Superseded by a more recent version

INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

G.782

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

(01/94)

GENERAL ASPECTS OF DIGITAL TRANSMISSION SYSTEMS
TERMINAL EQUIPMENT

TYPES AND GENERAL CHARACTERISTICS OF SYNCHRONOUS DIGITAL HIERARCHY (SDH) EQUIPMENT

ITU-T Recommendation G.782

Superseded by a more recent version

(Previously "CCITT Recommendation")

FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation G.782 was revised by ITU-T Study Group 15 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 20th of January 1994.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

CONTENTS

Recommendation G.782

TYPES AND GENERAL CHARACTERISTICS OF SYNCHRONOUS DIGITAL HIERARCHY (SDH) EQUIPMENT

(revised 1994)

1 Introduction

1.1 Scope

Recommendation G.781 gives the structure of Recommendations on SDH equipment. This Recommendation gives an overview of the functions of SDH equipment, examples of multiplexer and cross-connect equipment types and general performance requirements.

The possibilities of add/drop features, mixed payloads and flexible tributary/channel associations in SDH equipment make it difficult to provide a Recommendation which is unambiguous while remaining generic enough not to constrain implementation. To overcome these difficulties, the "functional reference model" approach has been adopted. Therefore this series of Recommendations describes the equipment in terms of various functional blocks. This logical partitioning is used to simplify and generalize the description. It does not imply any physical partitioning or implementation.

Only external interface requirements will be specified. For payloads these will conform to either STM-N (according to Recommendations G.707, G.708 and G.709) or Recommendation G.703. The interface to the telecommunications management network (TMN) will conform to Recommendation G.773. The points between functional blocks exist only as logical reference points and not as internal interfaces; there is therefore no interface description or interface specification associated with these points.

1.2 Abbreviations

For the purpose of this Recommendation, the following abbreviations are used:

AIS	Alarm Indication Signal
AU	Administrative Unit
AUG	Administrative Unit Group
C	Container
DCC	Data Communications Channel
ECC	Embedded Communications Channel
FEBE	Far End Block Error
FERF	Far End Receive Failure
HCS	Higher order Connection Supervision
HO	Higher Order
HOA	Higher Order Assembler
HOI	Higher Order Interface
HOVC	Higher Order Virtual Container
HP	Higher order Path
HPA	Higher order Path Adaptation
HPC	Higher order Path Connection
HPOM	Higher order Path Overhead Monitor
HPT	Higher order Path Termination
HUG	Higher order path Unequipped Generator
LCS	Lower order Connection Supervision
LO	Lower Order

LOI	Lower Order Interface
LOVC	Lower Order Virtual Container
LP	Lower order Path
LPA	Lower order Path Adaptation
LPC	Lower order Path Connection
LPOM	Lower order Path Overhead Monitor
LPT	Lower order Path Termination
LUG	Lower order Unequipped Generator
MCF	Message Communications Function
MSA	Multiplex Section Adaptation
MSOH	Multiplex Section OverHead
MSP	Multiplex Section Protection
MST	Multiplex Section Termination
NNI	Network Node Interface
OHA	OverHead Access
PDH	Plesiochronous Digital Hierarchy
POH	Path OverHead
PPI	PDH Physical Interface
RSOH	Regenerator Section OverHead
RST	Regenerator Section Termination
SDH	Synchronous Digital Hierarchy
SDXC	Synchronous Digital hierarchy Cross-Connect
SEMF	Synchronous Equipment Management Function
SETPI	Synchronous Equipment Timing Physical Interface
SETS	Synchronous Equipment Timing Source
SOH	Section OverHead
SPI	SDH Physical Interface
STM	Synchronous Transport Module
TMN	Telecommunications Management Network
TTF	Transport Terminal Function
TU	Tributary Unit
TUG	Tributary Unit Group
VC	Virtual Container

1.3 Definitions

NOTE – The following definitions are relevant in the context of SDH-related Recommendations. For a more complete definition of the functional blocks, see Recommendation G.783.

1.3.1 Administrative unit (AU)

See Recommendation G.708.

1.3.2 Administrative unit group (AUG)

See Recommendation G.708.

1.3.3 Data communications channel (DCC)

See Recommendation G.784.

1.3.4 Embedded communications channel (ECC)

See Recommendation G.784.

1.3.5 Far end block error (FEBE)

See Recommendation G.709.

1.3.6 Far end receive failure (FERF)

See Recommendation G.709.

1.3.7 higher order connection supervision (HCS): The HCS function is the combination of an HUG and an HPOM, both of which are described below.

1.3.8 higher order path (HO, HP): In an SDH network, the higher order (HO, HP) path layers provide a server network for the lower order (LO, LP) path layers. The comparative terms lower and higher refer only to the two participants in such a client/server relationship. VC-1/2 paths may be described as lower order in relation to VC-3 and VC-4 while the VC-3 path may be described as lower order in relation to VC-4.

1.3.9 higher order assembler (HOA): The HOA function is the combination of an HPA and HPT function, both described below. It assembles lower order VCs into higher order VCs.

1.3.10 higher order interface (HOI): The HOI function is a combination of the PPI, LPA, and HPT functions described below. It interfaces with a PDH signal and maps it into a higher order VC.

1.3.11 higher order path adaptation (HPA): The HPA function adapts a lower order VC (VC-1/2/3) to a higher order VC (VC-3/4) by processing the TU pointer, which indicates the phase of the first byte of VC-1/2/3 POH relative to the first byte of VC-3/4 POH, and assembling/disassembling the complete VC-3/4.

1.3.12 higher order path connection (HPC): The HPC function provides for flexible interconnection of higher order VCs (VC-3/4).

1.3.13 higher order path overhead monitor (HPOM): The HPOM function monitors the path overhead in a higher order VC without terminating the path or modifying the POH.

1.3.14 higher order path termination (HPT): The HPT function terminates a higher order path by generating and adding the appropriate VC POH to the relevant container at the path source and removing the VC POH and reading it at the path sink.

1.3.15 higher order path unequipped generator (HUG): When there is no valid higher order VC at an output of the HPC function, the HUG function generates a higher order VC with undefined payload and valid POH, including a signal label set to the value "unequipped".

1.3.16 lower order connection supervision (LCS): The LCS function is a combination of an LUG and an LPOM function, both of which are described below.

1.3.17 Lower order path (LO, LP)

See higher order path above.

1.3.18 lower order interface (LOI): The LOI function is a combination of a PPI, LPA, and LPT function, described below. It interfaces with a PDH signal and maps it into a lower order VC.

1.3.19 lower order path adaptation (LPA): The LPA function adapts a PDH signal to an SDH network by mapping/de-mapping the signal into/out of a synchronous container. If the signal is asynchronous, the mapping process will include bit level justification.

1.3.20 lower order path connection (LPC): The LPC function provides for flexible interconnection of lower order VCs.

1.3.21 lower order path overhead monitor (LPOM): The LPOM function monitors the path overhead in a lower order VC without terminating the path or modifying the POH.

1.3.22 lower order path termination (LPT): The LPT function terminates a lower order path by generating and adding the appropriate VC POH to the relevant container at the path source, removing the VC POH and reading it at the path sink.

1.3.23 lower order path unequipped generator (LUG): When there is no valid lower order VC at an output of the LPC function, the LUG function generates a lower order VC with undefined payload and valid POH, including a signal label set to the value "unequipped".

1.3.24 Message communications function (MCF)

See Recommendation G.784.

1.3.25 multiplex section adaptation (MSA): The MSA function processes the AU-3/4 pointer to indicate the phase of the first byte of VC-3/4 POH relative to the first byte of STM-N SOH and assembles/disassembles the complete STM-N frame.

1.3.26 multiplex section overhead (MSOH): The MSOH comprises rows 5 to 9 of the SOH of the STM-N signal.

1.3.27 multiplex section protection (MSP): The MSP function provides capability for switching a signal between and including two MST functions, from a working to a protection section.

1.3.28 multiplex section termination (MST): The MST function generates the MSOH in the process of forming an SDH frame signal and terminates the MSOH in the reverse direction.

1.3.29 overhead access (OHA): The OHA function provides integrated access to transmission overhead functions such as order wire.

1.3.30 Path overhead (POH)

See Recommendation G.708.

1.3.31 PDH physical interface (PPI): The PPI function converts a PDH interface signal into an internal logic level PDH signal, and vice-versa.

1.3.32 regenerator section overhead (RSOH): The RSOH comprises rows 1 to 3 of the SOH of the STM-N signal.

1.3.33 regenerator section termination (RST): The RST function generates the RSOH in the process of forming an SDH frame signal and terminates the RSOH in the reverse direction.

1.3.34 Synchronous digital hierarchy (SDH)

See Recommendation G.707.

1.3.35 synchronous equipment management function (SEMF): The SEMF converts performance data and implementation specific hardware alarms into object-oriented messages for transmission over the DCC(s) and/or a Q interface. It also converts object-oriented messages related to other management functions for passing across the Sn reference points.

1.3.36 synchronous equipment timing physical interface (SETPI): The SETPI function provides the interface between an external synchronization signal and the synchronous equipment timing source. The SETPI also provides a synchronization output signal for use by external equipment.

1.3.37 synchronous equipment timing source (SETS): The SETS function provides timing reference to the relevant component parts of an SDH equipment and represents the SDH network element clock.

1.3.38 Section overhead (SOH)

See Recommendation G.708.

1.3.39 SDH physical interface (SPI): The SPI function converts an internal logic level STM-N signal into an STM-N interface signal and vice-versa.

1.3.40 Synchronous transport module (STM)

See Recommendation G.708.

1.3.41 Telecommunications management network (TMN)

See Recommendation M.3010.

1.3.42 transport terminal function (TTF): The TTF function is a combination of an SPI, RST, MST, MSP, and MSA function, described above. It physically interfaces with an SDH signal and outputs a higher order VC.

1.3.43 Tributary unit (TU)

See Recommendation G.708.

1.3.44 Tributary unit group (TUG)

See Recommendation G.708.

1.3.45 Virtual container (VC)

See Recommendation G.708.

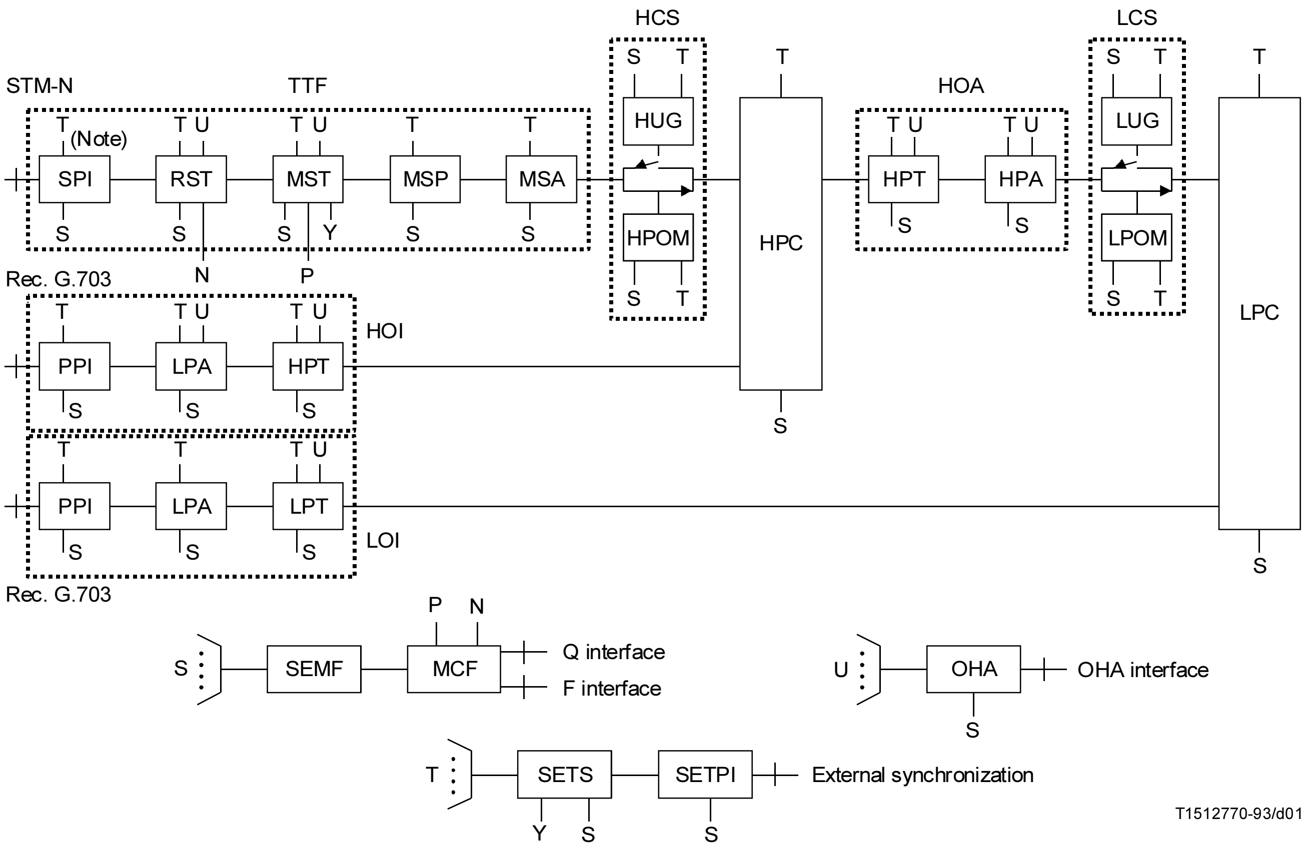
2 Overview of equipment functions

2.1 Multiplexing method

2.1.1 Generalized logical blocks

Figure 2-1 is a generalized logical block diagram showing basic and compound functions which may be combined to describe SDH equipment. It illustrates the steps that are required to assemble various payloads and multiplex them into an STM-N output. It does not represent a useful or practical network function. Examples of some configurations are given in clause 3.

