INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.803

(03/93)

DIGITAL NETWORKS

ARCHITECTURES OF TRANSPORT NETWORKS BASED ON THE SYNCHRONOUS DIGITAL HIERARCHY (SDH)

ITU-T Recommendation G.803

(Previously "CCITT Recommendation")

FOREWORD

The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the International Telecommunication Union. 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, established the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

ITU-T Recommendation G.803 was prepared by the ITU-T Study Group XVIII (1988-1993) and was approved by the WTSC (Helsinki, March 1-12, 1993).

NOTES

1 As a consequence of a reform process within the International Telecommunication Union (ITU), the CCITT ceased to exist as of 28 February 1993. In its place, the ITU Telecommunication Standardization Sector (ITU-T) was created as of 1 March 1993. Similarly, in this reform process, the CCIR and the IFRB have been replaced by the Radiocommunication Sector.

In order not to delay publication of this Recommendation, no change has been made in the text to references containing the acronyms “CCITT, CCIR or IFRB” or their associated entities such as Plenary Assembly, Secretariat, etc. Future editions of this Recommendation will contain the proper terminology related to the new ITU structure.

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

CONTENTS

Page

1 Introduction ... 1
  1.1 Scope ... 1
  1.2 Abbreviations ... 1
  1.3 Structure of Recommendation ... 2

2 Vocabulary for SDH network architecture ... 2
  2.1 Generic terms ... 2
  2.2 Terms specific to SDH ... 5
  2.3 Terms associated with protection ... 5

3 Transport functional architecture of SDH-based networks ... 8
  3.1 Introduction ... 8
  3.2 Architectural components ... 8
  3.3 Partitioning and layering ... 15
  3.4 Tandem connection monitoring [connection supervision] ... 26

4 Application of concepts to network topologies and structures ... 30
  4.1 PDH layers supported on SDH layers ... 30
  4.2 ATM cell layers supported on SDH layers ... 30

5 Transport network availability enhancement techniques ... 30
  5.1 Introduction ... 30
  5.2 Restoration ... 30
  5.3 Protection ... 30
  5.4 SDH trail protection examples ... 34
  5.5 SDH sub-network connection protection examples ... 37

6 Architecture of synchronization networks ... 41
  6.1 Introduction ... 41
  6.2 Synchronization network aspects ... 41
  6.3 Payload jitter and wander ... 49
  6.4 PDH/SDH interworking implications ... 50

7 Choice of primary rate mapping ... 51
  7.1 Features of the primary rate mappings ... 51
  7.2 Selection of mapping options ... 52

Annex A – Introduction of SDH-based transport networks ... 52

Recommendation G.803

ARCHITECTURES OF TRANSPORT NETWORKS BASED ON THE SYNCHRONOUS DIGITAL HIERARCHY (SDH)

(Helsinki, 1993)

1 Introduction

1.1 Scope

A telecommunications network is a complex network which can be described in a number of different ways depending on the particular purpose of the description. This Recommendation describes the network as a transport network from the viewpoint of the information transfer capability in the context of the SDH. More specifically, this Recommendation describes the functional and structural architectures of SDH-based transport networks. Many of the principles are also applicable to the plesiochronous digital hierarchy (PDH) network. This Recommendation does not consider issues in the circuit layer other than the definition of the inter-layer adaptation at the boundary between the circuit layer network and the transmission network.

NOTE – For the purposes of this Recommendation, a definition of circuit layer network is given in 2.

Although concerned with the definition and control of connectivity in path layer networks, as they relate to the network node interface (NNI), which may be exploited in the provision of leased lines, this Recommendation is not at all concerned with the service related issues in offering such services to users nor is it concerned at this time with the definition and control of connectivity in the section and physical media layers.

1.2 Abbreviations

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

ADM	Add/drop multiplex
AIS	Alarm indication signal
APS	Automatic protection switch
ATM	Asynchronous transfer mode
AUG	Administrative unit group
AU-n	Administrative unit (level) n
BIP-n	Bit interleaved parity (of order) n
B-ISDN	Broadband aspects of integrated services digital network
DXC	Digital cross-connect
LTE	Line termination equipment
MST	Multiplex section termination
NNI	Network node interface
PDH	Plesiochronous digital hierarchy
PRC	Primary reference clock
PSTN	Public switched telephony network
SDH	Synchronous digital hierarchy

STM-N	Synchronous transport module (level) N
TCP	Termination connection point
TMN	Telecommunication management network
TU-n	Tributary unit (level) n
VC-n	Virtual Container (level) n

1.3 Structure of Recommendation

Clause 2 contains a vocabulary of terms for defining SDH network architecture. Clause 3 contains the detailed description of the architecture in functional terms. The degree of rigour used is consistent with that required for the purposes of network design, network management and network performance analysis. Clause 4 uses the functional description and applies it to actual network topologies, structures and network elements which are likely to be required. Clause 5 contains a description of protection and restoration from a functional architecture viewpoint.

NOTE – The relationship and/or alignment of Recommendation I.311 "B-ISDN general network aspects" with this Recommendation is under study to determine the relationship between an ATM transport network and a layered model of the SDH based transport network.

Clause 6 addresses SDH network synchronization principles and corresponding architectural requirements including aspects of the evolution from existing synchronization architectures.

Clause 7 identifies the applications envisaged for the various types of primary rate mappings into the VC-11 and VC-12 defined in Recommendation G.709.

Annex A describes the introduction of SDH networks in terms of the choices which must be made by an operator and the implications on network aspects and on interworking between PDH and SDH.

2 Vocabulary for SDH network architecture

NOTES

1 The terms used here are specific to this Recommendation and should not be confused with the same terms used in, for example, Recommendations I.320, I.321, I.324, I.340.

2 Where a definition contains a term which is itself defined, that term is given in quotation marks.

2.1 Generic terms

The terms referring to generic entities can be further qualified in references to specific layers by adding the appropriate layer qualifier (e.g. SDH higher-order path termination, multiplex section connection, PDH 44 736 kbit/s path termination, ATM virtual path connection).

1 **network**: All of the entities which together provide communication services (such as equipment, plant, facilities).

2 **transport**: The functional process of transferring information between points at different locations.

3 **transmission**: The physical process of propagating information signals through a physical medium.

4 **transport network**: The functional resources of the "network" which conveys user information between locations.

5 **characteristic information**: A signal of characteristic rate and format which is transferred within and between "sub-networks" and presented to an "adaptation" function for "transport" by the server layer network.

6 **architectural component**: Any item required to generically describe "transport network" functionality independent of implementation technology.

7 **transport processing function**: An “architectural component” defined by the information processing which is performed between its inputs and outputs. It has one or more inputs and one or more outputs which may be associated with inputs and outputs of other functions and entities. Such associations are termed “binding” relationships.

8 **transport entity**: An “architectural component” which transfers information transparently between points at different locations. Information is transferred into the “transport entity” at its input and out of the “transport entity” at its output. “Transport entities” may be bound to each other or to “transport processing functions”. The points at which they are bound are the “reference points” of the “transport network”.

9 **topological component**: An “architectural component” which describes the “transport network” in terms of the topological relationships between sets of “reference points”. A topological description in terms of these components describes the routing possibilities of the network and hence its ability to support “transport entities”.

10 **reference point**: An “architectural component” which describes the “binding” between inputs and outputs of “transport processing functions” and “transport entities”. It is characterised by the information which passes across it.

11 **transport network layer (or layer network)**: A “topological component” solely concerned with the generation and transfer of particular “characteristic information”.

NOTES

1 “Transport networks” are built up of successive “transport network layers”, one upon another. Each “transport network layer” provides “transport” for the layer above and uses “transport” provided by the layer below. The layer providing “transport” is termed a server and the layer using “transport” is termed a client. Two such layers are said to participate in a “client/server” relationship. A “transport network layer” is defined, at the highest level, by the “trails” which it supports or is capable of supporting and is characterized by its “characteristic information”.

2 A “layer network” should not be confused with the layer concept used in the protocol reference model described in Recommendation I.311.

12 **sub-network**: A “topological component” used to effect routing and management. It describes the potential for “sub-network connections” across the “sub-network”. It can be partitioned into interconnected “sub-networks” and “links”. Each “sub-network” in turn can be partitioned into smaller “sub-networks” and “links” and so on. A “sub-network” may be contained within one physical node.

13 **matrix**: A “topological component” used to effect routing and management. It describes the potential for “matrix connections” across the “matrix”. A “matrix” is contained within one physical node. As such, it represents the limit to the recursive partitioning of a “sub-network”.

14 **access group**: A group of co-located “access points” together with their associated “trail termination” functions.

15 **link**: A “topological component” which describes the fixed relationship between a “sub-network” and another “sub-network” or “access group”.

16 **trail**: A “transport entity” in a server layer responsible for the integrity of transfer of “characteristic information” from one or more client network layers between server layer “access points”. It defines the association between “access points” in the same “transport network layer”. It is formed by combining a near-end “trail termination” function, a “network connection” and a far-end “trail termination” function.

17 **connection**: A “transport entity” which is capable of transferring information transparently between “connection points”. A “connection” defines the association between the “connection points” and the “connection points” delimit the “connection”.

18 **tandem connection**: A arbitrary series of “link connections” and “sub-network connections”.

19 **tandem connection bundle**: A parallel set of “tandem connections” with collocated end points.

20 **unidirectional connection**: A “connection” which is capable of transparently transferring information from input to output.

21 **bidirectional connection**: A “connection” consisting of an associated pair of “unidirectional connections” capable of simultaneously transferring information in opposite directions between their respective inputs and outputs.

22 **point-to-multipoint connection**: A “connection” capable of transferring information from a single input to multiple outputs.

23 **network connection**: A “transport entity” formed by the series of “connections” between “termination connection points”.

24 **sub-network connection**: A “transport entity” formed by a “connection” across a “sub-network” between “connection points”. It can be configured as part of the “trail management process”

25 **matrix connection**: A “sub-network connection” that is a “connection” across a “matrix”. It may be configured as part of the “trail management process” or it may be fixed.

26 **link connection**: A “transport entity” provided by the “client/server” association. It is formed by a near-end “adaptation” function, a server “trail” and a far-end “adaptation” function between “connection points”. It can be configured as part of the “trail management process” in the associated server layer.

27 **trail termination**: A “transport processing function” which generates the “characteristic information” of a layer network and ensures integrity of that “characteristic information”. The “trail termination” defines the association between the “access point” and “termination connection point” and these points therefore delimit the “trail termination”.

28 **trail termination source**: A “transport processing function” which accepts adapted client layer network “characteristic information”, adds “trail” overhead and assigns it to an associated “network connection” in the same “transport network layer”.

29 **trail termination sink**: A “transport processing function” which terminates a “trail”, extracts the “trail” overhead information, checks validity and passes the adapted client layer network “characteristic information” to the “adaptation” function.

30 **adaptation**: A “transport processing function” which adapts a server layer to the needs of a client layer. The “adaptation” function defines the “server/client” association between the “connection point” and “access point” and these points therefore delimit the “adaptation” function. “Adaptation” functions have been defined for many “client/server” interactions.

31 **access point**: A “reference point” where the output of an “adaptation” source function is bound to an input of a “trail termination source” or the output of a “trail termination sink” is bound to the input of an “adaptation” sink function. The “access point” is characterized by the adapted client layer “characteristic information” which passes across it. A bi-directional “access point” is formed by an associated contra-directional pair.

32 **connection point**: A “reference point” where the output of a “trail termination source” or a “connection” is bound to the input of another “connection” or where the output of a “connection” is bound to the input of a “trail termination sink” or another “connection”. The “connection point” is characterized by the information which passes across it. A bi-directional “connection point” is formed by the association of a contra-directional pair.

33 **termination connection point**: A special case of a “connection point” where a “trail termination” function is bound to an “adaptation” function or a “matrix”.

34 **client/server**: An association represented by the “adaptation” function performed at the periphery of a “transport network layer”. “Client/server” relationships never exist outside of network elements.

35 **binding**: A direct relationship between the output of a “transport processing function” or “transport entity” and the input of another “transport processing functions” or “transport entity” with no intervening points of interest. “Bindings” represent the static connectivity within a network element. “Binding” relationships can never extend outside of network elements.

36 **pairing**: A relationship between sink and source “transport processing functions” or “transport entities” which have been associated for the purposes of bi-directional transport.

37 **trail management process**: Configuration of network resources during network operation for the purposes of allocation, re-allocation and routing of "trails" to provide "transport" to client networks.

38 **commissioning process**: Configuration of network resources prior to network operation.

39 **connection supervision**: The process of monitoring the integrity of a "connection" or "tandem connection" which is part of a "trail".

2.2 Terms specific to SDH

40 **circuit layer network**: A "layer network" which is concerned with the transfer of information between circuit layer "access points" in direct support of telecommunication services.

41 **path layer network**: A "layer network" which is concerned with the transfer of information between path layer "access points" in support of one or more "circuit layer networks".

NOTE – In the case of SDH, there are higher-order "path layer networks" and lower-order "path layer networks". Higher-order "path layer networks" provide a server network for the lower-order "path layer networks". VC-1/VC-2 "path layer networks" may be described as 'lower-order' in relation to VC-3 and VC-4 while the VC-3 "path layer network" may be described as 'lower-order' in relation to VC-4. The term "path layer network" when used unqualified can refer to any of the defined SDH "path layer networks".

42 **transmission media layer network**: A "layer network" which may be media-dependent and which is concerned with the transfer of information between section layer "access points" in support of one or more "path layer networks". It is further divided into a "section layer network" and a "physical media layer network".

43 **section layer network**: A "layer network" which is concerned with the transfer of information between section layer "access points". In the case of SDH, the " section layer network" is further divided into the "multiplex section layer network" and the "regenerator section layer network".

44 **multiplex section layer network**: A "layer network" which may be media-dependent and which is concerned with the transfer of information between multiplex section layer "access points".

45 **regenerator section layer network**: A "layer network" which is media dependent and which is concerned with the transfer of information between regenerator section layer "access points".

46 **physical media layer network**: A "layer network" which is concerned with the actual optical fibre, metallic pair or radio frequency which supports the "section layer network".

47 **circuit**: A "trail" in the "circuit layer network".

48 **path**: A "trail" in the "path layer network".

49 **section**: A "trail" in the "section layer network".

50 **path termination**: A "trail termination" in the "path layer network".

51 **section termination**: A "trail termination" in the "section layer network".

52 **path termination source**: A "trail termination source" in the "path layer network".

53 **section termination source**: A "trail termination source" in the "section layer network".

54 **path termination sink**: A "trail termination sink" in the "path layer network".

55 **section termination sink**: A "trail termination sink" in the "section layer network".

2.3 Terms associated with protection

56 **trail protection**: A protection type that is modelled by a sub-layer that is generated by expanding the "trail" "access points".

57 **sub-network connection protection**: A protection type that is modelled by a sub-layer that is generated by expanding the "sub-network" "connection point".

58 **dedicated protection**: A protection architecture that provides capacity dedicated to the protection of traffic-carrying capacity (1+1).

59 **shared protection**: A protection architecture using m protection entities shared amongst n working entities (m:n). The protection entities may also be used to carry extra traffic when not in use for protection.

60 **single ended operation**: A protection operation method which takes switching action only at the affected end of the protected entity (e.g. “trail”, “sub-network connection”), in the case of a unidirectional failure.

61 **dual ended operation**: A protection operation method which takes switching action at both ends of the protected entity (e.g. “connection”, “path”), even in the case of a unidirectional failure.

Alphabetical list of terms defined

14	Access group
31	Access point
30	Adaptation
6	Architectural component
21	Bidirectional connection
35	Binding
5	Characteristic information
47	Circuit
40	Circuit layer network
34	Client/server
38	Commissioning process
17	Connection
32	Connection point
39	Connection supervision
58	Dedicated protection
61	Dual end operation
15	Link
26	Link connection
13	Matrix
25	Matrix connection
44	Multiplex section layer network
56	Multiplex section protection
1	Network
23	Network connection
36	Pairing
48	Path

41	Path layer network
50	Path termination
54	Path termination sink
52	Path termination source
46	Physical media layer network
22	Point-to-multipoint connection
10	Reference Point
45	Regenerator section layer network
49	Section
43	Section layer network
51	Section termination
55	Section termination sink
53	Section termination source
59	Shared protection
60	Single end operation
12	Sub-network
24	Sub-network connection
57	Sub-network connection protection
18	Tandem connection
19	Tandem connection bundle
33	Termination connection point
9	Topological component
16	Trail
37	Trail management process
56	Trail protection
27	Trail termination
29	Trail termination sink
28	Trail termination source
3	Transmission
42	Transmission media layer network
2	Transport
8	Transport entity
4	Transport network
11	Transport network layer
7	Transport processing function
20	Unidirectional connection

3 Transport functional architecture of SDH-based networks

3.1 Introduction

The various functions which constitute a telecommunications network can be classified into two broad functional groups. One is the transport functional group which transfers any telecommunications information from one point to another point(s). The other is the control functional group which realises various ancillary services and operations and maintenance functions. This Recommendation is concerned with the transport functional group.

A transport network transfers user information from one point to another point(s) bidirectionally or unidirectionally. A transport network can also transfer various kinds of network control information such as signalling and operations and maintenance information for the control functional group as well as for its own use.

Since the transport network is a large, complex network with various components, an appropriate network model with well defined functional entities is essential for its design and management. The transport network can be described by defining the associations between points in the network. In order to simplify the description, a transport network model, based on the concepts of layering and partitioning within each layer is used in a manner which allows a high degree of recursiveness. It is recommended that this method be used for describing the transport network.

3.2 Architectural components

The transport network has been analysed to identify generic functionality which is independent of implementation technology. This has provided a means to describe network functionality in an abstract way in terms of a small number of architectural components. These are defined by the function they perform in information processing terms or by the relationships they describe between other architectural components. In general the functions described here act on information presented at one or more inputs and present processed information at one or more outputs. They are defined and characterized by the information process between their inputs and outputs. The architectural components are associated together in particular ways to form the network elements from which real networks are constructed. The points at which the inputs and outputs of processing functions and transport entities are bound are the reference points of the transport network architecture.

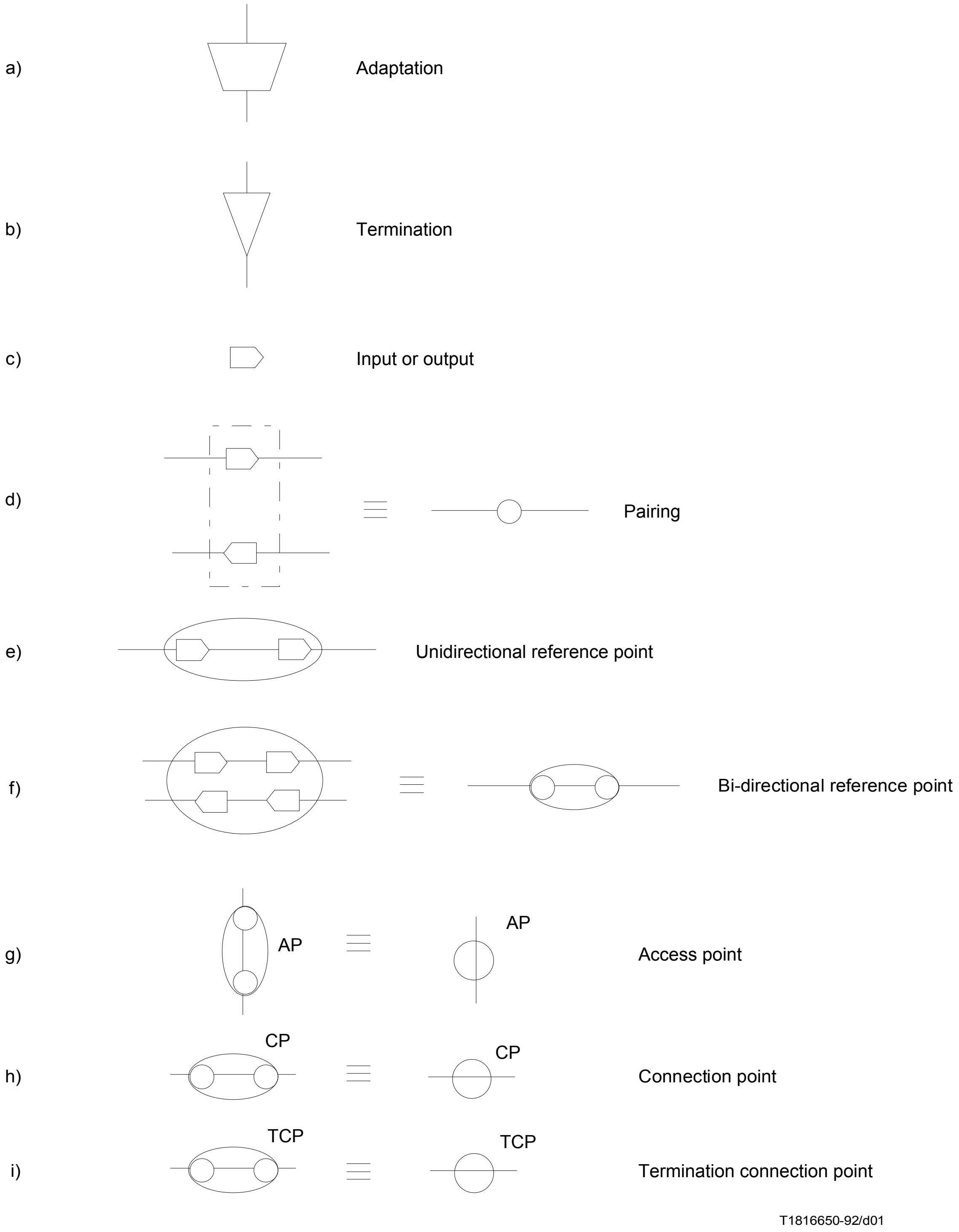
Some diagrammatic conventions have been developed to support the descriptions which follow and these are illustrated in Figures 3-1 to 3-4.

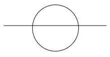
3.2.1 Topological components

The topological components provide the most abstract description of a network in terms of the topological relationships between sets of like reference points. Three topological components have been distinguished; these are the layer network, the sub-network and the link. Using only these components, it is possible to describe fully, the logical topology of a network.

