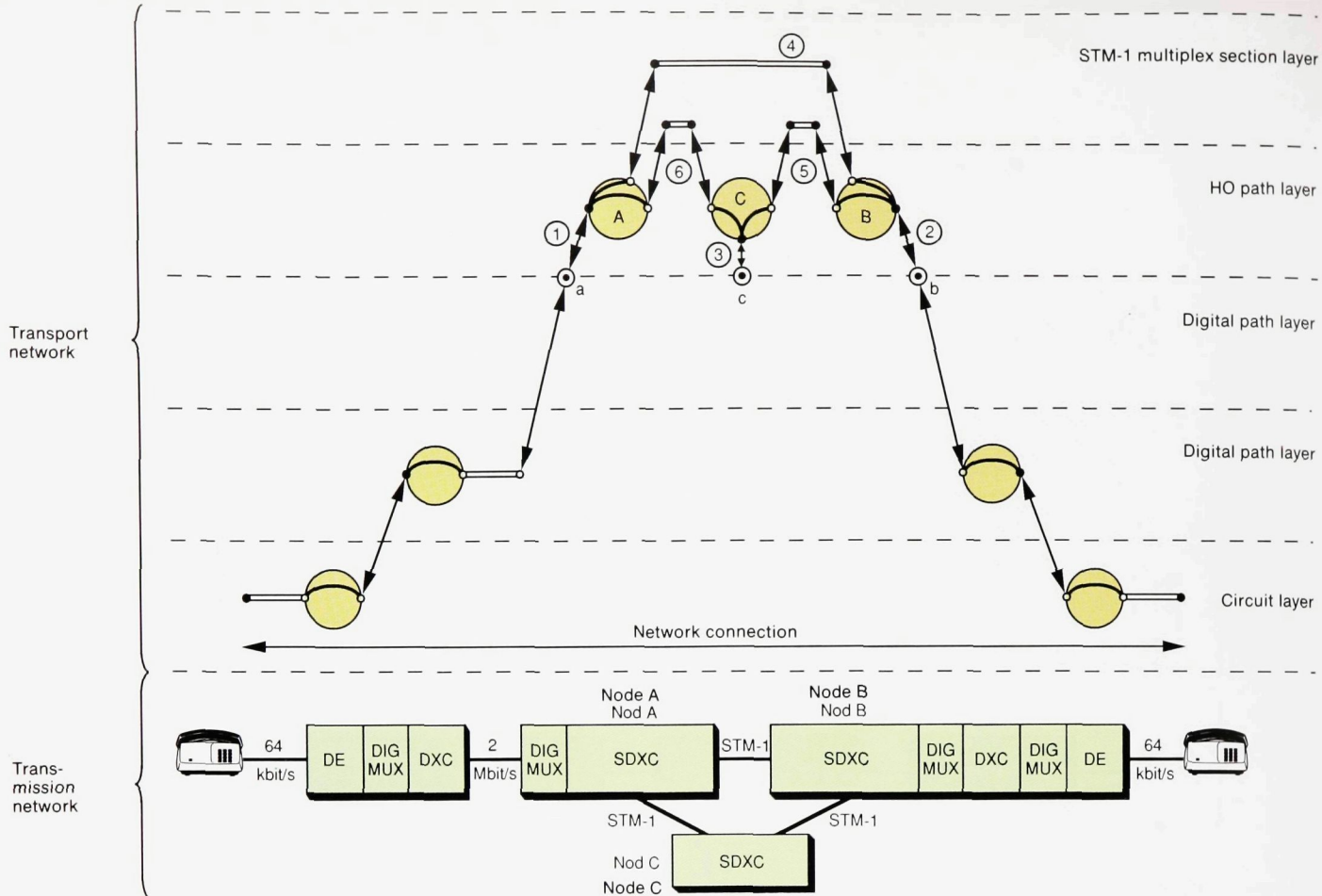
STM-1 multiplex section layer

HO path layer

Digital path layer

Digital path layer

Circuit layer

Transport network

Network connection

Trans-mission network

Node A
Nod A

Node B
Nod B

| | DE | DIG MUX | DXC | | DIG MUX | SDXC | | SDXC | DIG MUX | DXC | DIG MUX | DE | |

64 kbit/s   2 Mbit/s   STM-1   STM-1   64 kbit/s

STM-1   STM-1

Nod C   SDXC
Node C

Fig. 18
Network partitioning: the network shown in fig. 17 divided into subnetworks. The topology of the VC-4 higher order path layer is shown. This layer uses link connections in the multiplex section layer

⬤ Subnetwork connection

═══ Link connection

◄─► Linking

o Connection point, CP

● Termination connection point, TCP

Table 10
Example of network topology

	a	b	c	A	B	C
1	x			x		
2		x		x		
3			x			x
4				x	x	
5					x	x
6				x		x

A,B,C	Subnetworks
a, b, c	Layer access points
1–6	Link connections
x	Connected to

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FMAS—An Operations Support System for Transport Networks

Henry Tarle

HENRY TARLE
Ericsson Telecom AB

Ericsson has developed a Facility Management System (FMAS) enabling network operators to improve the administration, supervision and control of transport networks and leased lines. FMAS forms part of Ericsson's TMOS (TELECOMMUNICATIONS MANAGEMENT AND OPERATIONS SUPPORT) family of systems, which contains products that can be combined to provide efficient, flexible operations support for the entire telecommunications network and its services.
The author describes FMAS and its potentials for making operations support more efficient.

telecommunication network
management
telecommunication networks

Overview

The need for new sophisticated telecommunications services is rapidly growing; as are demands for greater availability and higher quality of these services. Operators require transport networks with a high degree of flexibility to be able to provide the requested services at short notice. At the same time it is essential that network operators can achieve efficient and cost-effective utilization of their transport networks. In order to meet all these needs Ericsson has developed a system family, TMOS (TELECOMMUNICATIONS MANAGEMENT AND OPERATIONS SUPPORT), containing products that together can provide operations support for an entire telecommunications network, and its services. The Facility Management System, FMAS, which forms part of the TMOS family, provides operations support dedicated to transport networks, including leased-line services. Basically, this operations support can be divided into administration, supervision and
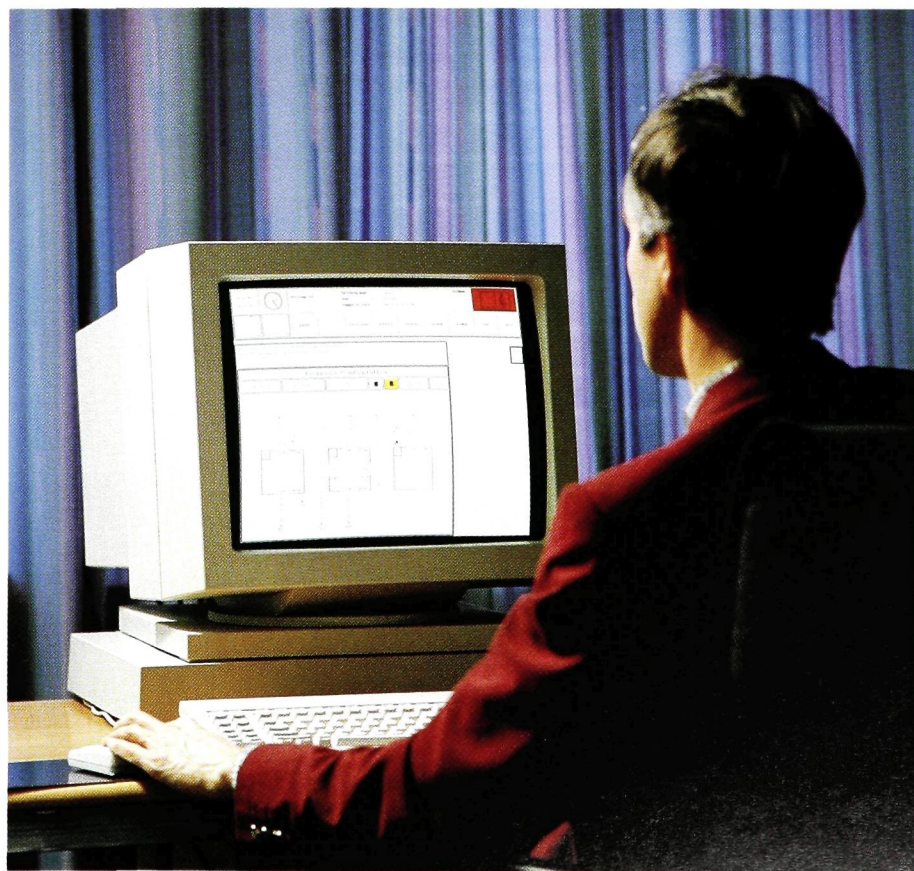

Fig. 1
FMAS enables the network operator to supervise and control the transport network and its leased lines from a terminal in an operations centre. The display shows three different types of digital cross-connect system in a network node. The desired operations are ordered with the aid of the keyboard and the mouse

control and can involve the whole transport network with its individual network elements and circuits.

A key benefit of FMAS is its ability to support *centralized supervision* of a complete transport network. Based on CCITT/TMN principles, FMAS integrates the administration and control of network elements from different vendors; Digital Cross-Connect systems (DXC) and transmission products of the synchronous (SDH) and plesiochronous (PDH) digital hierarchies. FMAS is designed to meet increasing management needs and can manage transport networks in a hierarchical fashion.

FMAS (TMOS) offers a programming tool that can be used to design applications as well as adaptations to network elements not supplied by Ericsson.

To *network operators* FMAS means increased cost-efficiency of network operations by automating the management of leased-line services, network performance/control and preservation, etc. An increased utilization of *network transport resources* in the order of 10–25 % may be possible through the Automatic Network Protection Routing facility, and a further 10–25 % through efficient repacking of digital transmission systems. This is achieved by combining FMAS with Ericsson's highly flexible DXC systems and SDH multiplexers. FMAS also offers a network planning tool for efficient optimization of complex transport networks.

To *priority customers* FMAS typically offers increased and controlled service availability and service quality. Network operators can provide leased lines at short notice, and an optional service enables the customers themselves to select routes and bandwidths for their circuits.

FMAS operations support applications are based on an open standards (X/Open, POSIX, OSI) computing platform (CAP) which is used in all TMOS applications. The TMOS architecture provides a framework for the network operators' own applications. It combines the latest technology and knowhow in the fields of telecommunication and data processing.

In addition to FMAS, the following TMOS operations support systems are defined, fig. 2:

BMAS   Business Management System for centrex and virtual private networks

CMAS   Cellular Management System for mobile telecommunications networks

NMAS   Network Management System for switched networks, *e.g.* AXE switching and SS7 signalling networks

SMAS   Service Management System for intelligent networks.

FMAS can interwork with other TMOS systems, thus ensuring efficient operations support for an entire telecommunications network.

