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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital networks – General aspects

Generic functional architecture of transport networks

ITU-T Recommendation G.805

(Formerly CCITT Recommendation)

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TESTING EQUIPMENTS	G.500–G.599
TRANSMISSION MEDIA CHARACTERISTICS	G.600–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
General aspects	**G.800–G.809**
Design objectives for digital networks	G.810–G.819
Quality and availability targets	G.820–G.829
Network capabilities and functions	G.830–G.839
SDH network characteristics	G.840–G.849
Management of transport network	G.850–G.859
SDH radio and satellite systems integration	G.860–G.869
Optical transport networks	G.870–G.879
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999

For further details, please refer to the list of ITU-T Recommendations.

ITU-T Recommendation G.805

Generic functional architecture of transport networks

Summary

This Recommendation describes the functional architecture of transport networks in a technology independent way. The generic functional architecture may be used as the basis for a harmonized set of functional architecture Recommendations for ATM, SDH, PDH transport networks, and a corresponding set of Recommendations for management, performance analysis and equipment specification.

Source

ITU-T Recommendation G.805 was revised by ITU-T Study Group 13 (1997-2000) and approved under the WTSC Resolution 1 procedure on 10 March 2000.

FOREWORD

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

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

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSC Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

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

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

ITU-T Recommendation G.805

Generic functional architecture of transport networks

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. More specifically, the functional and structural architecture of transport networks are described independently of networking technology.

This Recommendation describes the functional architecture of transport networks in a technology independent way. The generic functional architecture of transport networks should be taken as the basis for a harmonized set of functional architecture Recommendations for ATM, SDH, PDH networks, and a corresponding set of Recommendations for management, performance analysis and equipment specification.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

– ITU-T G.702 (1988), *Digital Hierarchy bit rates*.

– ITU-T G.703 (1998), *Physical/electrical characteristics of hierarchical digital interfaces.*

– ITU-T G.707 (1996), *Network node interface for the synchronous digital hierarchy (SDH)*.

– ITU-T I.320 (1993), *ISDN protocol reference model*.

– ITU-T I.321 (1991), *B-ISDN protocol reference model and its application*.

– ITU-T I.324 (1991), *ISDN network architecture*.

– ITU-T I.340 (1988), *ISDN connection types*.

– ITU-T I.361 (1999), *B-ISDN ATM layer specification*.

– ITU-T X.200 (1994) | ISO/IEC 7498-1:1994, *Information technology – Open systems interconnection – Basic Reference Model: The basic model*.

3 Terms and definitions

This Recommendation defines the following terms:

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

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

NOTE 3 – The terms can be further qualified by reference to a specific layer network by adding the appropriate layer network qualifier (e.g. SDH higher-order path termination, PDH 44 736 kbit/s path termination, ATM virtual path connection).

NOTE 4 – All architectural components are bidirectional unless qualified by the term sink or source or unidirectional.

3.1 access group: A group of co-located "trail termination" functions that are connected to the same "subnetwork" or "link".

3.2 access point: A "reference point" that consists of the pair of co-located "unidirectional access" points, and therefore represents the binding between the trail termination and adaptation functions.

3.3 adaptation: A "transport processing function" that consists of a co-located adaptation source and sink pair.

3.4 adaptation sink: A "transport processing function" which presents the client layer network characteristic information at its output by processing the information presented at its input by the server layer network trail.

3.5 adaptation source: A "transport processing function" which accepts client layer network characteristic information at its input and processes it to allow transfer over a trail (in the server layer network).

3.6 adapted information: a signal which is transferred on "trails". The specific formats will be defined in the technology specific Recommendations.

3.7 administrative domain: For the purposes of this Recommendation an administrative domain represents the extent of resources which belong to a single player such as a network operator, a service provider or an end-user. Administrative domains of different players do not overlap amongst themselves.

3.8 architectural component: Any item used in this Recommendation to generically describe transport network functionality.

3.9 binding: A direct relationship between a "transport processing function" or "transport entity" and another "transport processing function" or "transport entity" which represents the static connectivity that cannot be directly modified by management action.

3.10 characteristic information: A signal with a specific format, which is transferred on "network connections". The specific formats will be defined in the technology specific Recommendations.

3.11 client/server relationship: The association between layer networks that is performed by an "adaptation" function to allow the link connection in the client layer network to be supported by a trail in the server layer network.

3.12 connection: A "transport entity" which consists of an associated pair of "unidirectional connections" capable of simultaneously transferring information in opposite directions between their respective inputs and outputs.

3.13 connection point: A "reference point" that consists of a pair of co-located "unidirectional connection points" and therefore represents the binding of two paired bidirectional "connections".

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

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

3.16 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.

3.17 layer network: A "topological component" that represents the complete set of access groups of the same type which may be associated for the purpose of transferring information (see 5.2.1.1).

3.18 **link**: A "topological component" which describes a fixed relationship between a "subnetwork" or "access group" and another "subnetwork" or "access group".

3.19 **link connection**: A "transport entity" that transfers information between "ports" across a link.

3.20 **management domain**: A management domain defines a collection of managed objects which are grouped to meet organizational requirements according to geography, technology, policy or other structure, and for a number of functional areas such as configuration, security, (FCAPS), for the purpose of providing control in a consistent manner. Management domains can be disjoint, contained or overlapping. As such the resources within an administrative domain can be distributed into several possible overlapping management domains. The same resource can therefore belong to several management domains simultaneously, but a management domain shall not cross the border of an administrative domain.

3.21 **matrix**: It represents the limit to the recursive partitioning of a subnetwork.

3.22 **matrix connection**: A "transport entity" that transfers information across a matrix, it is formed by the association of "ports" on the boundary of the matrix.

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

3.24 **network connection**: A transport entity formed by a series of contiguous "link connections" and/or "subnetwork connections" between "termination connection points".

3.25 **pairing**: A relationship between sink and source "transport processing functions" or two contra directional unidirectional "transport entities" or between "unidirectional reference points" which have been associated for the purposes of bidirectional transport.

3.26 **path layer network**: A "layer network" which is independent of the transmission media and which is concerned with the transfer of information between path layer network "access points".

3.27 **port**: It consists of a pair of unidirectional ports.

3.28 **reference point**: An architectural component, which is formed by the binding between inputs and outputs of transport processing functions and/or transport entities.

3.29 **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.

3.30 **single ended operation**: A protection operation method which takes switching action only at the affected end of the protected entity (e.g. "trail", "subnetwork connection"), in the case of a unidirectional failure.

3.31 **subnetwork connection protection**: A protection type that is modelled by a sublayer that is generated by expanding the "subnetwork" "connection point".

3.32 **sublayer**: A set of additional transport processing functions and reference points encapsulated within a layer network. It is created by decomposition of transport processing functions or reference points.

3.33 **subnetwork**: A topological component used to effect routing of a specific characteristic information.

3.34 **subnetwork connection**: A "transport entity" that transfers information across a subnetwork, it is formed by the association of "ports" on the boundary of the subnetwork.

3.35 **tandem connection**: An arbitrary series of contiguous "link connections" and/or "subnetwork connections".

3.36 termination connection point: A reference point that consists of a pair of co-located unidirectional termination connection points and therefore represents the binding of a trail termination to a bidirectional connection.

3.37 topological component: An architectural component, used to describe the transport network in terms of the topological relationships between sets of points within the same layer network.

3.38 trail: A "transport entity" which consists of an associated pair of "unidirectional trails" capable of simultaneously transferring information in opposite directions between their respective inputs and outputs.

3.39 trail protection: A protection type that is modelled by a sublayer that is generated by expanding the "trail termination".

3.40 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.

3.41 trail termination: A "transport processing function" that consists of a co-located trail termination source and sink pair.

3.42 trail termination sink: A "transport processing function" which accepts the characteristic information of the layer network at its input, removes the information related to "trail" monitoring and presents the remaining information at its output.

3.43 trail termination source: A "transport processing function" which accepts adapted "characteristic information" from a client layer network at its input, adds information to allow the "trail" to be monitored and presents the characteristic information of the layer network at its output. The trail termination source can operate without an input from a client layer network.

3.44 transmission media layer network: A "layer network" which may be media dependent and which is concerned with the transfer of information between transmission media layer network "access points" in support of one or more "path layer networks".

3.45 transport: The functional process of transferring information between different locations.

3.46 transport entity: An architectural component which transfers information between its inputs and outputs within a layer network.

3.47 transport network: The functional resources of the network which conveys user information between locations.

3.48 transport processing function: An architectural component defined by the information processing which is performed between its inputs and outputs. Either the input or output must be inside a layer network; the corresponding output or input may be in the Management Network (e.g. output of a monitor function).

3.49 unidirectional access point: A "reference point" where the output of a "trail termination sink" is bound to the input of an "adaptation" sink or the output of an "adaptation" source function is bound to an input of a "trail termination source".

3.50 unidirectional connection: A "transport entity" which transfers information transparently from input to output.

3.51 unidirectional connection point: A "reference point" that represents the binding of the output of a "unidirectional connection" to the input of another "unidirectional connection".

3.52 unidirectional port: It represents the output of a trail termination source or unidirectional link connection, or the input to a trail termination sink or unidirectional link connection.

3.53 unidirectional termination connection point: A reference point that represents the following bindings: output of a trail termination source to the input of a unidirectional connection or; the output of a unidirectional connection to the input of a trail termination sink.

3.54 unidirectional trail: A "transport entity" responsible for the transfer of information from the input of a trail termination source to the output of a trail termination sink. The integrity of the information transfer is monitored. It is formed by combining trail termination functions and a network connection.

4 Abbreviations

This Recommendation uses the following abbreviations:

AIS	Alarm Indication Signal
APS	Automatic Protection Switch
ATM	Asynchronous Transfer Mode
PDH	Plesiochronous Digital Hierarchy
SDH	Synchronous Digital Hierarchy
STM-N	Synchronous Transport Module (level) N
TCP	Termination Connection Point
VC-n	Virtual Container (level) n

5 Functional architecture of transport networks

5.1 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 realizes 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 to another location 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.