3.2.1.1 Layer network

A layer network is defined by the complete set of like access points which may be associated for the purpose of transferring information. The information transferred is characteristic of the layer and is termed characteristic information. Access point associations in a layer network may be made and broken by a layer management process thus changing its connectivity. A separate, logically distinct layer network exists for each access point type. A layer network is made up of sub-networks and links between them. The structures within and between layer networks are described by the components defined below.





NOTE – This convention is not used further in this Recommendation but may appear elsewhere.

FIGURE 3-1/G.803

Diagrammatic conventions for processing functions and reference points

Output \ Input		Adaptation		Trail termination		Connection
		Source	Sink	Source	Sink	
Adaptation	Source	X	CP	AP	X	X
	Sink	CP	X	X	TCP	CP
Trail termination	Source	TCP	X	X	X	TCP
	Sink	X	AP	X	X	X
Connection		CP	X	X	TCP	CP

Allowable bindings

X Not allowed
CP Connection point
TCP Termination connection point
AP Access point

Reference point	Connection point	Termination connection point	Access point
Connection point	Link connection / Sub-network connection[a)]	Sub-network connection[a)]	X
Termination connection point	Sub-network connection[a)]	Network connection	X
Access point	X	X	Trail

Supported connection types between reference points

X No connection supported

[a)] The matrix connection is not shown explicitly because it is the limit of the recursion of sub-network connection

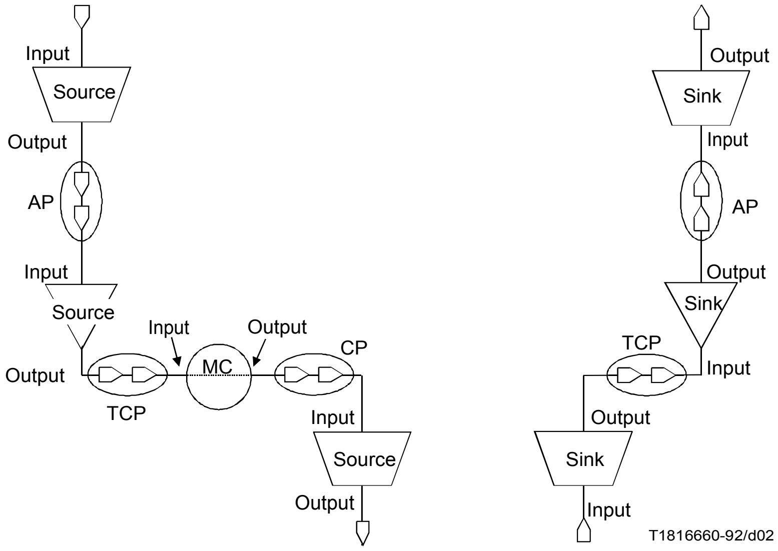


FIGURE 3-2/G.803

Allowable bindings and types of reference points

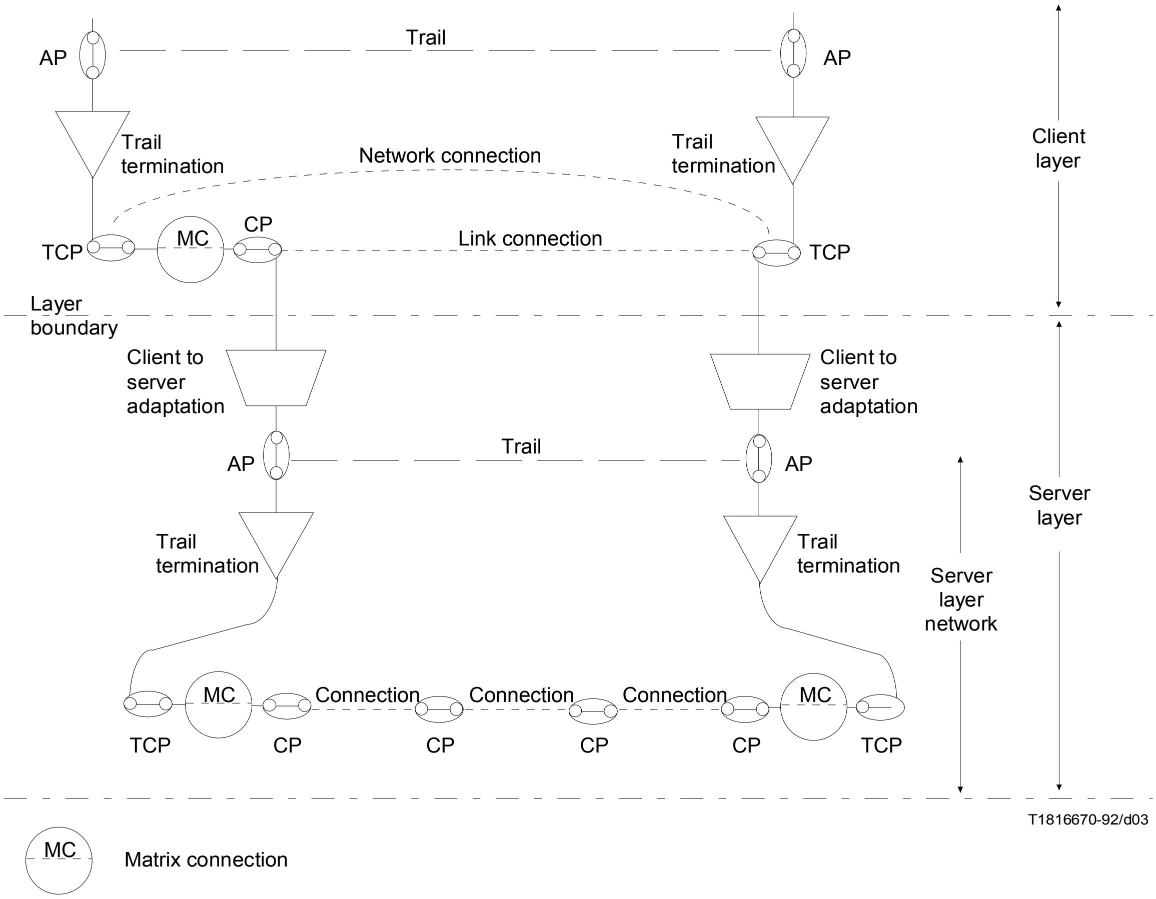


FIGURE 3-3/G.803

Example of functional model fragment illustrating use of some architectural components

3.2.1.2 Sub-network

A sub-network is defined by the complete set of like connection points which may be associated for the purpose of transferring characteristic information. The connection point associations in a sub-network may be made and broken by a layer management process thus changing its connectivity. Sub-networks are generally made up of lower level (i.e. smaller) sub-networks and links between them. The lowest level of this recursion that is of network architectural interest is the matrix (contained in an individual network element).

3.2.1.3 Link

A link is defined by the sub-set of connection points in one sub-network which are associated with a sub-set of connection points on another sub-network for the purpose of transferring characteristic information between sub-networks. The set of connection point associations which define the link cannot be made or broken by the layer management process. The link represents the topological relationship between a pair of sub-networks. In general, the link is used to describe the association between connection points contained in one network element with those in another. The lowest level of recursion of a link (through the layering concept) represents the transmission media.

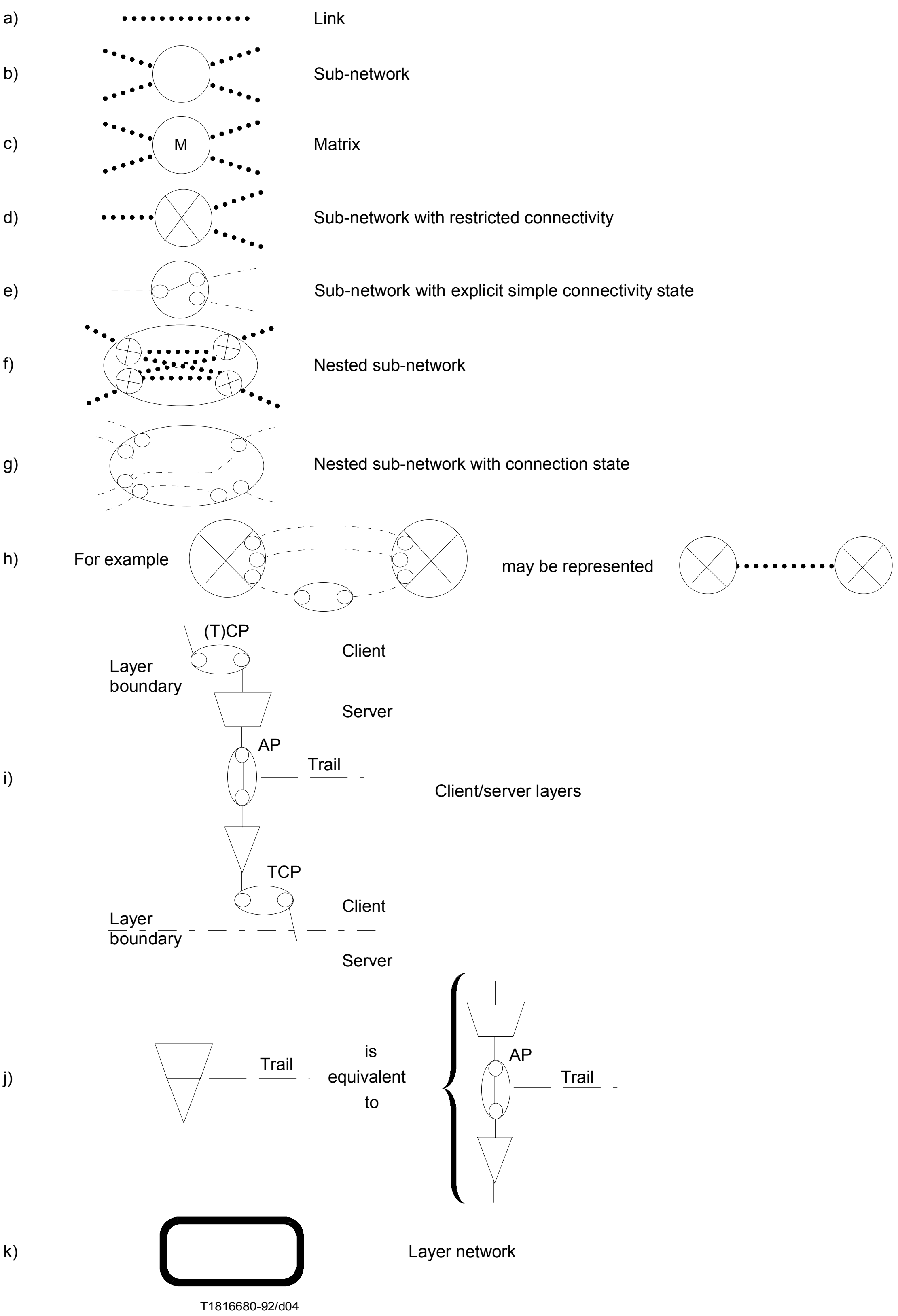


FIGURE 3-4/G.803

Other diagrammatic conventions

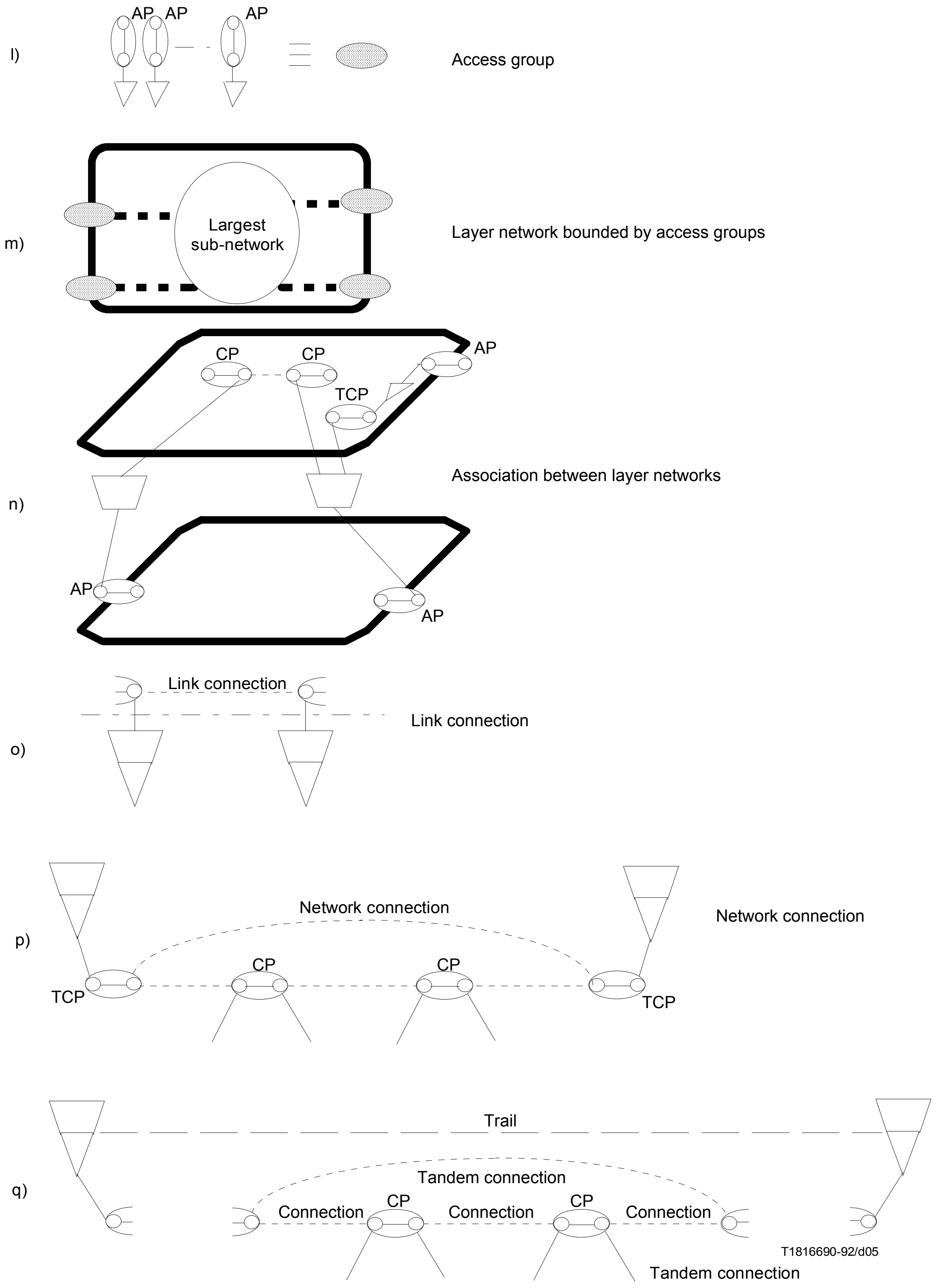


FIGURE 3-4/G.803 *(end)*

Other diagrammatic conventions

3.2.2 Transport entities

The transport entities provide transparent information transfer between layer network reference points. That is to say there is no information change between input and output other than that resulting from degradations in the transfer process.

Two basic entities are distinguished according to whether the information transferred is monitored for integrity. These are termed connections and trails. Connections are further distinguished into network connections, sub-network connections and link connections according to the topological component to which they belong.

3.2.2.1 Network connection

A network connection is capable of transferring information transparently across a layer network. It is delimited by termination connection points (TCPs). It is the highest level of abstraction within a layer and may be partitioned into a concatenation of sub-network connections and link connections. There is no information as to the integrity of the transferred information although information on the integrity of the connection itself can often be implied from other sources.

3.2.2.2 Sub-network connection

A sub-network connection is capable of transferring information transparently across a sub-network. It is delimited by connection points at the boundary of the sub-network and represents the association between connection points. Sub-network connections are, in general, made up of a concatenation of lower level sub-network connections and link connections and can be viewed as an abstraction of this more complex entity. The lowest level of this recursion, the matrix connection, represents a cross-connection on an individual matrix in a network element.

3.2.2.3 Link connection

A link connection is capable of transferring information transparently across a link between two sub-networks. It is delimited by connection points at the boundary of the link and the sub-networks and represents the association between such a connection point pair. Link connections are provided by trails in the server layer network.

3.2.2.4 Trail

A trail represents the transfer of validated characteristic information between access points therefore it represents the association between access points together with the incremental information regarding the information transfer integrity. A trail is formed from a network connection by including trail termination functions between the TCPs and the access points.

3.2.3 Transport processing functions

The two generic processing functions of adaptation and termination are distinguished in describing the architecture of layer networks. They occur together at layer boundaries and are defined by the information processing which is performed between their inputs and outputs.

3.2.3.1 Adaptation function

The adaptation source function is the process whereby the characteristic information of the client layer network is adapted to a form suitable for transport in the server layer network. The complementary function of recovering information which had been adapted is the adaptation sink function. The specific adaptation function depends on the characteristic information in the two layers. The following are examples of processes which may occur singly or in combination in inter layer adaptation functions; coding, rate changing, aligning, justification, multiplexing.

3.2.3.2 Trail termination function

Trail termination functions provide information related to the integrity of information transfer in a trail. This is typically achieved by inserting incremental information at a trail termination source function which is monitored at a corresponding sink function.

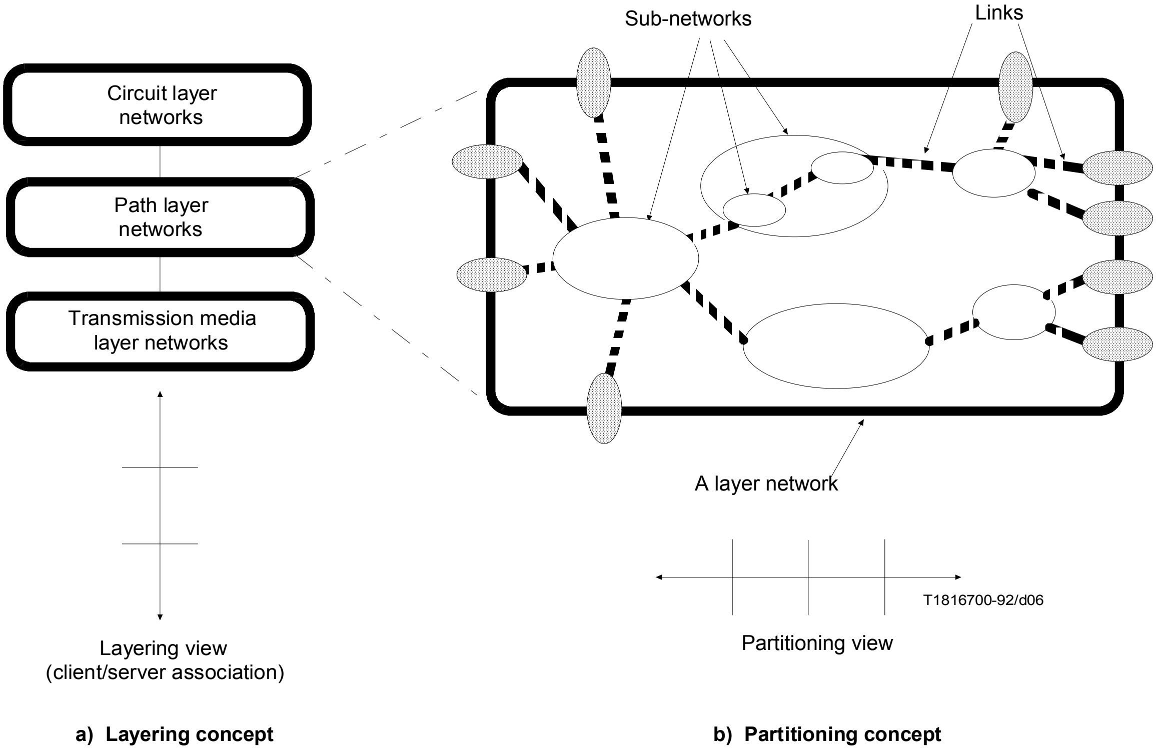
3.2.4 Reference points

Reference points in the layer network are formed by binding the input of one transport processing function or transport entity to the output of another. They are bi-directional if the associated transport processing function or transport entity inputs or outputs are paired. These binding relationships can never extend outside a network element. The allowable bindings and resultant specific types of reference points are shown in Figure 3-2. The connection types supported by these reference points are also shown in Figure 3-2.

3.3 Partitioning and layering

3.3.1 Introduction

A transport network can be decomposed into a number of independent transport network layers with a client/server association between adjacent layers. Each layer network can be separately partitioned in a way which reflects the internal structure of that layer. Thus the concepts of partitioning and layering are orthogonal as shown in Figure 3-5.



a) Layering concept **b) Partitioning concept**

FIGURE 3-5/G.803

Orthogonal views of layering and partitioning

3.3.1.1 Importance of the partitioning concept

The partitioning concept is important as a framework for defining:

a) the network structure within a network layer;

b) significant administrative boundaries between network operators jointly providing end-to-end paths within a single layer;

c) domain boundaries within the layer network of a single operator with a view to apportioning performance objectives to the sub-systems of which the network is composed;

d) independent routing domain boundaries in relation to the operation of the path management process.

3.3.1.2 Importance of the layering concept

The layering concept of the transport network is based on the following assumptions:

a) each layer network can be classified into similar functions;

b) it is simpler to design and operate each layer separately than it is to design and operate the entire transport network as a single entity;

c) a layered network model can be useful in defining the managed objects in the telecommunications management network (TMN);

d) each layer network is able to have its own operations and maintenance capability such as protection switching and automatic failure recovery against malfunctions or failures and mis-operations. This capability minimizes the operations and maintenance action and influences in other layers;

e) it is possible to add or change a layer without affecting other layers from the architectural viewpoint;

f) each network layer may be defined independently of the other layers.

3.3.2 Partitioning concept

The partitioning concept can be divided into two related areas: the partitioning of sub-networks which describes topology and the partitioning of network connections which describes connectivity.

3.3.2.1 Partitioning of sub-networks

A sub-network simply describes the capability to associate a number of connection points or TCPs and does not directly describe the topology of architectural components used to make up the sub-network. In general, any sub-network can be partitioned into a number of smaller sub-networks interconnected by links. The way in which the smaller sub-networks and links are bound to each other describes the topology of the sub-network. This can be expressed as follows:

Sub-network = Smaller sub-networks + Links + Topology.