A brief description of the signal flow between a Recommendation G.703 PDH interface and the STM-N output is provided in 2.1.2 and 2.1.3. Description of functions performed by each of the logical blocks in Figure 2-1 is provided in Recommendations G.783 and G.784. Further descriptions of the synchronous equipment management function (SEMF) and message communications function (MCF) are given in 2.2 and descriptions of the synchronous equipment timing source (SETS) and synchronous equipment timing physical interface (SETPI) are given in clause 4.



HCS	Higher order connection supervision
HOA	Higher order assembler
HOI	Higher order interface
HPA	Higher order path adaptation
HPC	Higher order path connection
HPOM	Higher order path overhead monitor
HPT	Higher order path overhead termination
HUG	Higher order unequipped generator
LCS	Lower order connection supervision
LOI	Lower order interface
LPA	Lower order path adaptation
LPC	Lower order path connection
LPOM	Lower order path overhead monitor
LPT	Lower order path termination
LUG	Lower order unequipped generator
MCF	Message communications function
MSA	Multiplex section adaptation
MSP	Multiplex section protection
MST	Multiplex section termination
N	Regenerator section DCC reference point
OHA	Overhead access function
P	Multiplex section DCC reference point
PPI	PDH physical interface
RST	Regenerator section termination
S	Management reference points: e.g. alarms, controls
SEMF	Synchronous equipment management function
SETPI	Synchronous equipment timing physical interface
SETS	Synchronous equipment timing source
SPI	SDH physical interface
T	Timing reference points
TTF	Transport terminal function
U	Overhead access reference points
Y	Synchronization status reference points

NOTE – SPI options:
- in-station electrical;
- in-station optical;
- inter-station optical.

FIGURE 2-1/G.782

Generalized logical block diagram

2.1.2 Signal flow G.703 input to STM-N output: multiplexing

- *PDH physical interface/lower order path adaptation* – Provides the appropriate G.703 PDH interface and maps the payload into the container as specified in Recommendation G.709.
- *Lower order path termination* – Adds the VC path overhead (VC-POH).
- *Lower order path connection* – Allows flexible interconnection of the VC-1/2/3.
- *Lower order path unequipped generator* – In the case of an "unused" connection, generates a valid VC-1/2/3 with a signal label value of "unequipped".
- *Higher order path adaptation* – Processes the TU pointer to indicate the phase of the first byte of VC-1/2/3 POH relative to the first byte of VC-3/4 POH and assembles the complete VC-3/4.
- *Higher order path termination* – Adds the VC-3/4 path overhead.
- *Higher order path connection* – Allows flexible interconnection of the VC-3/4.
- *Higher order path unequipped generator* – In the case of an "unused" connection, generates a valid VC-3/4 with a signal label value of "unequipped".
- *Multiplex section adaptation* – Processes the AU-3/4 pointer to indicate the phase of the VC-3/4 POH relative to the STM-N SOH. Byte-multiplexes the AU Groups (AUGs) to construct the complete STM-N frame.
- *Multiplex section protection* – Provides capability for branching the signal onto another line system for protection purposes.
- *Multiplex section termination* – Generates and adds rows 5 to 9 of the SOH.
- *Regenerator section termination* – Generates and adds rows 1 to 3 of the SOH; the STM-N signal is then scrambled except for row 1 of the SOH.
- *SDH physical interface* – Converts the internal logic level STM-N signal into an STM-N interface signal. This may be an in-station electrical signal, an in-station optical signal or an inter-station optical signal.

2.1.3 Signal flow STM-N input to G.703 output: demultiplexing

Except as noted below, the remaining operations are the inverse of those performed when multiplexing except that the lower order path adaptation function must provide a buffer store and smoothing circuit to attenuate the clock jitter caused by the multiplex process, pointer moves and bit stuffing (if applicable).

- *SDH physical interface* – Converts the interface signal into an internal logic level and recovers timing from the line signal.
- *Regenerator section termination* – Identifies the STM-N frame word, descrambles the signal, and processes rows 1 to 3 of the SOH.
- *Higher order path overhead monitor* – Monitors the VC-3/4 path overhead without modifying it.
- *Lower order path overhead monitor* – Monitors the VC path overhead without modifying it.

2.2 Operations, administration, maintenance and provisioning (OAM&P)

2.2.1 Overhead applications

Recommendation G.708 specifies bandwidth allocated within the SDH frame structure for various control and maintenance functions. Two types of overhead are identified: Virtual Container Path Overhead (VC-POH) and Section Overhead (SOH).

2.2.1.1 POH application

Details of the functions provided by the POH are contained in Recommendations G.708 and G.709.

The VC-POH is generated and terminated at the point where the payload is assembled or disassembled. It is used for end to end monitoring of the payload and may transit several network elements. Some of the VC-POH is completely payload independent, while other parts of the VC-POH are used in specific ways according to the type of payload. In all cases, the VC-POH is independent of user information. Thus it may be monitored at any point within an SDH network to confirm network operation.

2.2.1.2 SOH application

The section overhead (SOH) is subdivided into regenerator SOH (RSOH) comprising rows 1 to 3 and multiplex SOH (MSOH) comprising rows 5 to 9. The MSOH is accessible only at terminal equipment, whereas the RSOH is accessible at both terminal equipment and regenerators.

Details of the functions provided by RSOH and MSOH are given in Recommendation G.708. These functions include performance monitoring and section maintenance and operations functions.

In order to permit regenerators to read from and write to the RSOH without disrupting the primary performance monitoring, the RSOH is excluded from the B2 (BIP-24) calculation. Since B1 is recomputed at each regenerator, fault sectionalization is simplified.

The section overhead bytes E1, E2, F1, D1-D3 and D4-D12 are used for network operations purposes. In some applications it may be necessary to protect the channels provided by these bytes. The mechanisms to be used for the protection of these channels may be independent and are for further study.

2.2.1.3 Maintenance signals

The maintenance signals defined in 2.3.1/G.709 at the section layer are multiplex section AIS and far end receive failure (FERF). At the path layer, 2.3.2/G.709 defines path AIS and path status information in the form of path FERF and far end block error (FEBE). These path maintenance signals apply at both higher order and lower order path level. Figure 2-2 illustrates the layer-to-layer and peer-to-peer maintenance interaction provided in the SDH overhead.

2.2.1.4 Loss of signal at regenerators

If a regenerator loses its input signal, a standby clock is activated and a signal containing valid RSOH and MS-AIS is transmitted downstream. This enables the RSOH functions carried by the RSOH to be activated if required.

2.2.2 Grooming and consolidation

An important aspect of facilities management is the capability to "groom" traffic between layers and to consolidate traffic within a layer.

Grooming is the allocation of client layer connections to server layer trails on the basis of like criteria in the client layer. Thus it is possible to groom LO paths by service type, by destination, or by protection category into particular HO paths which can then be managed accordingly. It is also possible to groom HO paths according to similar criteria into STM-N sections.

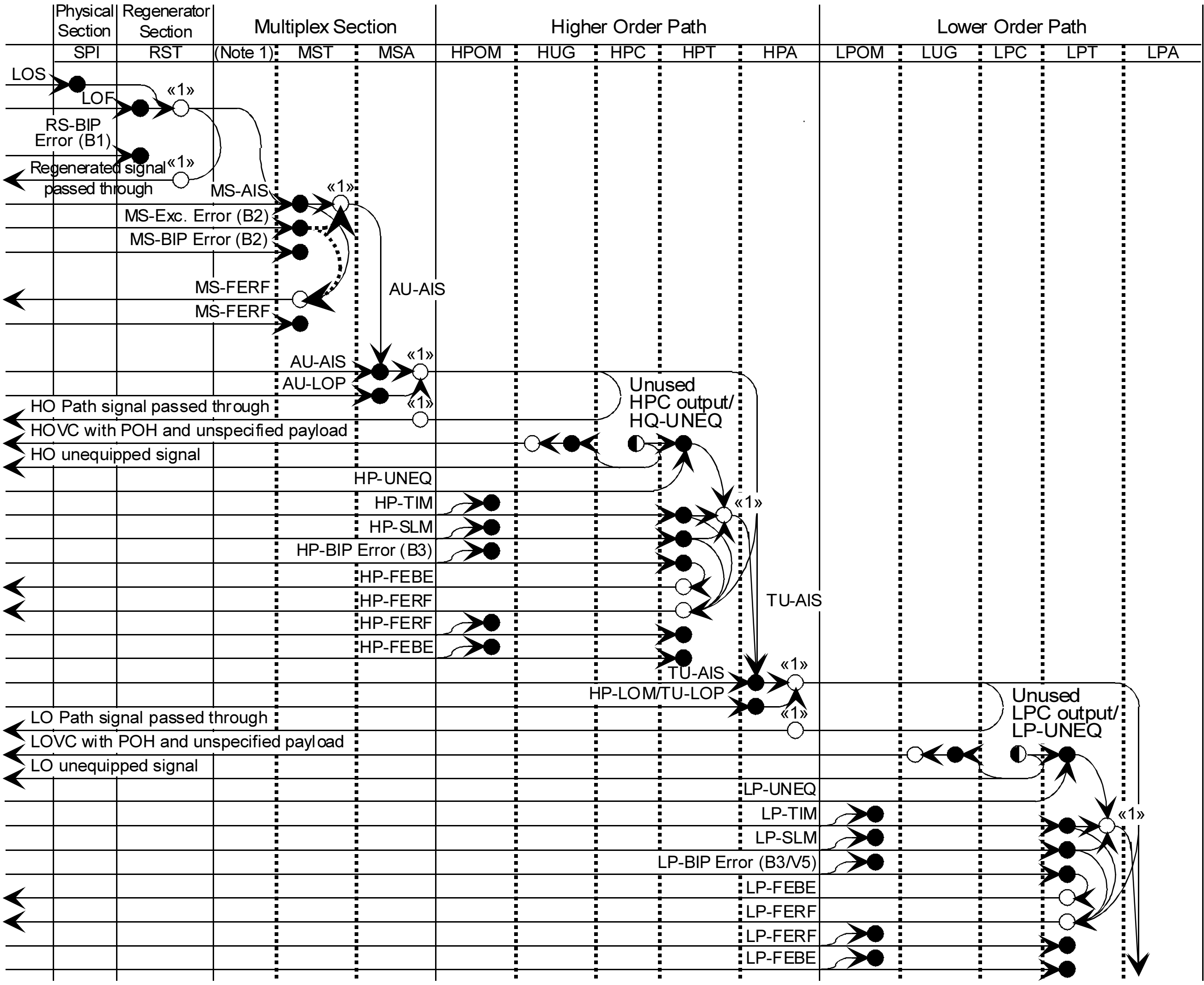
Consolidation is the process of improving the "fill factor" of a server layer by combining client connections from partially filled server layer trails into a smaller number of server layer trails. Thus a number of partially filled HO paths may be consolidated into one.