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 network is used in a manner which allows a high degree of recursiveness. It is recommended that this method is used for describing the transport network.

5.2 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 reference points of the transport network architecture are the result of binding the inputs and outputs of processing functions and transport entities.

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

5.2.1 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. Four topological components have been distinguished; these are the layer network, the subnetwork, the link and the access group. Using these components it is possible to completely describe the logical topology of a layer network.

5.2.1.1 Layer network

A layer network is defined by the complete set of access groups of the same type which may be associated for the purpose of transferring information. The information transferred is characteristic of the layer network and is termed characteristic information. The associations of the trail terminations (that form a trail) in a layer network may be made and broken by a layer network management process thus changing its connectivity. A separate, logically distinct layer network exists for each trail termination type. The topology of a layer network is described by access groups, subnetworks and the links between them. The structures within and between layer networks are described by the components defined below.

5.2.1.2 Subnetwork

A subnetwork exists within a single layer network. It is defined by the set of ports which are available for the purpose of transferring characteristic information. The associations between the ports at the edge of a subnetwork may be made and broken by a layer network management process thus changing its connectivity. When a subnetwork connection is established the reference points are also created by binding the ports to input and output of the subnetwork connection. In general, subnetworks may be partitioned into smaller subnetworks interconnected by links; this is described in 5.3.2. The matrix is a special case of a subnetwork that cannot be further partitioned.

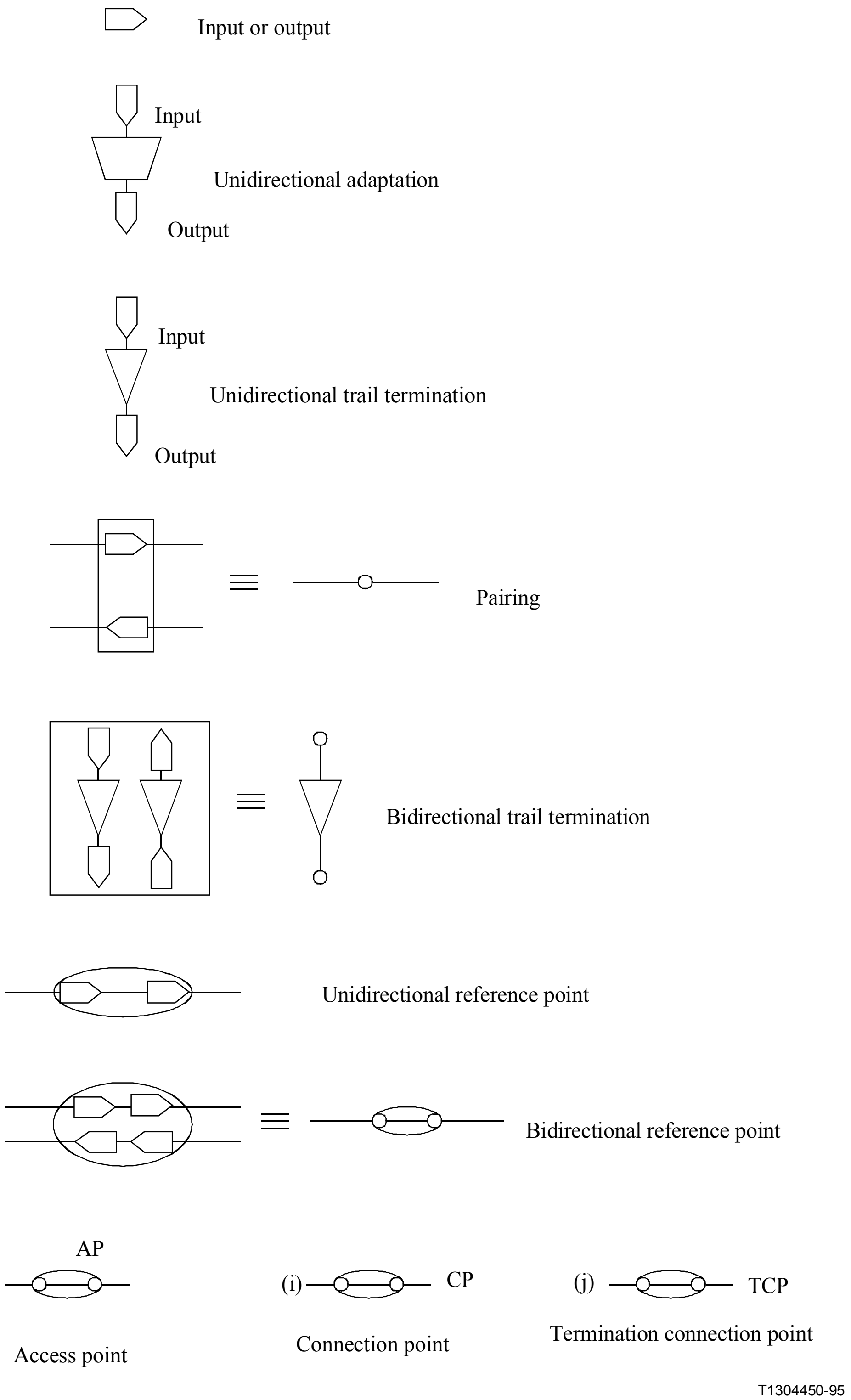


Figure 1/G.805 – Diagrammatic conventions for processing functions and reference points