Thus, it is possible with the partitioning concept to decompose recursively any layer network to reveal the desired level of detail. This level of detail is likely to coincide with the individual equipment which implement connection matrices in individual network elements which provide the flexible connection capability of the layer network.

Examples of sub-networks are the international portion and the national portions of a layer network, which can be further divided into transit portions and access portions and so on as shown in Figure 3-6.

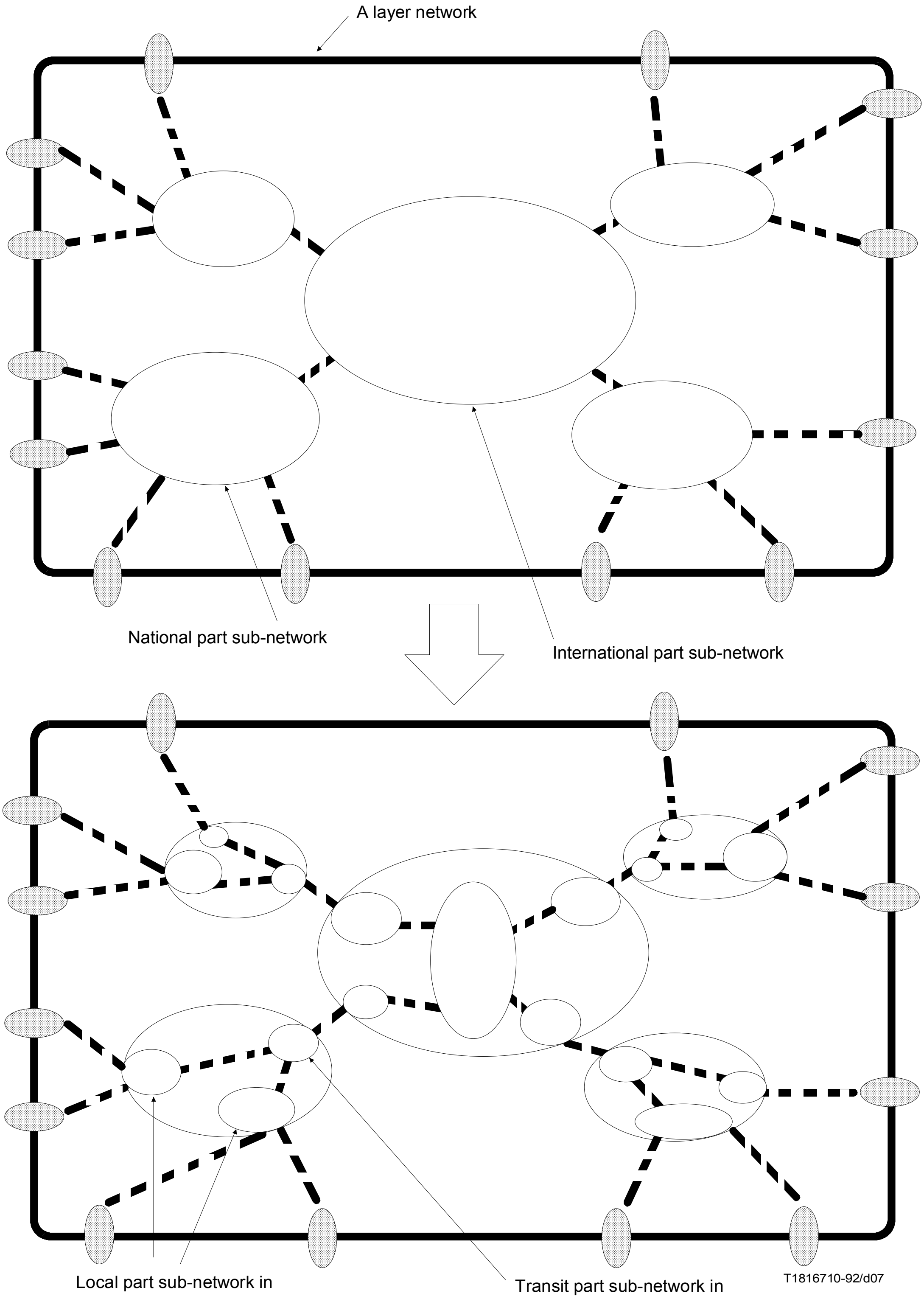


FIGURE 3-6/G.803

Partitioning of layer networks and sub-networks

3.3.2.2 Partitioning of network connections and sub-network connections

A trail is a transport entity formed by the binding of trail terminations to a network connection as shown in Figure 3-7 and is a particular instance of the capability of a layer network. The network connection is an instance of the capability of the largest sub-network definable within the layer network. In the same way that it is possible to partition a sub-network, it is also possible to partition a network connection. In general, a network connection can be partitioned into a serial combination of sub-network connections and link connections as follows:

Network connection = TCP + sub-network connections + link connections + TCP.

Each of the sub-network connections can be further partitioned into a serial combination of sub-network connections and link connections. In this case, the partitioning must start and finish with a sub-network connection as follows:

Sub-network connection = CP + smaller sub-network connections + link connections + CP.

The partitioning of network connections and sub-network connections will mirror the partitioning of the sub-networks. In this case, the normal limit of the recursive partitioning would be individual connection point associations on the basic matrices which are used to construct the layer network.

The way the partitioning of sub-network connections into smaller sub-network connections and link connections mirrors that of the sub-networks is shown in Figure 3-8.

3.3.2.3 Link connections and the layering concept

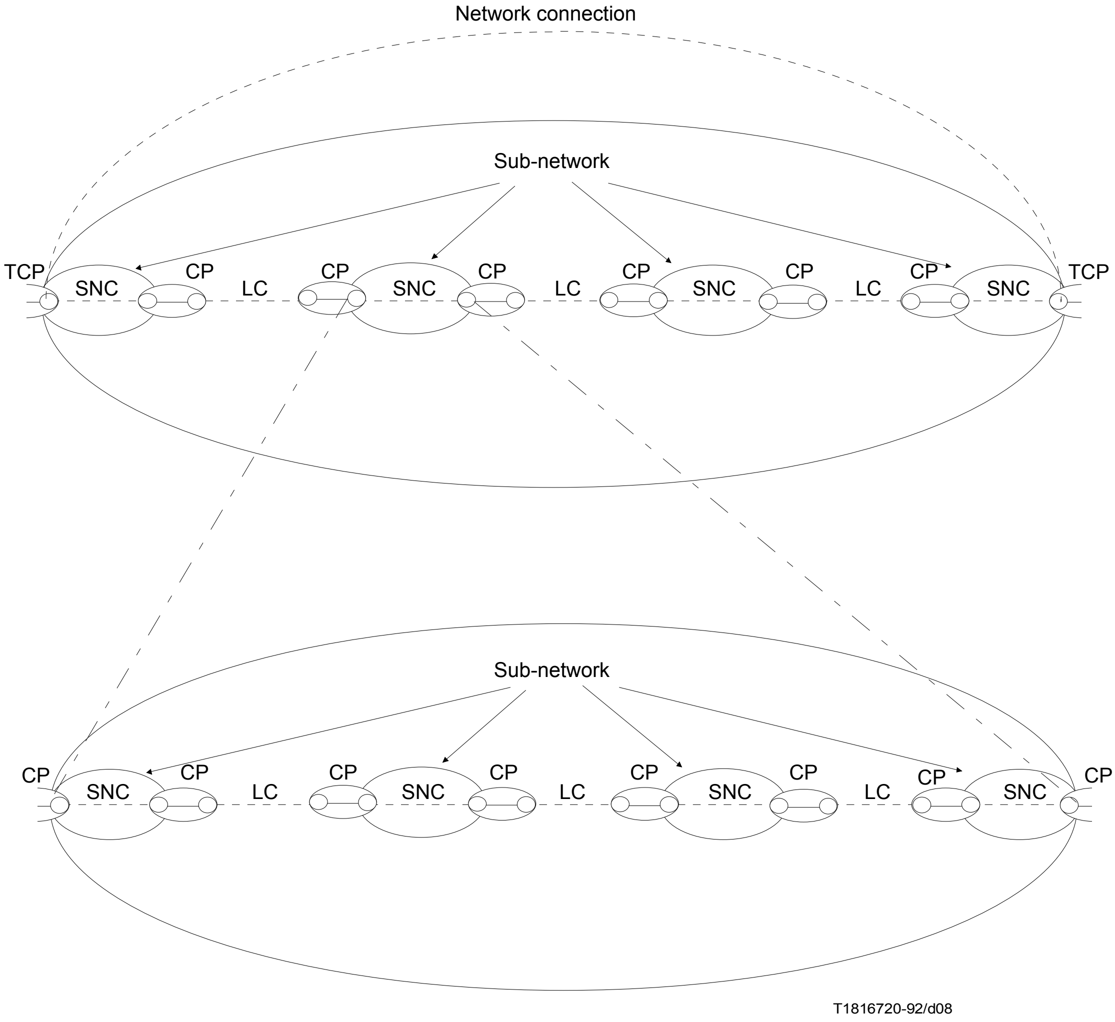
When a network connection has been fully decomposed into constituent link connections and sub-network connections, each link connection may be considered as an abstract transport entity composed of adaptation functions and a trail using the layering concept.

3.3.3 Layering concept

The client/server association between adjacent layer networks is one where a link connection in the client layer network is provided by a trail in the server layer network. Table 1 provides a record of the client/server associations currently defined in ITU-T Recommendations in which SDH layers participate.

The layer networks which have been identified in the transport network functional model should not be confused with the layers of the OSI Protocol Reference Model (PRM).

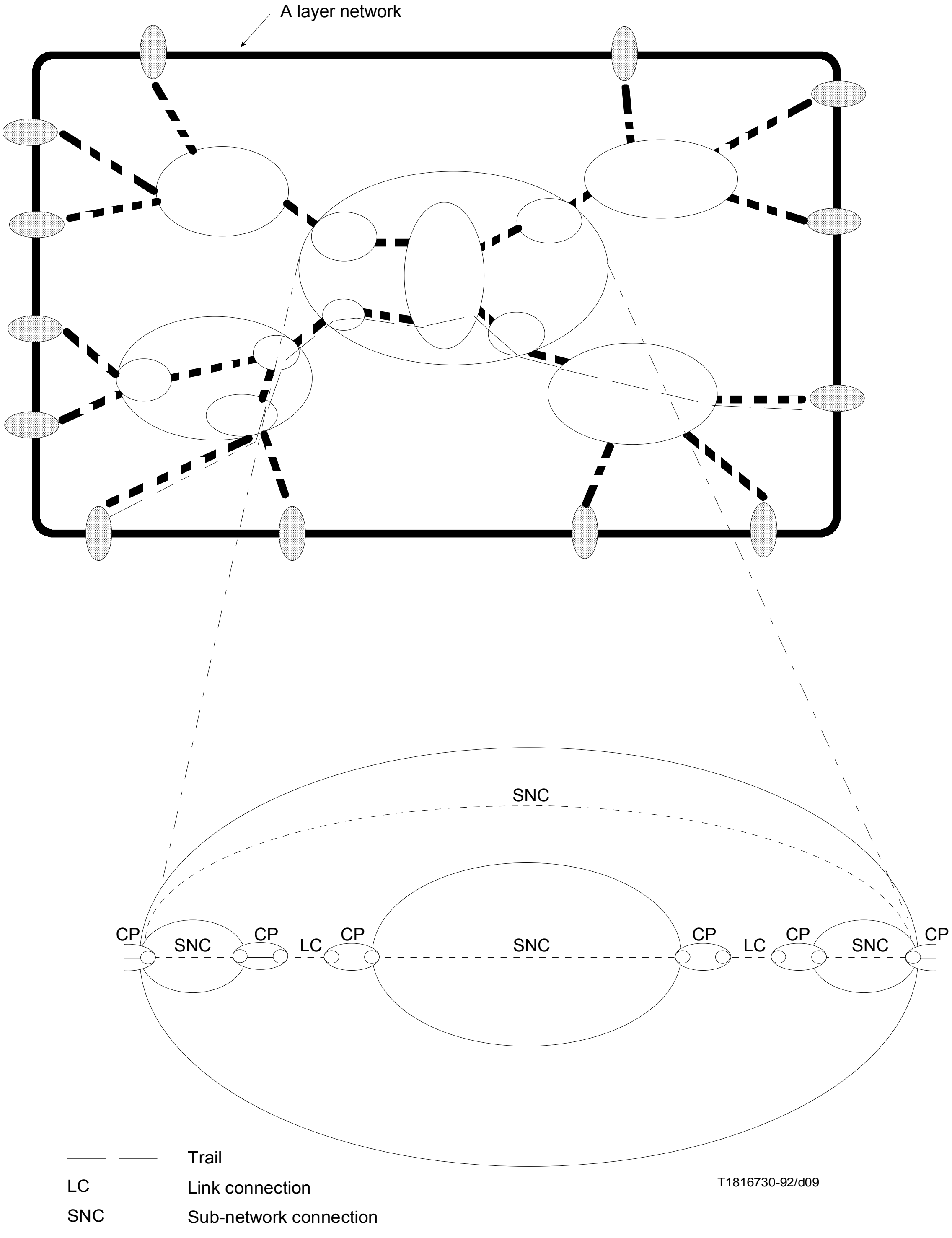
The concept of adaptation is introduced to allow layer networks with different characteristic information structure to support one another by the client/server relationship and this is the source of the recursion which is evident in the transport network model. It is also the reason why there is not the same concept of contiguous layer boundaries in the transport network model as in the OSI PRM. All the reference points belonging to a single layer network can be visualised as lying on a single plane as illustrated in Figure 3-4 m). From a transport network functional viewpoint therefore the adaptation function falls between the layer network planes. However, it is considered to belong from an administrative viewpoint to the server layer trail to which it is attached. This is the rationale behind the administrative layer boundary illustrated in Figure 3-4 n).



LC Link connection
SNC Sub-network connection

FIGURE 3-7/G.803

Partitioning of a network connection into sub-network connections



—— ——	Trail
LC	Link connection
SNC	Sub-network connection

FIGURE 3-8/G.803

Relationship between partitioning of sub-networks and partitioning of sub-network connections

TABLE 1/G.803

Adaptation function references

Client layer	Server layer	Adaptation reference	Client network characteristic information
1544 kbit/s asynch	VC-11 path	G.709	1544 kbit/s ± 50 ppm
1544 kbit/s bit synch	VC-11 path	G.709	1544 kbit/s nominal
1544 kbit/s byte synch	VC-11 path	G.709	1544 kbit/s nominal G.704 octet structured
2048 kbit/s asynch	VC-12 path	G.709	2048 kbit/s ± 50 ppm
2048 kbit/s bit synch	VC-12 path	G.709	2048 kbit/s nominal
2048 kbit/s byte synch	VC-12 path	G.709	2048 kbit/s nominal G.704 octet structured
6312 kbit/s asynch	VC-2 path	G.709	6312 kbit/s ± 30 ppm
34 368 kbit/s asynch	VC-3 path	G.709	34 368 kbit/s ± 20 ppm
44 736 kbit/s asynch	VC-3 path	G.709	44 736 kbit/s ± 20 ppm
139 264 kbit/s asynch	VC-4 path	G.709	139 264 kbit/s ± 15 ppm
B-ISDN ATM virtual path	VC-4 or VC-4-4c (note)	G.709	53-octet cells
VC-11 path	VC-3 HO path or VC-4 path	G.709	VC-11 + frame offset
VC-12 path	VC-3 HO path or VC-4 path	G.709	VC-12 + frame offset
VC-2 path	VC-3 HO path or VC-4 path	G.709	VC-2 + frame offset
VC-3 LO path	VC-4 path	G.709	VC-3 + frame offset
VC-3 HO path	STM-N section	G.709	VC-3 + frame offset
VC-4 path	STM-N section	G.709	VC-4 + frame offset

LO Lower-order
HO Higher-order

NOTE – Mappings into other SDH virtual containers are under study.

3.3.3.1 Transport network layers

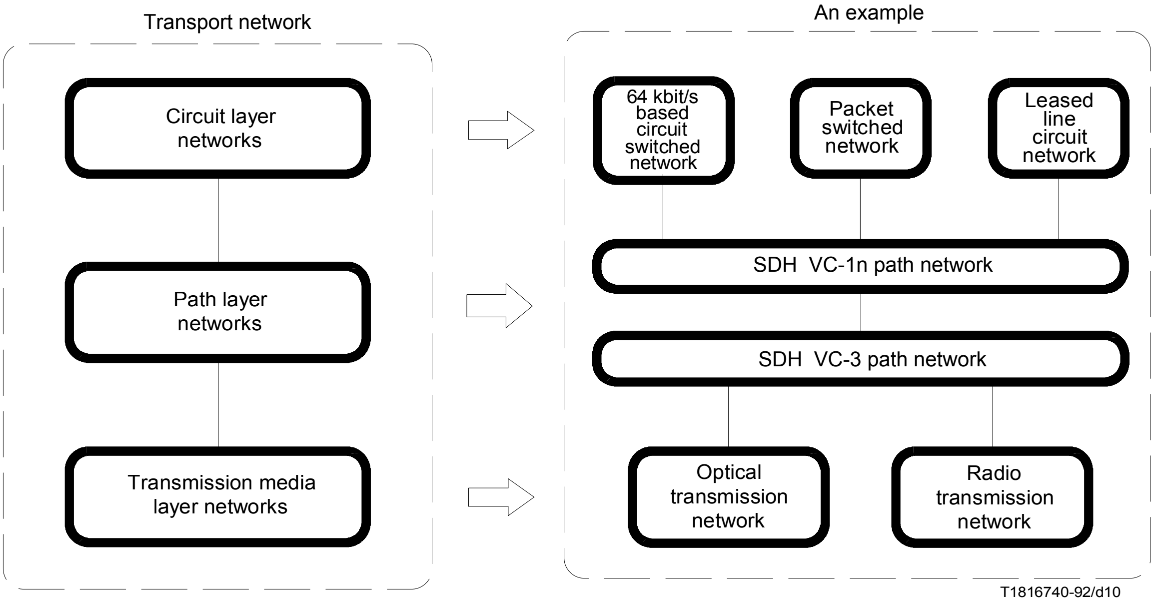
Figure 3-9 illustrates the layered model of the transport network. Features of the layered model are as follows:

- it is classified broadly into three classes of layer network: a circuit layer network, a path layer network and a transmission media layer network;
- the association between any two adjacent layers is a server/client association;
- each layer has its own operations and maintenance capability.

The three classes of layer networks are described as follows:

- circuit layer networks – provide users with telecommunications services such as circuit switched services, packet switched services and leased line services. Different circuit layer networks can be identified according to the services provided. Circuit layer networks are independent of path layer networks.

- path layer networks – are used to support different types of circuit layer networks. In the case of SDH there are two path layer networks: the lower-order path layer network and the higher-order path layer network. The potential for management control of the connectivity in path layer networks is a key feature of SDH networks. Path layer networks are independent of transmission media layer networks.



NOTE – The possibility of a third path layer network is for further study.

FIGURE 3-9/G.803

Layered model of the transport network

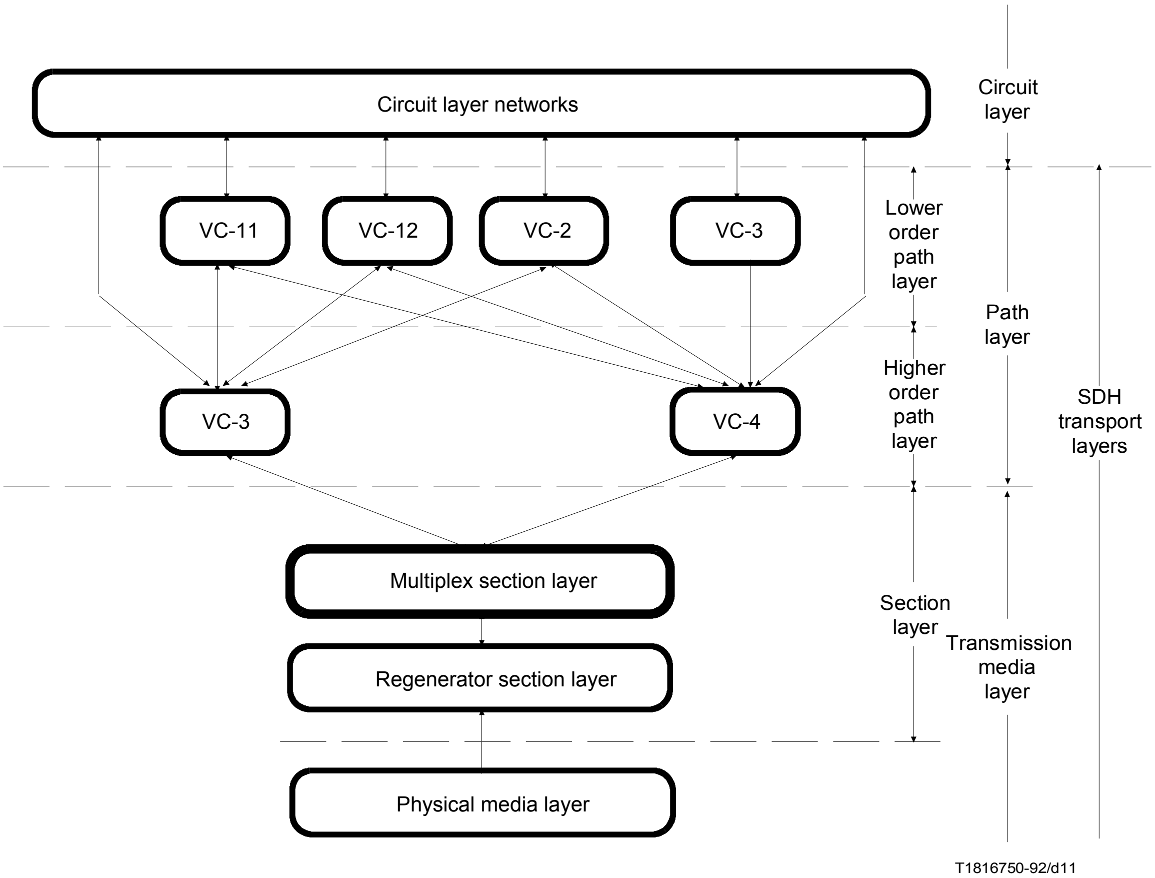
- transmission media layer networks – are dependent on the transmission medium such as optical fibre and radio. Transmission media layer networks are divided into section layer networks and physical media layer networks. Section layer networks are concerned with all the functions which provide for the transfer of information between two nodes in path layer networks whereas physical media layer networks are concerned with the actual fibre, metallic pair or radio frequency channel which supports a section layer network. In the case of SDH, there are two section layer networks: a multiplex section layer network and a regenerator section layer network. The multiplex section layer network is concerned with the end-to-end transfer of information between locations which route or terminate paths whereas the regenerator section layer is concerned with the transfer of information between individual regenerators and between regenerators and locations which route or terminate paths.