Box 1

ABBREVIATIONS

ADM	Add/Drop Multiplexer
AIS	Alarm Indication Signal
AU	Application Unit
AXE	Ericsson's digital circuit switching system
CAP	Common Application Platform
CSM	Central Subscriber Multiplex
DCN	Data Communications Network
DXC	Digital Cross-Connect
ECC	Embedded Control Channel in SDH systems
FMAS	Facility Management System
FMAS/N	FMAS for centralized control of a national network
FMAS/R	FMAS for control of a regional or metropolitan network
FMAS/L	FMAS for local control of network elements in a node
LAN	Local Area Network
LCN	Local Communications Network
MAS	Management Application System in TMOS
MML	Man Machine Language
MTP	Message Transfer Protocol. Ericsson's X.25 protocol
NE	Network Element
NMC	Network Management Centre
OMC	Operation and Maintenance Centre
OS	Operations System
OSI	Open Systems Interconnection
PCM	Pulse Code Modulation
PDH	Plesiochronous Digital Hierarchy

POSIX	Portable Operating System Interface based on UNIX
Q	Q-interface, a TMN protocol
Q_{DCN}	Q-interface for communication via an X.25 DCN in accordance with CCITT Rec. G.773 (previously Q3)
Q_{LCN}	Q-interface for local communication in accordance with CCITT Rec. G.773 Q-stack (previously Q2)
RSM	Remote Subscriber Multiplex
SDH	Synchronous Digital Hierarchy
SDXC	Synchronous Digital Cross-Connect
SMN	SDH Management Network, the support information carried by ECC
SQL	Standard Query Language
STM	Synchronous Transport Module
TAP	Telecommunication Application Platform
TMN	Telecommunications Management Network
TMOS	Telecommunications Management and Operations Support
UNIX	An operating system for multi-user systems. UNIX is owned by Unix International Corporation
WAN	Wide Area Network
WS	Workstation
X/Open	An international consortium of major computer manufacturers, dedicated to setting standards which permit the same software to run without modification on a wide variety of computer systems
X.25	A standard protocol, specified by CCITT for packet-switched data communication between computers and related equipment

Transport network

Evolution

Traditionally, digital transmission networks have been built up of separate, physically interconnected plesiochronous transmission systems. Basic transmission interfaces have been standardized to permit interconnection of products from different vendors. But the fact that the transmission systems represent different maintenance principles and interfaces has limited the possibilities of efficient centralization of operation and maintenance.[1,2]

This situation was acceptable when telephone traffic was stable and fairly predictable. Now, demands from business customers are becoming increasingly stringent, in pace with the introduction of new sophisticated services. There is a need for managed transport networks that can be centrally operated and maintained, provide automatic network restoration and permit control of transmission quality.

Transmission systems of the new SDH (Synchronous Digital Hierarchy) standard with embedded control channels for maintenance information, and operations support systems with standardized interfaces, will provide the necessary basis for flexible and controllable transport networks.

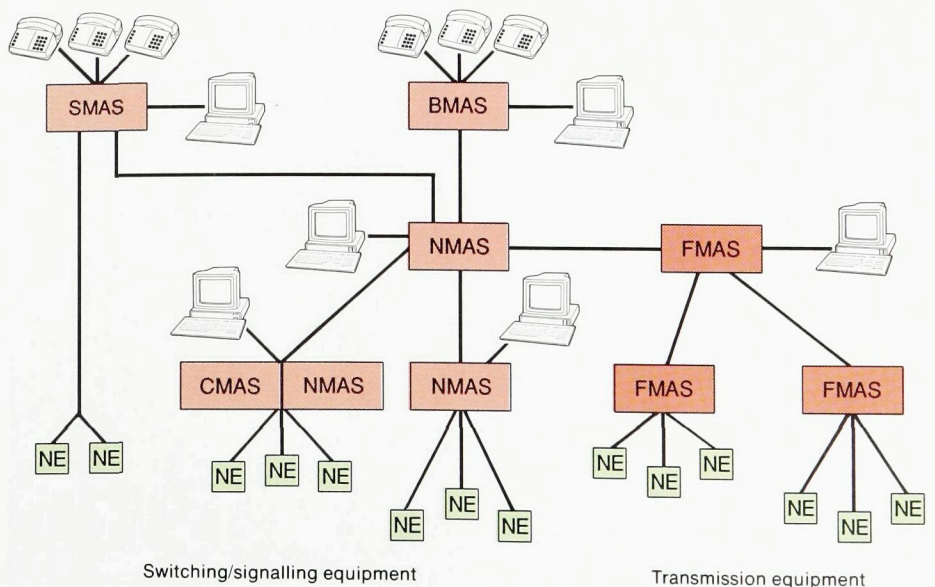### The integrated approach to transport networking

Transport Network Management Architecture

Ericsson's Transport Network Management Architecture integrates operations support/control systems (FMASs), the (built-in) local control of the transmission systems, and the interlinking data communication facilities. The architecture permits a hierarchical division of operations support, corresponding to the local, regional and national levels of a transport network. Various transport network elements − Ericsson's as well as those of other suppliers − can be controlled from FMAS.

Evolution towards a managed synchronous network

The chosen architecture permits simple, step-by-step transition from existing PDH (Plesiochronous Digital Hierarchy) networks − with their operations support systems − to the centrally managed SDH networks of tomorrow, at a pace set by the network operator. It should be noted that FMAS also permits enhancement of the operations support of existing PDH networks.

The introduction of an SDH network means that current investment in optical fibre cable can be exploited to the full. SDH systems can be introduced as small islands in an existing network or in the form of an overlay network.
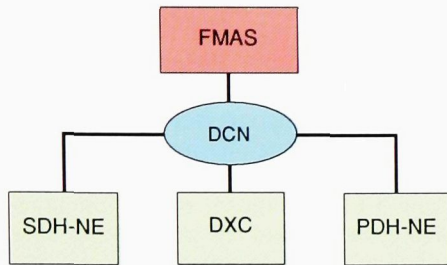
Fig. 2
Example of networking between TMOS Application Systems, maximizing total network operations support and service efficiency

BMAS   Business Management System for centrex and virtual private networks
CMAS   Cellular Management System for mobile telecommunications networks
NMAS   Network Management System for switched networks, e.g. AXE switching and SS7 signalling networks
SMAS   Service Management System for intelligent networks.
NE   Network Element

Switching/signalling equipment   Transmission equipment

Fig. 3
FMAS provides operations support for transport networks comprising network elements, such as DXC systems and SDH and PDH transmission systems. Communication between FMAS and supported network elements is via a data communications network using the Q-interfaces recommended by CCITT for TMN (Telecommunications Management Network)

SDH   Synchronous Digital Hierarchy
PDH   Plesiochronous Digital Hierarchy
DCN   Data Communications Network
DXC   Digital cross-connect system

Ericsson's new Transport Network Management Architecture is a total approach to successful operations support. Its implementation reduces the costs of network operation and maximizes the revenue-earning potential of the transport network.

Ericsson's product program for transport networks

Ericsson's product program for transport networks, defining the Ericsson Transport Network Architecture, comprises:
- A family of SDH transmission systems
- A family of digital cross-connect systems (DXC)
- A family of PDH transmission systems
- A facility management system (FMAS).

Similarities between different systems are used to the full. For example, in the cross-connect systems the interface printed board assemblies are the same as those used in the SDH transmission systems, and their computing platform (CAP) is the same as in FMAS.
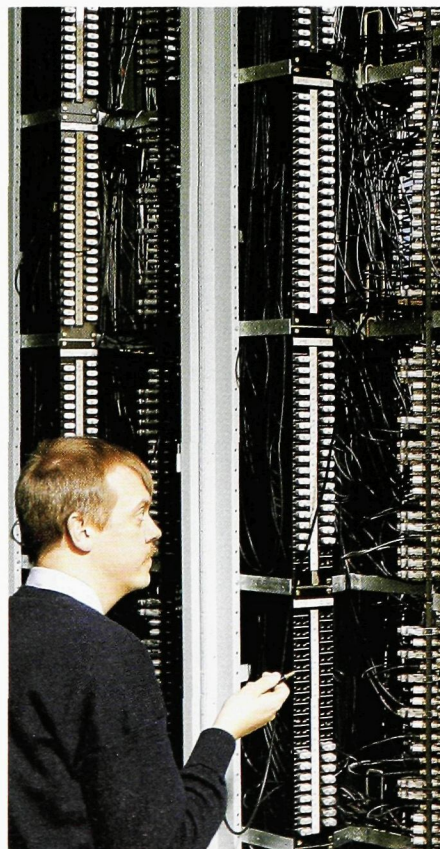

Fig. 4
Traditionally, cross-connections have been carried out manually, for example between digital multiplex and line equipment in coaxial digital distribution frames located in terminal repeater stations

SDH transmission systems
The SDH transmission systems constitute a new product family which conforms to the CCITT recommendations G.707, G.708 and G.709 for SDH:

ZAP 155 An optical fibre system with a bit rate of 155 Mbit/s (STM-1) for transport of up to 63 × 2 Mbit/s signals

ZAP 250 An optical fibre system with a bit rate of 620 Mbit/s (STM-4) for transport of up to four 140 Mbit/s signals

ZAP 250 An optical fibre system with a bit rate of 2.5 Gbit/s (STM-16) for transport of up to 16 × 140 Mbit/s signals.

The systems include line terminals, add-drop multiplexers and regenerators. They can be used to transport current 1.5, 2, 34 and 140 Mbit/s PDH signals and also future broadband signals.

Digital cross-connect systems
The digital cross-connect systems (DXC) constitute a new product family designed to provide network protection, and to improve management and utilization of lines and the quality of leased line services.[3] They function as semi-permanent switches for transmission channels with holding times of hours, days or weeks. They perform, under stored program control, transparent switching of digital transmission channels, which may be tributaries in higher-order transmission systems.

Ericsson's digital cross-connect systems conform to CCITT recommendations for DXC and SDXC (Synchronous Digital Cross-Connect). The program comprises three different types of system: DCC 1/0, DCC 4/1 and DCC 4/4. A cross-connect node may have common control equipment while the individual cross-connect systems have different switches in order to meet various requirements.

DCC 1/0 Terminates signals with bit rates 64 kbit/s, 1.5 and 2 Mbit/s. The signals are sorted, packed and cross-connected at the N × 64 kbit/s level (N=1−31)

DCC 4/1 Terminates signals at between 1.5 (2) and 155 Mbit/s and

cross-connects primarily 2, 34 and 140 Mbit/s signals

DCC 4/4 Terminates 140 or 155 Mbit/s signals and cross-connects at the same level. Also provides interfaces for STM-4 and STM-16 signals.

PDH transmission systems
Ericsson's product program "Series 7000 Plus" for the plesiochronous digital hierarchy comprises:
- PCM and RSM/CSM multiplexers and digital multiplexers for 2/8, 8/34 and 34/140 Mbit/s
- Symmetric-pair line systems for 2 Mbit/s
- Optical fibre line systems for 8, 34, 140 and 565 Mbit/s
- A Transmission Operation and Maintenance System for integration into an FMAS operations support network.

FMAS – Facility Management System for transport networks
The facility management system FMAS is designed to support the operation of new SDH, DXC and PDH systems, fig. 3. FMAS is based on a computing platform used in all TMOS systems.