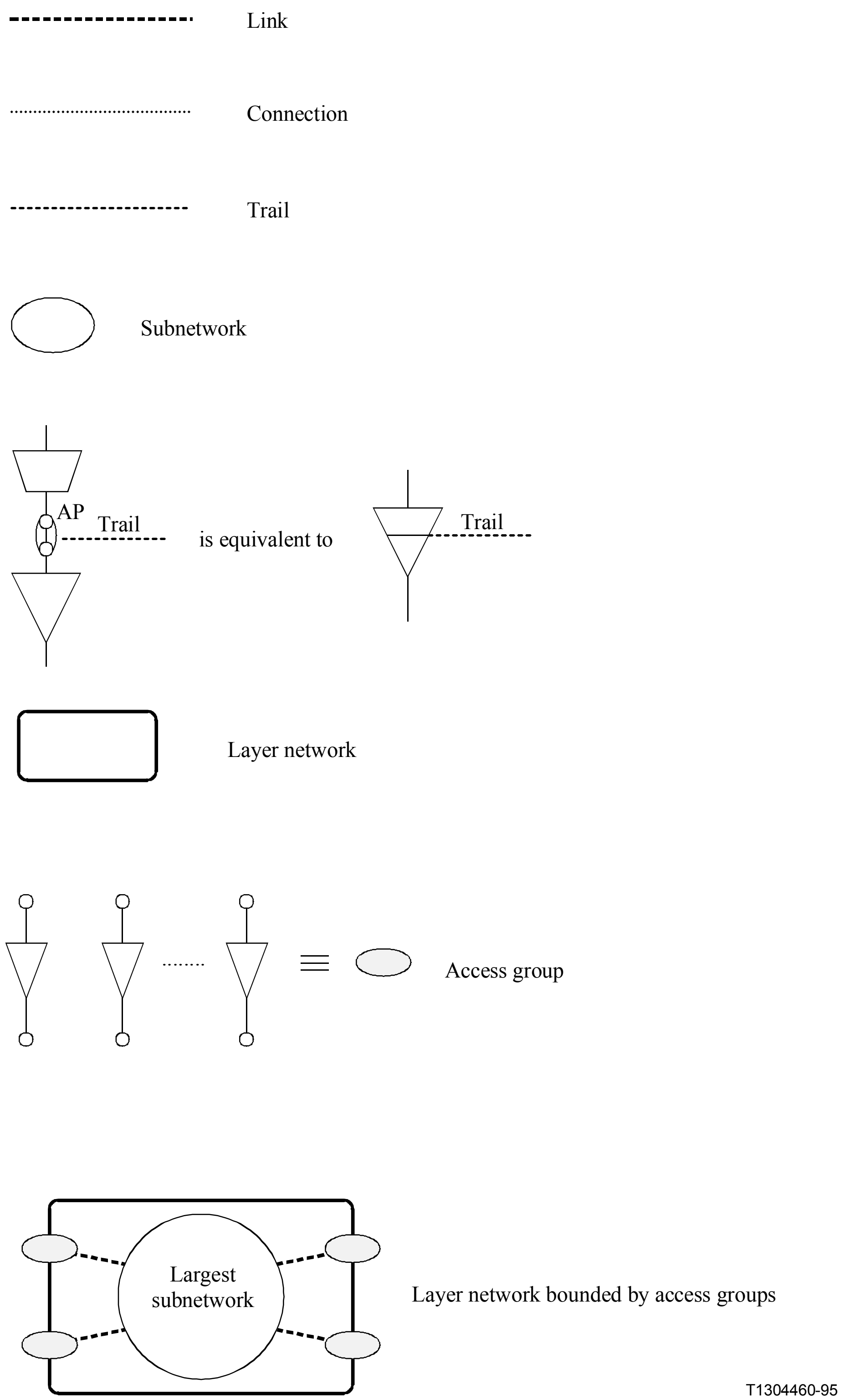


Figure 2/G.805 – Other diagrammatic conventions

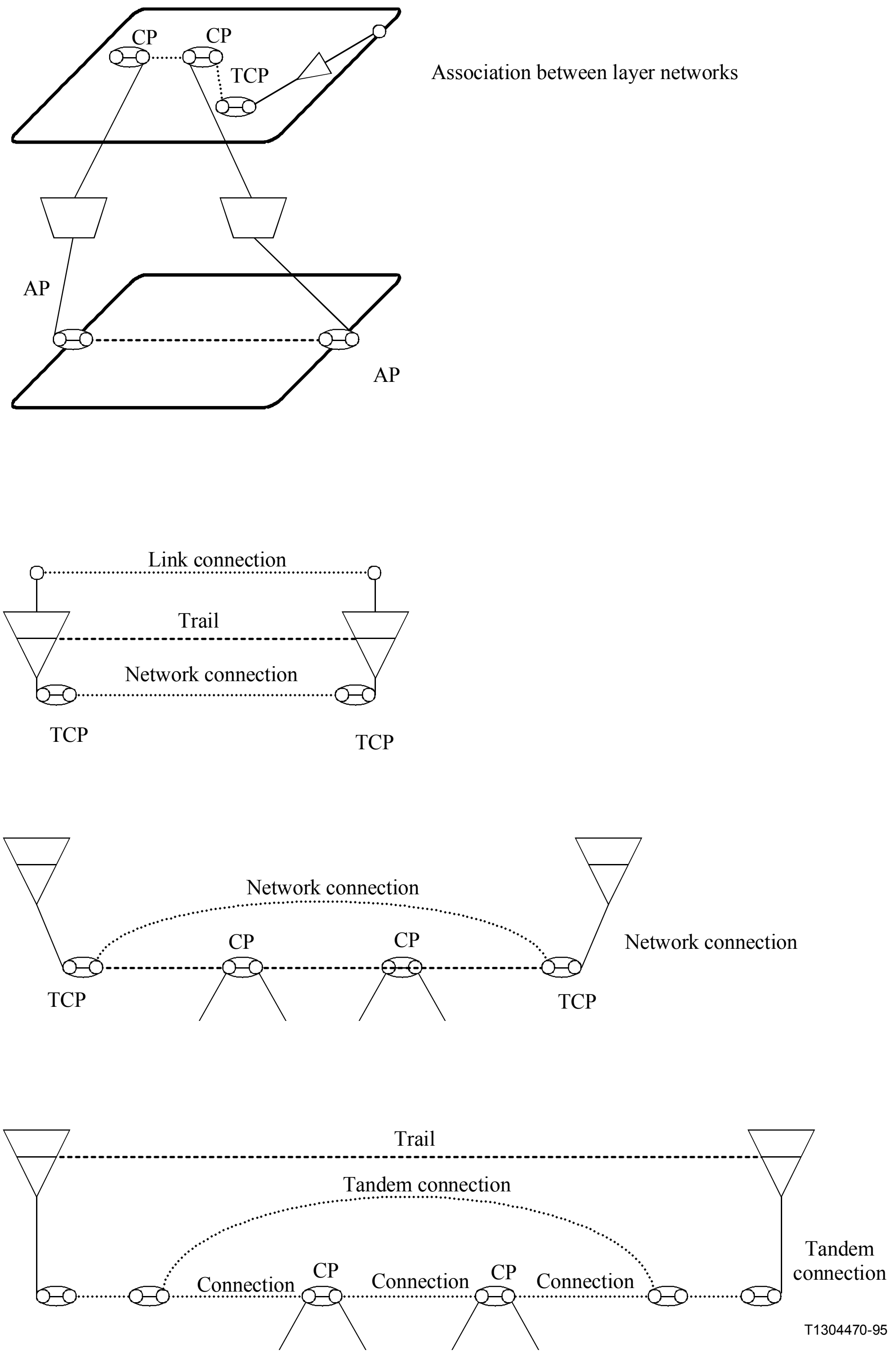


Figure 2/G.805 – Other diagrammatic conventions *(concluded)*

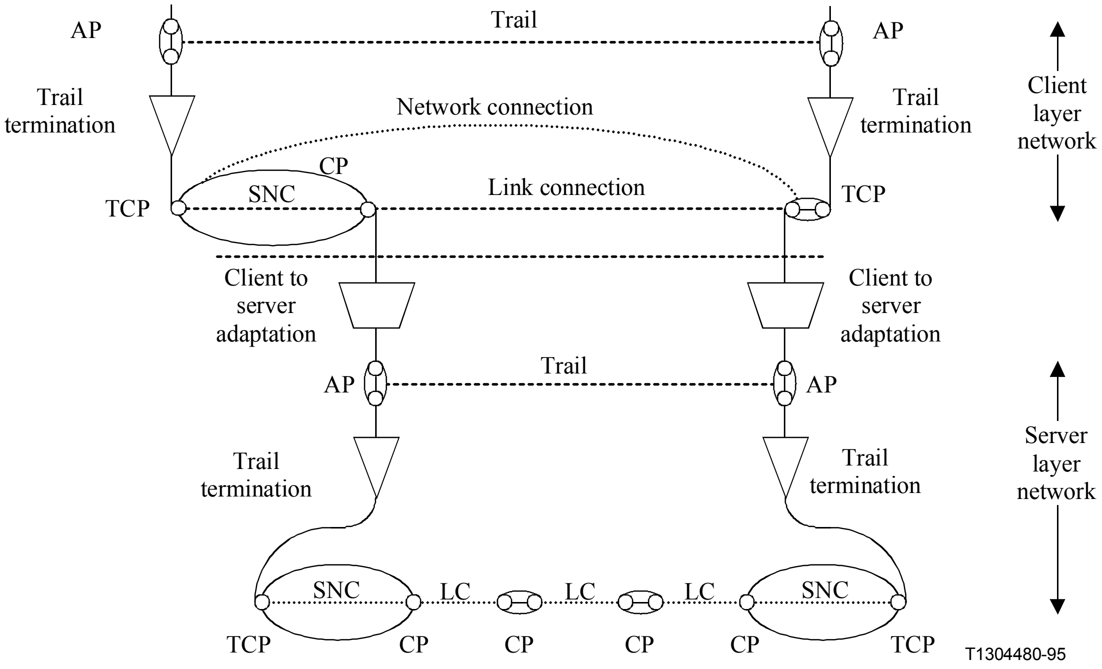


Figure 3/G.805 – Example functional model

5.2.1.3 Link

A link consists of a subset of the ports at the edge of one subnetwork or access group which are associated with a corresponding subset of the ports at the edge of another subnetwork or access group for the purpose of transferring characteristic information. The link represents the topological relationship and available transport capacity between a pair of subnetworks, or a subnetwork and an access group or a pair of access groups. Multiple links may exist between any given subnetwork and access group or pair of subnetworks or access groups. While links are established and maintained at the time scale of the server layer network, they are not limited to being provided by a server trail and can also be provided by client layer network connections.

5.2.1.4 Access Group

An access group is a group of co-located trail termination functions that are connected to the same subnetwork or link.

5.2.2 Transport entities

The transport entities provide transparent information transfer between layer network reference points. There is no information change between input and output other than that resulting from degradation 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, subnetwork connections and link connections according to the topological component to which they belong.

5.2.2.1 Link connection

A link connection is capable of transferring information transparently across a link. It is delimited by ports and represents the fixed relation between the ends of the link. A link connection represents a pair of adaptation functions and a trail in the server layer network.

The port at the input to a unidirectional link connection also represents the input to an adaptation source, the port at the output of a unidirectional link connection also represents the output of an adaptation sink. The unidirectional link connections and the associated ports and adaptation sink and source may be paired to provide bidirectional information transfer.

5.2.2.2 Subnetwork connection

A subnetwork connection is capable of transferring information transparently across a subnetwork. It is delimited by ports at the boundary of the subnetwork and represents the association between these ports. In general subnetwork connections are constructed from a concatenation of subnetwork connections and link connections. The matrix connection is a special case of the subnetwork connection that is formed by a single (indivisible) subnetwork connection.

5.2.2.3 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 formed from a concatenation of subnetwork connections and/or link connections. The TCP is formed by binding the port of the trail termination to either a subnetwork connection or the port of a link connection. There is no explicit information to allow the integrity of the transferred information to be monitored. Some techniques that allow the integrity to be monitored are described in 5.4.

5.2.2.4 Trail

A trail represents the transfer of monitored adapted characteristic information of the client layer network between access points. It is delimited by two access points, one at each end of the trail. It represents the association between the ends of the trail. A trail is formed by associating trail terminations with a network connection.

5.2.3 Transport processing functions

Two generic processing functions of adaptation and trail termination are distinguished in describing the architecture of layer networks.

5.2.3.1 Adaptation function

Adaptation source: A transport processing function which adapts the client layer network characteristic information into a form suitable for transport over a trail in the server layer network.

Adaptation sink: A transport processing function which converts the server layer network trail information into the characteristic information of the client layer network

Bidirectional Adaptation: A transport processing function that consists of a co-located adaptation source and sink pair.

The following are examples of processes which may occur singly or in combination in an adaptation function: coding, rate changing, aligning, justification, multiplexing.

Adaptation function cardinality: the Adaptation Source function input to output relation is a many-to-one relationship or a one-to-many. In the first case, one or more client layer network inputs are adapted into a single adapted information stream suitable for transport over a trail in the server layer network and this relationship is commonly used to represent the multiplexing of several clients into a single server. In the second case one composite stream is split over several outputs and this is used to describe the common processing involved in inverse multiplexing. The converse relationships hold for the Adaptation Sink function between its single input and one or more outputs.

5.2.3.2 Trail termination function

Trail termination source: a transport processing function which accepts adapted characteristic information from a client layer network at its input, adds information to allow the trail to be monitored and presents the characteristic information of the layer network at its output. The trail termination source can operate without an input from a client layer network.

Trail termination sink: a transport processing function which accepts the characteristic information of the layer network at its input, removes the information related to trail monitoring and presents the remaining information at its output. The trail termination sink can operate without an output to a client layer network.

Bidirectional Trail termination: a transport processing function that consists of a pair of co-located trail terminations source and sink functions.

Trail termination function cardinality: the Trail termination Source function input to output relation is a one-to-many relationship. The single adapted information input stream is distributed over one or more network connections in the server layer. This relationship is most commonly used in the one-to-one form to represent that addition of Trail Overhead to the adapted information which is transported via one network connection. In its more general form the relationship can be used to represent inverse multiplexing in which a single high capacity stream is split over several lower capacity network connections.

The converse relation holds for the Sink function between its one or more inputs and single output.

5.2.4 Reference points

Reference points are formed by the binding between inputs and outputs of transport processing functions and/or transport entities. The allowable bindings and resultant specific types of reference points are shown in Table 1.