2.2.3 TMN access

SDH equipment should provide interfaces for messages to or from the TMN via either the DCC or a Q interface or both. Messages arriving at the interface not addressed to the local SDH equipment should be relayed to the appropriate Q or DCC interface. The TMN can thus be provided with a direct logical link to any SDH equipment via a single Q interface and the interconnecting DCCs.

2.2.3.1 Q-interface

When access to the TMN is provided by a Q interface, the interface will conform to Recommendation G.773.



T1512780-93/d02

●	Detection
○	Generation
«1»	Insertion of all-ones (AIS) signal
AIS	Alarm Indication Signal
FEBE	Far End Block Error
FERF	Far End Receive Failure
LOF	Loss Of Frame
LOM	Loss Of Multiframe
LOP	Loss Of Pointer
LOS	Loss Of Signal
SLM	Signal Label Mismatch
TIM	Trace Identifier Mismatch
UNEQ	Unequipped signal per Recommendation G.709

NOTES

1 This column represents the degenerate connection function present in a regenerator.

2 The insertion of all-ones (AIS) and FERF on certain defects may be optional. This figure shows these options as dashed lines. See Recommendation G.783.

FIGURE 2-2/G.782

SDH maintenance signal interaction

2.2.3.2 Data communications channel (DCC)

The use of the DCC is dependent on the network operator's maintenance strategy and the specific situation. It may not always be required as it is possible to carry out the required functions by other means.

There are two ways of using the DCC:

i) use of the D1 to D3 bytes located in the RSOH (DCC_R) and accessible at regenerators and other network elements;

ii) use of the D4 to D12 bytes located in the MSOH (DCC_M) and not accessible at regenerators. These bytes are provided alternatively across either the P reference point (MCF function), or the U reference point (OHA function). The specific use of the D4 to D12 bytes is for further study.

These channels are message-based and provide communications between network elements. They can be used to support communications between sites and the TMN. Two examples are given in Figures 2-3 and 2-4.

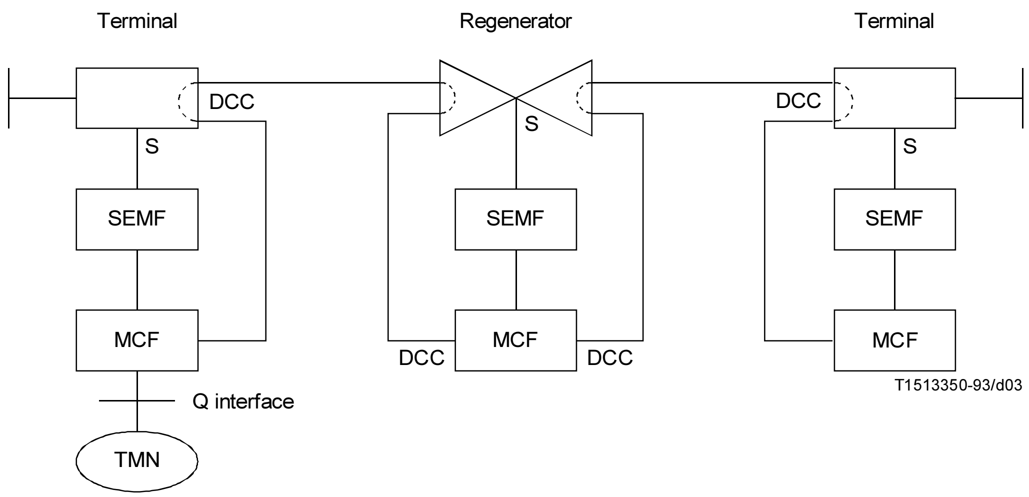


FIGURE 2-3/G.782

SDH linear system configuration

2.2.3.3 Functionalities

Specification of the protocol stack layers to be supported by the SEMF and MCF is for further study.

2.2.3.3.1 Synchronous equipment management function (SEMF)

This converts performance data and implementation specific hardware alarms into object-oriented messages for transmission on the DCC(s) and/or a Q interface. It also converts object-oriented messages related to other management functions for passing across the Sn reference points.

2.2.3.3.2 Message communications function (MCF)

This function receives and buffers messages from the DCC(s), Q and F interfaces and SEMF. Messages not addressed to the local site are relayed to one or more outgoing DCC(s) in accordance with local routing procedures and/or Q interface(s). The function provides layer 1 (and layer 2 in some cases) translation between a DCC and a Q interface or another DCC interface.

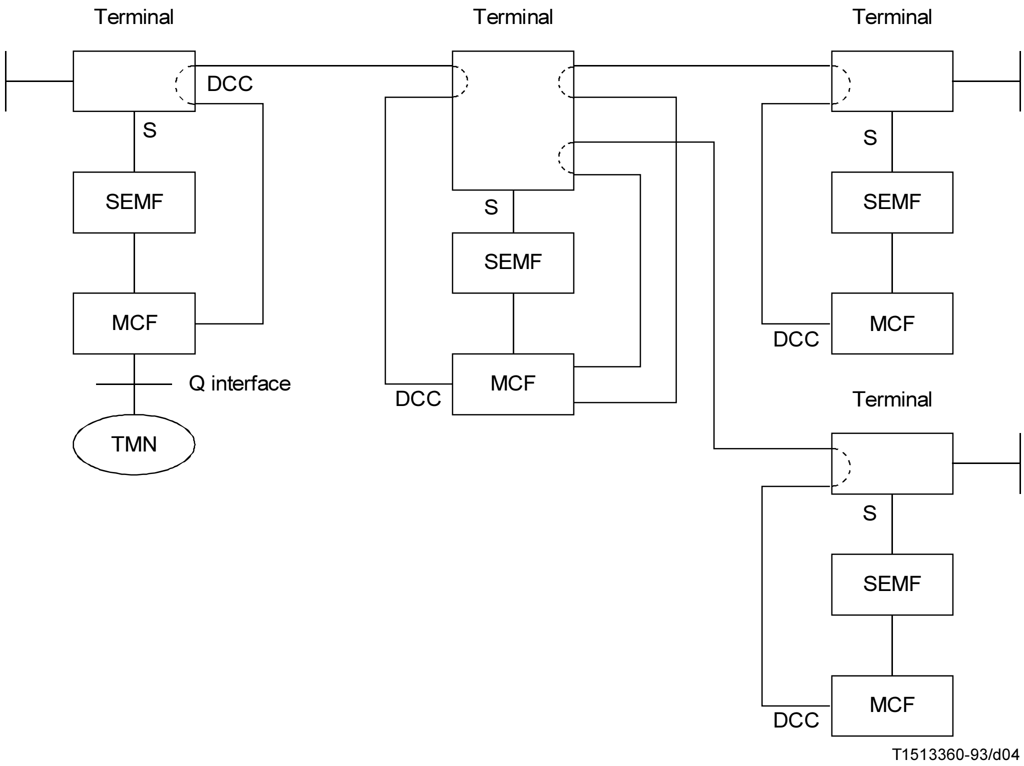


FIGURE 2-4/G.782

SDH tree configuration

2.2.4 Monitoring of incomplete path segments

To reduce restoration times, it is sometimes required to preset most of an alternative path so that, when required, it is only necessary to configure one, or at most two, cross-connects to complete the path. It is advantageous to be able to monitor such path segments prior to completion. An example is shown in Figure 2-5.

The sink and source of the signal sent via the preset path segment is the Higher order Connection Supervision function (HCS) located between HPC and TTF as shown in Figure 2-1. The HCS comprises a Higher order Path Overhead Monitoring function (HPOM) and a Higher order Unequipped Generator function (HUG) as shown in Figure 2-1.

The HUG generates a VC with undefined payload and full valid POH; HPOM performs monitoring functions similar to the HPT function described in Recommendation G.783. The HCS is also used to generate “unequipped” VC paths between network elements in cases where STM-N signals are not fully utilized for traffic, indicating available transmission capacity in the network.

2.2.5 Path monitoring

It is often necessary to monitor paths which transit a network element. This may occur frequently at operator boundaries, but may be also required within one operator’s network for fault sectionalization. Paths may be monitored by the HPOM/LPOM in a non-intrusive manner.

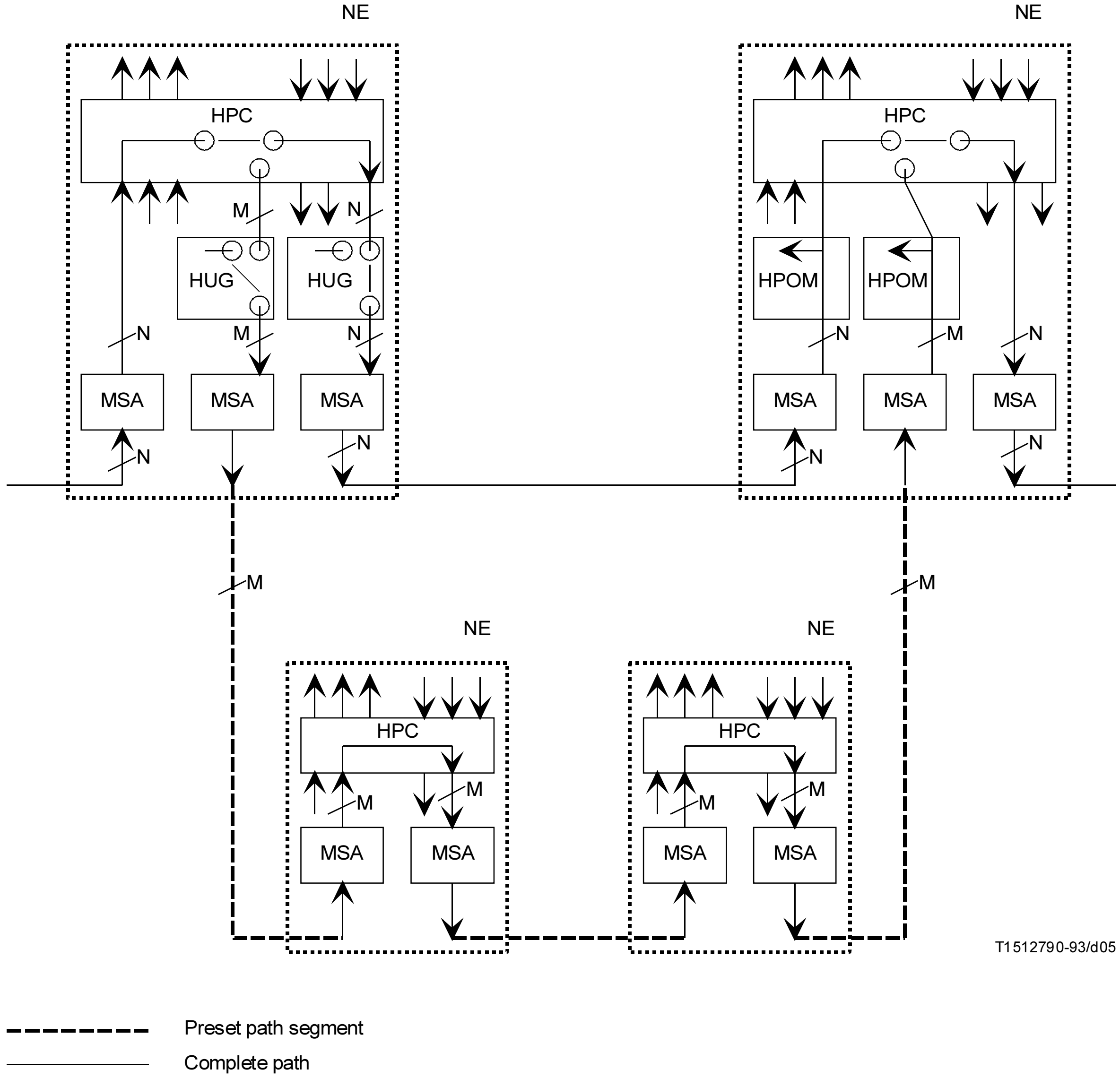


FIGURE 2-5/G.782

Monitoring of incomplete path segments

2.2.6 Order-wire

Use of the E1 and/or E2 bytes for providing an order-wire is optional. Byte E1 can be accessed at all regenerators and terminals to provide a local order-wire. Byte E2 can only be accessed at terminals and may be used to provide an order-wire between terminal sites.