3.3.3.2 Client/server association

The client/server association between adjacent layer networks is one where a link connection in the client layer network is provided by a trail in the server layer network. More specifically:

- a link connection in the circuit layer network is provided by a path in the path layer network;
- a link connection in the path layer network is provided by a section in the transmission media layer network.

The layered relationship for the SDH-based transport network is further illustrated in Figure 3-10.



NOTE – The necessity of an explicit description of a WDM layer in the transmission media layer is for further study.

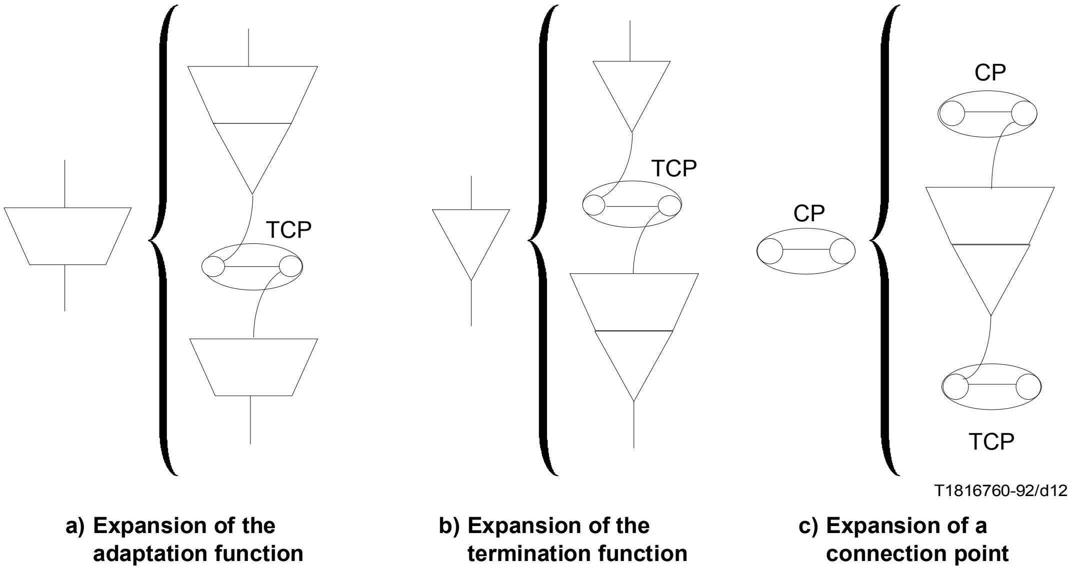
FIGURE 3-10/G.803

SDH-based transport network layered model

3.3.3.3 Decomposition of layer networks

3.3.3.3.1 General principles of decomposition of layers

It is possible to decompose a layer by expanding either the adaptations, terminations, or (termination) connection points of the layer. In each case, this decomposition results in a new layer boundary as illustrated in Figure 3-11. It should be noted that the new layer boundary will be different in each case.



a) Expansion of the adaptation function

b) Expansion of the termination function

c) Expansion of a connection point

FIGURE 3-11/G.803

Generation of sub-layers

3.3.3.3.2 Decomposition of the path layer into administrative path layers

It is possible to identify a set of layers within the path layer which are likely to be administered independently by a network operator by decomposing the path layer.

Each administrative path layer can have both the circuit layer and other administrative path layers as clients and can have the transmission media layer and other path layers as servers. The selection of the administrative path layers is likely to be the result of international agreement and meet the diverse requirements of the circuit layer. Each administrative path layer can have independent topology and it is likely that paths across an administrative path layer will be set up independently of the set-up of paths in other administrative path layers. This is illustrated generically in Figure 3-12.

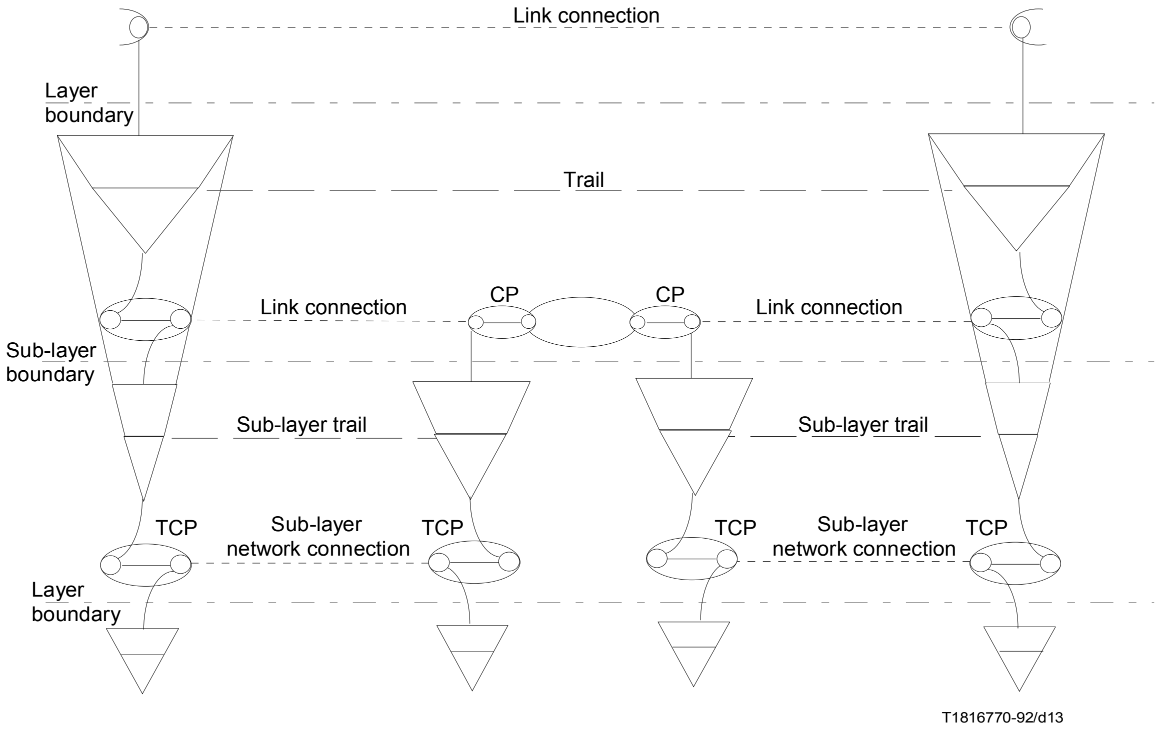


FIGURE 3-12/G.803

The concept of sub-layering

3.3.3.3.3 Decomposition of the transmission media layer into administrative transmission media layers

It is possible to identify a set of layers within the transmission media layer which are likely to be administered independently by a network operator by decomposing the transmission media layer.

While the transmission media layer is dependent on the media used, it may be useful for some media to identify administrative transmission media layers. For example, both optical fibre systems and radio relay systems distinguish an administrative layer which describes trails between path handling centres and a layer which describes trails between repeaters or regenerators.

Again this is illustrated in Figure 3-12.

In future it may be desirable to identify further layers to describe wavelength division multiplexing and wavelength routing on optical systems.

3.3.3.3.4 Decomposition of administrative layers into sub-layers

While the administrative layers are the layers of main interest to a network operator in the administration of the transport network, it is often important to distinguish sub-layers within the administrative layer. This can be done by decomposing the administrative layer. Examples include:

- identification of sub-layer A protection schemes (see 5) by the decomposition of the adaptation;
- identification of a sub-layer describing a trail which monitors a tandem connection across a sub-network by decomposing the termination;
- identification of a sub-layer describing a trail which an operator may add to a cross-connection to monitor its integrity across the cross-connect by decomposing the connection point.

This procedure has been used in developing functional models for protection and tandem connection monitoring.

3.4 Tandem connection monitoring [connection supervision]

The intended role of tandem connections is to represent the segment of a trail that exists within a particular administrative region. In this role, the following functions must be supported by the tandem connection (refer to Figure 3-13):

- tandem connection performance monitoring (error performance and failure/alarm conditions);
- tandem connection far-end performance monitoring (error performance and failure/alarm conditions);
- tandem connection incoming failure indication (failures before the tandem connection);
- tandem connection connectivity verification (i.e., trace) (between the ends of the tandem connection);
- tandem connection idle signal (including idle signal identity).

A proposed solution uses "sub-layer monitoring" (as described in 3.4.4). It uses the combination of an incoming error count and a data link, to support the needs above. This solution is for further study.

3.4.1 **Inherent monitoring** [refer to Figure 3-14 a)]

The tandem connection is indirectly monitored by using the inherently available data from the server layers and computing the approximate state of the client tandem connection from the available data.

The use of inherent monitoring will depend heavily on the use of a data network and distributed processing to correlate failure events, determine whether or not they are within the administration, and report the results to the appropriate management locations (such as both ends of the tandem connection).

When the adaptation function includes multiplexing, the error performance statistics for each of the tandem connections will not be available individually but can be deduced from error performance of the server layers if uniform distribution of errors amongst the clients is assumed.

Connection verification can only be implied from the verification of connections in the server layer between nodes, and the assumption that each node verifies its client layer connections internally.

Data channel emulation can be provided by addressing messages to the other node over an open system communications network.

This technique requires distributed processing, and so may be difficult to standardize. However, this technique will support arbitrary nesting or overlapping of tandem connections.

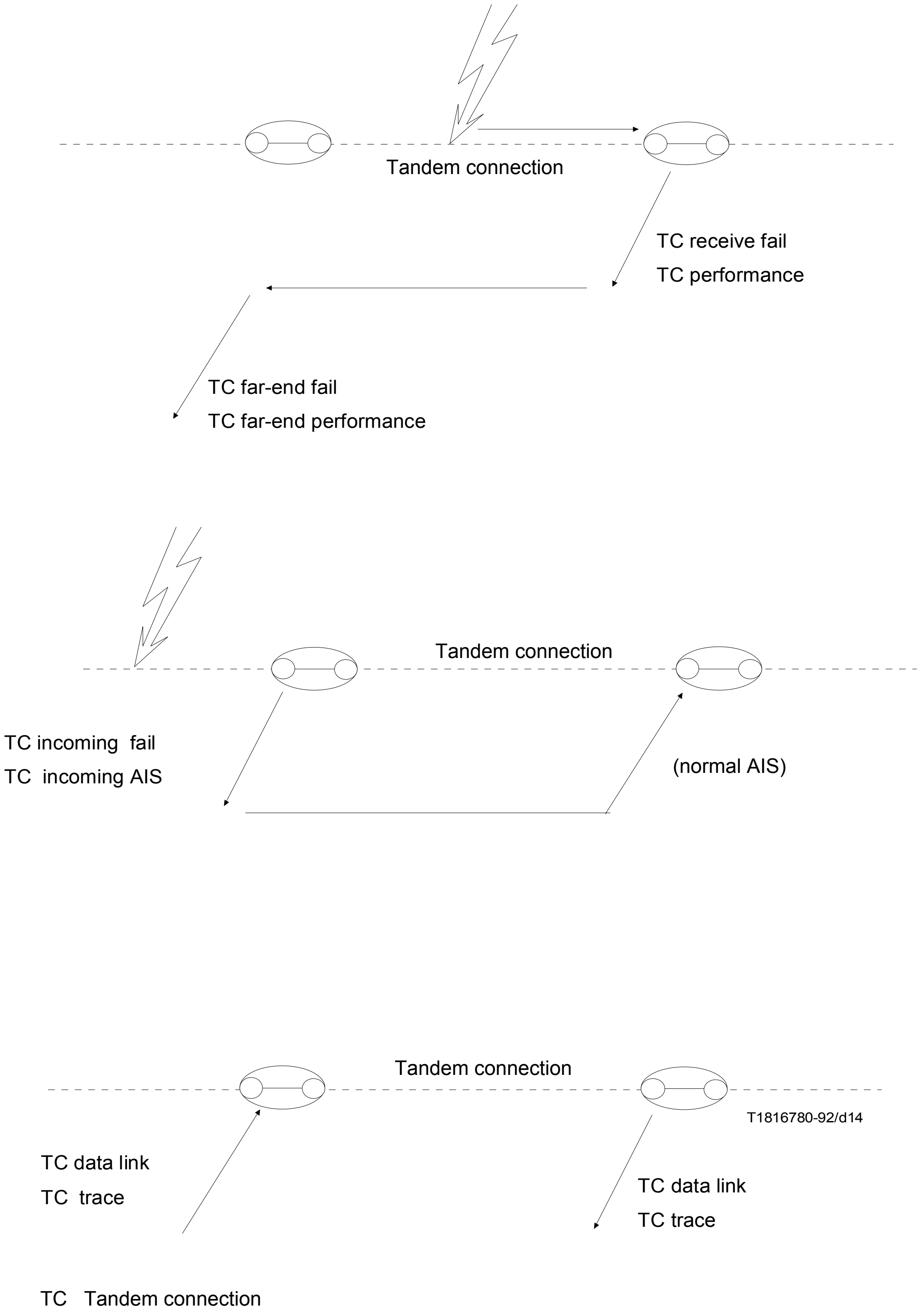


FIGURE 3-13/G.803

Explanation of tandem connection terms

3.4.2 **Non-intrusive monitoring** [refer to Figure 3-14 b)]

The tandem connection is directly monitored by use of listen only (non-intrusive) monitoring of the original data and overhead and then computing the approximate state of the tandem connection from the difference between the monitored states at each end of the tandem connection.

The use of non-intrusive monitoring will depend less on the use of a data network and distributed processing to correlate failure events in order to determine whether or not they are within the administration, and report the results to the appropriate management locations (such as both ends of the tandem connection). In this case, the desired information is available from the two ends and does not require communication with the nodes in the middle of the tandem connection.

The non-intrusive monitoring function may be dedicated to a single sub-network connection or it may be shared between a number of sub-network connections that require monitoring.

Error performance statistics for each of the tandem connections will be available directly from the difference in the error performance records at the two ends. Error performance difference calculations cannot be perfect, but statistically meaningful derived measurements should be possible.

Connection verification can be performed if the original signal was provided with a globally unique trace identifier (such as the E.164 code). Reasonable connection verification may also be possible by capturing some form of signature from the content of the signal at the head end and matching that signature at the tail end.

Data channel emulation can be provided by addressing messages to the other node over an open system communications network.

This technique requires some data communications requiring standardization. However, this technique will support arbitrary nesting or overlapping of tandem connections.

3.4.3 **Intrusive monitoring** [refer to Figure 3-14 c)]

The tandem connection is directly monitored by breaking the original trail and introducing a test trail that extends over the tandem connection for the duration of the test.

In this way, all parameters can be monitored directly, but the user trail is not complete so this can only be done either just at the beginning of the trail set-up, or possibly in an intermittent fashion.

This technique supports arbitrary nesting or overlapping of the tandem connections, but not simultaneous testing.

3.4.4 **Sub-layer monitoring** [refer to Figure 3-14 d)]

Part way between intrusive and non-intrusive monitoring, some portion of the original trail's overhead is over-written such that the tandem connection can be directly monitored. In this case, the tandem connection is the network connection of the monitored sub-layer. If the original overhead was unused then this monitoring is effectively non-intrusive on the original trail.

With this technique all parameters can be tested directly, assuming that sufficient bandwidth can be over-written in the original overhead. This scheme is unlikely to be able to support overlapping or nested tandem connections.

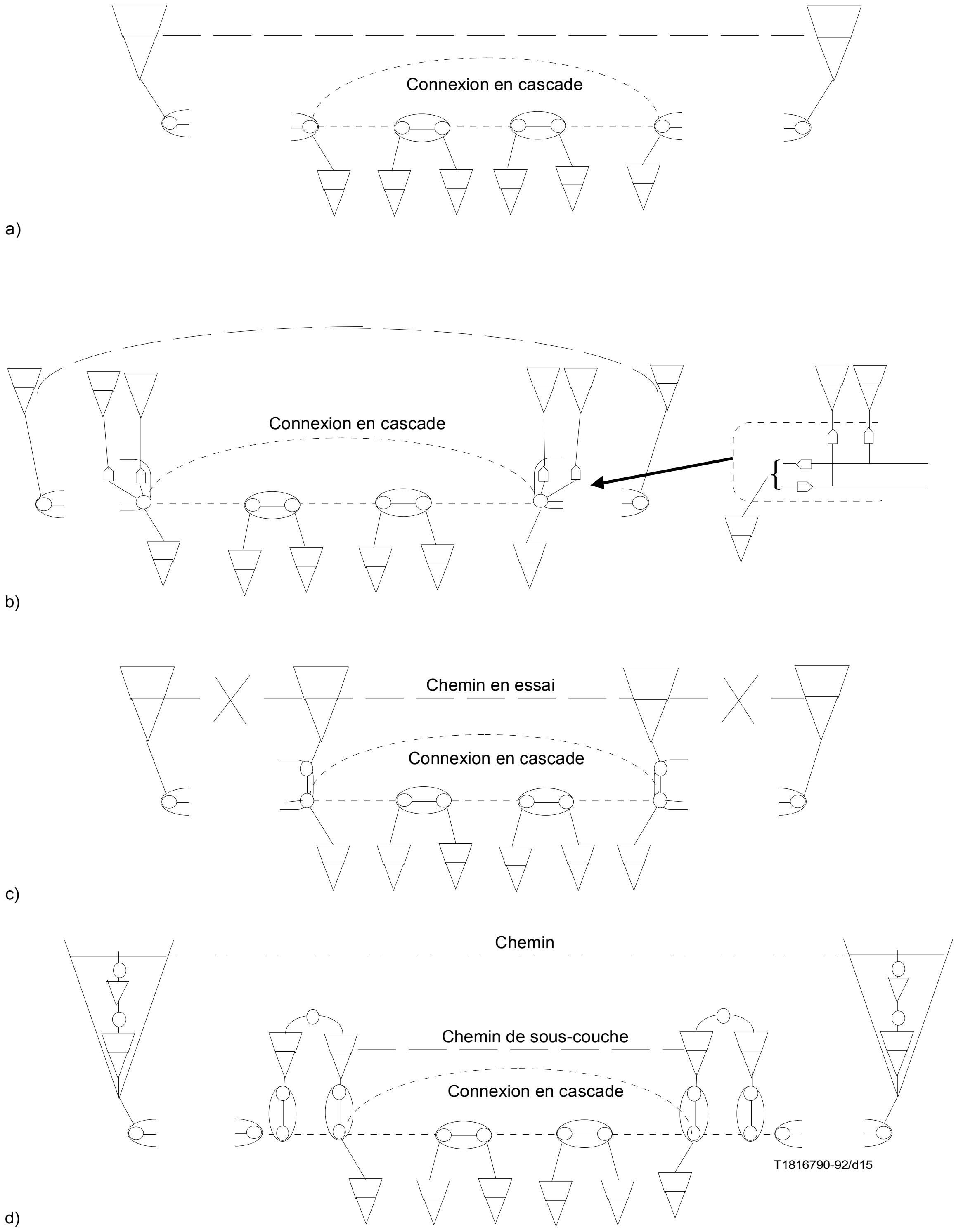


FIGURE 3-14/G.803

Surveillance d'une connexion en cascade

4 Application of concepts to network topologies and structures

4.1 PDH layers supported on SDH layers

Figure 4-1 shows the case where PDH signals are supported on SDH. Five layer networks are shown:

a) PDH G.702 path (e.g. 2048 kbit/s) layer;

b) PDH G.703 intra-office section layer;

c) SDH lower-order path (e.g. VC-12) layer;

d) SDH higher-order path (e.g. VC-4) layer;

e) SDH STM-N section layer.

The example shows two SDH multiplexers with tributaries at the PDH path bit rates interconnected with an SDH lower-order path cross-connect and an SDH higher-order path cross-connect at intermediate locations. All interfacing (except the tributaries at the PDH path bit rates) uses the SDH STM-N section layer.

4.2 ATM cell layers supported on SDH layers

Figure 4-2 shows an example of the case where ATM cells are supported on SDH. Three layer networks are shown:

a) ATM virtual path layer;

b) SDH higher-order path (e.g. the VC-4) layer;

c) SDH STM-N section layer.

The example shows two ATM virtual path terminations interconnected with an ATM virtual path switch and an SDH higher-order path cross-connect at intermediate locations. All interfacing uses the SDH STM-N section layer.

5 Transport network availability enhancement techniques

5.1 Introduction

This sub-clause describes the architectural features of the main strategies which may be used to enhance the availability of a transport network. This enhancement is achieved by the replacement of failed or degraded transport entities. The replacement is normally initiated by the detection of a defect, performance degradation or an external (e.g. network management) request.

Protection – This makes use of pre-assigned capacity between nodes. The simplest architecture has one dedicated protection entity for each working entity (1+1). The most complex architecture has m protection entities shared amongst n working entities (m: n).