Table 1/G.805 – Allowable bindings and resulting reference points

Architectural components				Reference point	
Adaptation	Source output	Trail term	Source input	AP	uni
	Sink input		Sink output		uni
	Source/sink pair		Source/sink pair		bi
Trail term	Source output	LC	uni input	TCP	uni
	Sink input		uni output		uni
	Source/sink pair		Source/sink pair		bi
Trail term	Source output	SNC	uni input	TCP	uni
	Sink input		uni output		uni
	Source/sink pair		Source/sink pair		bi
LC	uni input	SNC	uni output	CP	uni
	uni output		uni input		uni
	Source/sink pair		Source/sink pair		bi
LC	uni input	LC	uni output	CP	uni
	uni output		uni input		uni
	Source/sink pair		Source/sink pair		bi
Adaptation	Source input	Adaptation	Sink output	CP	uni
	Sink output		Source input		uni
	Source/sink pair		Source/sink pair		bi

AP	Access Point	TCP	Termination Connection Point
bi	bidirectional	Trail term	Trail termination
LC	Link Connection	uni	unidirectional
SNC	Subnetwork connection		

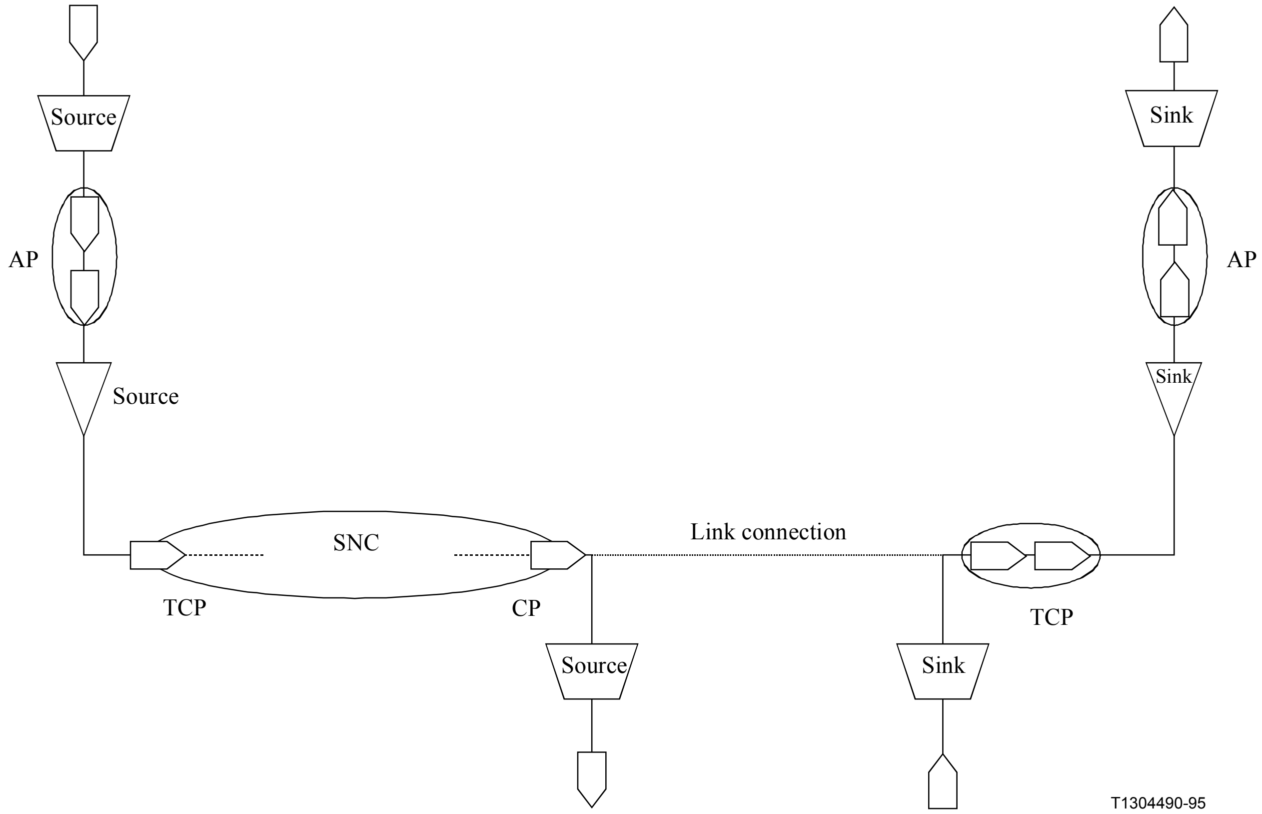
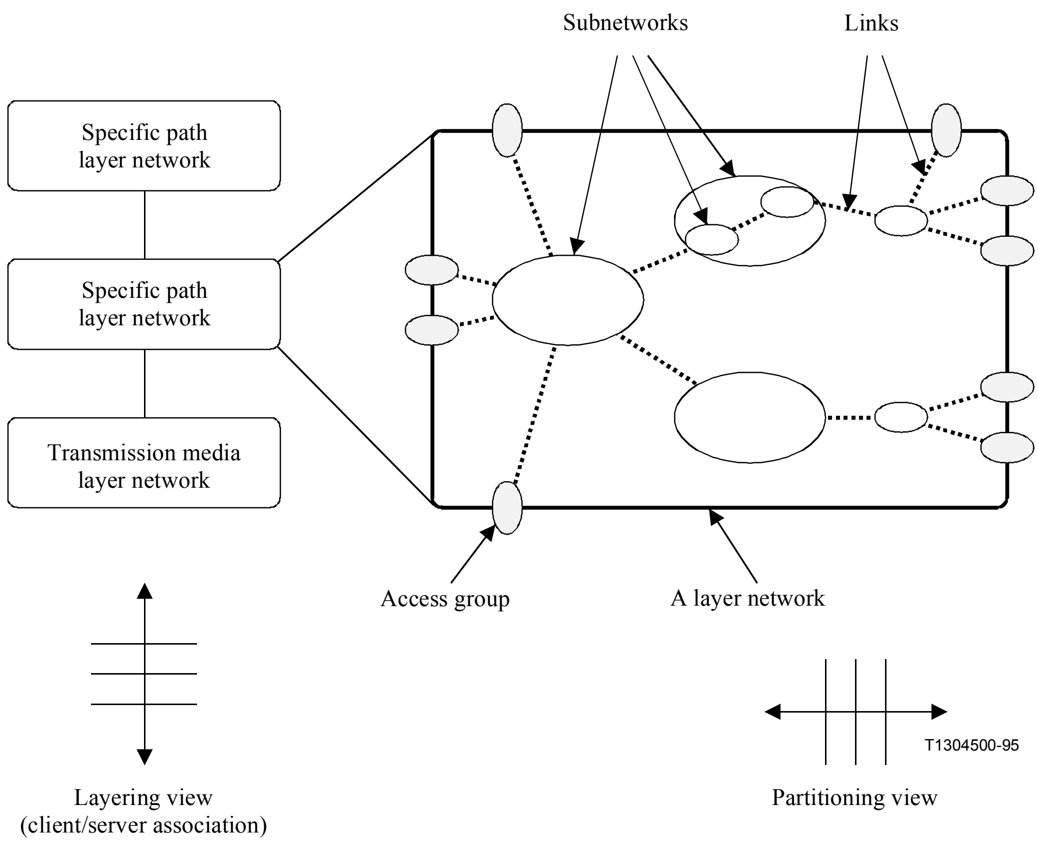


Figure 4/G.805 – Bindings and types of reference points

5.3 Partitioning and layering

5.3.1 Introduction

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



a) **Layering concept**

b) **Partitioning concept**

Figure 5/G.805 – Orthogonal views of layering and partitioning

5.3.1.1 Application of the partitioning concept

The partitioning concept is important as a framework for defining:

a) the network structure within a layer network;

b) administrative boundaries between network operators jointly providing connections within a single layer network;

c) domain boundaries within a layer network of a single operator to allow the apportioning of performance objectives to the architectural components;

d) routing domain boundaries within the layer network of a single operator;

e) the part of a layer network or subnetwork that is under the control of a third party for routing purposes (e.g. customer network management).

5.3.1.2 Application of the layering concept

The layering concept of the transport network allows:

a) each layer network to be described using similar functions;

b) the independent design and operation of each layer network;

c) each layer network to have its own operations, diagnostic and automatic failure recovery capability;

d) the possibility of adding or modifying a layer network without affecting other layer networks from the architectural viewpoint;

e) simple modelling of networks that contain multiple transport technologies.

5.3.2 Partitioning concept

5.3.2.1 Subnetwork partitioning

In general a subnetwork is constructed by representing the physical implementation as links and subnetworks, starting from the matrix that is the smallest (indivisible) subnetwork. A set of subnetworks and links may be abstracted as a higher (containing) subnetwork. The way in which the contained subnetworks are interconnected by links describes the topology of the containing subnetwork. The ports at the boundary of the containing subnetwork and the interconnection capability must fully represent, but not extend, the connectivity supported by the contained subnetworks and links. Therefore a higher level subnetwork may be partitioned to show the level of detail required.

Thus in general, any subnetwork may be partitioned into a number of smaller (contained) subnetworks interconnected by links. The partitioning of a subnetwork cannot extend or restrict its connectivity, i.e.:

- The ports on the boundary of the containing subnetwork and the interconnection capability must be represented by the contained subnetworks and links.
- The contained subnetworks and links cannot provide connectivity that is not available in the containing subnetwork.

Examples of subnetworks are the international portion and the national portions of a layer network, which can be further divided into transit portions and access portions as shown in Figure 6.

A network connection or subnetwork connection may be decomposed into a concatenation of other transport entities (link or subnetwork connection) which reflects the partitioning of a subnetwork. This is illustrated in Figures 7 and 8.