2.2.7 User channel

Use of the F1 byte for providing a special user channel is optional. Byte F1 can be accessed at all regenerators and terminals.

2.2.8 Test access

In this application, network test facilities connected to spare (STM-N) ports of a network element can be connected to network facilities under test. Tests may range from a simple check of valid overhead to the application of special test sequences, e.g. pointer test sequences. This application requires a broadcasting capability for in-service testing and a split access capability for out-of-service testing as described in 2.5.

1) *For in-service testing* – In-service testing capability is given by the broadcast capability (see 2.5) providing the feature of bridging an incoming VC-1/2/3/4 to a port to which test equipment is connected.

2) *For out-of-service testing* – Out-of-service testing can be done by using a unidirectional connection capability (see 2.5) to route any incoming VC-1/2/3/4 to a port to which test equipment is connected and to insert all-ones (AIS) onto the affected outgoing VC-1/2/3/4. This provides split access capability. Such tests may be carried out routinely on spare resources in the network or on demand from an OS.

2.3 Protection

Protection is defined in Recommendation G.803 as the use of pre-assigned capacity between nodes to replace a failed or degraded transport entity. Two protection architectures are identified: trail protection and sub-network connection protection.

2.3.1 Trail protection

Specific types of trail protection are described in this subclause.

2.3.1.1 Multiplex section protection

Protection switching of a signal provides a capability, using equipment redundancy and switching action, such that in the event of the failure of a working channel, the signal is available via a protection channel.

The use of protection switching is dependent on the network operator's maintenance strategy. It may not always be required. If required on SDH systems, redundancy is provided for functions and physical medium between, and including, two MST functions, i.e. for the multiplex section. Thus, the Multiplex Section Protection (MSP) function provides protection for the STM-N signal against failures within a multiplex section.

The MSP function communicates with the corresponding far end MSP function to coordinate the switch action, via a bit-oriented protocol defined for the K bytes of the MSOH. It also communicates with the SEMF for automatic and manual switch control. Automatic protection switching is initiated based on the condition of the received signals. Manual protection switching provides both local and remote switching from commands received via the SEMF. The details of switch initiation, control and operation are described in Recommendation G.783.

The MSP may switch either bi-directionally or uni-directionally and in either a revertive or non-revertive mode, depending on the network management.

In bi-directional switching, the channel is switched to the protection section in both directions, and switching of only one direction is not allowed. In uni-directional switching, the switching is complete when the channel in the failed direction is switched to protection.

In revertive mode of operation, the working channel is switched back to the working section, i.e. restored, when the working section has recovered from failure. In non-revertive mode of operation, the switch is maintained even after recovery from failure.

Two MSP architectures are defined: 1 + 1 (one plus one) and 1 : n (one for n). For 1 : n architectures, only revertive mode is allowed.

1 + 1 architecture

In a 1 + 1 MSP architecture shown in Figure 2-6, the STM-N signal is transmitted simultaneously on both multiplex sections, designated working and protection sections; i.e. the STM-N signal is permanently connected (bridged) to the working and protection sections at the transmitting end. The MSP function at the receiving end monitors the condition of the STM-N signals received from both sections and connects (selects) the appropriate signal. Due to permanent bridging of the working channel, the 1 + 1 architecture does not allow an unprotected extra traffic channel to be provided.

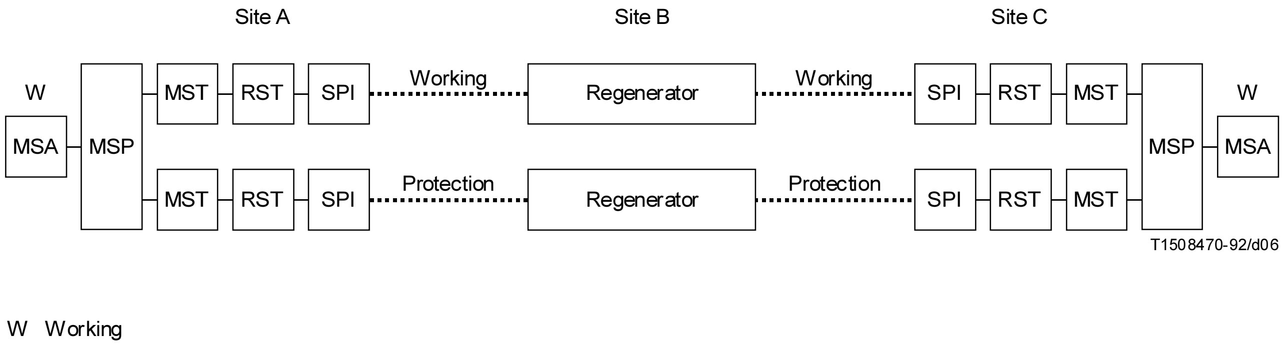


FIGURE 2-6/G.782

1 + 1 MSP protection switch architecture

1 : n architecture

In a 1 : n MSP architecture shown in Figure 2-7, the protection section is shared by a number of working channels; the permitted values for n are 1 through 14. At both ends, any one of the n STM-N channels or an extra traffic channel (or possibly a test signal) is bridged to the protection section. The MSP functions monitor and evaluate the conditions of the received signals and perform bridging and selection of the appropriate STM-N signals from the protection section.

Note that 1 : 1 architecture is a subset of 1 : n (n = 1) and may have the capability to operate as 1 + 1 for interworking with a 1 + 1 architecture at the other end.

2.3.2 Sub-network connection protection

Sub-network connection protection can be provided using connection functions HPC and LPC. The response time requirement in this case is for further study. Recommendation G.803 provides examples and applications of sub-network connection protection.

2.4 Restoration

Restoration is defined in Recommendation G.803 as the use of capacity available between nodes to replace a failed or degraded transport entity. In general the algorithms used for restoration involve re-routing of working traffic over the percentage of network capacity reserved for this purpose. Equipment aspects of restoration are for further study.

2.5 Connection types

The connection types are as follows:

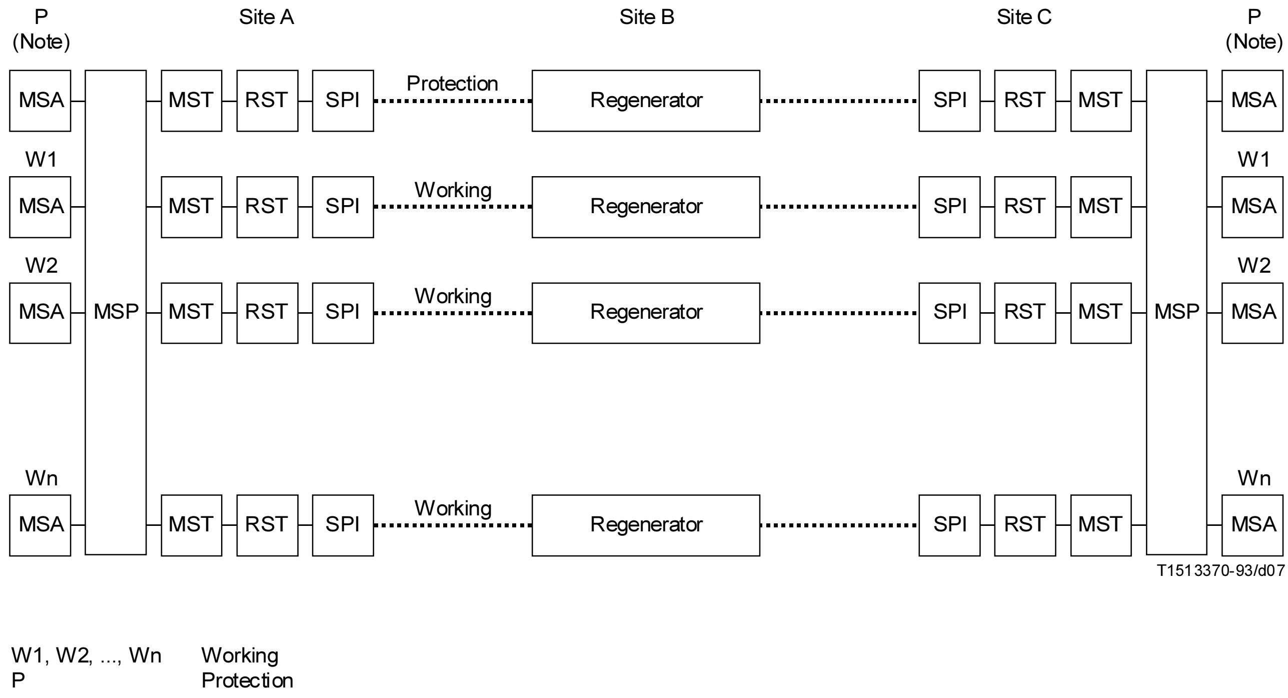
a) *Unidirectional* – This type provides one-way connection through the SDH network element and may be used, for example, for transporting video signals.

b) *Bidirectional* – This type sets up a two-way cross-connection through the SDH network element.

c) *Broadcast* – This type will connect an incoming VC-n to more than one outgoing VC-n.

d) *Loopback* – This type connects a VC-n to itself.

e) *Split-Access* – This type terminates the VC-n in an incoming STM-N and provides test signal on the corresponding VC-n of the outgoing STM-N.



NOTE – Needed only for extra traffic.

FIGURE 2-7/G.782

1 : n MSP protection switch architecture

3 Examples of equipment types

Historically, network elements (equipment) were identified by their application: line system, terminal multiplexer, add/drop multiplexer, and cross-connect. With the introduction of SDH, those applications may be combined in one network element, making historical terminology redundant. This clause provides some examples of configurations for SDH equipment, based on the generalized logical block diagram (see Figure 2-1) and illustrating the principle of functional modeling. The description of these examples is generic, and no particular physical partitioning of functions is implied.

3.1 Examples of multiplexing equipment types

3.1.1 Multiplexer type I.1

This provides a simple G.703 to STM-N multiplex function (see Figure 3-1). For example, 63 signals at 2048 kbit/s could be multiplexed to form an STM-1 output or, 12 signals at 44 736 kbit/s could be multiplexed to form an STM-4 (see Figure 3-1). The location of each of the tributary signals in the aggregate signal is fixed and dependent on the multiplex structure chosen.

3.1.2 Multiplexer type I.2

The ability to provide flexible assignment of an input to any position in the STM-N frame can be provided by including a VC-1/2/3 and/or VC-3/4 path connection function (see Figure 3-2).