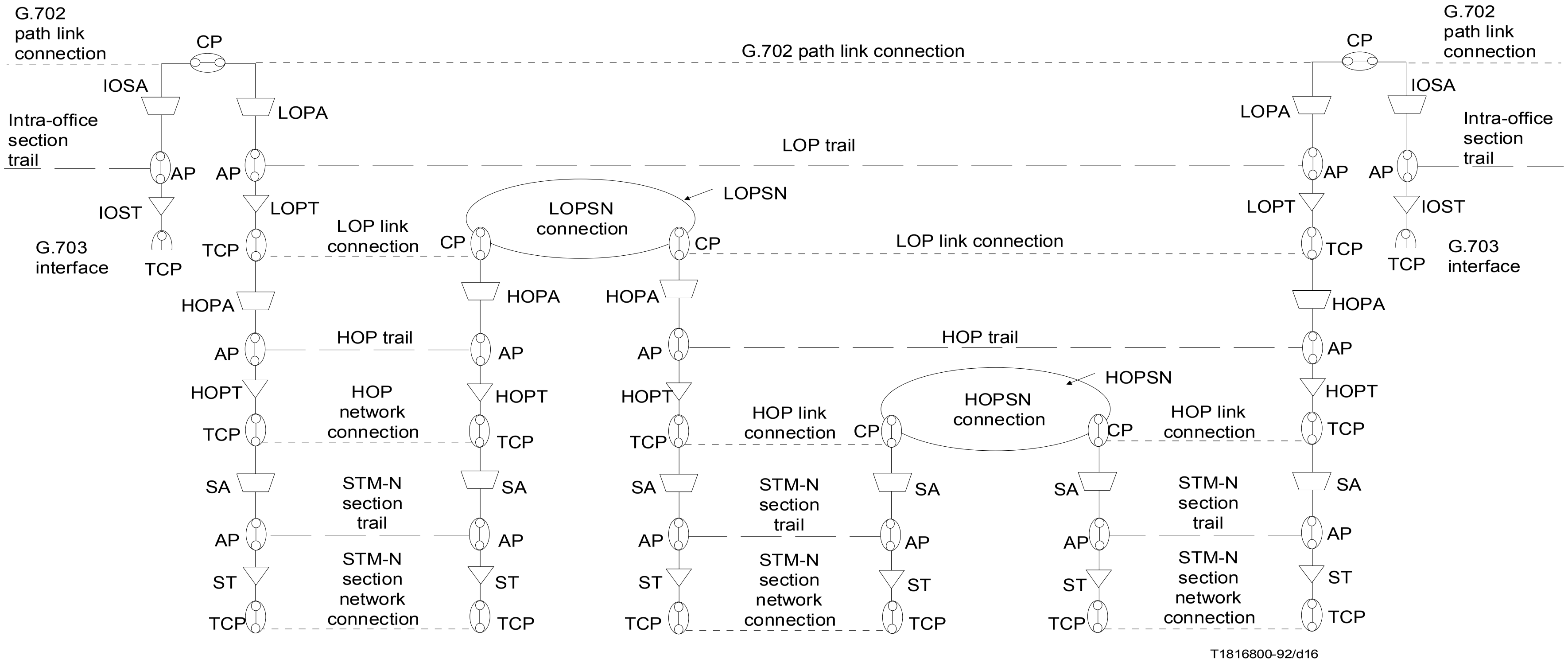
Restoration – This makes use of any capacity available between nodes. In general, the algorithms used for restoration will involve re-routing. When restoration is used, some percentage of the transport network capacity will be reserved for re-routing working traffic.

5.2 Restoration

For further study.

5.3 Protection

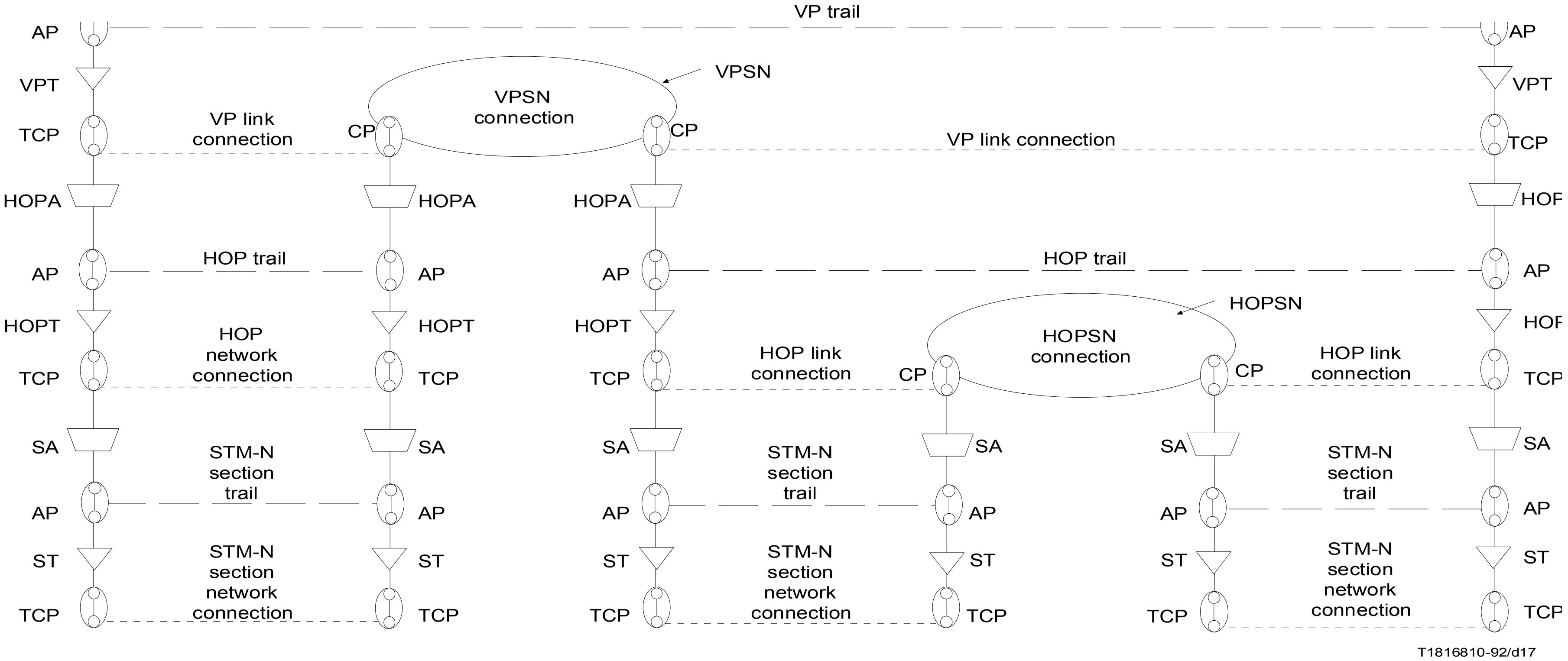
Two types of protection architecture have been identified.



IOST	Intra-office section termination
IOSA	Intra-office section adaptation
LOP	Lower-order path (e.g. VC-12)
LOPA	Lower-order path adaptation
LOPT	Lower-order path termination
LOPSN	Lower-order path sub-network
HOP	Higher-order path (e.g. VC-4)
HOPA	Higher-order path adaptation
HOPT	Higher-order path termination
HOPSN	Higher-order path sub-network
SA	STM-N section adaptation
ST	STM-N section termination
AP	Access point
TCP	Termination connection point
CP	Connection point

FIGURE 4-1/G.803

Application of functional architecture to case of PDH supported on SDH



VP	Virtual path
VPT	Virtual path termination
VPSN	Virtual path sub-network
HOP	Higher-order path (e.g. VC-4)
HOPA	Higer-order path adaptation
HOPT	Higher-order path termination
HOPSN	Higher-order path sub-network

SA	STM-N section adaptation
ST	STM-N section termination
AP	Access point
TCP	Termination connection point
CP	Connection point

FIGURE 4-2/G.803

An example of application of functional architecture to case of ATM supported on SDH

5.3.1 Trail protection

A working trail is replaced by a protection trail if the working trail fails or if the performance falls below the required level. This is modelled by introducing a protection sub-layer as shown in Figure 5-1. The layer access point is expanded, according to the rules given in Figure 3-11, into the protection adaptation function and protection trail termination function to provide the protection sub-layer. A protection matrix is used to model the switching between the protection and working connections. The status of the trails in the protection sub-layer is made available to the protection matrix (trail signal fail in Figure 5-1). The protection adaptation function provides access to an Automatic Protection Switch (APS) channel. This supports communication between the control functions of the protection matrices. The trail termination provides the status of the server trail, the protection trail termination provides the status of the protected trail.

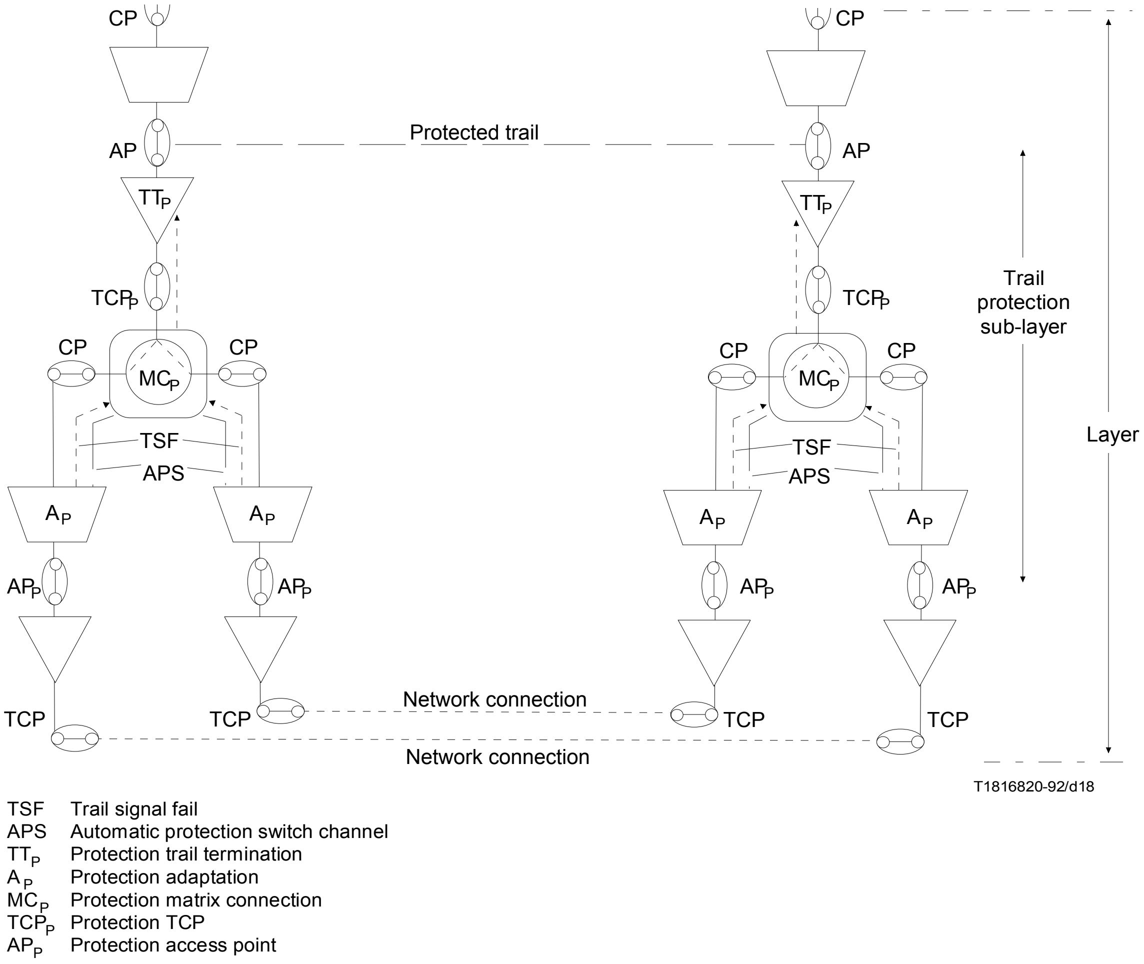


FIGURE 5-1/G.803

Generic trail protection model (1+1 protection)

5.3.2 Sub-network connection protection

A working sub-network connection is replaced by a protection sub-network connection if the working sub-network connection fails or if the performance falls below the required level.

Note that sub-network connection protection may be applied at any layer in a layer network, also the sub-network connection being protected may be made up of a concatenation of lower level sub-network connections and link connections.

Some network operators have indicated that it may be desirable to use dual ended operation in certain applications. The need for this method of operation and the implementation is for further study.

Sub-network connections have no inherent monitoring capability, hence sub-network protection schemes may be further characterized by the method used to monitor the sub-network connection. This is modelled by a protection sub-layer as shown in Figure 5-2. The sub-network connection points are expanded, according to the rules given in Figure 3-11. The general case, using protection trail termination and adaptation functions, is illustrated in Figure 5-3. The status of the trails in the server layer is made available to the matrix (server signal fail in Figure 5-3). The protection functions may be implemented by using one of the connection supervision schemes identified in 3.4:

> Inherent monitoring – The information derived by the server layer, as described in 3.4.1, is used to initiate protection switching. This is illustrated in Figure 5-4.
>
> Non-intrusive monitoring – The sub-network connection is monitored by employing a trail termination function that is bridged onto the sub-network connection as illustrated in Figure 5-5.
>
> Intrusive monitoring – Use of this type of monitor is not recommended as part of a protection scheme.
>
> Sub-layer Monitoring – The introduction of a monitoring sub-layer allows the use of trail protection.

5.4 SDH trail protection examples

Some specific types of multiplex section protection schemes used in SDH are given below. They are characterized by the detection of failure events by the multiplex section termination (MST) function and the resultant reconfiguration uses the protection switching functions that are in the multiplex section protection sub-layer.

The resultant reconfiguration may involve protection switching in multiple SDH network elements. The co-ordination of such switching in multiple SDH network elements is by means of an automatic protection switching (APS) protocol.

5.4.1 SDH multiplex section 1+1 protection (refer to Figure 5-1)

SDH multiplex section 1+1 protection is characterized by two parallel multiplex sections, each of which have a capacity capable of supporting the maximum capacity of the higher-order paths.

The APS protocol for multiplex section 1+1 protection is given in Recommendation G.783.

5.4.2 SDH multiplex section 1: N protection

SDH multiplex section 1: N protection is characterized by there being one more multiplex section than actually required to support the higher-order path capacity to be protected. When not required to support protected higher-order paths, this additional multiplex section capacity can be used to support “extra traffic”. This extra traffic is not itself protected.

The APS protocol for multiplex section 1: N protection is given in Recommendation G.783.

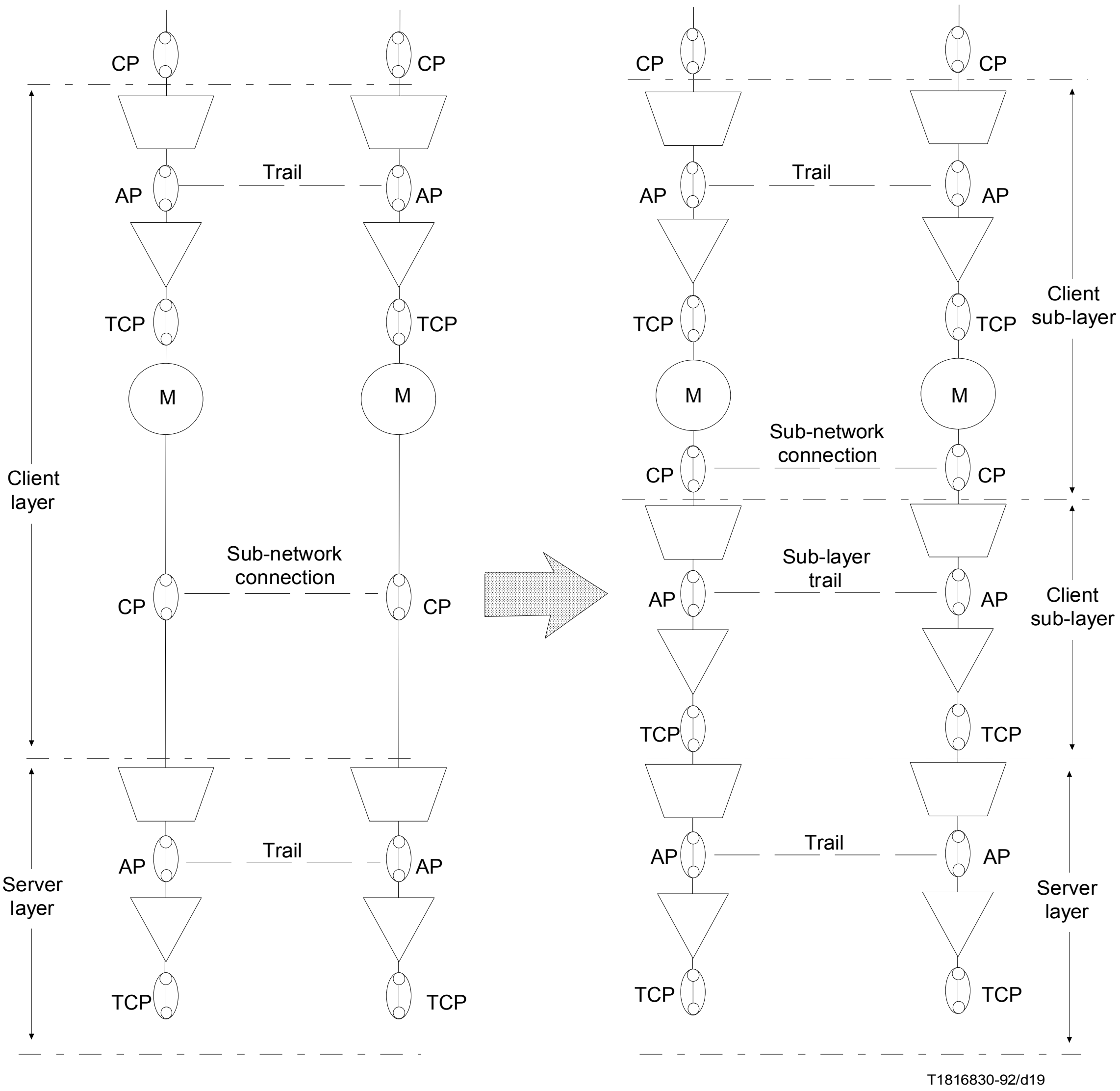


FIGURE 5-2/G.803

Expansion of connection points to provide sub-network protection

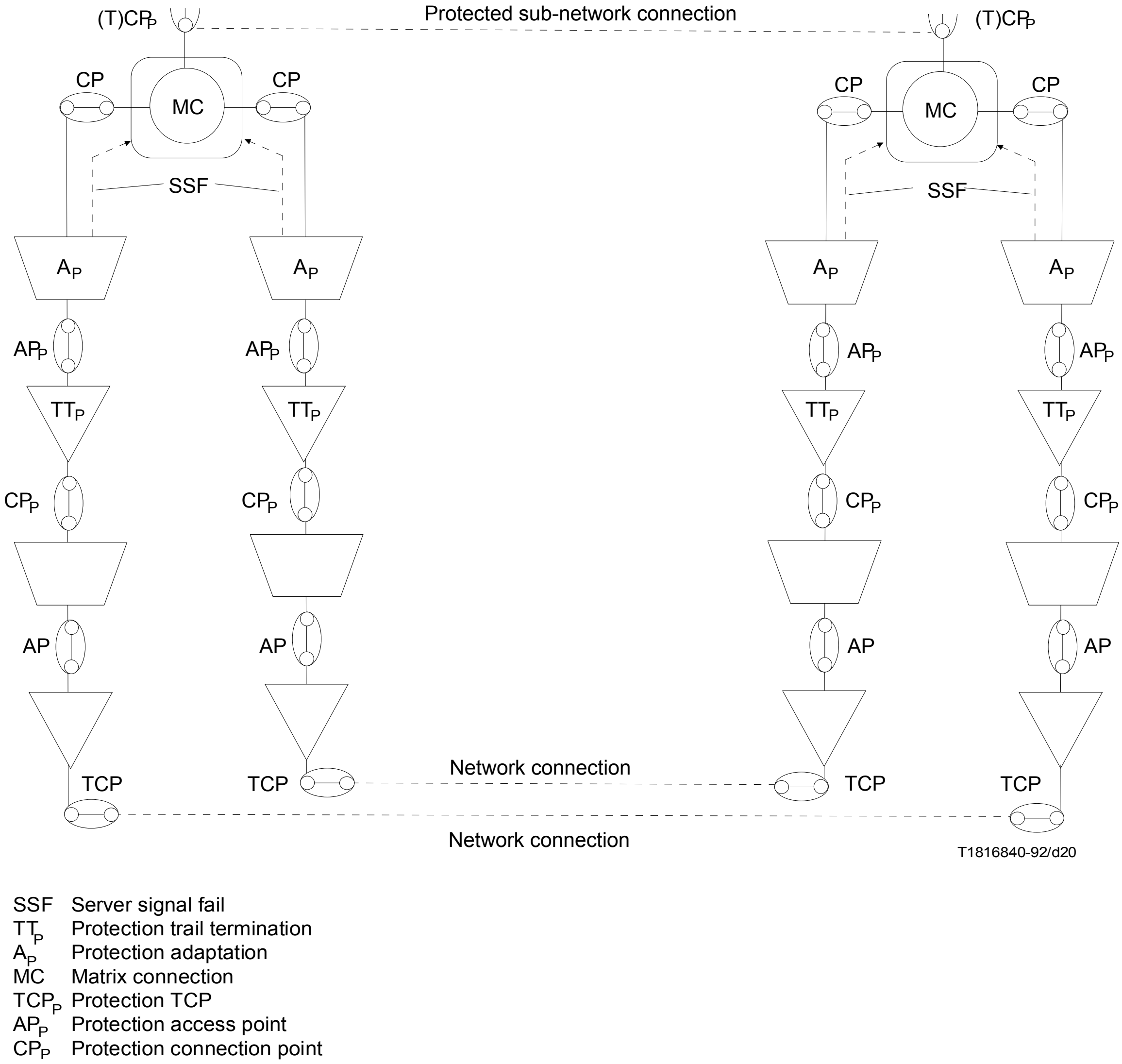


FIGURE 5-3/G.803

Generic sub-network connection protection model

5.4.3 SDH multiplex section shared protection rings (refer to Figure 5-6)

Multiplex section shared protection rings are characterized by dividing the total payload per multiplex section equally into working and protection capacity, e.g. for a two fibre STM-N ring, there are N/2 administrative unit groups (AUGs) available for working and N/2 AUGs for protection whilst in a four fibre STM-N ring, there are N AUGs available for working and N AUGs available for protection. The notation of sharing refers to the fact that the ring protection capacity can be shared by any multiplex section of a multinode ring under a section or node failure condition. Sharing of protection capacity may lead to improved traffic carrying under normal conditions over other ring types.

Multiplex section ring protection is based on detection of failures by the multiplex section function on both sides of the failed portion of the ring and reconfiguration takes place in the protection switching client layer.