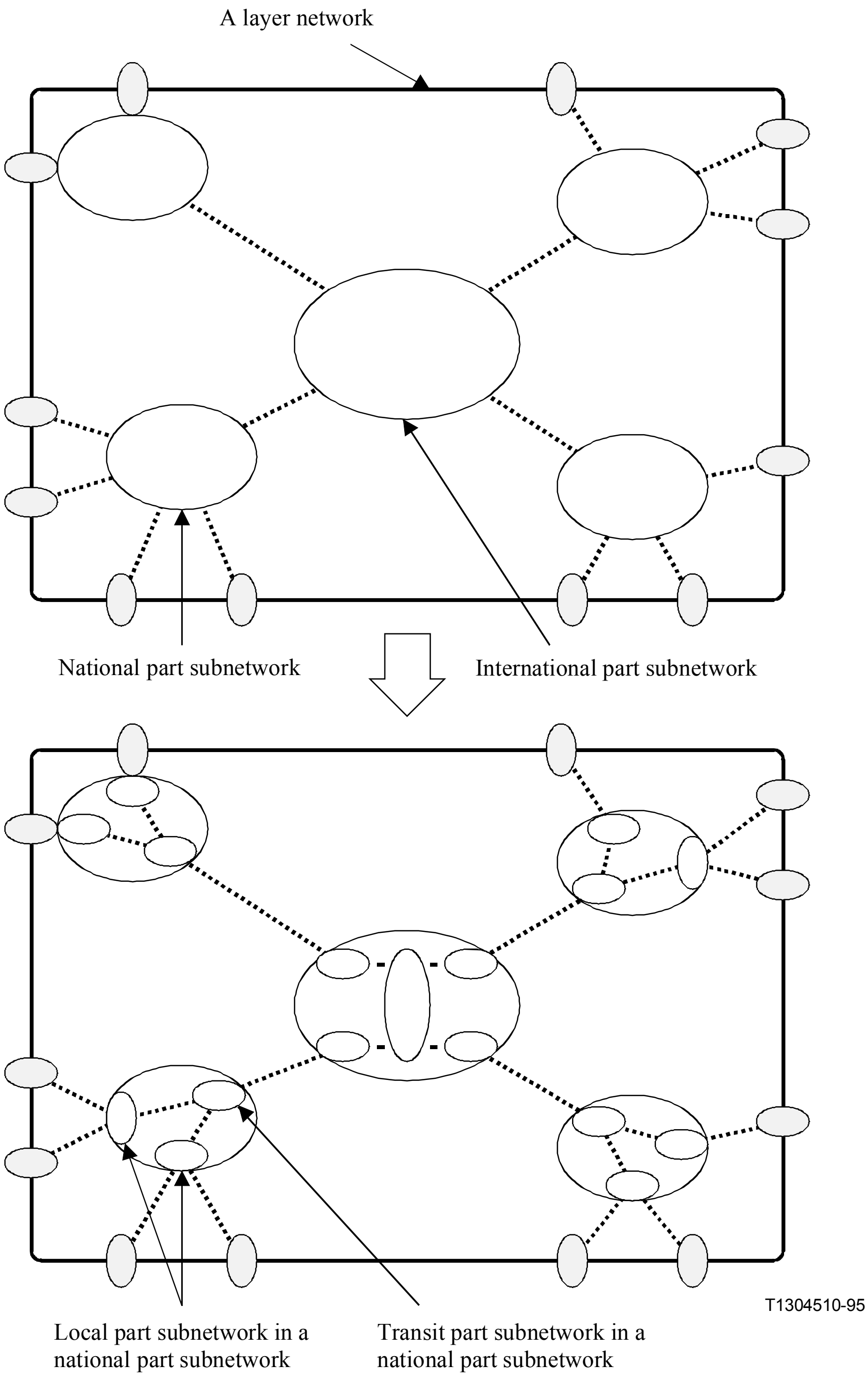
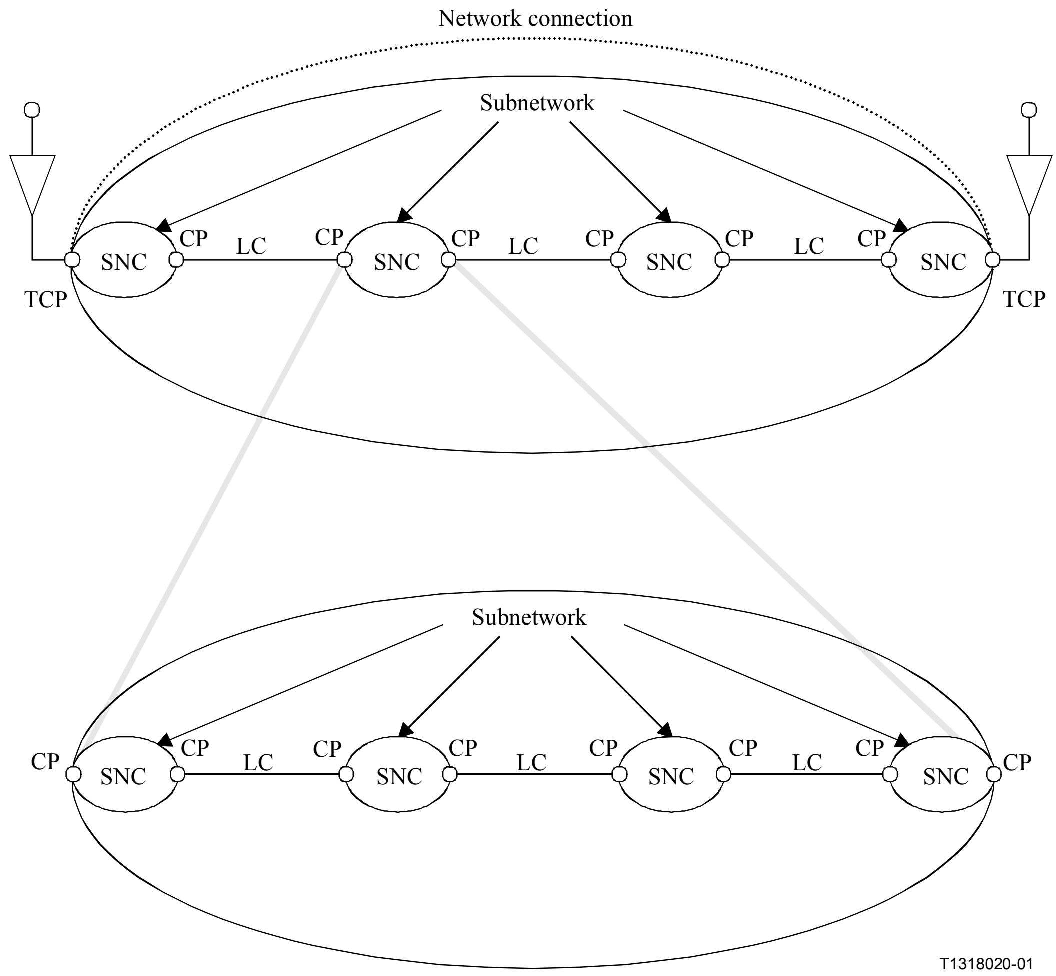
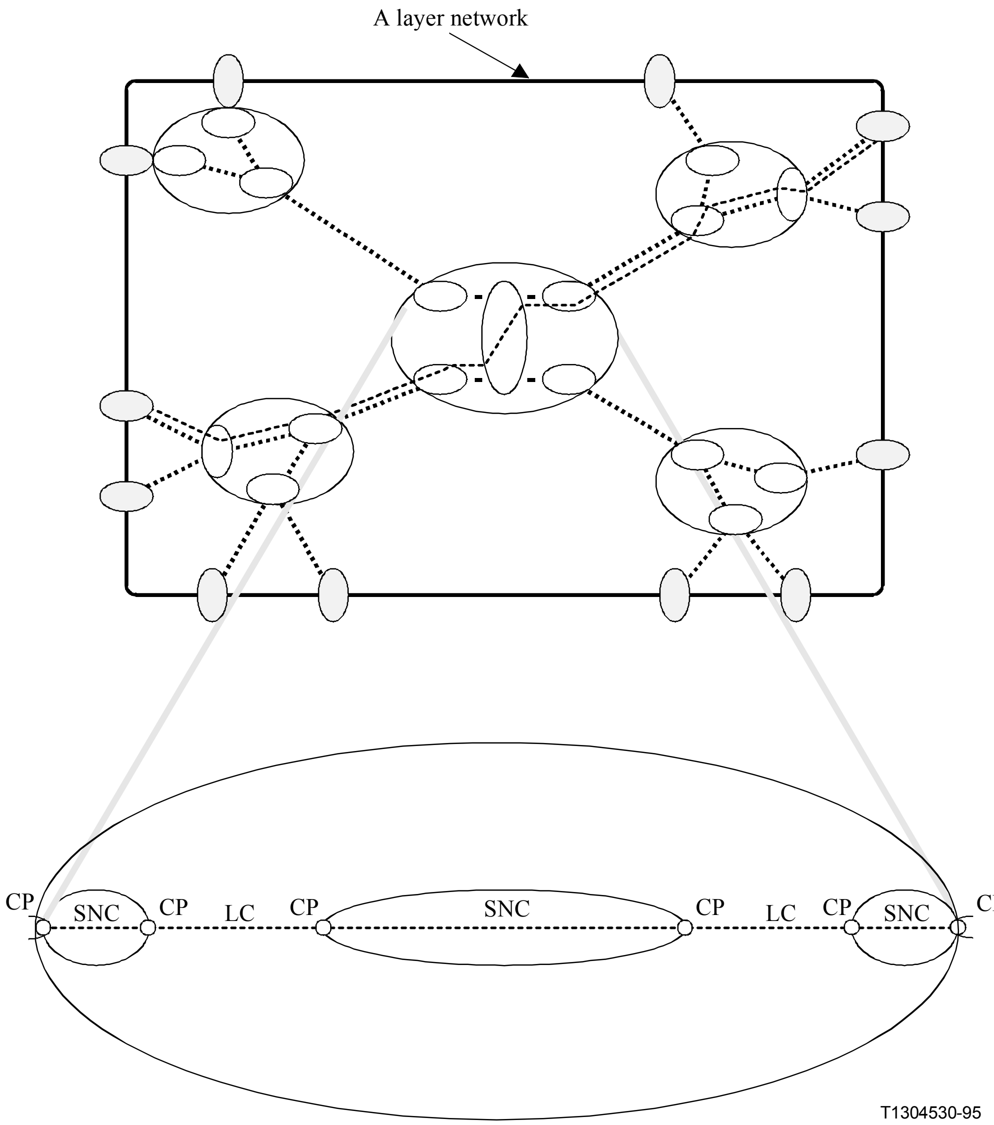


Figure 6/G.805 – Partitioning of layer networks and subnetworks



CP Connection Point
LC Link Connection
SNC Subnetwork Connection
TCP Terminator Connection Point

Figure 7/G.805 – Decomposition of a network connection



-------------	Trail
CP	Connection Point
LC	Link Connection
SNC	Subnetwork connection

Figure 8/G.805 – Relationship between partitioning of subnetworks and decomposition of connections

5.3.2.2 Link partitioning

In general a link is constructed by bundling a set of link connections, the smallest unit of manageable capacity, that are equivalent for the purposes of routing. Links may also be further bundled to provide for any desired capacity visibility. Links may be partitioned into a set of parallel links (or link connections) or into a serial arrangement of link connection – subnetwork – link connection as illustrated in Figures 9 and 10. The partitioned links may themselves be recursively further partitioned.