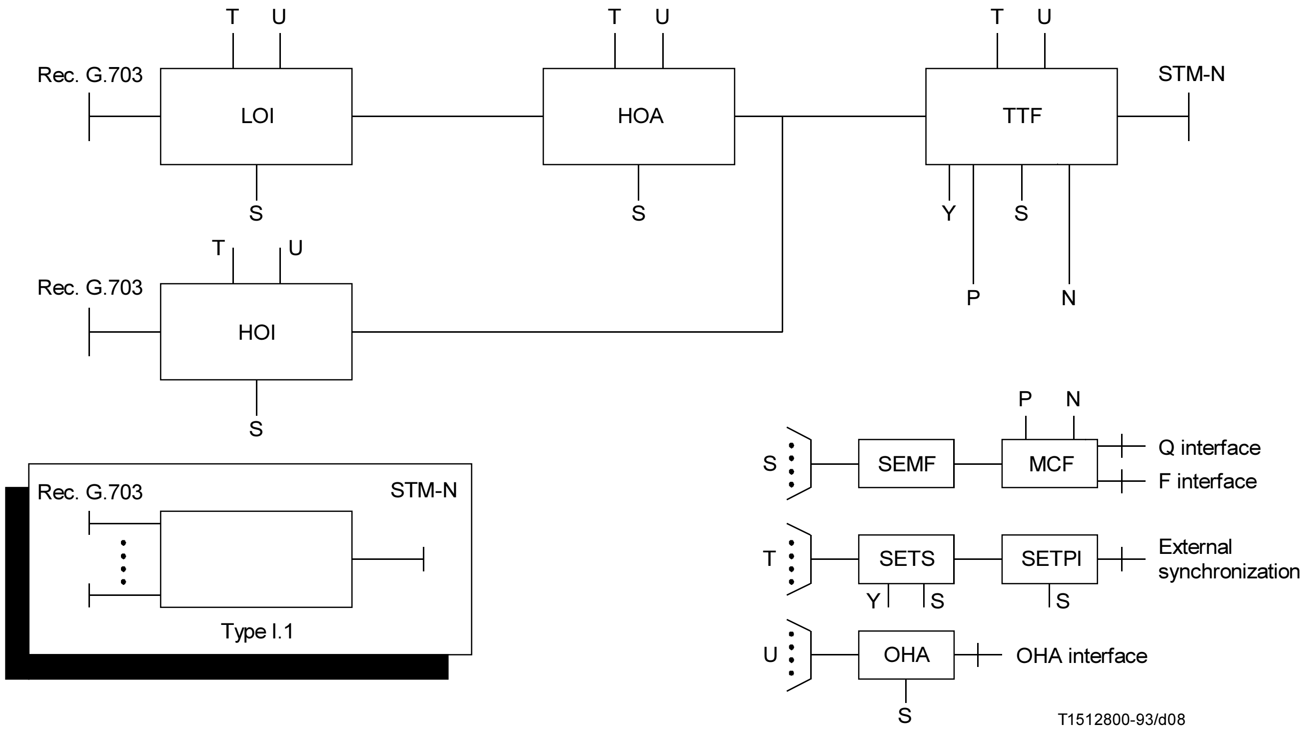


FIGURE 3-1/G.782

Multiplexer type I.1

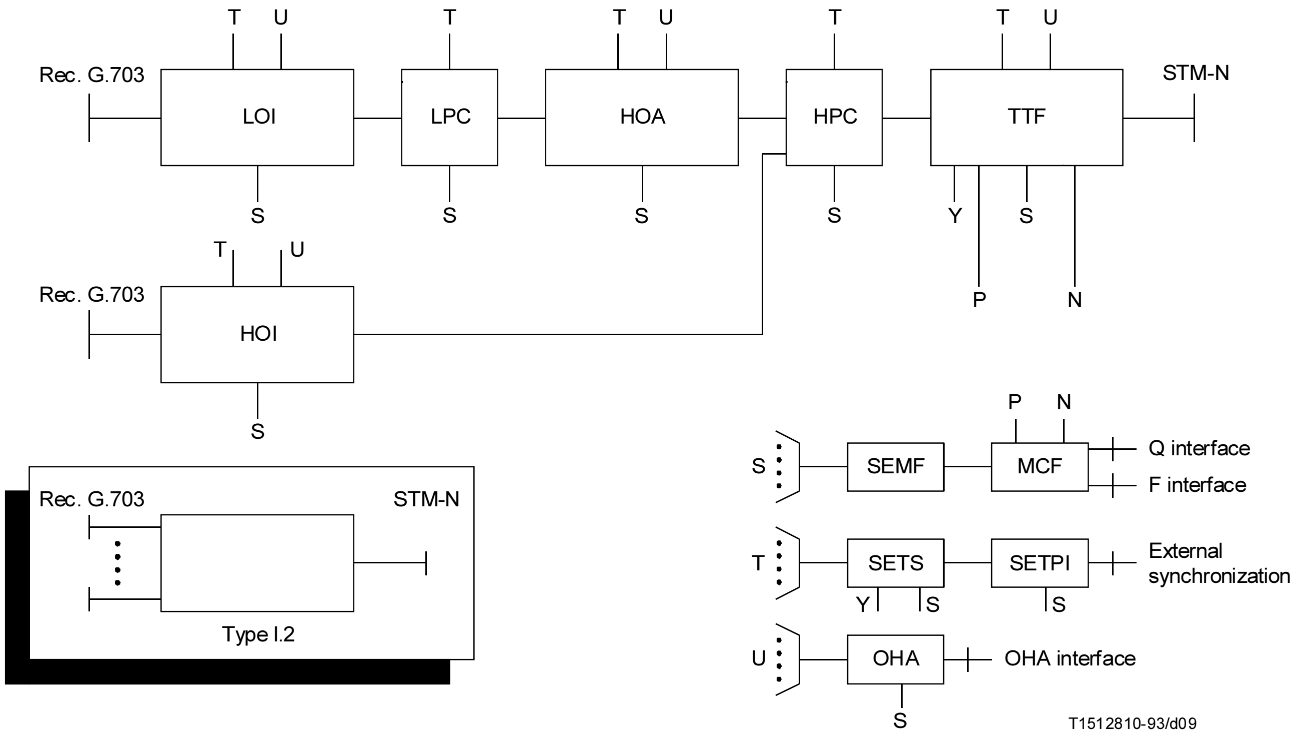


FIGURE 3-2/G.782

Multiplexer type I.2

3.1.3 Multiplexer type II.1

This provides the ability to combine a number of STM-N signals into a single STM-M signal (see Figure 3-3). For example, the VC-3/4s of four STM-1 signals (from multiplexers or line systems) could be multiplexed to provide the payload of a single STM-4 signal. The location of each of the VC-3/4s of the STM-N signals is fixed in the aggregate STM-M signal.

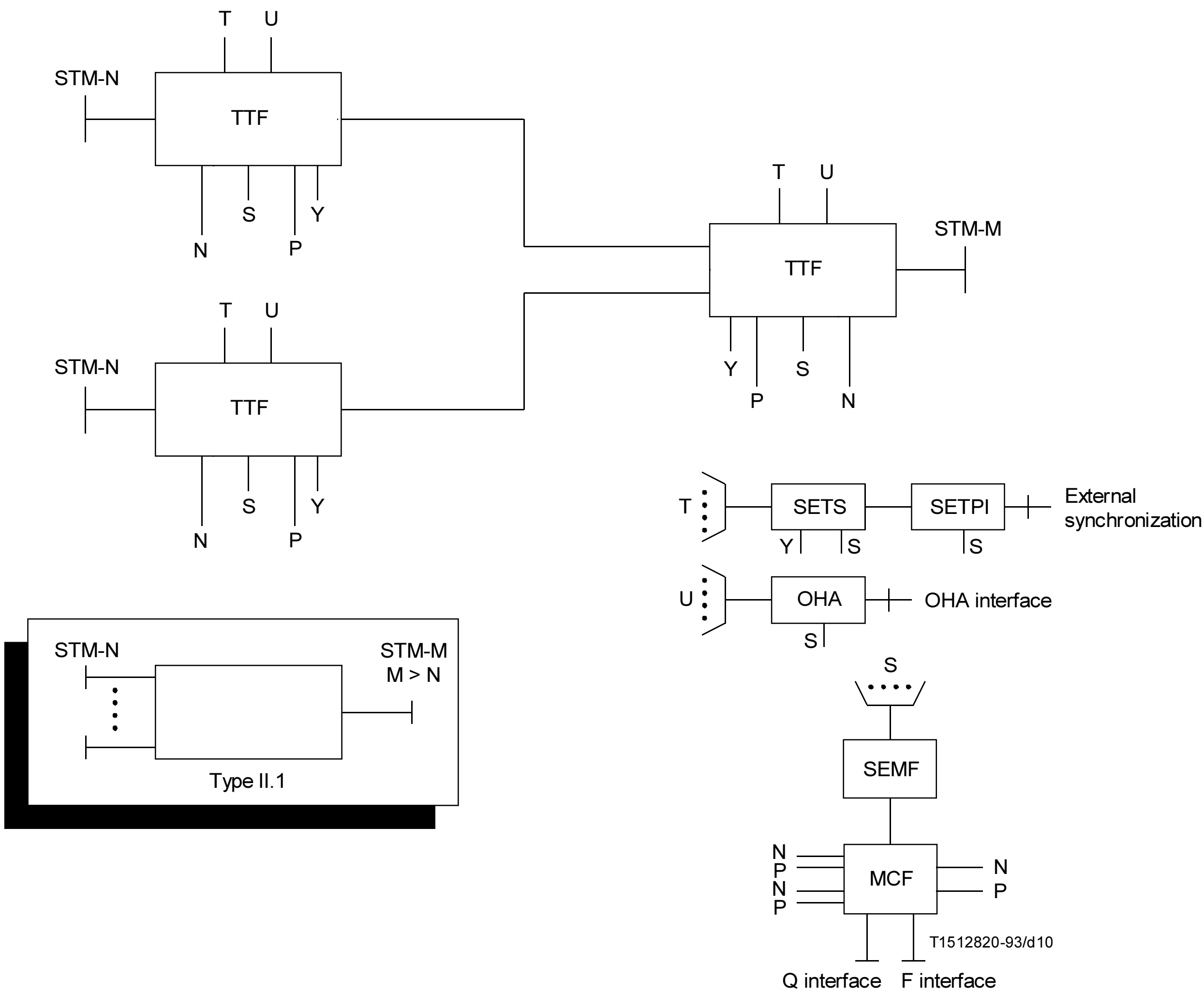


FIGURE 3-3/G.782

Multiplexer type II.1

3.1.4 Multiplexer type II.2

The ability to assign flexibly a VC-3/4 on one STM-N to any position in the STM-M frame can be provided by including a VC-3/4 path connection function (see Figure 3-4).

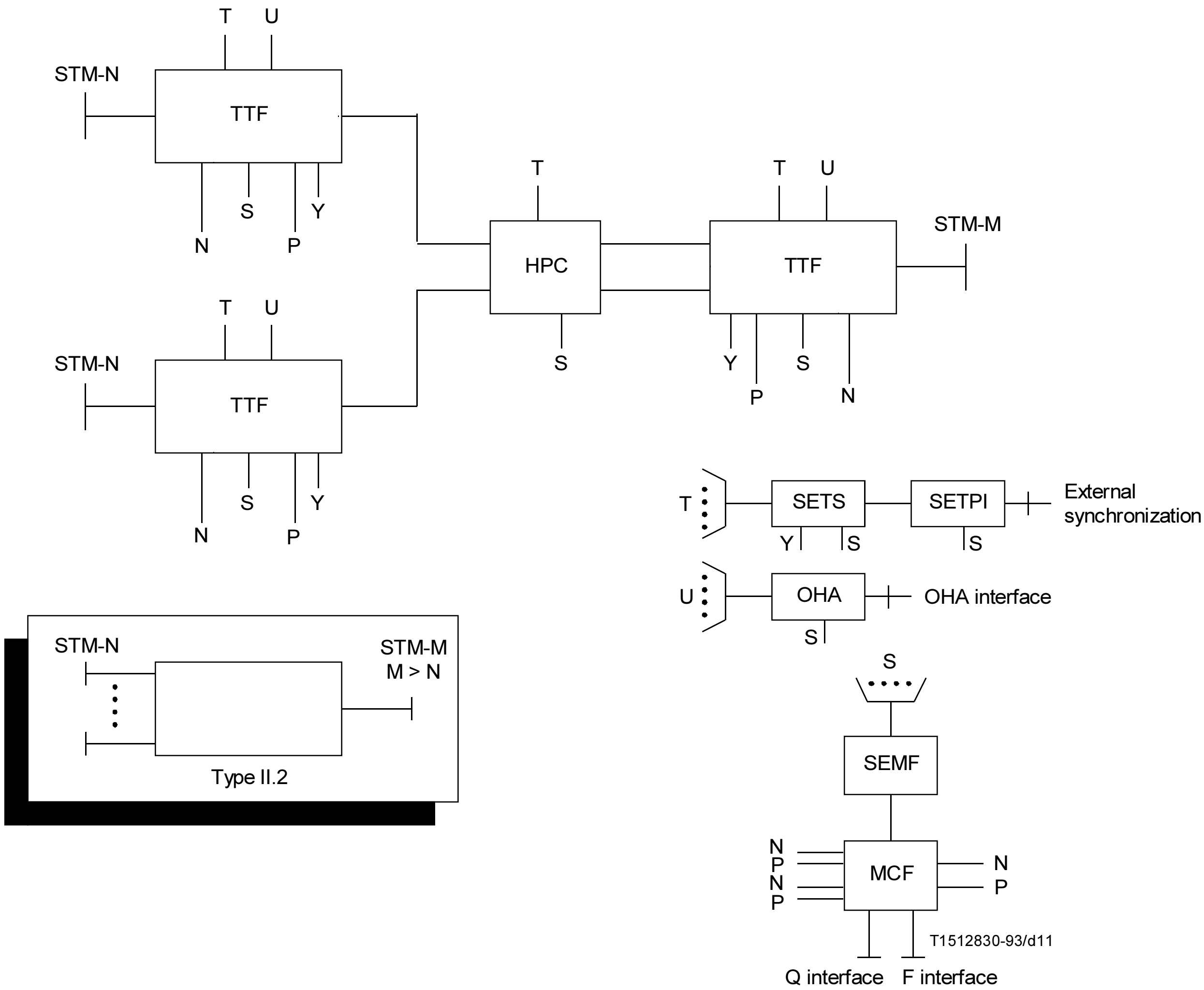


FIGURE 3-4/G.782

Multiplexer type II.2

3.1.5 Multiplexer types III.1 and III.2

These provide the ability to access any of the constituent signals within an STM-M signal without demultiplexing and terminating the complete signal. The interface provided for the accessed signal could be either according to Recommendation G.703 or an STM-N (M > N). These are described in more detail below.