The continuous development of FMAS will result in the ability to provide net-work management for transport networks consisting of new and different types of network element. A uniform TMN/Q-interface between FMAS and the network elements will enable an operator to obtain a consistent network management environment for his transport network.

Applications
The new network elements represented by DXCs and SDH multiplexers are of particular interest. The latter are available in different versions with slightly different functions, fig. 5:

ADM Add-drop multiplexers make it possible to open an STM-N signal and drop or insert signals of lower-order bit rates. For example, a 2 Mbit/s signal can be dropped directly from an STM-1 signal (155 Mbit/s) without any demultiplexing

SDH SDH multiplexers provide multiplexing of signals from the PDH and SDH hierarchies into STM-1, STM-4 or STM-16 signals, and vice versa

SDXC The digital cross-connect systems DCC 4/1 and DCC 4/4 can switch transmission channels with the desired bandwidth and also form a bridge between PDH and SDH networks.

Fig. 5
Example of a transport network with operations support. The diagram shows Ericsson's operations support system and network elements and the data network that transmits control information

FMAS	Facility Management System
Q	Q-interface in TMN, in accordance with CCITT
STM	Synchronous Transport Module
SDXC	Digital cross-connect system
PNE	PDH Network Element
SNE	SDH Network Element
ADM	SDH Add/drop Multiplexer
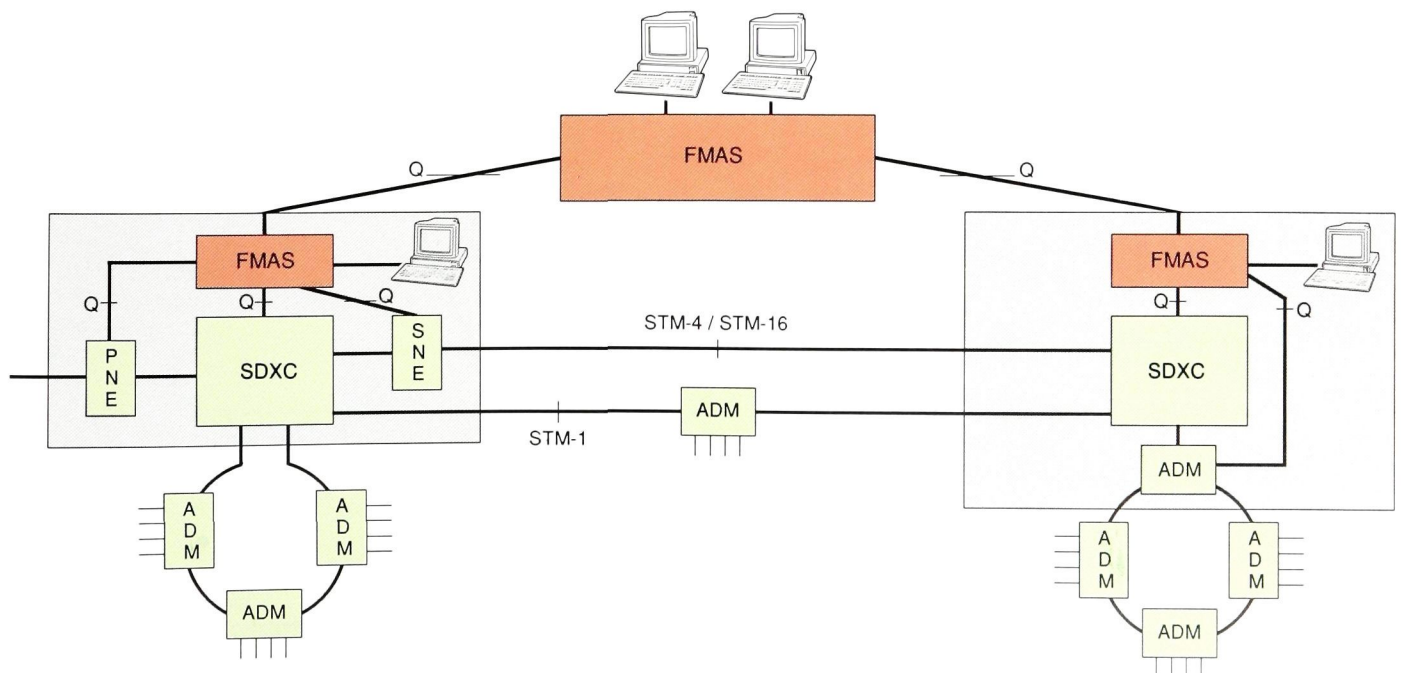
Strategic benefits

New and extended demands on the transport network are mainly made by large enterprises that are dependent on connections beteween their private nodes. They need communications
– between PABXs
– between computers
– between MANs (Metropolitan Area Networks)
– between WANs (Wide Area Networks)
– for video conferences.

Such major customers require high availability and performance and short service delivery time. Network operators, on their part, want to reduce their costs. FMAS and supported DXC and SDH transmission products offer cost-efficient solutions to these problems – solutions that may turn present operating cost trends in a more favourable direction, fig. 6.

FMAS offers network operators and their customers strategic and competitive benefits, as described below.

Benefits to network operators
Improved operations support
– Operations support of a complete transport network. A key feature of FMAS is its ability to support network operators with centralized management, integrating and coordinating the administration and control of different types of network element
– Automation of configuration and performance control of leased-line services and transport circuits, ranging from 64 kbit/s to broadband
– Automation of operation and maintenance of network elements (DXC, SDH, PDH).

More efficient use of network resources
– Increased network utilization in the order of 10–25 %. FMAS increases the pay-off from network investments through the Automatic Network Protection Routing facility, primarily operating on DCC 4/4 and 140 (155) Mbit/s transport circuits. In the case of a network failure, FMAS automatically and in real time orders the DXCs

Fig. 6
FMAS significantly reduces operating costs for transport networks, while increasing the availability and performance quality of the transport network and supported services
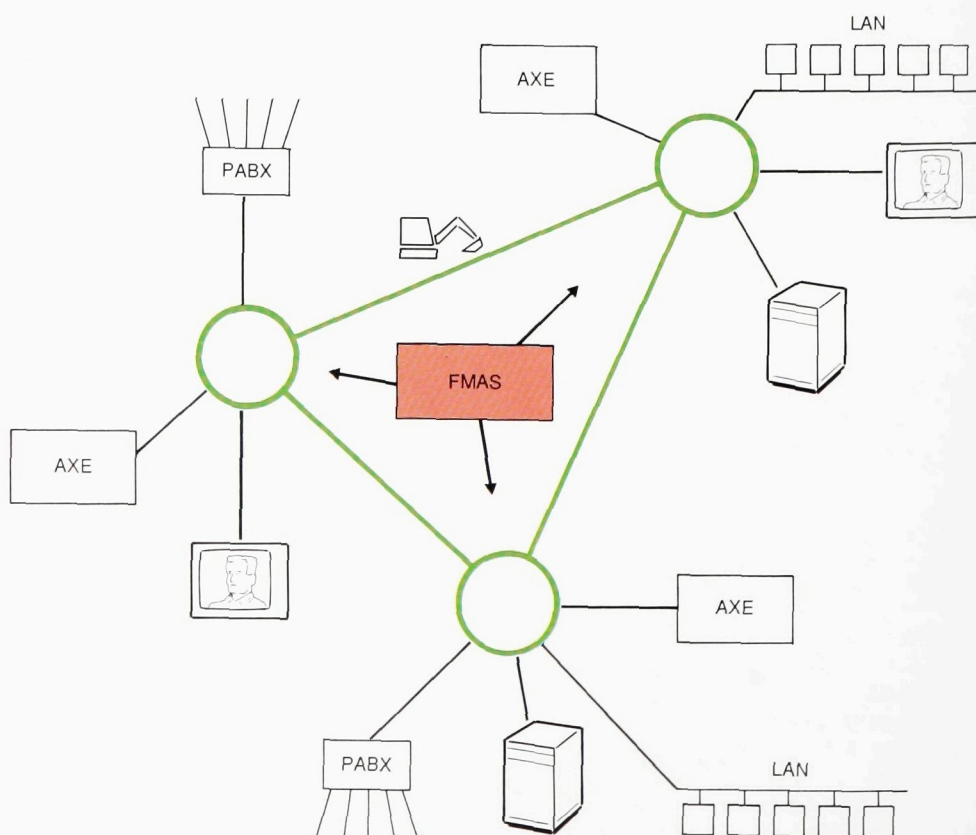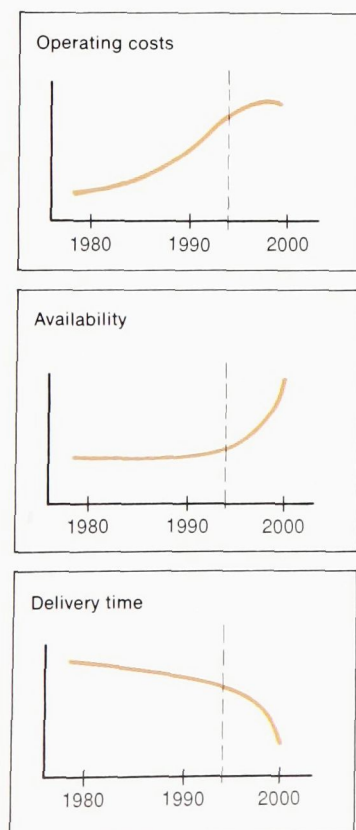
⚪ Digital cross-connect system

Table 1

Equipment	Typical applications of FMAS and network elements
DCC 1/0	Management of leased lines for n × 64 kbit/s (n = 1–31), e.g. setting up 64 kbit/s leased lines and paths through the network. 64 kbit/s signals can be sorted and packed in DCC 1/0 nodes to give 2 Mbit/s transmission systems a high fill factor
DCC 4/1	Automated management of circuits, from 2 Mbit/s up to 140/155 Mbit/s. With its ability to handle all bandwidths, it improves the fill factors of existing 140/155 Mbit/s transmission networks. It replaces the traditional back-to-back multiplexing in exchanges. Bridging between SDH and PDH networks can be arranged
DCC 4/4	Automatic protection routing of 140/155 Mbit/s circuits in case of circuit failure. Provisioning of broadband leased-line services, etc.
SDH/PDH	Centralized alarm supervision, fault localization, performance monitoring, provisioning of circuits, synchronous add/drop multiplexing, etc.

to set up the *logically* best alternative route between end points in the network

- Increased line system fill factor by 10–25 %. Efficient repacking of lower-order line systems into higher-order systems will increase the fill factor. This is achieved by combining FMAS with Ericsson's highly flexible DXC and SDH multiplexers
- Bridging between SDH and PDH networks. The combination of Ericsson DXCs and FMAS permits the interfacing between optical transmission systems, using the SDH standard, to be gradually and smoothly introduced into an existing PDH network. This means that there will be no need for operating a separate SDH network
- Modular expandability. FMAS permits a network operator to economically control anything from a single DXC, using a basic FMAS single workstation configuration, to an FMAS multi-computer configuration controlling a large number of network elements of different types
- FMAS-TMOS networking. Since FMAS is built on the TMOS common platform completed by FMAS application software, FMAS can cooperate with, or incorporate wholly or partially, the other members of the TMOS family. This will guarantee a network operator full flexibility and adaptability to future needs of operations support.