Under non-failure conditions, the protection capacity can be used to support lower priority traffic.

The APS protocol for multiplex section shared protection rings will be based on an enhancement of the K-byte protocol for 1: N APS currently defined in Recommendation G.783. The operation of this type of ring is always dual ended.

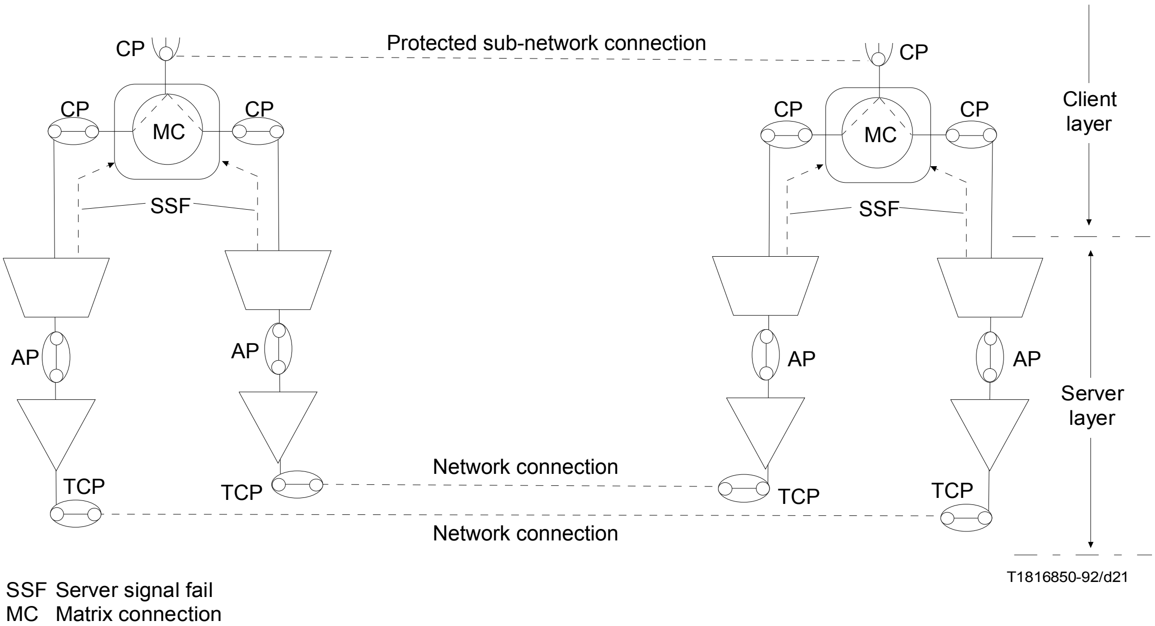


FIGURE 5-4/G.803

Sub-network connection protection with inherent monitoring by means of server signal fail

5.4.4 SDH multiplex section dedicated rings (refer to Figure 5-7)

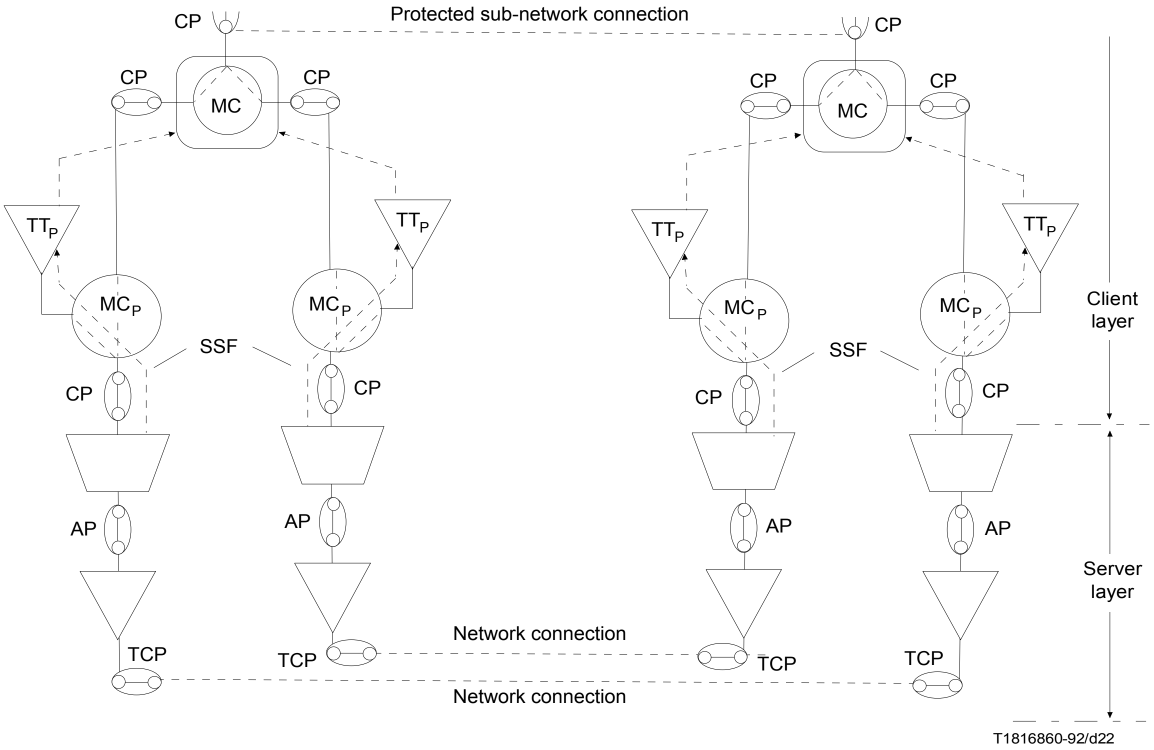
The multiplex section dedicated ring protection is characterized by a 1:1 protection scheme. The scheme is based on unidirectional operation.

Under failure conditions, the entire AUG is looped to the protection channel. Multiplex section dedicated ring protection is based on the detection of failures by the MST functions in the SDH network elements. The operation of this type of ring class is always dual ended.

The APS protocol of multiplex section dedicated protection rings will be based on an enhancement of the K-byte protocol for 1:1 APS currently defined in Recommendation G.783.

5.5 SDH sub-network connection protection examples

Examples of SDH higher-order path layer and lower-order path layer ring applications are given below.



SSF	Server signal fail
MC	Matrix connection
MC_P	Protection matrix connection
TT_P	Protection trail termination

FIGURE 5-5/G.803

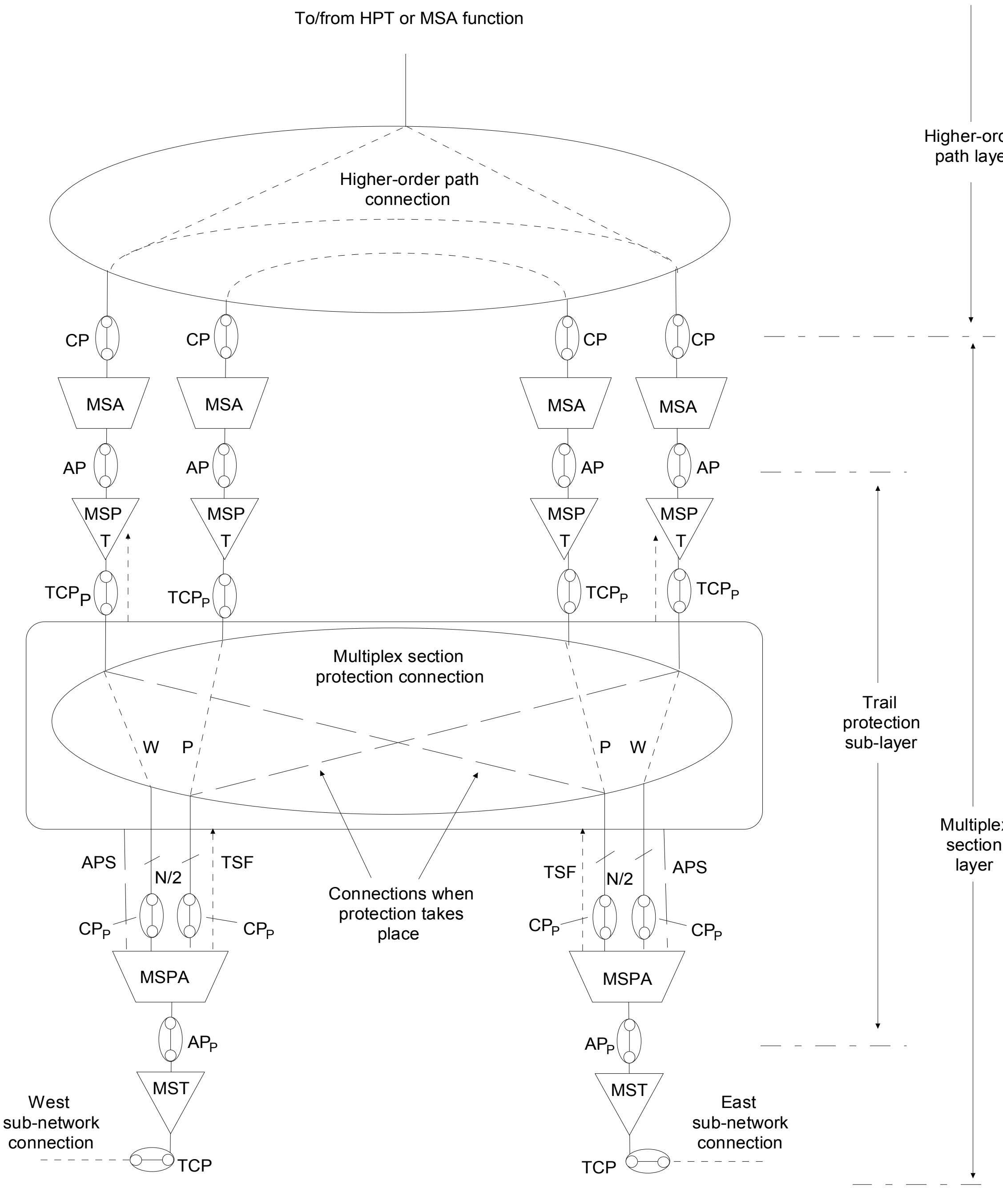
Sub-network connection protection with non-intrusive monitoring

5.5.1 SDH higher-order ring protection

Higher-order ring protection, sometimes known as "higher-order path switched ring protection," is characterized by transmission of the higher-order path characteristic information both ways round the ring (using a higher-order path protection switching function at the network element at which the higher-order path enters the ring). At the network element at which the higher-order path exits the ring, one of the signals is selected. The higher-order paths are switched individually and unidirectionally based on purely local information at the network element at which the higher-order path exits the ring. Therefore, it is possible to implement higher-order ring protection without any APS protocol.

Using inherent monitoring – The detection of the failure events "administrative unit loss of pointers" or "administrative unit AIS" (or local MST detected failures which result in AIS on all administrative units) at the network element at the exit from the ring results in reconfiguration of the higher-order path protection switching functions. This scheme does not detect (or protect against) impairments that impact only the monitored high order paths, but not the multiplex section that terminates at that site (e.g. errors introduced in a preceding multiplex section).

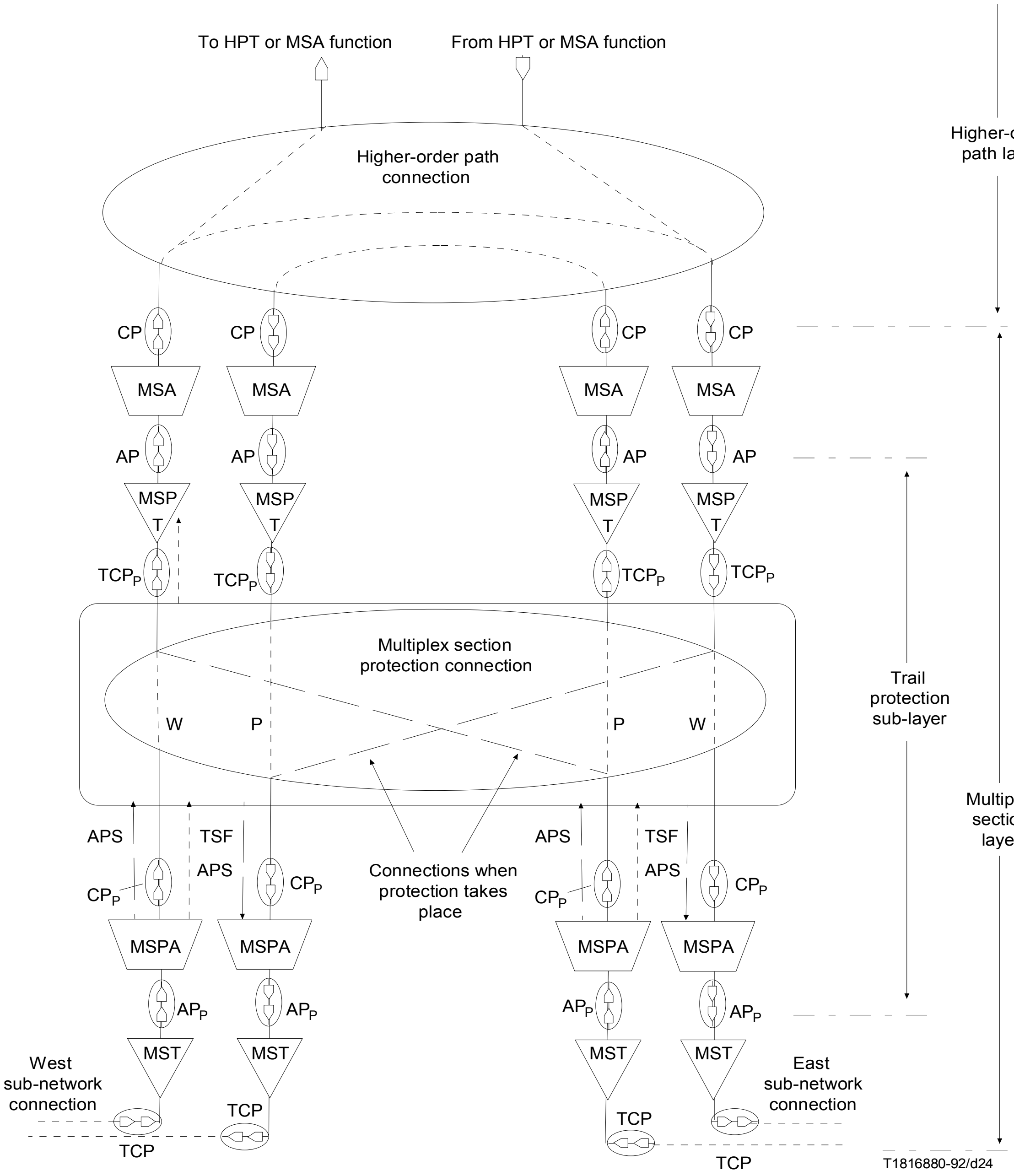
Using non-intrusive monitoring – This is implemented by adding a higher order path protection termination function as indicated in Figure 5-5. This allows the detection of failures or degradations on individual paths.



TSF	Trail signal fail
APS	Automatic protection switch channel
HPT	Higher-order path termination
MSPT	Multiplex section protection termination
MSPA	Multiplex section protection adaptation
MSA	Multiplex section adaptation
MST	Multiplex section termination
TCP_P	Protection TCP
AP_P	Protection access point
CP_P	Protection connection point

FIGURE 5-6/G.803

Multiplex section shared protection ring



TSF	Trail signal fail
APS	Automatic protection switch channel
HPT	Higher-order path termination
MSPT	Multiplex section protection termination
MSPA	Multiplex section protection adaptation
MSA	Multiplex section adaptation
MST	Multiplex section termination
TCP$_P$	Protection TCP
AP$_P$	Protection access point
CP$_P$	Protection connection point

FIGURE 5-7/G.803

Multiplex section dedicated protection ring

5.5.2 SDH lower-order ring protection

SDH lower-order ring protection is similar in principle to higher-order ring protection as shown generically in Figure 5-3.

Lower-order ring protection is characterized by transmission of the lower-order path characteristic information both ways round the ring (using a lower-order path protection switching function at the network element at which the lower-order path enters the ring). At the network element at which the lower-order path exits the ring, one of the signals is selected. The lower-order paths are switched individually and unidirectionally based on purely local information at the network element at which the lower-order path exits the ring. Therefore, it is possible to implement lower-order ring protection without any APS protocol.

Inherent monitoring – The detection of the failure events "tributary unit loss of pointers" or "tributary unit AIS" (or local MST or higher-order path termination detected failures which result in AIS on all tributary units) at the network element at the exit from the ring results in reconfiguration of the lower-order path protection switching functions. This scheme does not detect (or protect against) impairments that impact only the monitored low order paths, but not the higher order path that terminates at that site (e.g. errors introduced in a preceding higher order path).

Using non-intrusive monitoring – This is implemented by adding the lower order path protection termination function as indicated in Figure 5-5. This allows the detection of failures or degradations on individual paths.

6 Architecture of synchronization networks

6.1 Introduction

This subclause describes architectural aspects of the distribution of timing information within an SDH network. It focuses on the need for SDH clocks to be traceable to a primary reference clock (PRC) and have good short term stability performance.

It is further explained that, provided the SDH clock meets the short term stability mask, there are no practical limitations to the number of pointer processing elements that can be cascaded in an SDH network to comply with the payload output jitter requirements at an SDH/PDH boundary.

Evolutionary scenarios are presented to identify how SDH network synchronization can be integrated with the existing synchronization network.

6.2 Synchronization network aspects

6.2.1 Synchronization methods

There are two fundamental methods of synchronizing nodal clocks. These are identified in Recommendation G.810:

- master-slave synchronization;
- mutual synchronization.

Master-slave synchronization is appropriate for synchronizing SDH networks and the following material offers guidance on using this method. The feasibility of employing mutual synchronization is left for further study.

Master-slave synchronization uses a hierarchy of clocks in which each level of the hierarchy is synchronized with reference to a higher level, the highest level being the PRC. Clock reference signals are distributed between levels of the hierarchy via a distribution network which may use the facilities of the transport network. The hierarchical levels are shown below:

– PRC	G.811
– Slave clock (transit node)	G.812
– Slave clock (local node)	G.812
– SDH network element clock	See note

NOTE – A new Recommendation under preparation will specify the quality level of clocks suitable for operation in SDH equipment.

The distribution of timing between hierarchical node clocks must be done by a method which avoids intermediate pointer processing. Two possible methods are as follows:

1) Recover timing from a received STM-N signal. This avoids the unpredictable effect of a pointer adjustment on the downstream slave clock. The exact technique to adopt is for further study.

2 Derive timing from a synchronization trail that is not supported by an SDH network.

The master-slave method uses a single-ended synchronization technique with the slave clock determining the synchronization trail to be used as its reference and changing to an alternative if the original trail fails. This is a unilateral control scheme.

6.2.2 Synchronization network architecture

The architecture employed in SDH requires the timing of all network element clocks to be traceable to a PRC which is compliant with Recommendation G.811. The discussion below details the target architecture for SDH network synchronization. Evolutionary aspects are discussed in 6.2.6.

The distribution of synchronization can be categorized into intra-station within stations containing a G.812 level clock and inter-station as follows:

a) Intra-station distribution within stations containing a G.812 level clock conforms to a logical star topology. All lower level network element clocks within a station boundary derive timing from the highest hierarchical level in the station. Only the clock of the highest hierarchical level in the station will recover timing from synchronization links from other stations. Timing is distributed from network elements within the boundary to network elements beyond the boundary via the SDH transmission medium. The relationship between clocks within a station is shown in Figure 6-1.

b) Inter-station distribution conforms to a tree-like topology and enables all the stations in the SDH network to be synchronized. The hierarchical relationship between clocks is shown in Figure 6-2. With this architecture, it is important for the correct operation of the synchronization network that clocks of lower hierarchical level only accept timing from clocks of the same or higher hierarchical level and that timing loops are avoided. To ensure this relationship is preserved, the distribution network must be designed so that, even under fault conditions, only valid higher level references are presented to hierarchical clocks.

Clocks of a lower hierarchical level must have a capture range sufficiently wide to ensure they can automatically acquire and lock to the timing signal generated by the same or higher level clock that they are using as a reference.

The structure of the distribution network is illustrated in Figure 6-3 using the diagrammatic conventions of 3. Phase reference information is transferred between synchronization nodes by means of a synchronization trail. When a trail becomes disabled then the node controller must select another reference from a set of valid alternatives. When none exist, the clock enters holdover mode.

The distribution trail is provided by one or more synchronization link connections each supported by a synchronized primary or secondary rate PDH trail or an SDH multiplex section trail. When the distribution network is based on SDH, one or more link connections each supported by a multiplex section trail is recommended to conform to the requirement in 6.2.1. The sub-network connections (switches) in the synchronization trail must be set to maintain only valid hierarchical relationships between clocks. The algorithms for achieving this in SDH reference distribution networks are under study.

Figure 6-3 suggests that a synchronization link that distributes timing from the public network across a user/network interface should be timed from the SDH network element clock. The performance characteristics of this method and other techniques, such as deriving timing from the TU-1x within which the data signal is carried, are under study.