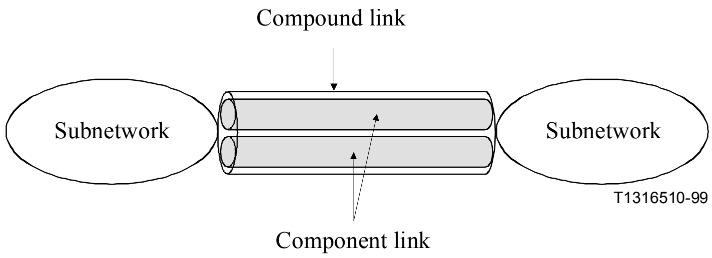


Figure 9/G.805 – Parallel partitioning of a link into links

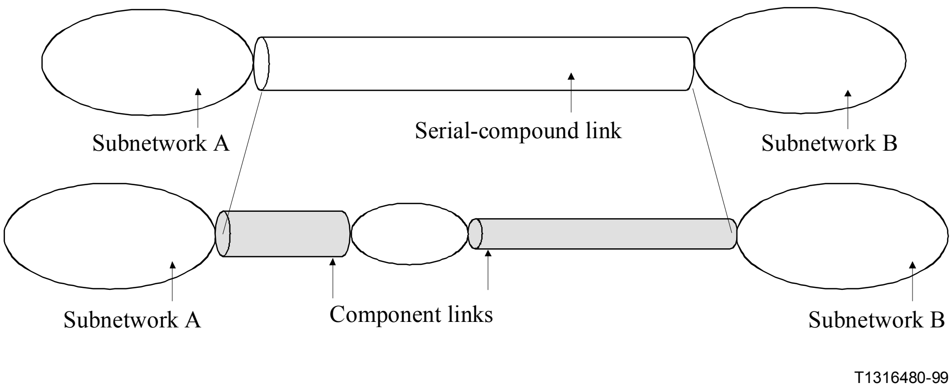


Figure 10/G.805 – Serial partitioning of a link

5.3.3 Layering concept

The transport network can be decomposed into a number of independent layer networks with a client/server relationship between adjacent layer networks. A layer network describes the generation, transport and termination of a particular characteristic information.

The layer networks which have been identified in the transport network functional model should not be confused with the layers of the OSI Model (ITU-T X.200). An OSI layer offers a specific service using one protocol among different protocols. On the contrary, each layer network (in this Recommendation) offers the same service using a specific protocol (the characteristic information).

5.3.3.1 Client/server relationship

The client/server relationship between adjacent layer networks is one where a link connection in the client layer network is supported by a trail in the server layer network.

The concept of adaptation is introduced to describe how the client layer network characteristic information is modified so that it can be transported over a trail in the server layer network. From a transport network functional viewpoint therefore the adaptation function falls between the layer networks. All the reference points belonging to a single layer network can be visualized as lying on a single plane as illustrated in Figure 2. (Example layer network bounded by access groups.) This is the reason why there is not the same concept of contiguous layer boundaries in the transport network model as in the OSI protocol reference model.

The client/server relationship can be a one-to-one, many-to-one or one-to-many relationship. The one-to-one relationship represents the case of a single client layer link connection supported by a single server layer trail.

5.3.3.1.1 Multiplexing

The many-to-one relationship represents the case of several link connections of client layer networks supported by one server layer trail at the same time as shown in Figure 11. Multiplexing techniques are used to combine the client layer signals. The client signals could be of the same or of different types. The adaptation function may consist of specific processes for each client signal and common processes associated with the server layer signal

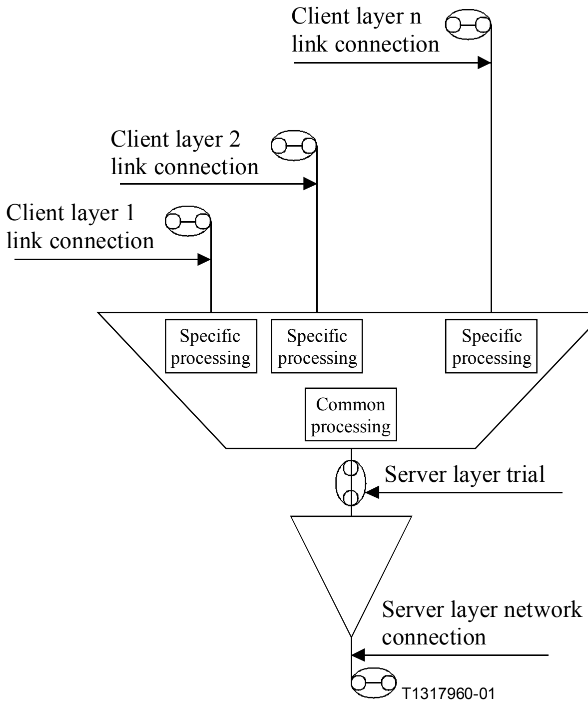


Figure 11/G.805 – Many-to-one client/server relationship (multiplexing)

5.3.3.1.2 Inverse multiplexing

The one-to-many relationship represents the case of a client layer link connection supported by several server layer trails in parallel as shown in Figure 12. Inverse multiplexing techniques (e.g. ATM inverse multiplexing, virtual concatenation) are used to distribute the client layer signal. The server signals could be of the same or of different types.

The functional model for general inverse multiplexing is depicted in Figure 12. Inverse multiplexing is realized by means of an inverse multiplexing sublayer including an inverse multiplexing trail termination function (I_TT) and an inverse multiplexing adaptation function (X[Y,Z]/I). The inverse multiplexing trail termination function represents the trail supervision for the composite signal. The inverse multiplexing adaptation function performs the dis-interleaving/interleaving of the compound signal to and from the n individual server layer trails. These two sublayer functions and the n server layer network termination functions (X[Y,Z]_TT) form the inverse multiplexing trail termination compound function (Ic_TT).

Note that the n server layer trails could be of different layer networks.

As the n server layer trails can have different routes (diverse routes) the individual trails may have different signal delays. The inverse multiplexing adaptation sink function has to compensate these delay differences (differential delay) in order to interleave the individual signals to recreate the compound signal. The maximum differential delay is application specific. An operator may limit the maximum differential delay processed by the adaptation sink (e.g. if all server layer trails use the same route through the network) in order to reduce the transfer delay of the adaptation sink function. The detection range for differential delay should be much larger than the maximum delay that could be compensated to prevent aliasing effects from occurring, which would corrupt the transport without being detected. A differential delay greater than the maximum delay that could be compensated shall result in an alarm.

The quality of service of the inverse multiplex sub-layer trail is defined by the quality of service of the individual server layer trails provided by the server layer trail termination functions and the defects detected by the re-interleaving process provided by inverse multiplexing sub-layer trail termination function. At intermediate measurement points (e.g. non-intrusive monitors) only the quality of service of the individual server layer trails is available.

The introduction of inverse multiplexing should not result in additional supervision functionality for the server layer trails.

In case of a client signal with fixed bandwidth the number of server layer trails is also fixed. Layer interworking as defined in 5.5 is in this case possible between a single server layer trail that supports the full client signal and the n server layer trails of the inverse multiplexing signal if the two server layer networks have similarly characteristic information.

In case of a client signal with variable bandwidth the number of server layer trails could also be variable. The number of server layer trails could change on demand (e.g. network operator request, client layer request) or in failure conditions. In the first case the change should not be service affecting. In the later case one or more server layer trails may not be available due to a failure in the network. Diverse routing of the individual server layer trails should be used in order to minimize the possibility of a single failure affecting all server layer trails. The decrease of the bandwidth due to a failed trail will be service affecting, while the increase of bandwidth due to the recovery of a failed trail can be non service affecting. In case of a bidirectional connnection the number of server layer trails in both directions could be different.

If inverse multiplexing is introduced in an existing network, it should not impose additional requirements on that network.