Less complex network layout and easy planning make for reliable and efficient operation

- Hierarchic configuration. Operations support can be divided into hierarchic levels, e.g. local (node), regional and national. FMAS operations centres can be allocated different geographical areas in a "flat" network or different transport network layers (logical levels) of an SDH network[4]
- Network planning tool. The FMAS Network Planning Tool (NPT) may be necessary for routing optimization and fault tolerance evaluation. The NPT operates on a network model that can easily be updated from the FMAS operating database
- Duplicated FMAS. FMAS can be duplicated so that operation can be maintained even in case of a system breakdown. The two systems – one

executing and the other standby – may be placed in geographically separate centres
- FMAS benefits from all the significant characteristics and features of the TMOS concept.

Benefits to customers

In response to business customer needs, FMAS offers the following important quality and time and cost saving benefits.

- Increased service availability. The automatic protection routing system reconfigurates the network in the case of a failure in a path or circuit. Leased lines can be allocated different priority classes. They can thus be given the highest possible availability when required
- Secured service quality. Through monitoring and performance analyses of leased lines, FMAS permits contracted service quality to be secured. Weak parts of the network, with deteriorated performance, can be detected early and localized
- Service privisioning with short delivery time
- Customer control of leased lines, enabling end users to partly control routing and bandwidth reconfigurations of their own circuits.

Applications

Typical applications for different network elements

Certain applications can be considered more or less typical of the network element in question, table 1.

Major FMAS applications providing operations support for transport networks and leased lines are described in the following section. DXC and SDH/PDH systems are used in the way described in table 1.

MANAGEMENT OF THE TRANSPORT NETWORK

Compliance with international standards

FMAS applications are based on the Management Framework defined by OSI (Open Systems Interconnection) principles for the TMN (Telecommunications Management Network). According to these standards/recommendations,

FMAS functions/applications are categorized in a number of functional areas, fig. 7.

Configuration management

FMAS configuration management functions provide means for adding and removing network elements and paths/circuits in the transport network. Facilities for network restoration and network planning are also supported. Some examples of functions are given here.

Network configuration

Network configuration denotes a group of functions needed to identify and configure physical resources in order to achieve a network infrastructure: the putting into service and removal of network elements and their physical interconnections, or of equipment in the network elements, etc. Whenever changes are made, the FMAS database is updated.

Path and circuit provisioning

Path and circuit (leased-line) provisioning involves the establishment of logical connections through the network. The paths/circuits are set up by FMAS issuing cross-connect commands to the DCCs. Provisioning can be made *ad hoc* when ordered by the operator or according to a predefined schedule. Scheduling of reconfigurations is a valuable tool that enables the operator to meet customers' demands for flexibility and to utilize network resources more efficiently over periods of specified lengths.

Protection switching

For a transport network section a protection switching function (1:N) can be defined from FMAS. This switching function is invoked autonomously by the network elements at both ends of the section in which a transmission failure has occurred. The function is limited to switching to a standby network resource between the original pair of network elements.

Protection routing

In the case of a network failure – loss of signal, high bit error rate, a major cable failure, etc. – the protection routing function automatically and in real time restores the affected paths and circuits (leased lines), fig. 8. FMAS builds up an alarm picture of all alarms arriving from the network elements concerned. A protection routing analysis is then made by FMAS based on this alarm picture, on the preset priorities of the affected paths, etc.
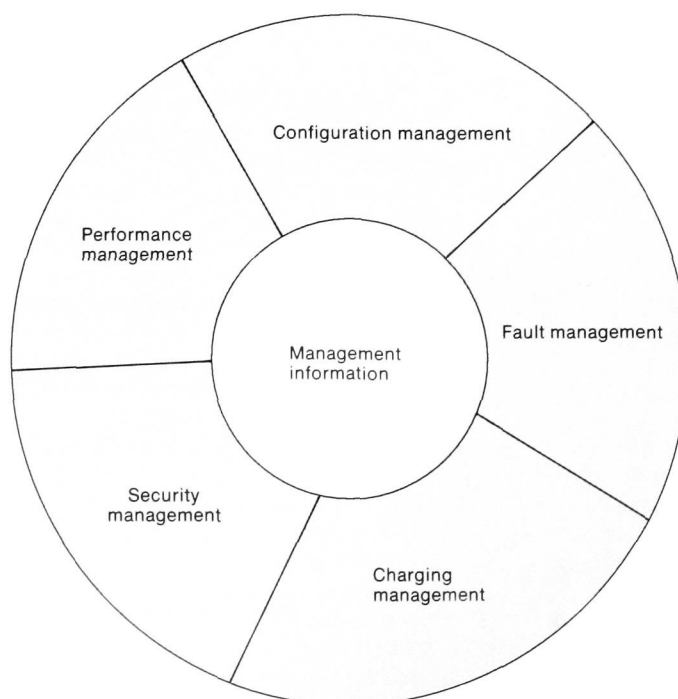

Fig. 7
FMAS functional areas according to TMN principles

FMAS calculates a new optimal routing for all paths/circuits affected by the fault. Then the appropriate orders are issued by FMAS to each individual network element, which performs the desired sequence of cross-connections.

FMAS is capable of restoring paths at one predefined bit rate level; that is, at one multiplexing level between 1.5/2 and 155 Mbit/s.

If requested by the operator, the protection routing function can be set to a mode that requires the rerouting to be acknowledged before being effected by FMAS.

Fault management
FMAS fault management functions minimize the impact of failures on service through functions for fault detection, identification and localization. This support enables the operator to make decisions on corrective action with a minimum of delay.

Alarm supervision and monitoring
FMAS checks the operating status of
– the FMAS system
– network elements
– paths and circuits
– the links between FMAS and the network elements.

FMAS requests and receives from the network elements alarm signals that indicate status changes, such as loss of signal, synchronization error and high bit error rate. On the basis of these reports, FMAS determines the nature and severity of a fault and informs the operator. All alarms are logged, together with the operator's confirmation and comments.

Alarm analysis and fault localization
FMAS analyses alarms in order to be able to identify and locate network failures. Alarm filtering is used to trace the source of a major alarm by separating primary and secondary alarms. For example, when a transmission fault results in many network elements sending alarm indication signals (AIS), FMAS analyses these signals to localize the source of the fault.

Alarm reporting
FMAS presents alarm reports, which can be tailored to the requirements of the network operator. Reports can be presented via terminals and printers or be displayed graphically on workstation VDUs.

Tests
Fault diagnosis and localization is facilitated by FMAS functions that automatically order network elements to carry out tests. These tests are chosen on the basis of continual analysis of the alarm situation. Actions that can be ordered include: testing of circuits between FMAS and network elements or of the latters' hardware and software, loopback of traffic, injection of error signals to test alarm functions. Tests can also be initiated on operator command.

Performance management
FMAS performance management functions analyse the quality of service and overall performance of the transport network.

Performance monitoring
The status and performance of the network are monitored continuously by the network elements, from their own perspective. FMAS requests data from the
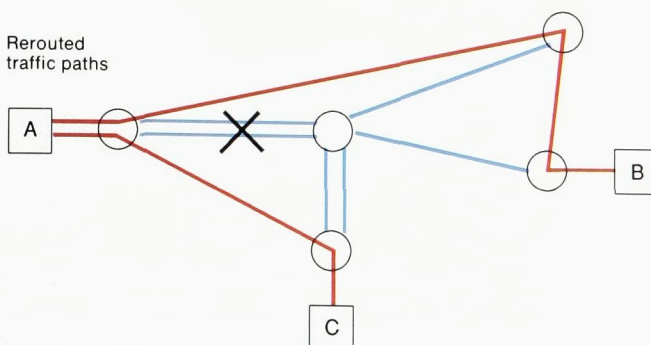
Fig. 8
Automatic protection routing controlled by FMAS. The necessary rerouting is performed in DXC systems on command from FMAS

A, B, C   Circuit terminations

⸻   Traffic-carrying line

⸻   Unused line

✕   Circuit break

Original traffic paths
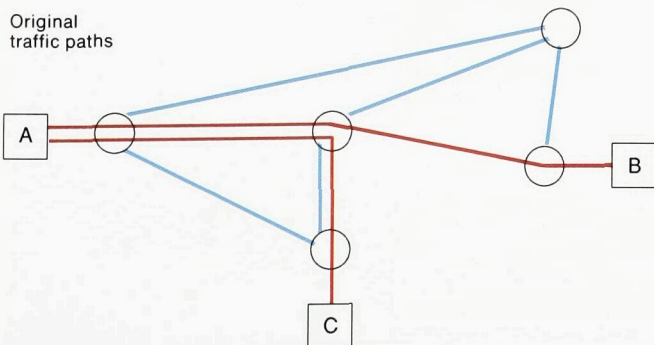
Rerouted traffic paths

network elements and collects and stores this information for further processing. FMAS produces reports on path/ circuit end-to-end performance: bit error rate, unavailable seconds, errored seconds, etc.

Network performance analysis
FMAS network performance analysis functions produce information on various issues from data collected from the network elements. Causes for intermittent traffic fault conditions and other types of troublesome degraded performance can be analysed and localized to a specific equipment, transport network section, etc. This will help operators to direct preventive maintenance to where it is needed.

Performance reporting and presentation
FMAS can produce performance reports on command from operators, on schedule or when a preset threshold value for some parameter has been exceeded. Performance reports can be tailored to the operator's requirements. They can be presented on terminals, printers or graphically on workstation VDUs.

Security management
FMAS functions for security management protect the resources and services of the transport network, for example:

Transaction security
FMAS allows for assigning different levels of authority and user profiles to different operators. Thus, operators' access can be limited to those FMAS functions which they have been trained to handle and which concern their individual tasks.

Data communication security
Commands from other FMASs and external operations systems are checked as regards the authority of the source, the validity of the command and consistency with previously received commands.

MANAGEMENT OF LEASED LINES
TMOS/FMAS supports management of leased lines of various bandwidths in a number of functional areas, such as:
− Configuration management
− Fault management
− Performance management
− Security management
− Charging
− Customer control.