3.1.5.1 Multiplexer type III.1 (see Figure 3-5)

Figure 3-5 illustrates the case of a Type III.1 multiplexer where access to the constituent signal is via a G.703 PDH interface.

The higher order path connection function allows the VC-3/4 signals within the STM-M signal to be either terminated locally or re-multiplexed for transmission. It also allows the VC-3/4 signals generated locally to be assigned to any vacant position in the STM-M output. The lower order path connection function allows the VC-1/2/3 signals (from the VC-3/4 terminated by the HPT function) to be terminated locally or directly re-multiplexed back into an outgoing VC-3/4. The lower order path connection function also allows the locally generated VC-1/2/3 signals to be routed to any (vacant) position on any outgoing VC-3/4.

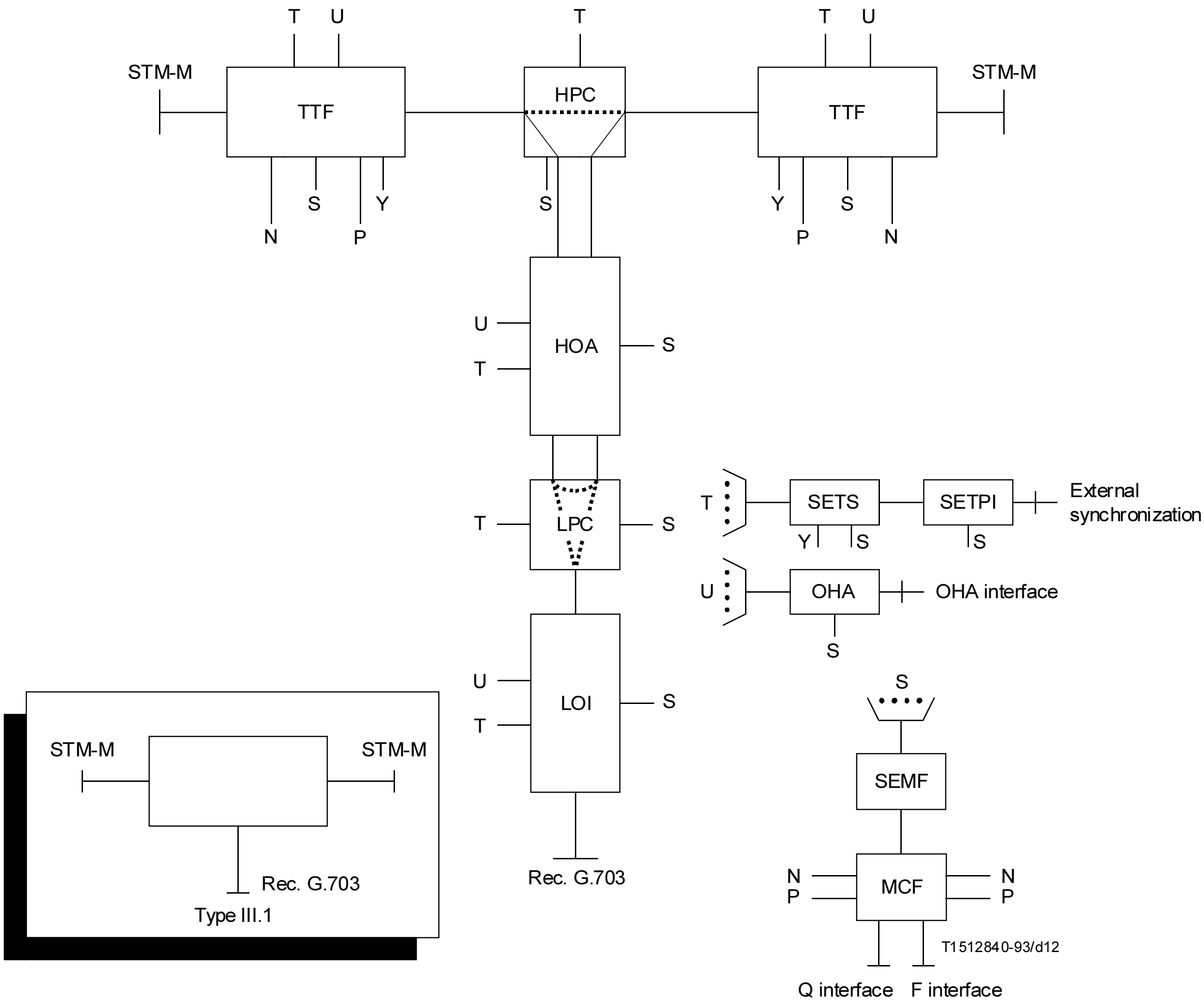


FIGURE 3-5/G.782

Multiplexer type III.1

3.1.5.2 Multiplexer type III.2 (see Figure 3-6)

Figure 3-6 illustrates the case of a Type III.2 multiplexer where access to the constituent signal is via an STM-N interface.

This type has some additional functions to those required for Type III.1, namely those for demultiplexing the STM-N signal into VC-1/2/3 signals.

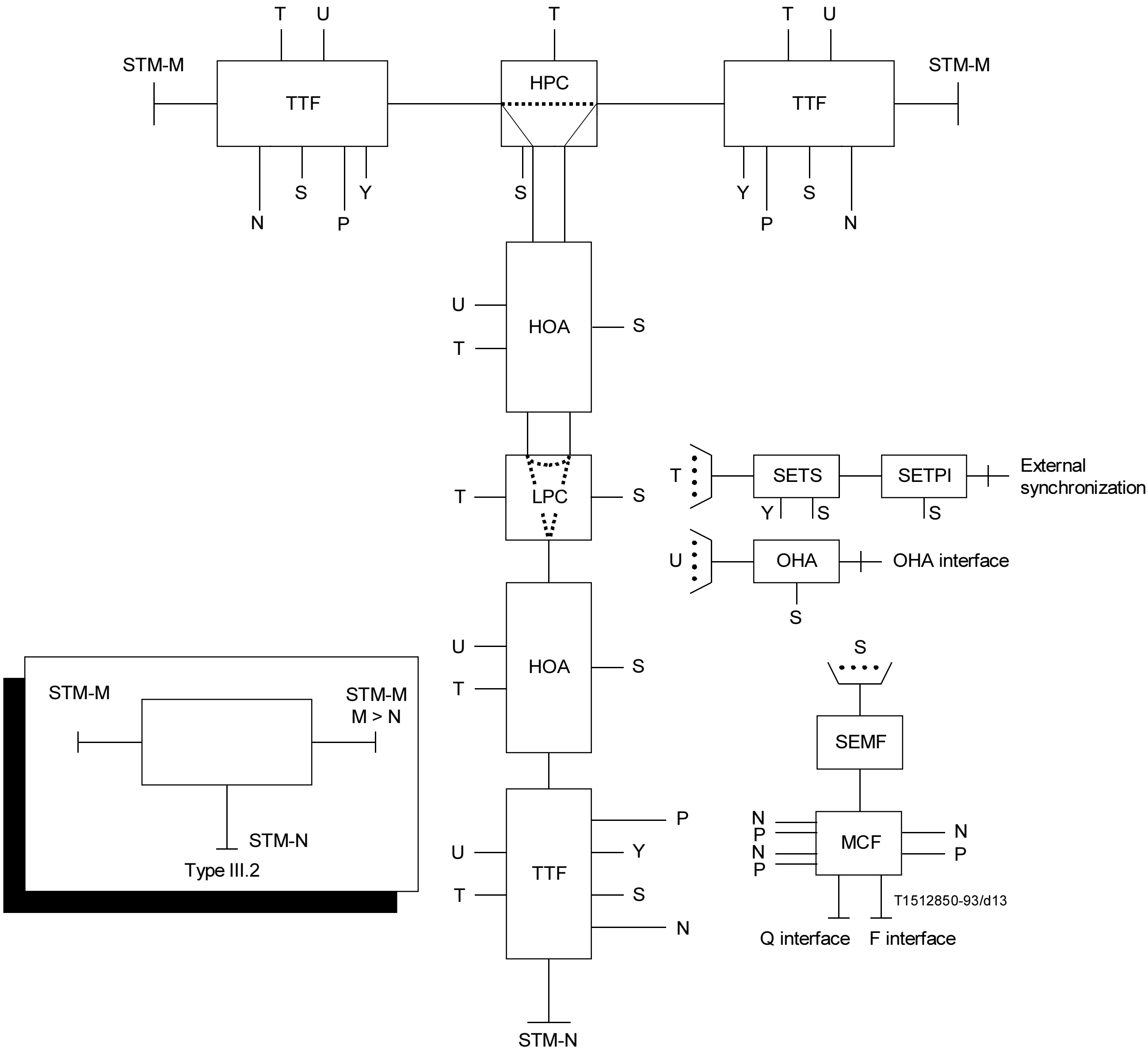


FIGURE 3-6/G.782

Multiplexer type III.2

3.1.6 Multiplexer type IV

This provides the translation function to allow C-3 payloads in VC-3s to transit between AU-3 and AU-4 based networks (see Figure 3-7). Information on interworking is given in Recommendation G.708. Note that this example applies to VC-3s containing C-3s, and not to VC-3s containing TUG-2s.

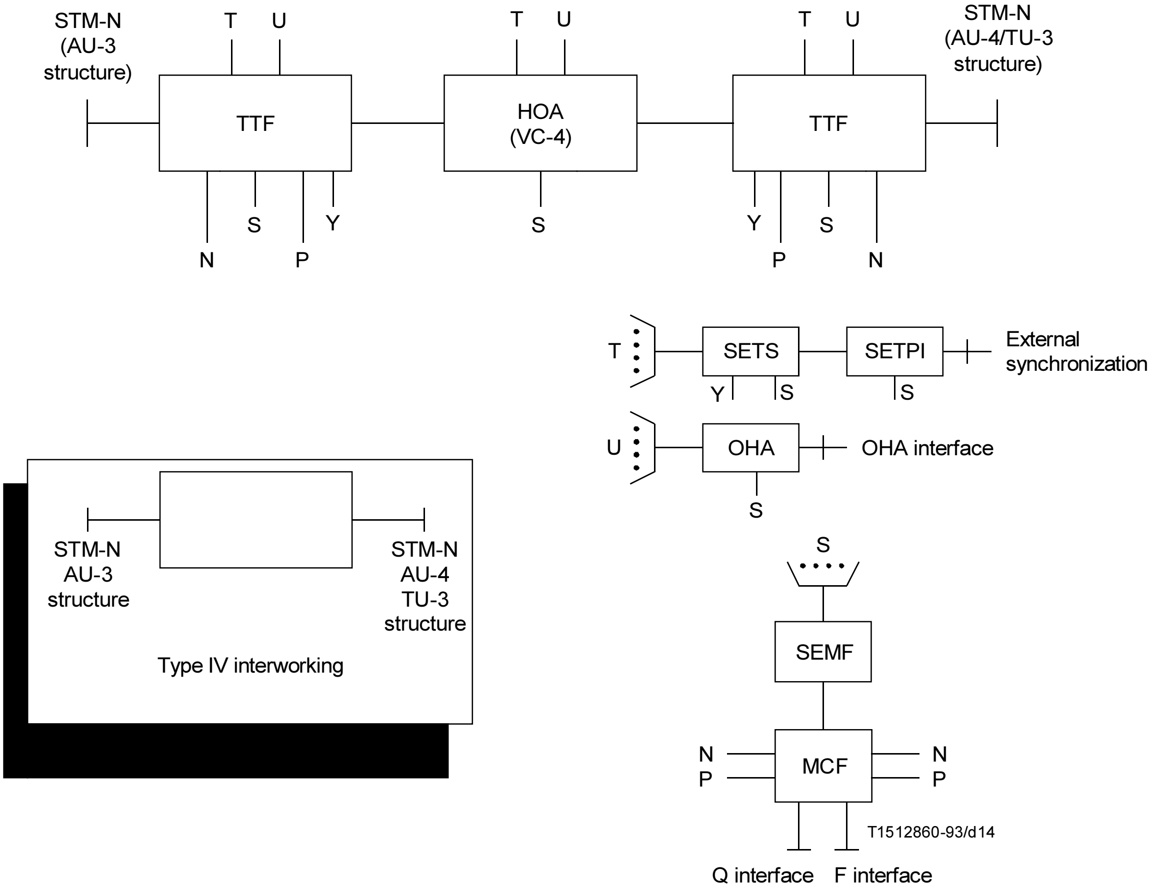


FIGURE 3-7/G.782

Multiplexer type IV

3.2 Examples of cross connect equipment types

3.2.1 Cross-connect type I

This provides cross-connection of higher order VCs only (see Figure 3-8). External access to HOVCs is via a TTF for STM-N interfaces or via an HOI function for G.703 (PDH) interface signals. In the former case, the HCS function is included. Control of the HPC connection matrix is via the SEMF.