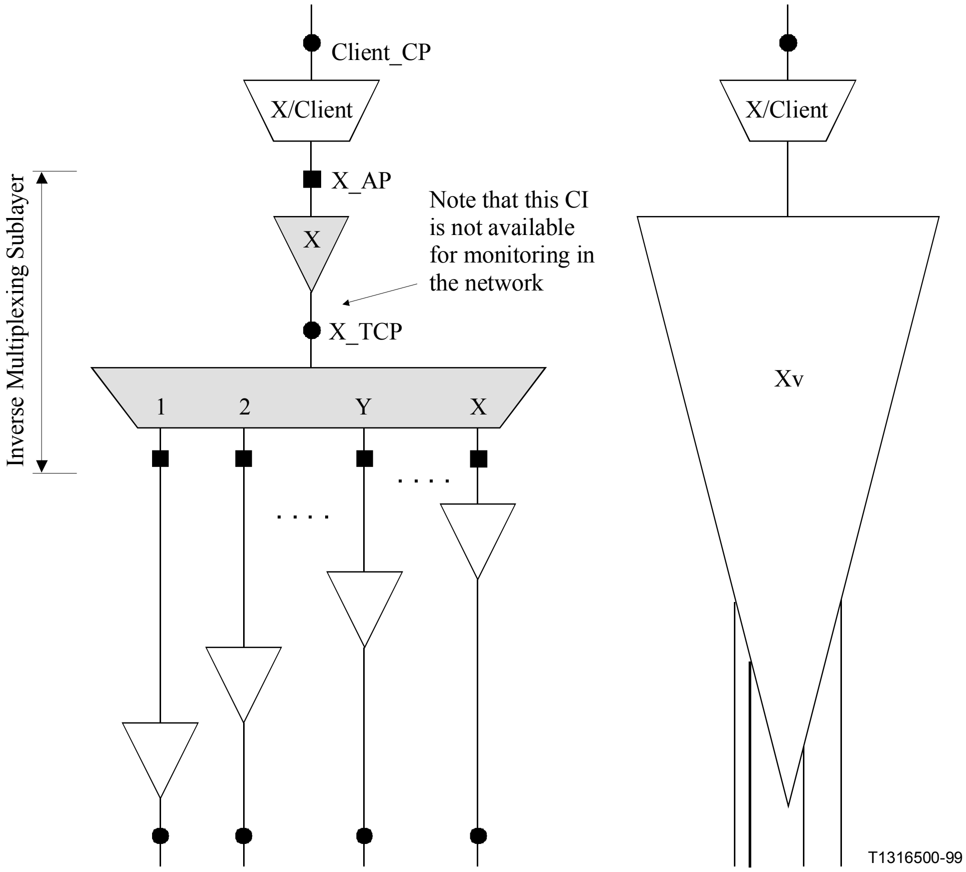


Figure 12/G.805 – One-to-Many client/server relationship (inverse multiplexing)

5.3.3.2 Transport layer networks

The transport functional group may be classified broadly into two classes of layer network: a path layer network and a transmission media layer network:

- Path layer network – provides the information transfer capability required to support various types of services. Path layer networks are independent of transmission media layer networks. The description of the path layer network is the main application of this Recommendation.
- Transmission media layer network – is supported by trails and link connections, subnetwork connections are not provided. A transmission media layer network may be dependent on the physical media used for transmission such as optical fibre and radio.

5.3.3.3 Decomposition of layer networks

5.3.3.3.1 General principles of decomposition of layers

It is possible to decompose a layer network by expanding either the trail terminations, or (termination) connection points of the layer network.

5.3.3.3.2 Decomposition of the path layer network into specific path layer networks

It is possible to identify a set of specific path layer networks within the path layer network which are likely to be independently managed by a network operator.

Each specific path layer network may have both the information transfer capability required to support various types of services and other specific path layer networks as clients and can have the transmission media layer network or other specific path layer networks as servers. The actual decomposition used to generate the specific path layer networks is dependent on the technology.

Each specific path layer network can have independent topology and it is likely that paths across a specific path layer network will be set up independently from the setup of paths in other specific path layer networks. Examples of the decomposition of the path layer network are given in clause 6.

5.3.3.3.3 Decomposition of the transmission media layer network into specific transmission media layers

It is possible to identify a set of layer networks within the transmission media layer network which is likely to be independently administered by a network operator by decomposing the transmission media layer network. The connectivity of a transmission media layer network cannot be directly modified by management action. 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 locations in path layer networks. The section layer network may be decomposed into specific section layer networks as described in the examples in clause 6.

Physical media layer networks are concerned with the actual fibres, metallic wires or radio frequency channels which support a section layer network. The physical media layer network may be decomposed into specific physical media layer networks to represent, for example, wave division multiplexing. Since a server layer network does not exist for the lowest layer network (e.g. the physical media layer network) the network connection is directly supported by the media and not by a trail.

Advances in the technologies available to implement the transmission media layer network may at some time in the future allow the connectivity of the transmission media layer to be modified by management action. The modelling of this capability is for further study.

5.3.3.3.4 Decomposition of specific layer networks into sublayers

It is often useful to identify sublayers within a specific layer network in order to identify additional transport processing functions and reference points. This can be done by decomposing the trail termination function or connection point of a specific layer network. A sublayer is encapsulated into the specific layer network.

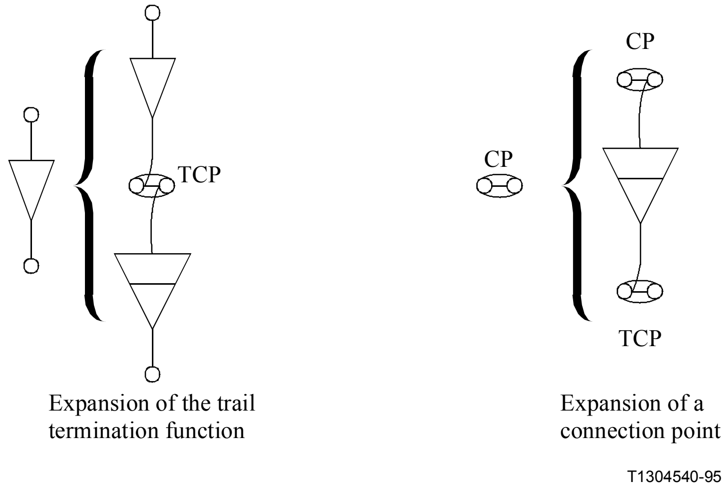
The distinction between a layer network and a sublayer is that a sublayer is not directly accessible to clients outside of its encapsulating layer network and offers no transport service for a client network.

Example applications include:

- identification of trail protection schemes by the expansion of the trail termination (see 7.2.1);
- identification of sublayer protection schemes by the expansion of the connection point (see 7.2.2);
- identification of a sublayer describing a trail which monitors a tandem connection;
- the expansion of the connection point (see 5.4.2.2).

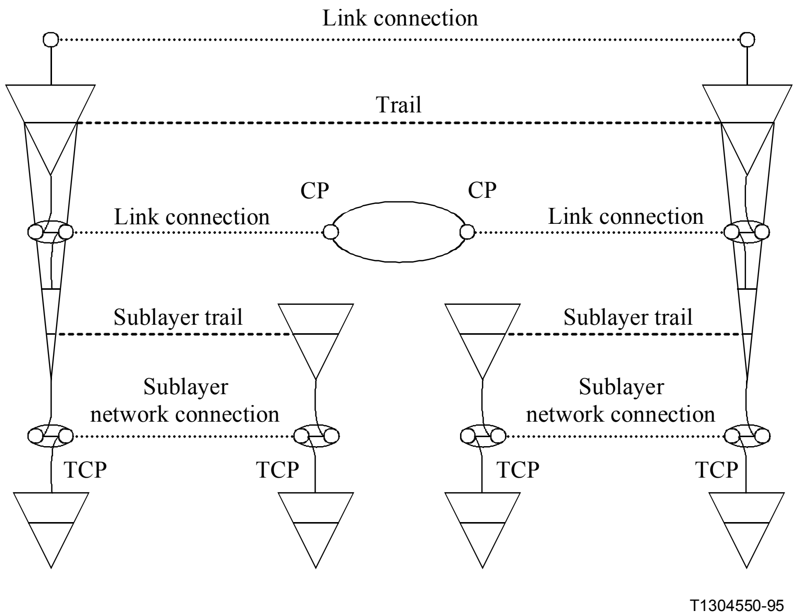
The expansion of the trail termination function and connection point is illustrated in Figure 13. The concept of sublayers is illustrated in Figure 14.

Sublayers may be further sublayered.



CP Connection Point
TCP Termimination Connection Point

Figure 13/G.805 – Generation of sublayers



CP Connection Point
TCP Termination Connection Point

Figure 14/G.805 – The concept of sub layering

5.4 Connection supervision

5.4.1 Connection monitoring techniques

5.4.1.1 Inherent monitoring

[Refer to Figure 15 a).]

Connections may be indirectly monitored by using the data that is inherently available from the server layer network. If the trail in a server layer network fails [e.g. 1st server layer trail within tandem connection in Figure 15 a)] then it may provide an indication (e.g. AIS) at the output of the link connections that are being supported. This indication is forwarded over the next (series of) link connection(s), which are supported by other trails in the server layer, and the output of the last link connection in the tandem connection may provide the signal fail indication.

NOTE – The output of each SDH VC-n link connection is able to detect the indication (AIS) that the transport through one of the trails in the server layer upstream of this point failed. The output of link connections in ATM and PDH are not able to detect this fail indication.

The trail in the server layer network may also provide some error performance information about a single link connection. When the adaptation function includes multiplexing, the error performance statistics for each of the link connections, supported by the server layer trail, will not be available individually; it must be estimated from the error performance of the trail. The information from each link connection that forms the overall connection of interest may be collected and correlated via a management network. The overall status of the connection cannot be provided by this technique since the adaptation functions and matrix connections are not included in the monitoring scheme.

5.4.1.2 Non-intrusive monitoring

[Refer to Figure 15 b).]

The connection may be directly monitored by use of listen-only (non-intrusive) monitoring of the original characteristic information. The information derived from this monitor reflects the status of the connection from the original trail termination source to the connection point at which the monitor is attached. The status of a particular part of a connection may be derived by correlating, via the management network, the results obtained from non-intrusive monitors attached to the connection points that delimit the segment. This status may include both the error performance and connectivity of the segment if the original signal was provided with a unique identifier signal. This correlation technique will support arbitrary nesting or overlapping of connection segments.

5.4.1.3 Intrusive monitoring

[Refer to Figure 15 c).]

A connection may be directly monitored by breaking the original trail and introducing a test trail that extends over the part of the connection of interest for the duration of the test.