FMAS provides a central resource for managing leased-line services of various bandwidths; their provision, the collection and analysis of data relating to quality of service, security management and automated billing and accounting.
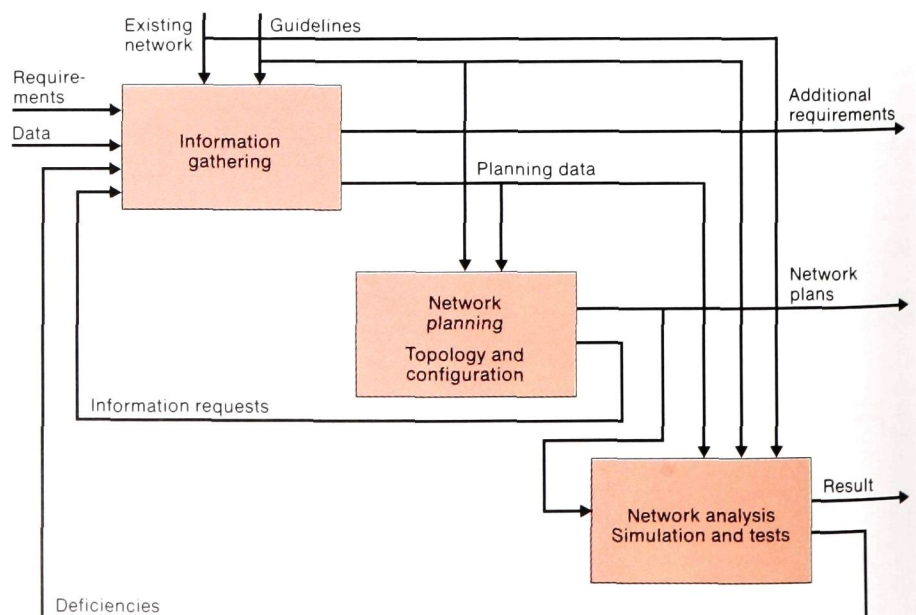
Customers can be assigned different

Fig. 9
FMAS Network Planning Tool

priority levels in the network, which allows the network operator to offer premium-quality services to subscribers who require them.

Customer control

Network operators can offer their more advanced customers control of leased lines. Such a customer, usually a large company with geographically distributed units, is given its own "logical" FMAS which controls the company's transport network including all leased lines. The customer only sees and manages his own virtual private network and has no detailed knowledge of the complete transport network.

A first step towards complete customer control is to provide the customers with network information, such as
- the results of performance monitoring, e.g. quality-of-service parameters
- fault management data, e.g. alarms in the virtual private network
- an overall view of their "own" network.

The right to information can be provided as an individual service, separate from that which permits the customer to make changes in the network by means of commands.

NETWORK PLANNING TOOL

The FMAS Network Planning Tool, NPT, is an efficient aid for network operators in planning transport networks with a high degree of complexity, fig. 9. The main applications are described here.

Network design
The network planner can plan and optimize a new network, or modify or extend an existing network.

Analysis, test and simulation of network behaviour
The planner can determine the degree of utilization and efficiency of a network. He can also simulate different fault situations or additional traffic load and in this way determine the survivability margin of the network.

NPT environment
The NPT provides a graphics, menu-driven user interface, similar to that of FMAS. This facilitates an FMAS operator's interpretation of the network planning environment, fig. 10.

Fig. 10
The FMAS graphics user interface, which is based on Open Look, supports the use of the Network Planning Tool (NPT) included in the system. In this example the NPT is used to display the current network diagram (View), to input current network data (File) and to calculate (Analysis) the economically optimum path (Shortest Path) between two network nodes. Other calculations give the maximum transport capacity and show potential bottlenecks

▬▬▬▬ Shortest Path
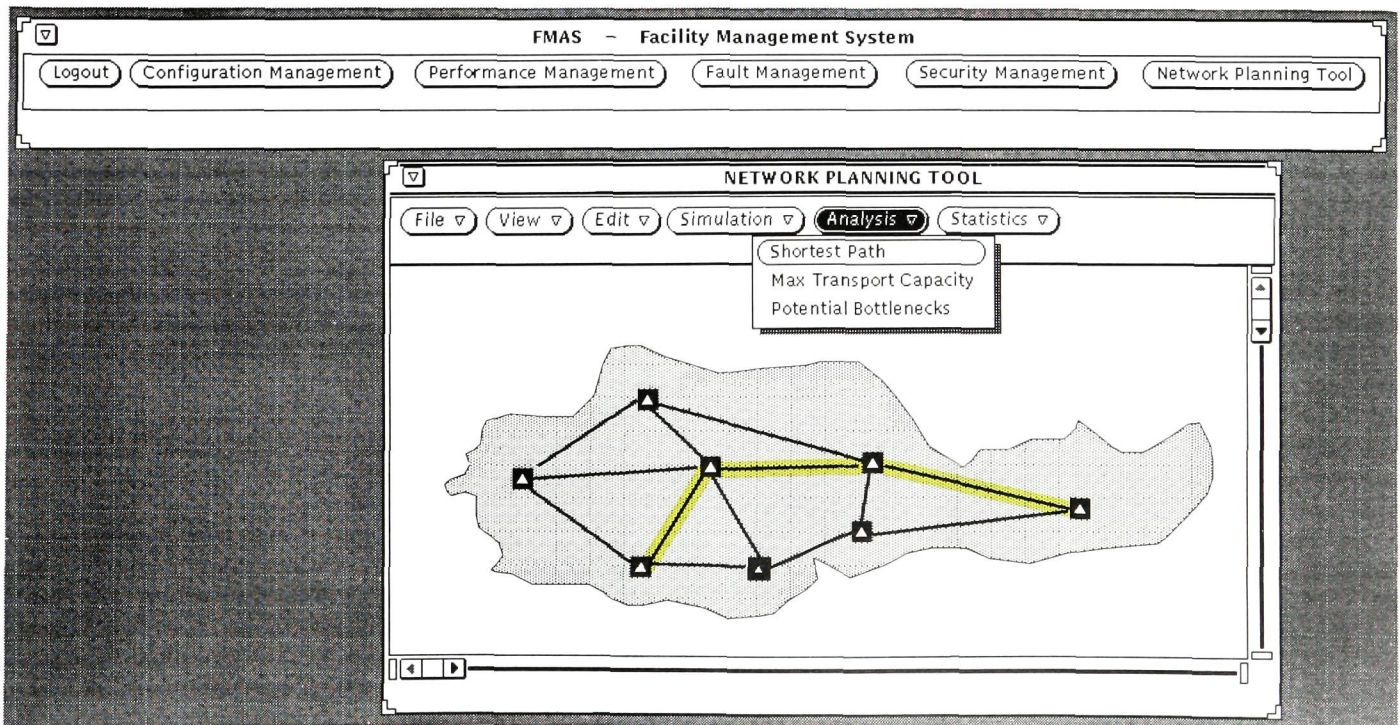
The NPT can be connected to a network operating FMAS, thus allowing the network planner to easily transport all necessary information on-line from the continuously updated FMAS network database to the NPT. The network planner can also send planning results from the NPT to the operating FMAS. The NPT can also be run, independently of an operating FMAS, on its own separate computer system, CAP.

Network control architecture

Local, regional and national control levels

FMAS management functions can be divided into different hierarchic function levels: local (FMAS/L), regional (FMAS/R) and national (FMAS/N), fig. 11. Physically, this functionality may be integrated into one, or divided into a number of operations sites. For example, in some implementations FMAS/N may have only a rudimentary picture of the network; all detailed administration of individual network elements is left to the lower-level FMAS/R and FMAS/L systems. In other implementations all FMASs may have access to the same detailed information.

Advantages of a hierarchic control structure

Operations support systems – such as FMAS – that permit a hierarchic control

structure offer a number of major advantages.

Decentralization for greater operational reliability
The impact of a system breakdown of a centralized (national) support system is considerably reduced. In such a case the lower-level support systems maintain control over their networks.

Hierarchic control structure of a flat transport network
In principle, each geographical area of a large network can be planned and operated individually, which reduces administration complexity. Different FMASs can interwork to coordinate activities that concern more than one geographical area, fig. 12.

A flat transport network is not layered; all resources in the network are placed in the same physical layer regardless of bit rate, type of network element, etc. The network is partitioned into regions of varying sizes, which in turn can be partitioned into subregions at a lower logical level. The regions, with the associated operations support systems, may preferably coincide with the geographical areas of responsibility in the network operator's organization.

Hierarchic control structure of a layered transport network
A transport network can be divided into layers, fig. 13, primarily with respect to the bit rates used. Each layer can be provided with its own operations support system and be controlled and planned independently of the other layers. Such an arrangement has all the advantages described above.

Fig. 13 shows a simplified SDH transport network divided into three layers (logical levels).
- A national network based on STM-16 systems for 2.5 Gbit/s, possibly with some additional STM-4 systems for 620 Mbit/s
- Several regional networks, ring or mesh shaped, based on STM-4 systems with some additional STM-1 systems for 155 Mbit/s
- Several local networks, ring or mesh shaped, based on STM-1 systems.

All three layers may contain different

Fig. 11
Example of the division of the overall FMAS operations support function into hierarchic levels

|	
FMAS/N	Centralized national FMAS for control of one or more regional transport networks
FMAS/R	Regional FMAS for control of one or more local transport networks
FMAS/L	Local FMAS for control of one or more individual network elements in a network node
NE	Network Element
OS	External Operations System connected to FMAS
Q	Q-interface in TMN in accordance with CCITT
DCN	Data Communications Network
LCN	Local Communications Network
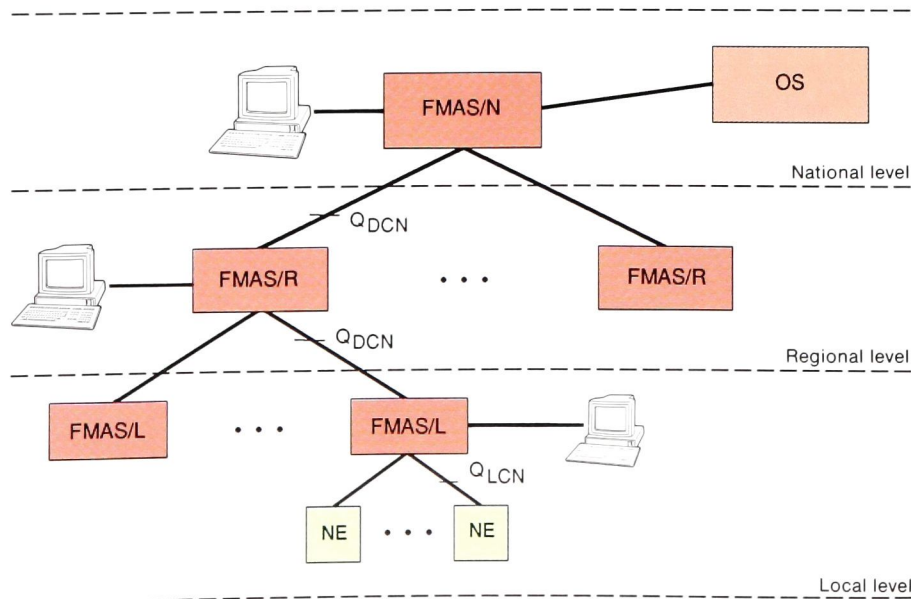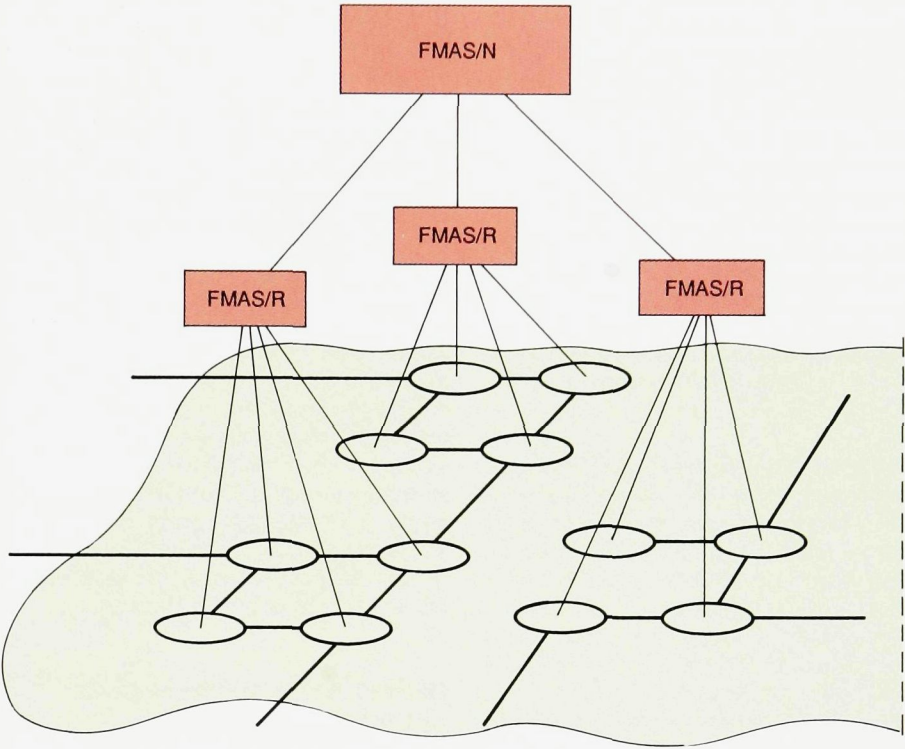
Fig. 12
Example of a "flat" transport network with a
hierarchic control structure