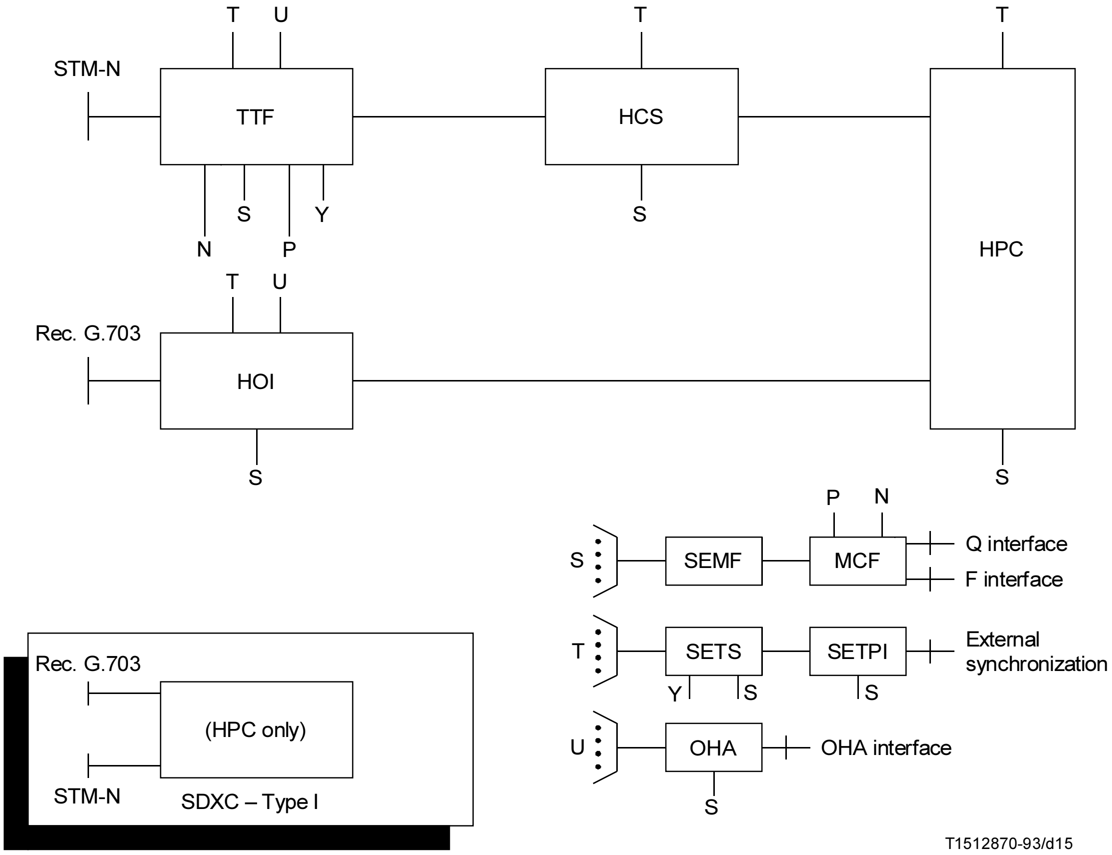


FIGURE 3-8/G.782

Cross-connect type I

3.2.2 Cross-connect type II

This provides cross-connection of lower order VCs only (see Figure 3-9). External access to LOVCs is via TTF and HOA functions for STM-N interfaces or via an LOI function for G.703 (PDH) interface signals. In the former case, the LCS function is included. Control of the LPC connection matrix is via the SEMF.

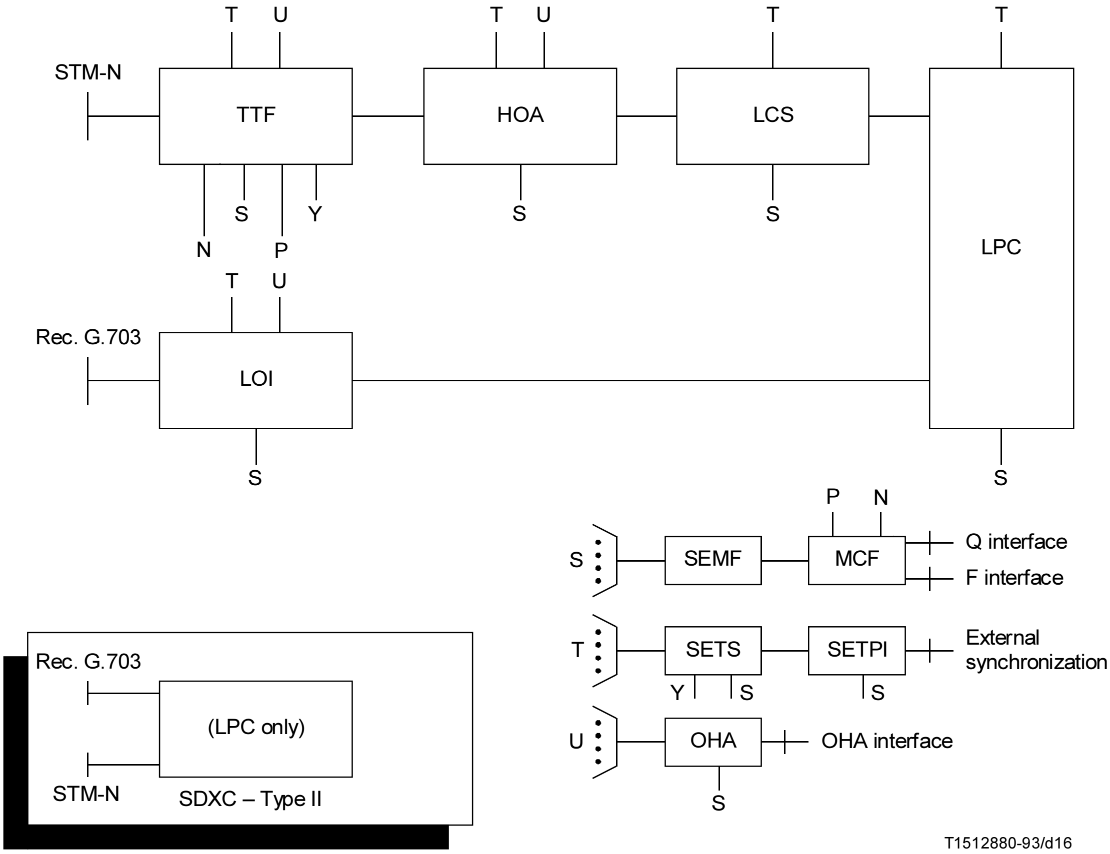


FIGURE 3-9/G.782

Cross-connect type II

3.2.3 Cross-connect type III

This provides cross-connection of both higher and lower order VCs (see Figure 3-10). Presentation of HOVCs to the HPC function is via the TTF and HOI functions for STM-N and G.703 (PDH) interface signals respectively. Presentation of LOVCs to the LPC function from the HPC function is via the HOA function. Presentation of LOVCs derived from G.703 (PDH) interface signals is via an LOI function. Control of the HPC and LPC connection matrices is via the SEMF.

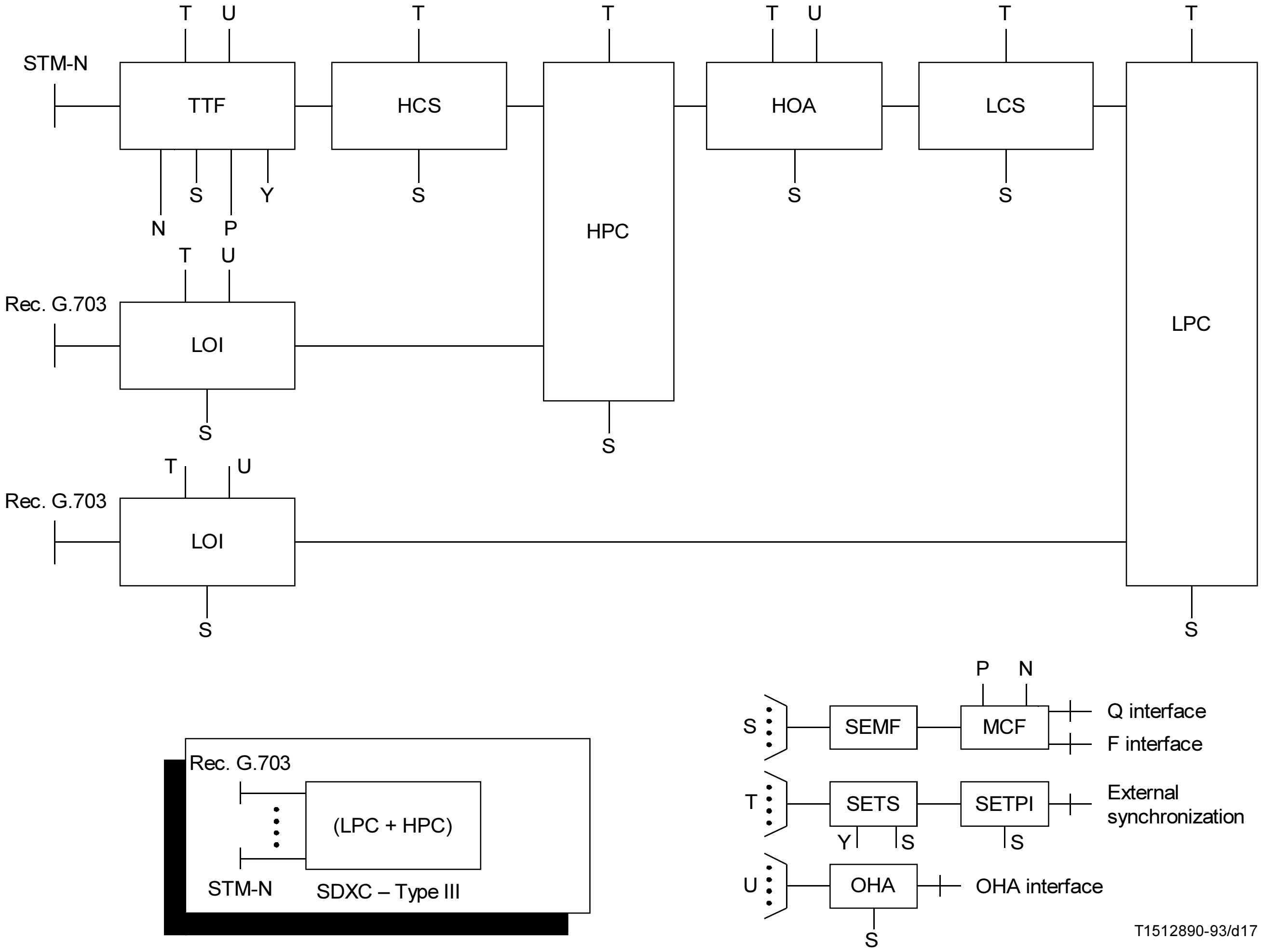


FIGURE 3-10/G.782

Cross-connect type III

4 General performance requirements

4.1 Timing and synchronization overview

The SDH has been designed to operate as a synchronized network, accommodating G.811 plesiochronous operation and network wander by a scheme of pointer adjustments. SDH network jitter/wander performance is determined by SDH internal and external clock performance, network output wander at synchronization interfaces, and SDH line system jitter/wander. Pointer adjustment statistics, and related G.703 tributary output jitter/wander, are determined by SDH network jitter/wander performance and the design of the SDH equipment at the boundary of an SDH network. This clause provides general principles and applications guidelines for synchronization of SDH equipment. Detailed timing and synchronization specifications are given in Recommendation G.783.