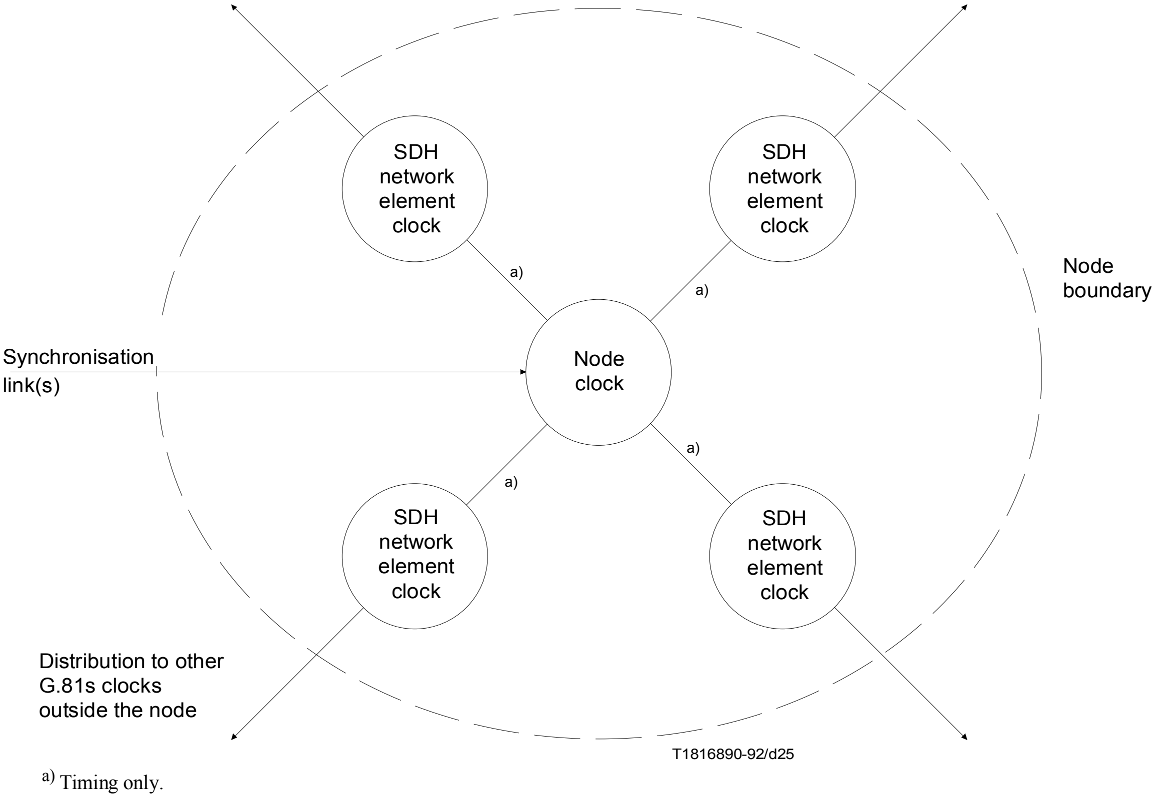


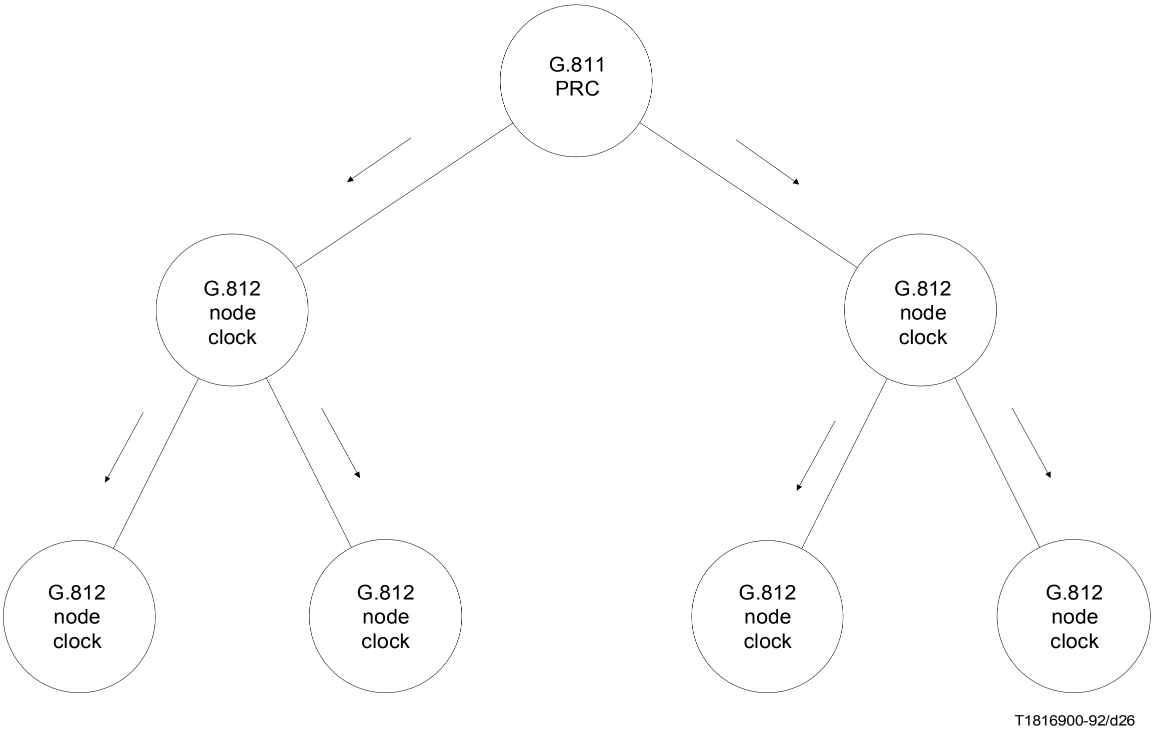
FIGURE 6-1/G.803

Synchronisation network architecture intra-node distribution

6.2.3 Synchronization modes

Four synchronization modes can be identified. These are:

- synchronous;
- pseudo-synchronous (described below);
- plesiochronous;
- asynchronous.



PRC Primary reference clock

FIGURE 6-2/G.803

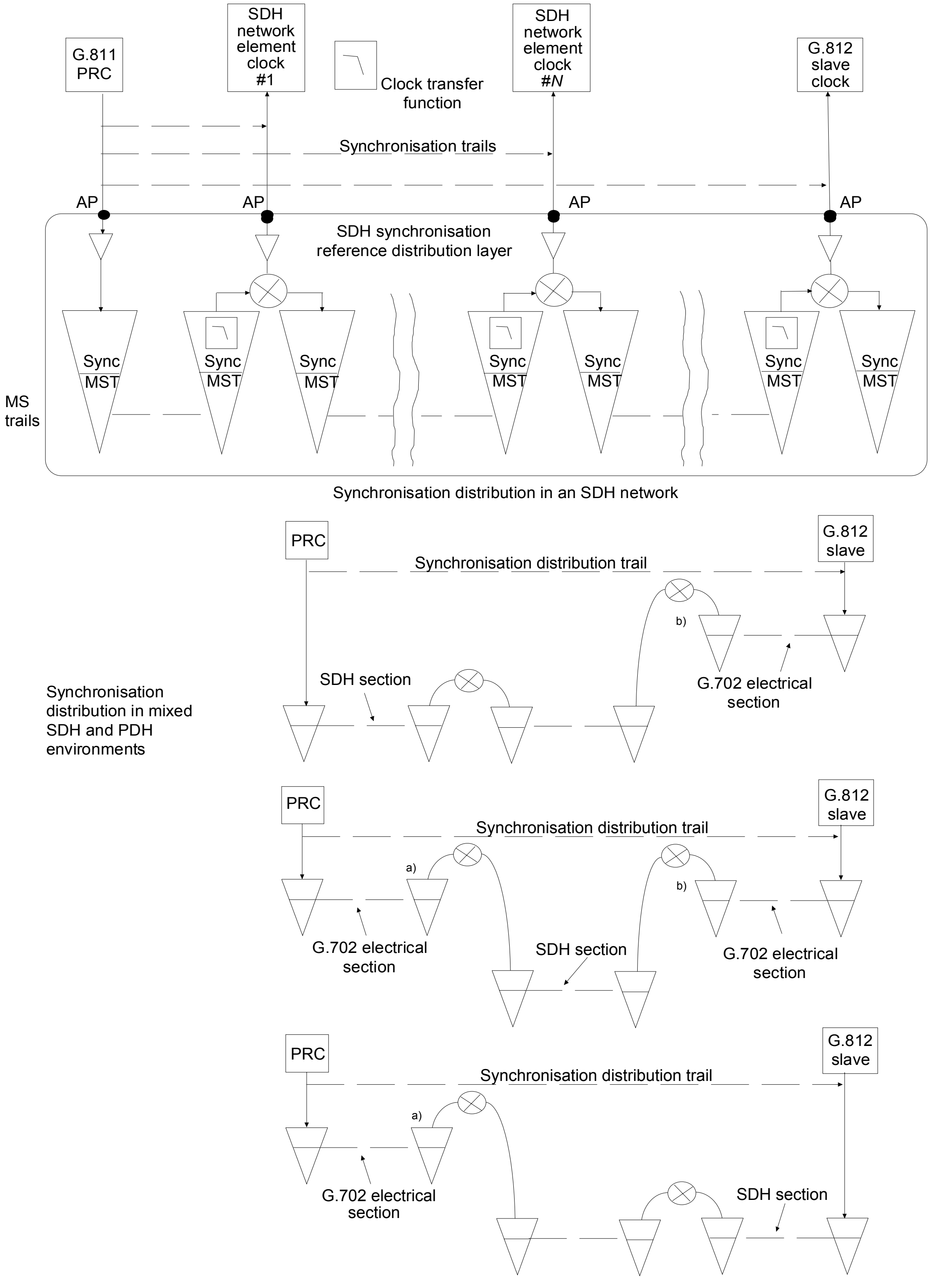
Synchronisation network architecture inter-node distribution

In synchronous mode, all clocks in the network will be traceable to the network PRC. Pointer adjustments will only occur randomly. This is the normal mode of operation within a single operator's domain.

In pseudo-synchronous mode, not all clocks in the network will be synchronized traceable to the same PRC. However, each PRC will comply with Recommendation G.811 and therefore pointer adjustments will occur at the synchronization boundary network element. This is the normal mode of operation for the international and inter-operator network.

In plesiochronous mode, the synchronization trail and the fallback alternatives to one or more clocks in the network will have been disabled. The clock will enter holdover or free-run mode. If synchronization is lost to a gateway SDH network element performing asynchronous mapping, the frequency offset and drift of the clock will cause pointer adjustments persisting through the whole SDH network connection. If synchronization is lost to the last network element in the SDH network connection (or the penultimate network element in the case where the last one is slaved, e.g. consists of a loop-timed multiplexer), there will also be pointer adjustments to cater for at the SDH network output. However, if the synchronization failure occurs at an intermediate network element, this will not result in a net pointer movement at the final output gateway network element provided the input gateway network element remains synchronized with the PRC. Pointer movement at the intermediate network element will be corrected by the next network element in the connection which is still synchronized.

Asynchronous mode corresponds to the situation where large frequency offsets occur. The SDH network is not required to maintain traffic with a clock accuracy less than that to be specified in a future Recommendation on SDH network element clocks. A clock accuracy of $\pm$ 20 ppm is required to send AIS (applicable for regenerators and any other SDH equipment where loss of all synchronization inputs implies loss of all traffic).



a) SDH network element synchronised to G.702 tributary input.

b) G.702 tributary output retimed from SDH network element.

FIGURE 6-3/G.803

Synchronisation distribution

6.2.4 Synchronization network reference chain

The synchronization network reference chain is shown in Figure 6-4. The node clocks are interconnected via N network elements each having clocks compliant with a future Recommendation on SDH network element clocks.

The longest chain should not exceed K slave clocks compliant with Recommendation G.812. Only one type of G.812 slave clock is shown because the difference in holdover performance of the transit and local clock is not relevant for SDH network synchronization. This contrasts with the situation in the PDH environment which is sensitive to long term instability.

The quality of timing will deteriorate as the number of synchronization links increases.

The value of N will be limited by the quality of timing required by the last network element in the chain. This ensures the short term stability mask of Recommendation G.783 is met.

To determine synchronization clock specifications, the values for the worst case synchronization reference chain are: $K = 10$, $N = 20$ with the total number of SDH network element clocks limited to 60. These values have been derived from theoretical calculations; practical measurements are required for their verification. It should be noted, however, that in practical synchronization network design, the number of network elements in tandem should be minimized for reliability reasons.

6.2.5 Synchronization strategy

The synchronization strategy is to integrate SDH network synchronization with the existing PDH network synchronization architecture with the minimum of disruption and reconfiguration. Present node clocks are either separate units or integrated in the exchanges. With the introduction of SDH there is also the possibility to integrate the node clock in certain types of SDH equipment, typically in large SDH cross-connects. In that case, there may not be an identifiable SDH network element clock.

6.2.6 Synchronization network evolution

The SDH is designed to operate in pseudo-synchronous mode. The network elements can be integrated into existing synchronization hierarchies.

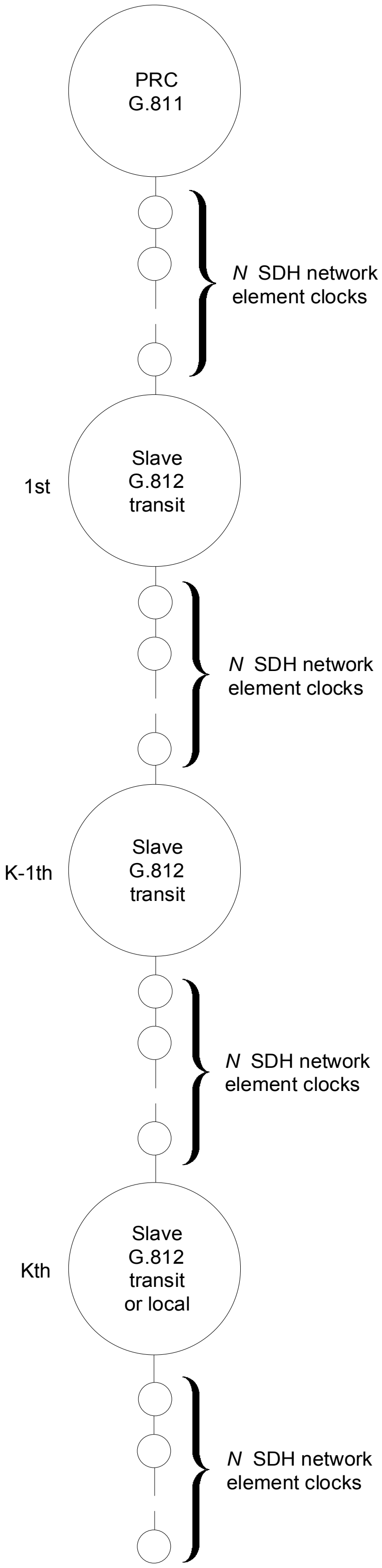
When SDH equipment is initially introduced, the gateway network element must be timed from either the PRC or one of the slave clocks. Timing is distributed throughout the SDH network using the master-slave approach. This may require a new interface on the slave clock to time the SDH gateway network element.

If the SDH network introduction results in PDH islands, steps must be taken so that synchronization links supported by primary rate PDH trails so not transit the SDH network. This requires a reconfiguration of the synchronization architecture since all synchronization links transiting the SDH network must be supported on SDH multiplex section trails. This may require new interfaces on the slave clocks and on the PRC.

Where a network is fully SDH-based, then the synchronization distribution will be determined solely by the synchronization network reference chain.

During the evolution of the network to SDH, the network synchronization plan will have to be altered to accommodate the SDH network elements. This requires careful planning to ensure that network synchronization is not jeopardized.

Evolutionary scenarios with multiple SDH islands supporting the transport of a PDH payload need further study.



For worst-case scenario calculation purposes:

$K = 10$

$N = 20$ with restriction that total number of SDH network element clocks is limited to 60

T1816920-92/d28

FIGURE 6-4/G.803

Synchronisation network reference chain

6.2.7 Synchronization network robustness

It is preferable if all node clocks and network element clocks are able to recover timing from at least two synchronization trails. The slave clock must reconfigure to recover timing from an alternative trail if the original trail fails. Where possible, synchronization trails should be provided over diversely routed paths.

In the event of a failure of synchronization distribution, all network elements will seek to recover timing from the highest hierarchical level clock source available. To effect this, both G.812 and SDH network element clocks may have to reconfigure and recover timing from one of their alternate synchronization trails. This will ensure that an SDH network element clock-timed network element rarely enters holdover or free-run mode. However, it may have to recover timing from a G.812 clock which is itself in holdover if this is the highest hierarchical level source available to it.

Within SDH sub-networks, timing is distributed between network nodes via a number of network elements with clocks of lower hierarchical level. A timing quality marking scheme is provided to allow selection and confirmation of the highest quality synchronization trail (including under synchronization failure conditions).

The quality marking scheme provides an indication of the quality of the timing using a status messaging approach. The status message is conveyed in the section overhead as described in Recommendation G.708.

To provide an example of a reconfiguration, if the first network element from the PRC loses its synchronization trail from the PRC, it must reconfigure and accept timing from the G.812 slave clock. This is shown in Figure 6-5.

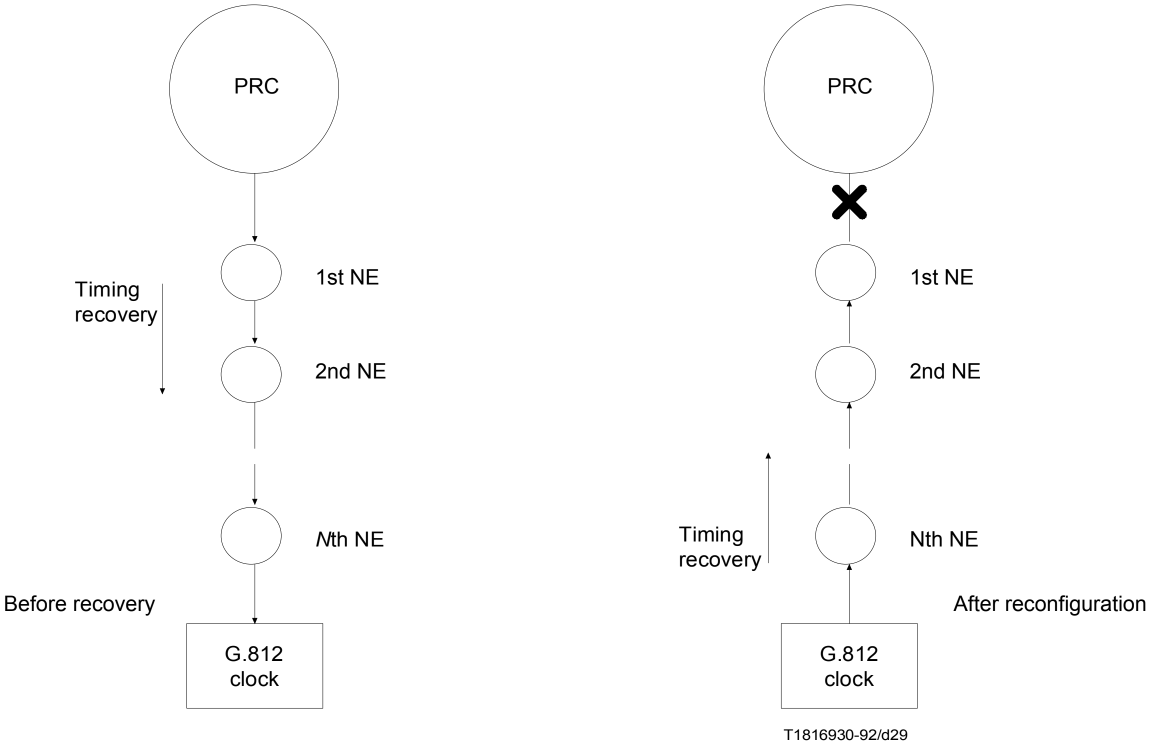


FIGURE 6-5/G.803

Reconfiguration example

6.3 Payload jitter and wander

In SDH, the quality of the timing information of a payload signal is influenced by several sources:

- the synchronization network;
- the pointer processing mechanism;
- the payload mapping mechanisms.

Subclause 6.2 defines a synchronization reference chain which is used to calculate the accumulation of jitter and wander in the synchronization network. The resulting short-term stability mask, which is specified in Recommendation G.783, represents a network limit for the clock stability of the timing source internal to a network element. This clock stability determines the statistics of the pointer adjustments resulting from the pointer processing mechanism.

The purpose of this subclause is to define the network topologies that have to be supported by an SDH network taking into account the network limits for payload jitter and wander given in Recommendations G.823 and G.824. In addition, reference configurations are specified that may occur when SDH is introduced in the existing PDH environment.

6.3.1 SDH network model for pointer activity simulation

For the transport of PDH signals through an SDH network, the model shown in Figure 6-6 is used to simulate the accumulation of jitter and wander through a reference connection due to pointer activity. The clock acting upon each pointer processing node is assumed to have the stability specified in Recommendation G.783. Since this specification reflects the network limit, this represents a worst case scenario.

Simulations have shown that the pointer statistics are bounded when the number of processing nodes increases. With the pointer processor buffer threshold spacings specified in Recommendation G.783, pointer adjustments at the TU-1 level are an extremely rare event, even when intermediate pointer processing at the administrative unit level is taken into account. This means that the pointer mechanism does not impose a practical upper bound on the number of tributary unit processing nodes that can be put in tandem. At the administrative unit level, pointer adjustments, including some double pointer adjustments, do occur with statistical saturation starting to show at about 10 nodes. This implies that there is also no practical constraint on the number of administrative unit pointer processing nodes that can be cascaded, provided the short term stability mask is met at each node clock.

6.3.2 Jitter at an SDH/PDH boundary

Jitter appearing at an SDH/PDH boundary consists of pointer adjustment jitter and payload mapping jitter. Since pointer adjustments occur in 8 unit interval steps (24 unit intervals at the AU-4 level), stringent requirements are placed on the desynchronizer at the SDH/PDH boundary. This also applies at the TU-1 level since, although pointer adjustment events are unlikely under normal operational conditions (i.e. all nodes synchronized), they will occur under degraded conditions (i.e. pseudo-synchronous or plesiochronous modes) when the originating or terminating node looses synchronization. This requires desynchronizers with relatively narrow equivalent bandwidth. It should be noted that, even with narrowband desynchronizers, the effect of pointer justifications on signals that are used to convey third party timing may be larger than assumed in the design of customer premises equipment synchronization utilities. Therefore, they may not be able to adequately track the phase variations. The desynchronizer will also filter the line jitter that may accumulate along a chain of regenerators if not already filtered by the characteristics of the SDH network element clock equipment clock. Mapping jitter is generated at the originating node at the SDH/PDH boundary but does not accumulate across an SDH network. Its relative contribution to the output jitter at an SDH/PDH boundary will depend upon desynchronizer design. Its maximum value is specified in Recommendation G.783.

As a result, the output jitter limit at an SDH/PDH boundary is dominated by pointer adjustment jitter which in turn is governed by the short-term stability of the clocks at each node.