◯   Digital cross-connect system

National transport
network (2.5 Gbit/s)

Regional transport
networks (620 Mbit/s)
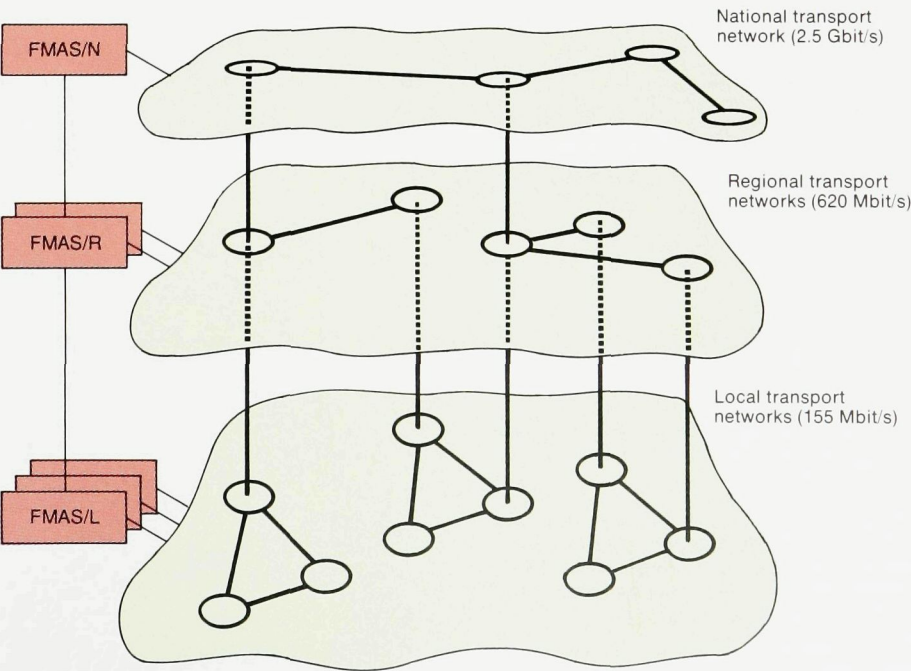
Local transport
networks (155 Mbit/s)

Fig. 13
Example of a layered transport network with a
hierarchic control structure.
Typical bit rates for the different layers are
indicated

◯   Digital cross-connect system

types of DXC system, whereas AddDrop Multiplexers (ADM) are used primarily in the regional and local transport networks.

In a hierarchic transport network with extremely reliable links between the layers (protection switching system 1:1 is used), each layer can be given its own operations support system that is independent of other layers. Protection routing is then best arranged separately within each layer and is controlled by the FMAS belonging to the layer. Different FMASs interwork in order to simplify the problems associated with the provisioning of switching paths between subscribers belonging to different FMAS regions. The example given shows the strong relationship between the division of the transport network into layers and the levels of operations support.

Flexibility of the SDH Management Network (SMN)
The new network elements, the Digital Cross-Connect Systems and SDH systems (Add/Drop Multiplexers, etc), can be controlled by FMAS through a data communications network and through

Embedded Control Channels (ECC) in the SDH transport network.

FMAS is capable of monitoring and controlling various types of SDH network structure in a flexible way. Fig. 14 shows an example with standardized Q-interfaces: Q/DCN and Q/LCN interfaces between FMAS and DCC/SDH network elements, and Q/ECC interfaces between SDH network elements. Control information to a network element, with no direct DCN link from FMAS, reaches its destination network element through the ECC after having passed other network elements.

Step-by-step implementation of SDH networks with operations support
The flexibility of FMAS and the control systems in Ericsson's various network elements permit different strategies for the implementation of transport networks with the associated operations support functions. A major advantage of FMAS is that the support for PDH networks can be integrated into the overall operations support network.

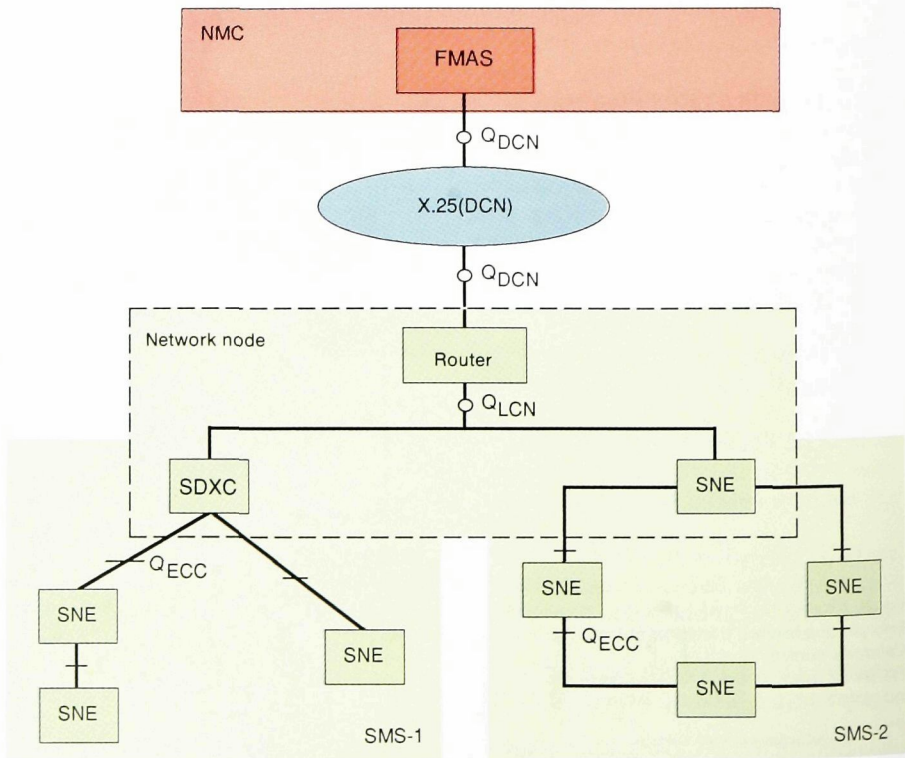The following example shows step-by-step implementation of a national trans-

Fig. 14
Example of an SDH Management Network (SMN) for control of DXC/SDH network elements from FMAS. A star and a ring SDH Management Subnetwork (SMS-1 and SMS-2) are indicated

NMC   Network Management Centre
SNE   SDH Network Element
ECC   Embedded Control Channel (in SDH circuit)
SMS   SDH Management Subnetwork

port network with operations support, fig. 15. The network is divided into two layers, the long-distance network and regional networks. The latter also include metropolitan networks. The following steps are proposed.

Step 1
SDH line systems are introduced into the long-distance network, and ADM rings are built up in metropolitan networks. An FMAS/LD for the long-distance network managing the SDH line systems (STM-4 and STM-16) is implemented, providing for basic functionality, such as collection of alarm and performance data.

The ADM ring networks are equipped with local FMAS/L systems (not shown in fig. 15). FMAS/L contains functions for collecting alarm and performance data and also functions that support traffic routing in the ring networks.

Step 2
DXCs are introduced into the long-distance network, primarily for protection routing. The FMAS/LD system is upgraded with functions to support the management of DCC 4/4 (STM-1). Specific DXC functions and applications of

FMAS, such as protection routing, are tested and put into operation.

Step 3
Metropolitan networks are growing with the introduction of more and larger ADMs and DCC 4/1. More local FMAS/L systems are introduced and/or upgraded to support DCC 4/1 as well. A regional FMAS/R system is introduced to serve as a superior management system throughout a Regional/Metropolitan area. This system also provides protection routing functions in this area.

Step 4
Regional and long-distance networks continue to grow, with further introduction of all types of network element. The various FMASs for local, regional and long-distance networks are gradually upgraded with respect to processing capacity and functionality. A superior FMAS function, FMAS/N, is introduced to provide coordination between FMASs and end-to-end control of circuits throughout the network.

This and other introduction strategies are possible, taking advantage of the heriarchic control structure of FMAS and Ericsson's flexible SDH network elements.

Fig. 15
Example of a layered transport network with operations support.
The network is divided into two layers, both of which contain DXC nodes. One layer contains the long-distance network and the other regional networks, some of which may be metropolitan networks

FMAS/LD   FMAS supporting the long-distance network

○   Digital cross-connect system
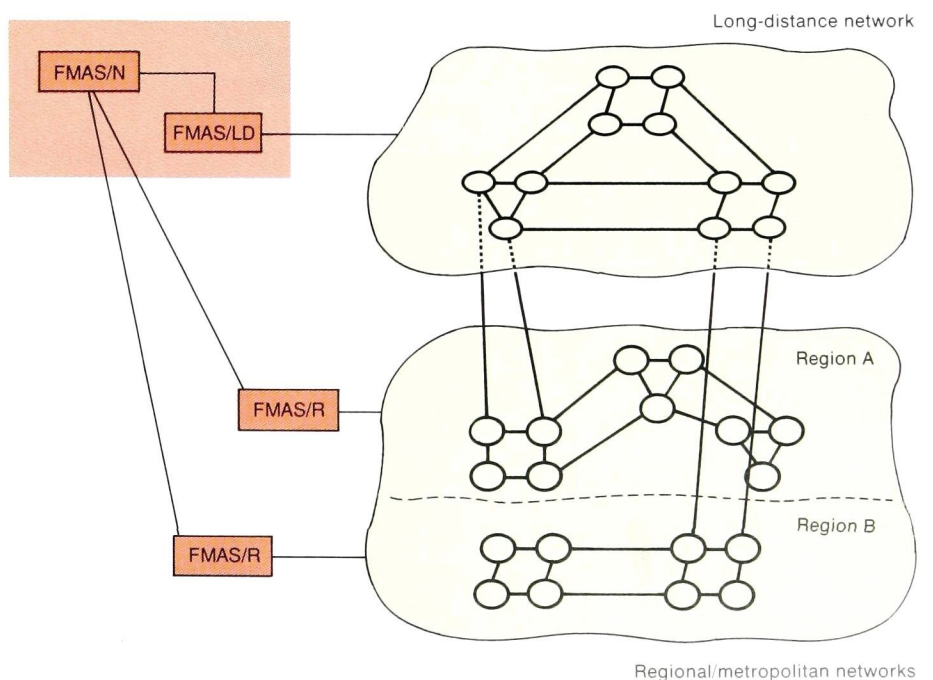
FMAS system architecture

General

FMAS configurations can be designed to match the individual transport network requirements as regards operations support, network size, etc. The general FMAS system architecture comprises a number of FMASs, communicating via services defined in the TMN/Q/DCN and LCN interfaces over Data Communications and Local Communications Networks, fig. 11.