Figure 2-1 includes the following functional blocks related to timing and synchronization:

– SETPI – Provides the appropriate interface for G.703 based synchronization inputs/outputs.

– SETS – Provides the internal timing signals to the multiplexer equipment based on either an external input or internal oscillator.

4.1.1 Guidelines for synchronization

4.1.1.1 SDH network application

An SDH network application is one in which at least one of the tributary signals is an SDH signal, thus requiring pointer processing in the TU and/or AU paths. Two examples of SDH network applications are given below:

– SDH network comprising externally synchronized SDH network elements containing internal clocks. The specification of the quality of these clocks is under study;

– SDH network including network elements for which the transmit clock for a particular signal is derived directly from the corresponding receive clock (loop timing). Loop timing is typically used in small terminal stations, particularly in star networks, where an external synchronization reference interface is not available; e.g. access networks and equipment in customer premises.

All SDH network elements whose synchronization is traceable to a primary reference clock(s), shall be integrated into existing synchronization hierarchies. Primary reference and slave clocks are specified in Recommendations G.811 and G.812, respectively.

NOTE – Specification of network output wander requirements at synchronization interfaces is under study.

4.1.1.2 SDH point-to-point application

An SDH point-to-point application is one in which all tributary signals are asynchronous or plesiochronous according to Recommendation G.703, with no pointer processing in either the TU or AU paths. Synchronization is not required in this application but must be provided as soon as networking is extended beyond simple point-to-point.

4.1.1.3 External synchronization interfaces

Timing reference in a network element can be derived from three types of inputs:

i) G.703 external synchronization interface (for 2048 kHz, Recommendation G.703 applies; the case of 1544 kHz is for further study);

ii) G.703 tributary interface (carrying reference synchronization);

iii) STM-N interface.

Depending on the type of network element, one or more timing reference inputs may be available. SDH equipment should have the ability to switch automatically to another timing reference if the selected timing reference is lost. Timing reference is considered to be lost under the following conditions:

– loss of signal on the selected timing reference interfaces;

– all-ones (AIS) on the selected timing reference interface.

If the selected timing reference is an STM-N signal, switching to another timing reference should only take place after it has been established that any available protection switching of the STM-N and its terminating circuitry has failed to recover the STM-N. The synchronization source selection algorithm using the synchronization source message in Z1(5-8) is for further study.

4.1.1.4 Loss of timing reference

Loss of all incoming timing reference is a major fault calling for immediate maintenance action. In cases where some traffic remains, a sufficient timing accuracy can be maintained over a limited time period by using a clock in holdover mode. The action taken by the synchronous equipment under such conditions will depend on the network synchronization strategy. The effect of this on national and international paths is under study.

In some cases, where loss of reference timing signal due to a loss of the incoming signal results in loss of data from the network element, the only requirement for signaling loss of timing reference is to transmit all-ones (AIS), for which entry into free-running mode is necessary. This is applicable, for example, to regenerators.

4.1.2 Specification of jitter and wander

SDH jitter and wander is specified at both STM-N and G.703 PDH interfaces in order to control overall network jitter/wander accumulation. In order to assure control of this accumulation, the jitter and wander characteristics of all SDH based equipment are specified. The jitter and wander characteristics of SDH based multiplex and cross-connect equipment are given in Recommendation G.783 and those of SDH based line systems are given in Recommendation G.958.

4.2 Equipment error performance

The general error performance design objective is that no errors shall be introduced by the equipment when operating within design limits.

The specific requirement is that, when operating within design limits, the equipment should be capable of providing a level of performance which is consistent with the support of paths meeting the high grade performance classification identified in Recommendation G.821.

NOTE – Work is proceeding to change the basis of error performance from the bit error ratio established in Recommendation G.821 to a new block error concept.

4.3 Transit delay

To derive the total transit delay of a signal through an SDH network element, all processes which could contribute non-negligible delay must be taken into account. Since it is only possible to measure transit delay from NNI to NNI, that value is the only one which must be derived.

The contributing processes which have been identified to date are:

– Pointer buffer processing. (A distinction could be made between pointer buffer threshold spacing and pointer adjustment processes.)

– Fixed stuff processing. SOH and POH could be regarded as fixed stuffing for a particular VC level.

– Processing which is implementation-dependent, e.g. internal interface processing.

– Connection processing.

– Mapping processing.

– Demapping processing.

Depending on NNI’s and processing levels, various of the above-mentioned processes must be taken into account. The total delay is then calculated as the sum of the processes involved. Table 4-1 shows which total delays are to be derived. Table locations for which delay values are to be calculated are marked with an X. These values are for further study. These values could be given as minimum, average, or maximum values under normal operating conditions or in worst case failure scenarios. The specific conditions under which the values are to be met are also for further study.

Another parameter associated with delay is the differential transit delay of lower order paths within the same server trail. From a network perspective, the specification of the differential transit delay of virtually concatenated VC-2s across the network is under study.

TABLE 4-1/G.782

Transit delay specification

		Output						
Input	Processing level	STM-N (µs)	140 Mbit/s (µs)	45 Mbit/s (µs)	34 Mbit/s (µs)	6 Mbit/s (µs)	2 Mbit/s (µs)	1.5 Mbit/s (µs)
STM-N	Regen.	X						
STM-N	VC-4	X	X					
STM-N	VC-3	X		X	X			
STM-N	VC-2	X				X		
STM-N	VC-12	X					X	X
STM-N	VC-11	X						X
140 Mbit/s	VC-4	X	X					
45 Mbit/s	VC-3	X		X				
34 Mbit/s	VC-3	X			X			
6 Mbit/s	VC-2	X				X		
2 Mbit/s async	VC-12	X					X	
2 Mbit/s byte sync	VC-12	X					X	
2 Mbit/s bit sync	VC-12	X					X	
1.5 Mbit/s async	VC-12	X						X
1.5 Mbit/s byte sync	VC-12	X						X
1.5 Mbit/s bit sync	VC-12	X						X
1.5 Mbit/s async	VC-11	X						X
1.5 Mbit/s byte sync	VC-11	X						X
1.5 Mbit/s bit sync	VC-11	X						X

4.4 Response time

The response time is specified with respect to Figure 4-1.

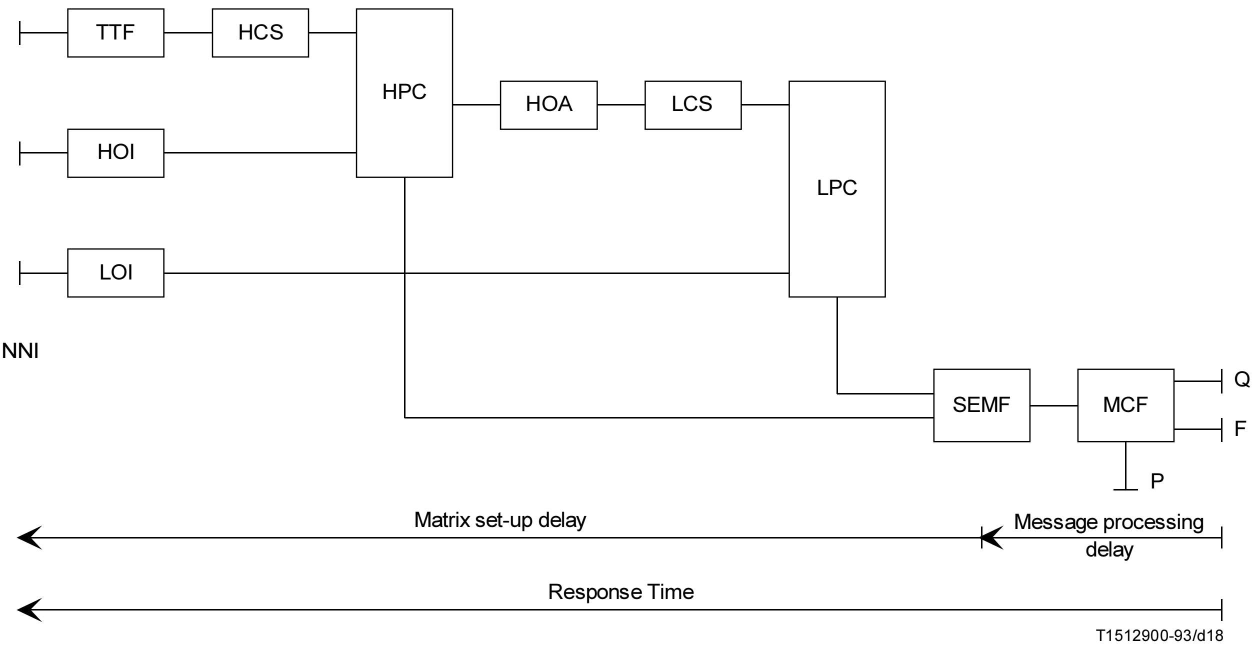


FIGURE 4-1/G.782
Response Time

Matrix set-up delay is the time taken from generation of primitive within the SEMF to the change of transport information at NNI. It may be necessary to distinguish between preset configurations, subject to an execute primitive and a normal set.

Message processing delay is the time from the end of message at Q until the primitive is generated within the SEMF; i.e. the message has been decoded to an actionable level.

4.5 Blocking

The existence of cross-connections in a cross-connect equipment can prevent the set-up of a new cross-connection. The blocking factor of a cross-connect is the probability that a particular connection request cannot be met, normally expressed as a decimal fraction of 1. Fully non-blocking (i.e. blocking factor = 0) cross-connects can be built. Some simplification in design, and hence cost, can be realized if a finite blocking factor is acceptable. It is not the intention of this Recommendation to specify target blocking factors for individual cross-connect equipment. The impact of non-zero blocking factor on network performance is dependent on network design and planning rules.

There is a class of cross-connect matrices known as conditionally non-blocking in which there is a finite probability that a connection request may be blocked. In such cross-connects, it is possible, by re-arranging existing connections, to make a cross-connection which would otherwise be blocked. As an objective, in such cases, rearrangements should be made without interruption to rearranged paths.

It may be necessary in a nominally non-blocking, or conditionally non-blocking cross-connect, to accept some blocking penalty associated with extensive use of broadcast connections. This is for further study.

4.6 Availability and reliability

The node availability requirement applies to SDH cross-connect equipment.

The format for specifying the unavailability requirement is given below:

1) The unavailability of any VC, AU-4-xc or TU-2-mc as measured between input and output ports shall not exceed the Xn value in Table 4-2 for that level of signal. (The values of the Xn are for further study.)

2) The unavailability of 50% of the VCs, AU-4-xc s or TU-2-mc s as measured between input and output ports shall not exceed the Yn value in Table 4-2 for that level of signal. (The values of the Yn are for further study.)

3) The unavailability of the SDH cross-connect equipment, including transmission and management functions, shall not exceed Z% of any year, where the value of Z is for further study.

4) The unavailability of the SDH cross-connect equipment to reconfigure within a specified time [TBD] shall not exceed W% of any year. (The value of W is for further study.)

NOTE – Availability and reliability requirements for other equipment types are for further study.

TABLE 4-2/G.782

Cross-connect unavailability requirements

Signal level	X_n (% of any year)	Y_n (% of any year)
AU-4-xc	X_{4x}	Y_{4x}
VC-4	X_4	Y_4
VC-3	X_3	Y_3
TU-2-mc	X_{2mc}	Y_{2mc}
VC-2	X_2	Y_2
VC-12	X_{12}	Y_{12}
VC-11	X_{11}	Y_{12}