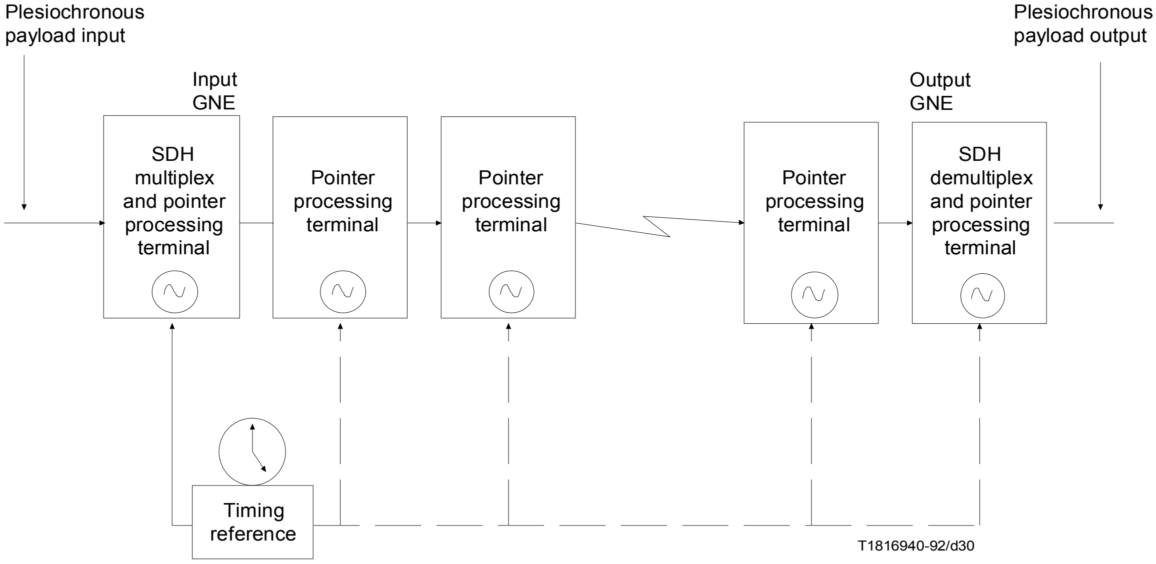


FIGURE 6-6/G.803

SDH network model for pointer activity simulation

6.4 PDH/SDH interworking implications

In many evolutionary scenarios, there is a need to carry a PDH payload across multiple SDH islands. This is shown in Figure 6-7. Although the payload jitter and wander specification in Recommendation G.783 have been determined with this application in mind, there is no absolute guarantee that every PDH multiplex chain will accept the output jitter appearing at the SDH/PDH boundary. This is because there is no specified lower limit to the corner frequency of the PDH demultiplex transfer characteristic.

If synchronous islands are put in tandem, a certain accumulation of the phase transients caused by more or less simultaneous pointer adjustments in multiple islands will occur. The nature of the pointer statistics is such that this will limit the maximum number of cascaded islands for the transport of 34, 45 and 140 Mbit/s signals, unless the desynchronizer specification is enhanced to provide adequate attenuation of jitter and wander appearing at the input of the SDH island. The trade-off between the maximum number of islands, short-term clock stability and desynchronizer specification is for further study.

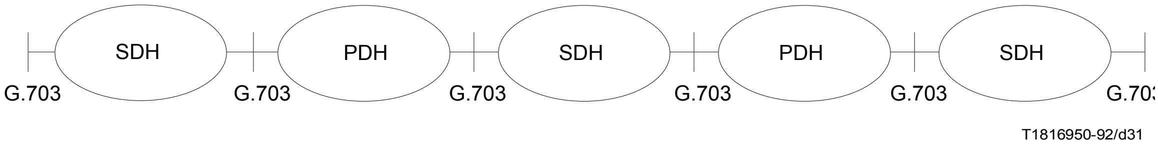


FIGURE 6-7/G.803

PDH/SDH interworking

7 Choice of primary rate mapping

7.1 Features of the primary rate mappings

There are three ways of mapping 1544 and 2048 kbit/s primary rate signals into the VC-11 and VC-12, respectively, as defined in Recommendation G.709: asynchronous, bit synchronous and byte synchronous. These mappings have different features and networking considerations. The choice of mapping is application-dependent. The features of the three types of mapping are described below.

7.1.1 Asynchronous mapping

This mapping has the following features:

a) it provides bit sequence independent support of the primary rate signal without any assumptions on its structure (the signal can be framed, as defined in Recommendation G.704, or unstructured);

b) it does not allow the VC-*n* direct visibility of any 64 or *N* × 64 kbit/s signals contained within the primary rate signal; the primary rate signal must be reconstructed in order to access any 64 or *N* × 64 kbit/s signals;

c) it includes a justification process which can accommodate a primary rate signal with a timing tolerance of ± 50 ppm;

d) it is potentially universally applicable although, in cases where 64 kbit/s switches or DXCs have STM-N interfaces, the lack of direct visibility of the constituent 64 or *N* × 64 kbit/s signals may be a significant drawback (see also Annex A).

7.1.2 Bit synchronous

This mapping has the following features:

a) it provides bit sequence independent support of the primary rate signal without any assumptions on its structure (the signal can be framed, as defined in Recommendation G.704, or unstructured);

b) it does not allow the VC-*n* direct visibility of any 64 or *N* × 64 kbit/s signals contained within the primary rate signal; the primary rate signal must be reconstructed in order to access any 64 or *N* × 64 kbit/s signals;

c) it does not include any justification processes so the primary rate signal must be synchronous with the VC-*n*;

d) it has no planned use for international interconnection.

7.1.3 Byte synchronous

This mapping has the following features:

a) it requires the primary rate signal to be framed according to Recommendation G.704;

b) it allows the VC-*n* direct visibility of the 64 or *N* × 64 kbit/s signals when the payload of the primary rate signal is octet-structured. In this case, the primary rate signal need not be reconstructed in order to access the 64 kbit/s or the *N* × 64 kbit/s signals since the octets of the primary rate signal (including the primary rate signal framing information) are mapped into defined positions in the VC-*n*;

c) it does not include any justification processes so the primary rate signal must be synchronous with the VC-*n*;

d) it has two versions:

   i) *floating mode* – in this mode, the VC-1xs can "float" in frequency and phase with respect to each other within the higher-order VC-*n*. Their location in the higher-order VC-*n* is identified using the pointer mechanism which also allows the VC-lxs to be independently switched in a VC-1x DXC or ADM with minimum delay;

ii) *locked mode* – in this mode, the VC-1xs are locked in frequency and phase with respect to each other and to the higher-order VC-*n*. The VC-1xs do not have a pointer which means that they cannot be independently switched in a VC-lx DXC or ADM without a significant delay penalty. Locked mode is essentially a direct mapping of 64 kbit/s or *N* × 64 kbit/s signals into the higher-order VC-*n*;

e) when the frame is octet-structured, the mapping can be used on 64 kbit/s switches and 64 kbit/s DXCs with STM-N interfaces.

7.2 Selection of mapping options

Given the features of the mappings the following is recommended for SDH networking:

a) asynchronous mapping should be used only for asynchronous/plesiochronous type signals. This includes PDH path mappings into SDH paths (i.e. 64 kbit/s signals in PDH format may be carried via the asynchronous mapping);

b) bit synchronous mapping should not be used in international interconnection;

c) byte synchronous floating mode mapping should be used for primary rate signals as defined in Recommendation G.704; the signal must be framed and the payload can be either octet-structured (64 kbit/s and *N* × 64 kbit/s) or not;

d) byte synchronous locked mode mapping can be used as an alternative for c) above for primary rate signals with octet-structured payload (64 kbit/s and *N* × 64 kbit/s signals) but only in cases where VC-1x DXCs or ADMs are not used nor envisaged to be used.

Annex A provides more information on interworking of 64 and *N* × 64 kbit/s signals between PDH-based transport networks and SDH-based transport networks.

Annex A

(to Recommendation G.803)

Introduction of SDH-based transport networks

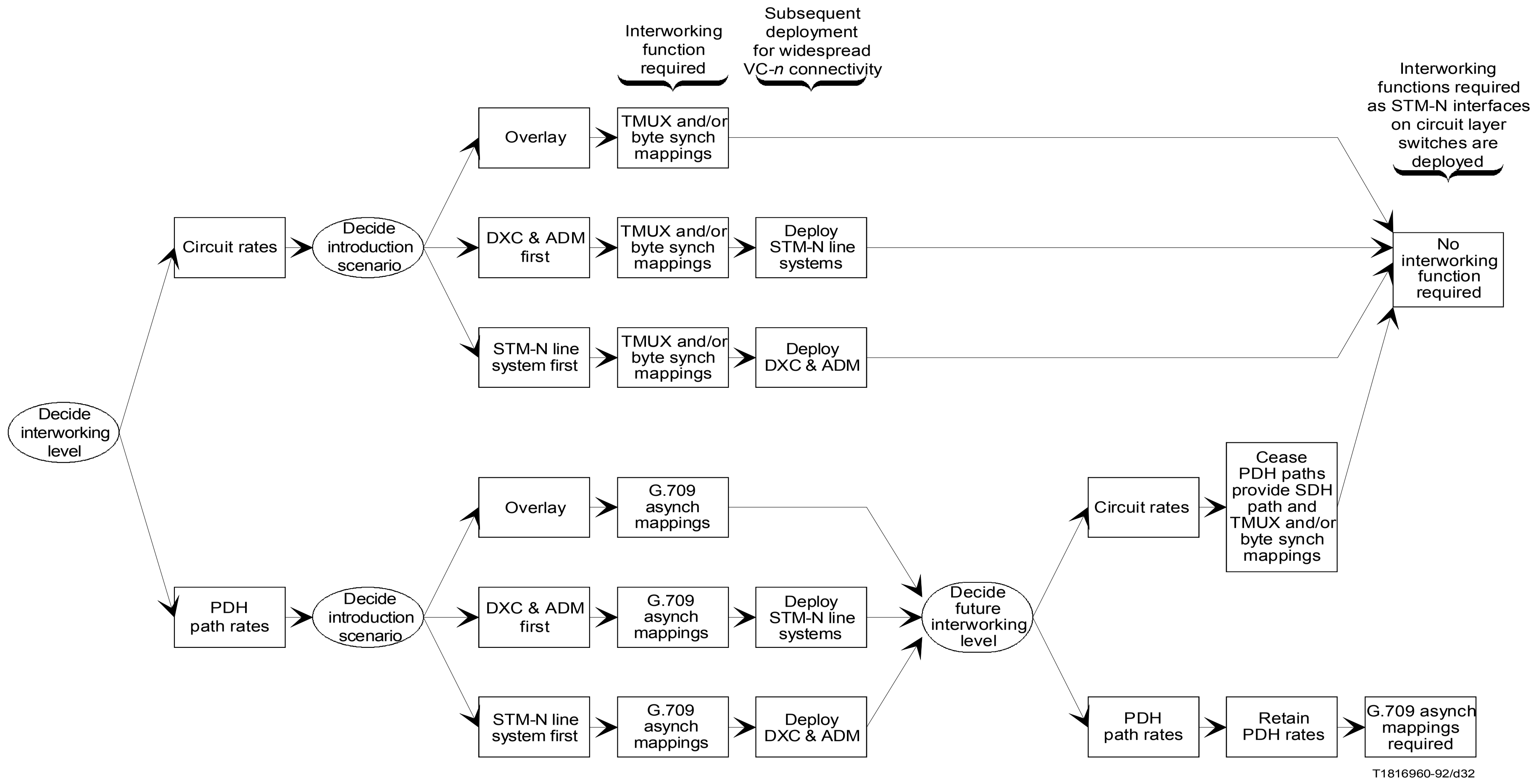
(This Annex forms an integral part of this Recommendation)

A.1 General

This annex provides information on how a transport network could evolve to one based on SDH. There are many choices which must be made when introducing SDH-based transport networks. These choices, such as the time order in which different types of SDH-based equipment are introduced and the types of mapping used, will affect subsequent stages of evolution to SDH-based transport networks and may pose networking or PDH/SDH interworking constraints. These choices and the level of deployment of SDH-based transport networks compared with PDH or other transport networks are a matter for the network operator concerned. Although this annex illustrates the issues by discussing the steps required to migrate to fully SDH-based transport networks, fully SDH-based transport networks are not necessarily the goal.

This annex firstly identifies the types of circuit layer signals which can be supported on SDH paths and the types of circuit layer signals which can be supported on PDH paths. It then describes the three basic introductory scenarios for SDH-based equipment. For each type of circuit layer signal and introductory scenario, the annex describes the consequences on networking, PDH/SDH interworking and subsequent transport network evolution.

Figure A.l shows the introductory paths that are available and illustrates the basic choices and provides a reference during the following discussion.



DXC	Digital cross-connect	PDH	Plesiochronous digital hierarchy
ADM	Add/drop multiplex	TMUX	Transmultiplex

FIGURE A.1/G.803

Introductory paths for SDH-based transport networks

A.2 Types of circuit layer signals

A.2.1 SDH case

In the case of SDH, path layers support the following two types of circuit layer signals in accordance with the mappings defined in Recommendation G.709:

a) circuit layer signals which directly support telecommunications services. These circuit layer signals include:

   i) 64 kbit/s-based signals (adapted into the SDH path layers using byte synchronous mappings);

   ii) leased line signals at G.702 bit rates at or above the primary rate;

   iii) other signals (e.g. ATM cells) the bit rate of which might be optimized to the payload of the SDH path layers.

b) PDH path layer signals (at G.702 bit rates at or above the primary rate) which, in turn, support either:

   i) circuit layer signals as in A.2.1 a);

   ii) lower-order PDH path layer signals.

SDH-based transport network equipment is concerned with control of connectivity of SDH paths and not with control of connectivity of the circuit layer. Therefore, in case b) above, the SDH-based equipment cannot be used to individually network the signals identified in b) i) and ii); primary rate and/or higher-order PDH multiplexing functionality is required to facilitate this connectivity. This constraint could be significant in cases where SDH-based transport networks become widespread. Where this is likely to be the case, it is recommended that the support of such signal is minimized from the outset or, that during subsequent stages of transport network evolution, steps are taken to minimize the redundant PDH path layer signals.

A.2.2 PDH case

In the case of PDH, path layer signals support the following two types of circuit layer signals:

a) circuit layer signals which directly support telecommunications services. These circuit layer signals include:

   i) 64 kbit/s-based signals (adapted into the PDH path layers in accordance with Recommendation G.704),

   ii) leased line signals at G.702 bit rates at or above at the primary rate,

   iii) other signals (e.g. ATM cells) the bit rate of which might be optimized to the payload of the PDH layers;

b) SDH path layer signals which, in turn, support circuit layer signals identified in A.2.1 (see note below).

NOTE – Mappings of SDH path layer signals into PDH path layer signals are not presently defined in ITU-T Recommendations. The possibility is mentioned in this annex in order to outline a possible transitional stage of transport network evolution. The functionality required to provide these mappings is referred to below as “modem” functionality (since it is analogous to the transition from the “old” analogue network to the “new” digital network where modems allowed signals from the “new” network to be supported over the “old” network). In cases where the modem functionality provides multiplexing of several SDH path layer signals into the PDH path layer, control of the connectivity of the individual SDH path layer signals is not possible in the PDH path layer network.

A.3 Initial introduction of SDH-based equipment

There are three basic ways of initially introducing SDH-based equipment:

a) Deployment of an overlay network comprising the simultaneous deployment of SDH line systems and VC-*n* cross-connect functionality to provide widespread path layer connectivity (see note below). In addition, to increase geographical coverage in such overlay network, the link connections in the SDH path layer could be adapted into PDH paths using the modem functionality as mentioned in A.2.2 b). Initially, this overlay network is likely to be "thin" and might be targetted at supporting particular circuit layer types (e.g. circuit layers which support leased line services) but later "thickened" to include other services.

NOTE – VC-*n* cross-connect functionality is realised in SDH digital cross-connect equipment (DXC) and/or add/drop multiplex equipment (ADM). Such functionality is referred to below as DXC/ADM.

b) Deployment of SDH DXC/ADMs only with interfaces at G.702 bit rates. This is likely to take the form of DXCs in central locations where control of the connectivity of PDH paths at the site is the desired initial benefit. In terms of the functional network architecture, VC-*n* paths in the DXC/ADMs provide sub-network connections in the PDH path layer. SDH line systems could be deployed at a later stage to provide more widespread VC connectivity. Similarly, PDH paths with the modem functionality could be used as mentioned in a) above to provide more widespread VC-*n* connectivity.

c) Deployment of SDH line systems only with intra-office interfaces at G.702 bit rates. Such systems are functionally similar to PDH line systems in that they support link connections in the PDH path layer. In terms of the functional network architecture, VC-*n* paths in the SDH line systems provide link connections in the PDH path layer. SDH DXC/ADMs could be deployed at a later date to provide more widespread VC-*n* connectivity.

Each option is a valid and the choice of one or more options is determined by the initial requirements of the network operator. The choice of one option by one network operator need not affect the choice of another network operator. The three options can co-exist.

A.4 Interworking between PDH and SDH-based transport networks

A.4.1 Interworking levels

lnterworking between PDH-based transport networks and SDH-based transport networks can occur at one of the following three levels:

a) at the circuit level for signals identified in A.2.1 a) and A.2.2 a). Such interworking generally requires the termination of the respective PDH and SDH paths and the adaptation functions between the respective path layers and the circuit layer. This combination of functions is referred to below as transmultiplexing (TMUX). This approach does not necessarily imply additional physical interfaces. In the particular case of 64 kbit/s circuit layer signals, the byte synchronous mappings given in Recommendation G.709 allow circuit level interworking without necessarily terminating the PDH path. In the particular case of leased line signals at G.702 bit rates at or above the primary rate, the asynchronous mappings given in Recommendation G.709 allow circuit level interworking. In cases where the PDH and SDH circuit layer signals have the same bit rate, interworking at the circuit level does not necessarily require processing of the circuit layer signal.

b) at the PDH path level for signals identified in A.2.1 b). Such interworking requires the adaptation of the PDH path layer signals into appropriate SDH path layers using the asynchronous mappings described in Recommendation G.709 for G.702 bit rates.

c) at the SDH path level where the SDH path layer signals, described in A.2.2 b), are adapted into PDH paths using the modem functionality. This case is for further study.

The choice of interworking level and SDH equipment introduction scenario will have an impact on subsequent transport network evolution stages as discussed below.

A.4.2 SDH overlay

The two interworking levels are considered as follows:

a) The requirements for interworking at the circuit level are given in A.4.1 a).

In cases where PDH paths are used to provide VC-*n* connectivity, "modem" functionality will be required for adaptation to the PDH path layer.

In cases where subsequently STM-N interfaces are provided on network elements which process the circuit layer signals (e.g. circuit layer switches), there are no interworking requirements between such network elements and the SDH transport network.

b) The requirements for interworking at the PDH path level are given in A.4.1 b). Primary rate and/or higher-order PDH multiplexing functionality will continue to be required in the PDH-based transport network.

In cases where PDH paths are used to provide VC-*n* connectivity, "modem" functionality will be required for adaptation to the PDH path layer.

In cases where subsequently STM-N interfaces are provided on network elements which process circuit layer signals, primary rate and/or higher-order PDH multiplexing functionality and G.709 asynchronous mappings of G.702 bit rates will continue to be required to provide interworking functionality between such network elements and the SDH transport network.

In cases where it is subsequently desired to interwork at the circuit level, it will be necessary to cease the SDH paths supporting PDH path layers and provide new SDH paths which directly support the circuit layer. Primary rate and/or higher-order PDH multiplexing functionality will not be required.

A.4.3 SDH DXC/ADMs

The two interworking levels are considered as follows:

a) The requirements for interworking at the circuit level are given in A.4.1 a).

In cases where subsequently more widespread SDH path layer networking is required, SDH line systems could be deployed; interworking functionality is not required between DXC/ADM and the SDH line systems. The considerations in A.4.2 a) also apply.

b) The requirements for interworking at the PDH path level are given in A.4.1 b).

In cases where subsequently more widespread SDH path layer networking is required, SDH line systems could be deployed; interworking functionality is not required between the DXC/ADM and the SDH line systems. The considerations in A.4.2 b) also apply.

A.4.4 SDH line systems

The two interworking levels are considered as follows:

a) The requirements for interworking at the circuit level are given in A.4.1 a).

In cases where subsequently more widespread SDH path layer networking is required, SDH DXC/ADMs could be deployed; interworking functionality is not required between DXC/ADM and the SDH line systems. The considerations in A.4.2 a) also apply.

b) The requirements for interworking at the PDH path level are given in A.4.1 b).

In cases where subsequently more widespread SDH path layer networking is required, SDH DXC/ADMs could be deployed; interworking functionality is not required between the DXC/ADM and the SDH line systems. The considerations in A.4.2 b) also apply.

A.5 Introduction of STM-N interfaces on 64 kbit/s switches (and DXCs)

In the case of PDH-based transport networks, 64 kbit/s switches are interconnected by G.704 structured primary or secondary rate synchronous paths. In terms of the functional architecture, the link connections between sub-networks in the 64 kbit/s circuit layer are supported by paths in the PDH path layer network. The introduction of STM-N interfaces on one of two interconnected 64 kbit/s switches requires PDH/SDH interworking.

Interworking can take place at either the 64 kbit/s circuit level or the PDH path level. Considering these two cases:

a) interworking at the 64 kbit/s circuit level requires the use of byte synchronous mappings to adapt the 64 kbit/s circuit layer signals into the SDH path layer (see note below).

NOTE – Recommendation G.709 defines byte synchronous mappings into VC-11 and VC-12 only. ITU-T Recommendations do not define byte synchronous mappings into higher bit rate VC-*n*s.

b) interworking at the PDH path level requires the use of asynchronous mappings to adapt the PDH paths into the SDH path layer.

In the case where subsequently STM-N interfaces are introduced on the other 64 kbit/s switch and there is the potential for SDH path layer connectivity between the two switches, interworking functionality will be required if one switch uses byte synchronous mapping and the other switch uses asynchronous mapping. In cases where the two switches are in different operators networks, responsibility for providing the interworking functionality (if required) rests with the operator of the switch which uses asynchronous mapping unless otherwise agreed bilaterally.

Printed in Switzerland
Geneva, 1993