For communication with other FMASs, or operations systems from other vendors, FMAS provides a TMN/Q protocol. (TMN-Q covers services from all layers – 1-7 – in the OSI Reference Model. The X.25 protocol is used for layers 1-3 in this model).

For each specific FMAS implementation the system can be designed for the best balance of cost versus reliability. Different versions are available, including a fault-tolerant hardware variant. FMAS can be configured to operate economically from small to large numbers of network elements.

System configuration

The FMAS hardware configuration can flexibly meet the network operator's requirements in order to achieve proper functionality and performance at the specific site. Processor capacity, memory size, number of communications interfaces and workstations etc. are all scalable. Some examples are given below.
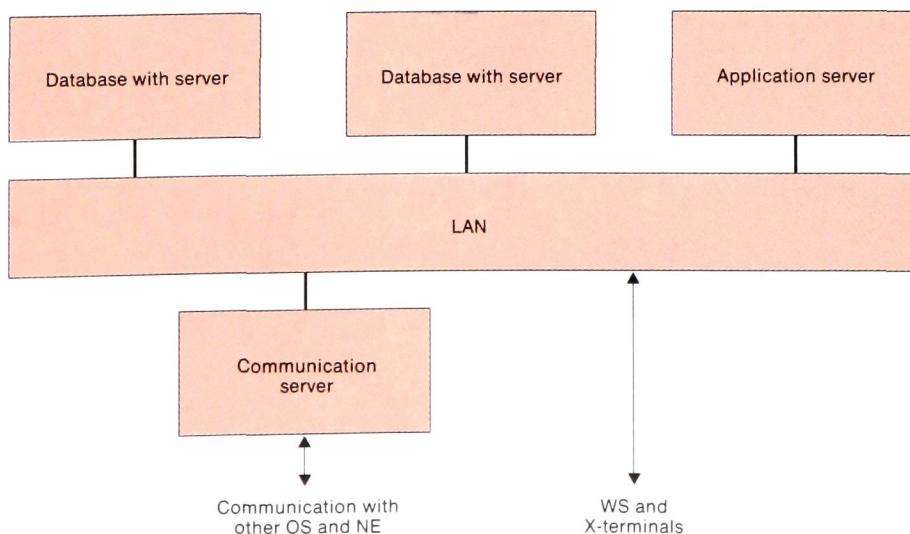
A typical FMAS implementation consists of a multi-computer configuration comprising a number of servers, fig. 16.

The *database server* has two discs attached which can be used in what is called a mirror-write configuration, thus increasing safety in case of failure on one disc. Different disc sizes are available. In the example shown in fig. 16 the database server also acts as a file server for the other computers connected to the LAN cluster.

The *application server* can be dimensioned for the intensive computing that is required in certain FMAS applications.

The *communication server,* which may hold additional circuit boards, e.g. for the X.25 interfaces, handles external communication and closely related tasks.

Each workstation includes a graphics colour display and a mouse (pointing device) for use by the operator. FMAS provides an easy-to-use menu system conforming to the Open Look specification.

Configurations for large systems
There is no maximum configuration of the FMAS operations system, which means that each installation can be adapted according to site-specific conditions. Demanding applications may need a greater number of servers than those shown in fig. 16.

Several workstations and X-terminals for FMAS operators' interaction are available, one of which can be used as a system console.

Configurations for small systems
Three different configurations are available for small FMASs:
A data file server with a graphics VDU and at least one disc store
> The single server handles databases, communication and FMAS applications
A workstation with disc store
> The CPU capacity is on par with that of a file server, but the disc capacity and internal memory size are limited although entirely adequate for most small configurations

Fig. 16
A typical FMAS hardware configuration, comprising a number of computers in servers and workstations connected via an LAN

LAN   Local Area Network
X   Graphics terminal
WS   WorkStation

Personal computer
If a PC is used, the system performance must be analysed in each individual case.

Remote control
FMAS can be controlled remotely from a stand-alone workstation connected via a DCN. The workstation can be configured in the manner described above for small configurations.

User interface
Workstations for graphics presentation in accordance with the X Window System, an industry *de facto* standard for graphics terminals[5], can be connected to the operators' user interface. The interface is designed so as to minimize the risk of operator errors, thus making operations support easy and cost-effective. Some characteristic features of the interface are:

Task-oriented menus
FMAS users work in a user-friendly environment based on the Open Look User Interface, providing task-oriented menus and forms tailored to each user's unique job requirements. It is an application design task to define the menus and forms, using tools provided by CAP.

Multi-access
Using FMAS menus, a user can perform several tasks, for one or several FMASs or other operations support systems. Multiple active windows allow a user to start an operation in one window and to continue in another with a minimum of effort and knowledge of background operations.

Graphics presentations
FMAS displays network status, reports and maps in a user-friendly graphics format, fig. 17.
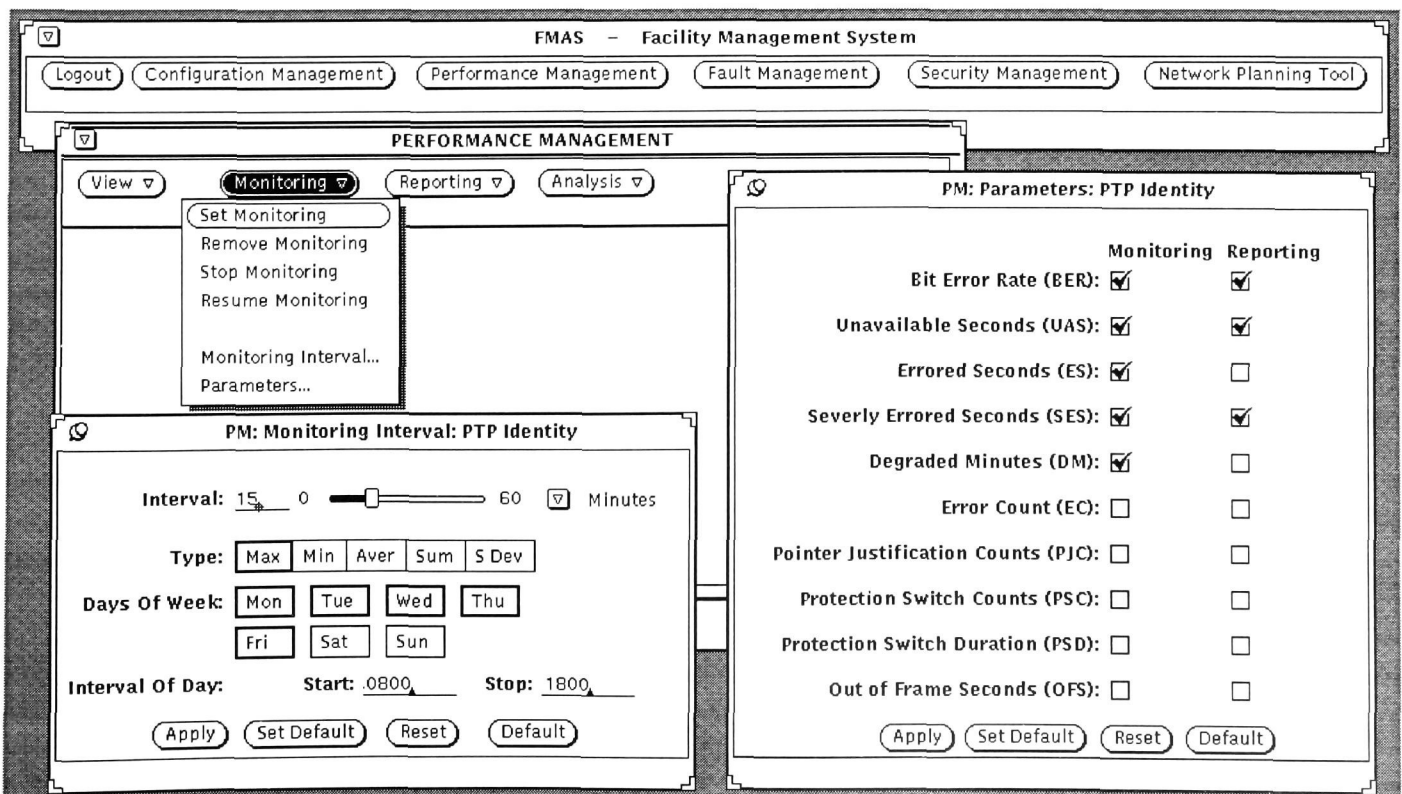
On-line help
When the Help key is pressed from any menu screen, an FMAS "help window" appears in a separate window, giving information at the relevant level of detail.

FMAS – an Applications System of the TMOS family

FMAS belongs to the TMOS family and

Fig. 17
The FMAS graphics user interface, which is based on the Open Look industry standard, supports five functional areas, which are shown at the top in the main FMAS window.
The area *Performance Management* has been chosen from the menu, and the associated main window is displayed. The relevant object is selected from the View items and displayed graphically in suitable detail, but in this figure it is hidden behind another window. The next menu item chosen is Monitoring, and the associated pull-down menu is shown. From this menu, the windows Parameters and Monitoring Interval have been chosen. In this example the displayed parameters concern a Path Termination Point (PTP).
The desired alternatives are selected and activated by the operator with the aid of the mouse

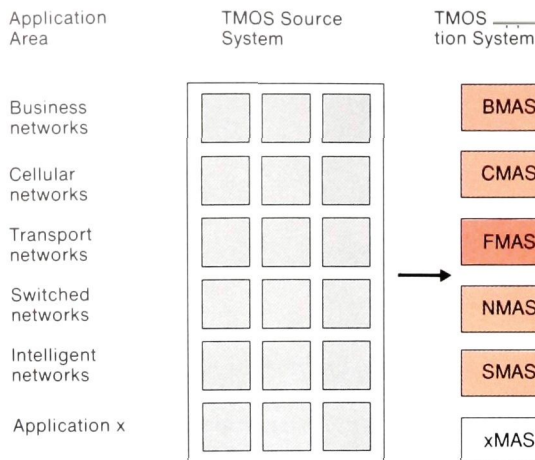| Application Area	TMOS Source System	TMOS ___ tion System
Business networks		BMAS
Cellular networks		CMAS
Transport networks		FMAS
Switched networks		NMAS
Intelligent networks		SMAS
Application x		xMAS

Fig. 18
TMOS application systems can be created by selecting and combining Application Units (AU) from the TMOS source system

benefits from all the characteristic features of the family as described below.

Integrated management of a telecommunications network

Technology advances

TMOS belongs to the next generation of operations support (operation and management) systems that are focusing on new and traditional telecom services in an competitive environment. It covers both network and service management.

The latest advances in the field of information technology have been employed when developing TMOS operations support systems and related functions, in terms of reliability, manageability, capacity and user friendliness, etc.

Physically, TMOS consists of a multi-computer configuration of workstations and servers in a local area network (LAN). Operations support systems of the TMOS family can be employed by all types of operation and maintenance centre (OMC and NMC).

Integrated operations support

The concept of integrated operations support means efficient management, within one concept/system, of the increasing complexity of operations in a multi-service and multi-vendor telecommunications environment.

The TMN Q-interface standards under development in different standardization bodies will pave the way for inte-

grated operation and maintenance. TMOS will fully support this interaction process − from present proprietary interfaces to open interfaces connecting different network elements and operations support systems.

Terms and definitions

TMOS comprises products that can be combined to meet the operations support requirements for different classes of applications, and a system for development of new functions and applications.

TMOS − source system and application systems

TMOS is a source system out of which different application systems can be created by combining selected TMOS building blocks (Application Units).

A specific combination of building blocks that is selected, tested and delivered is called a TMOS Application System, fig. 18.

A central part of each TMOS application system is a relational database containing a model of the supported network. The model is continuously updated, with information from the network elements − e.g. alarms − and with commands from and actions taken by the network operation and maintenance staff. Thus, the network model reflects the current status of the supported network.

Management application systems

At present, the following classes of TMOS Management Application Systems (MAS) are defined:

BMAS Business Management System for centrex and virtual private networks

CMAS Cellular Management System for mobile telecommunications networks

FMAS Facility Management System for transport networks

NMAS Network Management System for switched networks, e.g. AXE switching and SS7 signalling networks

Fig. 19
TMOS main building blocks
FMAS, for example, comprises Application Units (AU) dedicated to transport network support, as well as applicable AUs of the CAP and TAP platforms

AU   Application Unit
TAP   Telecommunication Application Platform
CAP   Common Application Platform

BMAS AUs	CMAS AUs	FMAS AUs	NMAS AUs	SMAS AUs	xMAS AUs

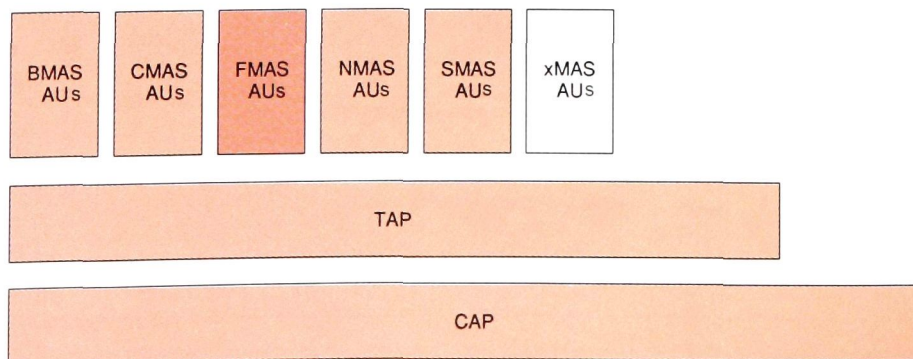| TAP |
|---|

CAP

Fig. 20
TMOS in a multi-vendor environment

TMOS/I TMOS system that integrates operations support for several areas, e.g. networks or network parts with equipment from different vendors
TMOS/E TMOS system for support of Ericsson network elements
O-OS Operations support system for network elements not supplied by Ericsson. O-OS may be a TMOS system
O-NE Network elements not supplied by Ericsson
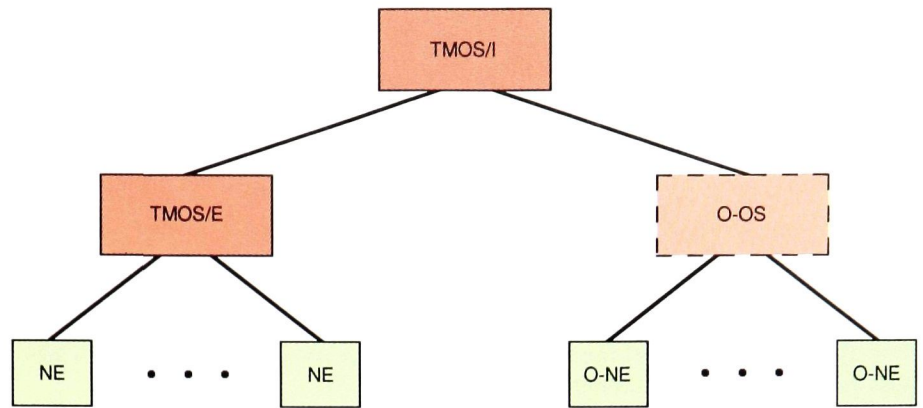
SMAS Service Management System for intelligent networks.

xMAS denotes any future TMOS application system not yet defined.

Application Units
An MAS is a combination of Application Units (AU), some of which may be identical with those of other MASs. An AU may contain optional functions and alternative performance data.

Platforms and programming tools
TMOS programming (i.e. design) capabilities are expressed with the TMOS platform concept. A TMOS platform provides an open, layered infrastructure for the implementation of application functions, fig. 19. 'Open', in this context, means that such functions can be developed by Ericsson or by network operators.

TMOS has optional programming tools; a set of Application Programming Interfaces (API), suitable for C++ programming. The following functions can be implemented with the aid of API and added to the TMOS standard programs:
– Extended or new applications
– Gateway functions towards computer systems for administrative applications
– Interfaces for connection of network elements not supplied by Ericsson.

The programming tools comprise a set of AUs including programming rules, a number of APIs, a test environment and a list of suitable programming tools. An API contains functions for external communications, command handling, file management, time activation, log handling, authorization checking, and access to preprocessed data.

The following platforms are now available, fig. 19:
CAP Common Application Platform or "the computer system"
CAP defines the computing environment that ensures an open and flexible architecture. CAP supports the use of X/Open, UNIX System V, the database interface language SQL, C++, X Window System
TAP Telecommunication Application Platform or "the information system"
TAP provides a network model database that stores the attributes of each network element and also alarms and commands. User (operator) interfaces to network facilities, etc, can also be included.

Characteristics and benefits
One system – many applications
TMOS is a modular system. Different application systems can be created by combining a wide range of Application Units.

This modularity and one-system feature will provide the users with specific means to enhance operation, but without the disadvantages of increasing the number of different systems.

System interworking
The modular structure of TMOS also means that two or more application systems, such as FMAS and BMAS, can co-exist and interwork on the same hardware and software platform while still operating as independent applications.

Networking
The TMOS concept provides flexible allocation and use of functions and resources within and between interconnected TMOS Application Systems. For example, status reports can be created by processing data from different TMOS systems and their supported networks, fig. 2.

The benefits of networking between TMOS systems can be applied to different modes of operation. Strategically, this networking may provide a competitive edge to an operator's ability to maximize network and service efficiency, and to generate revenues.

Support of a multi-vendor environment
TMOS programming tools can be used to adapt TMOS to network elements and operations support systems from other vendors, fig. 20. TMOS provides inter-

faces that conform to TMN recommendations/specifications defined by CCITT, ANSI and ETSI, i.e. X.25, ACSE/ROSE, CMISE/CMIP and FTAM.

The ability to handle equipment of different manufacture contributes to the realization of integrated network management with all its advantages, such as high quality of service, fast service provisioning and staff efficiency.

Open application environment based on standards
The TMOS system architecture is prepared for the management of new and future services and network concepts, and for the integration of new software and hardware technology. This is due to the open system architecture and the use of internationally agreed standards.

Portability
The division of the TMOS system into three separate components – CAP, TAP and application – means that any component can be improved or exchanged independently. Industry standards are applied throughout when designing TMOS and, hence, the system software as a whole can be transferred between a number of different hardware platforms, enabling new technology to be introduced into TMOS systems.

Tailored adaptations
The use of standards such as X/Open and SQL makes it possible for network operators to tailor their own adaptations on-line in existing application systems. (The programming tool API is not necessary for this purpose.)

Scalability
TMOS offers configurations that meet different requirements for capacity and reliability. Resources can be adapted to both the network size and the number of users.

Reliability and availability
High reliability requirements can be met by the use of fault-tolerant computers. FMAS also permits duplication to geographically separated centres with executive and standby operation. In this way, operations support is protected against the effects of catastrophic failures.

Consistent operations support environment
The TMOS concept, and the similarities between the various TMOS application systems, enable the operating company to handle different types of network and network element in a homogenous way. This simplifies training of staff and enables them to cover a wider range of tasks. The layered concept and the portability of TMOS application systems also enable the operating company to establish a consistent hardware and software environment as far as network management systems are concerned, resulting in simplified purchasing procedures and lower maintenance costs.

User-friendly man-machine interface
The use of modern workstations for the operator positions brings about a whole new way of working with network management systems, in a manner that is efficient, logical and easy to learn. All TMOS Application Systems offer user interfaces based on graphics, menus and forms, resulting in high staff performance.

Summary
The Facility Management System FMAS is Ericsson's response to the new and rapidly changing needs of efficient operations support for transport networks. FMAS, together with Ericsson's highly flexible digital cross-connect systems and SDH network elements, provide a competitive state-of-the-art edge to operators' ability to maximize network utilization, and to generate revenues from supported leased-line services, with controlled quality and short lead time. Typical expanding applications to be supported are: communication between private nodes, computer-to-computer communication, wide area networks, and video conferences.

FMAS is the cornerstone of Ericsson's new Transport Network Management Architecture, focusing on operations support. This architecture creates new facilities for totally integrated, cost-effective operations support based on the following elements:
– Firstly, FMAS offers a total network management approach through its ability to support new and existing transport network products, in cooperation with other TMOS or other vendors' operations support systems
– Secondly, the new network elements – the digital cross-connect systems and SDH systems (Add-Drop Multiplexers, etc) – can be effectively controlled by FMAS via a data communications network, and via Embedded Control Channels (ECC) located within the SDH transport network
– Thirdly, the Transport Network Management Architecture is uniquely supported by the openness of the TMOS/FMAS system concept; FMAS meets the current development of TMN standards and interfaces. It is built on a computing platform (CAP) on which functions/features can be developed, by Ericsson or by network operators, allowing the system to be adapted to present and future requirements.

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