In this way all parameters can be monitored directly, but the user trail is interrupted so this can only be done either just at the beginning of the trail setup, or possibly in an intermittent fashion.

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

5.4.1.4 Sublayer monitoring

[Refer to Figure 15 d).]

Some portion of the original trail's capacity[1] is over-written such that the part of the connection that is of interest can be directly monitored by a trail created in a sublayer.

With this technique all parameters can be tested directly, assuming that sufficient bandwidth can be over-written in the original capacity. This scheme can provide for nested sublayer trail monitored connections assuming that sufficient overhead is available to support the nesting. This ability is technology dependent.

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[1] In networks based on SDH or PDH the capacity over-written must be part of the trail overhead; in networks based on ATM OAM cells may be inserted.

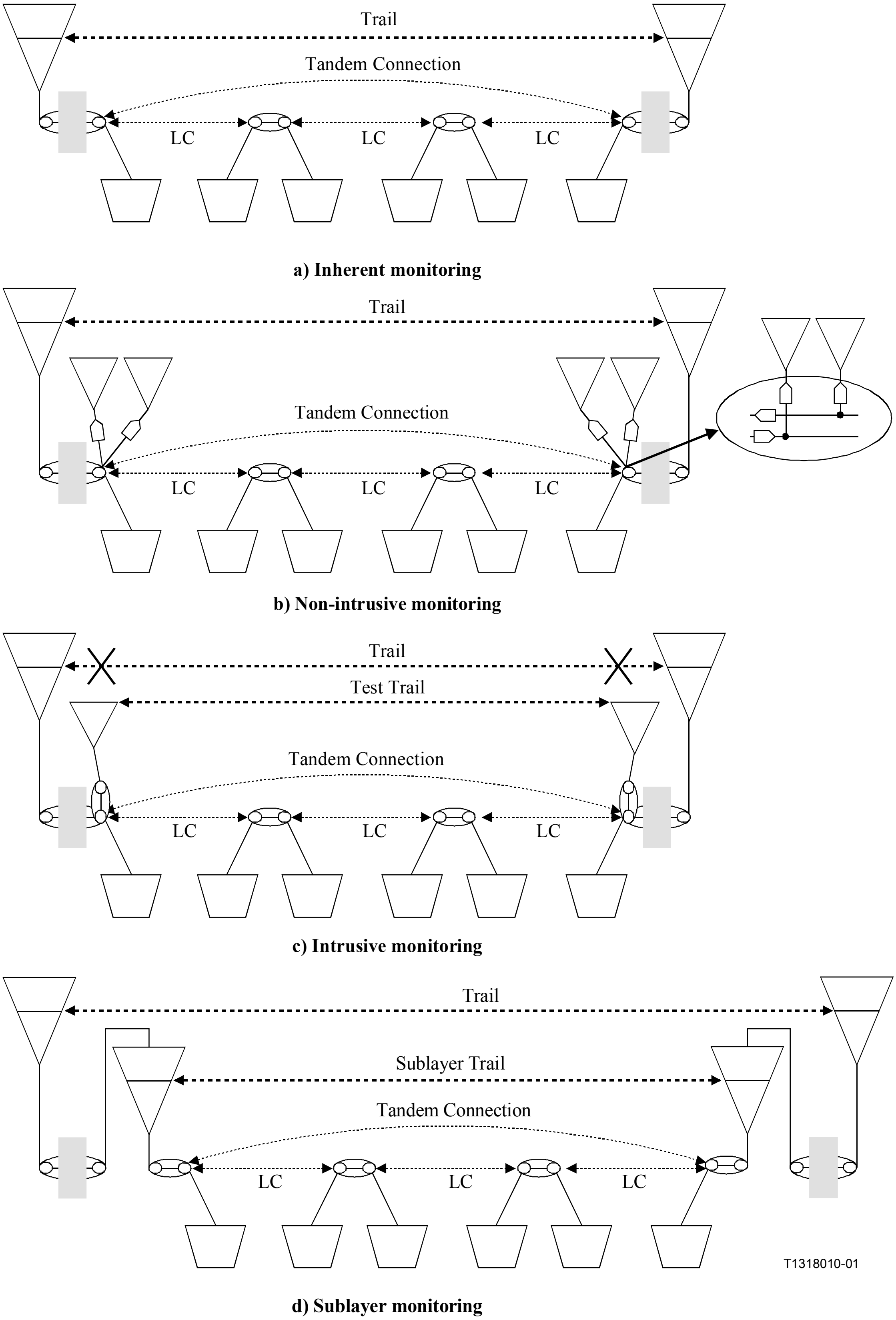


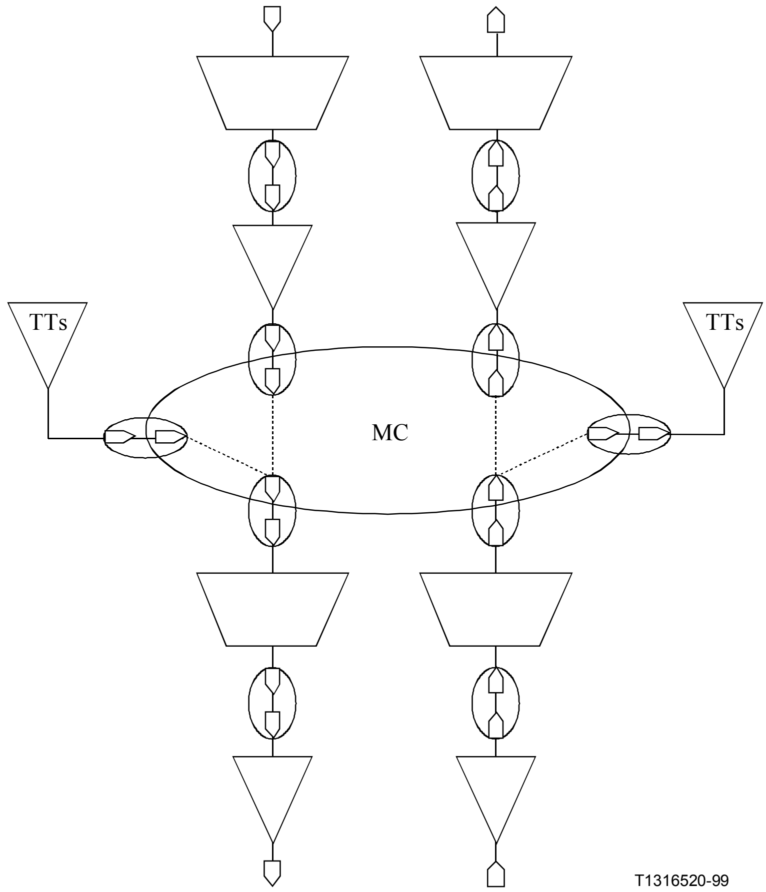
Figure 15/G.805 – Connection Monitoring Techniques

5.4.2 Connection monitoring applications

5.4.2.1 Monitoring of unused connections

A connection is unused if one of the ports that delimit the connection is not involved in a binding relationship. An unused connection may be monitored by using a supervisory trail termination source (that provides minimum client layer overhead required for monitoring) in combination with a supervisory trail termination sink as shown in Figure 16.

NOTE – Any regular trail termination source/sink function may be used as a supervisory trail termination function if it can be operated without a payload signal.



MC Matrix connection

TTs Supervisory Trail Termination

Figure 16/G.805 – Monitoring of unused connections

5.4.2.2 Tandem connection monitoring

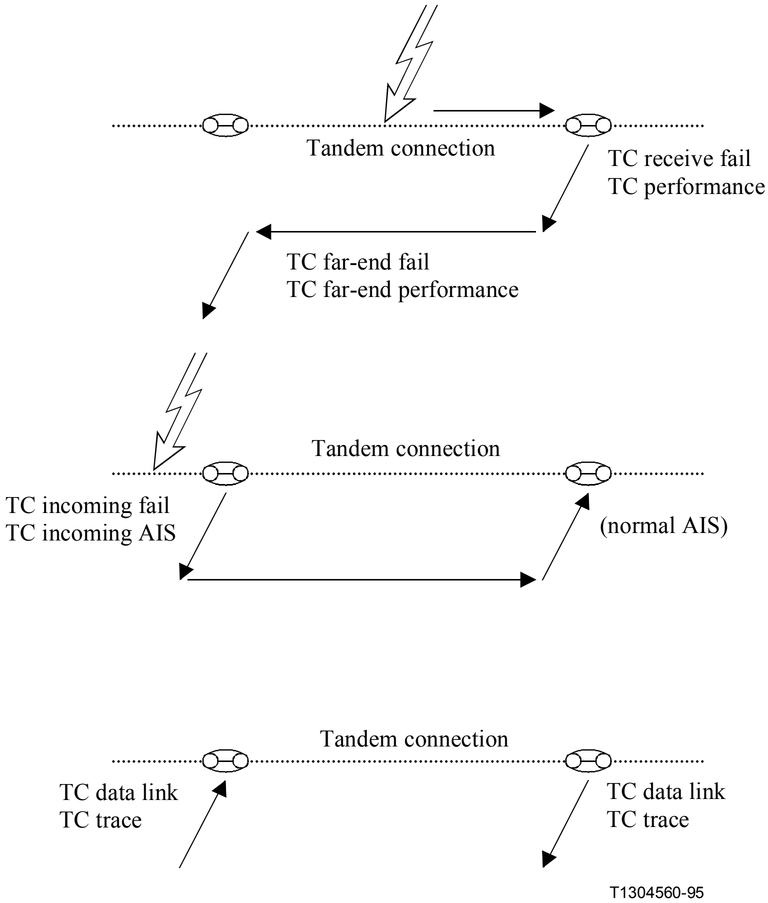
A tandem connection represents the part of a trail that requires monitoring independently from the monitoring of the complete trail. In this role, the following functions may be required by the tandem connection (refer to Figure 17):

- tandem connection near end fault management and performance monitoring (error performance and failure/alarm conditions);
- tandem connection far end fault management and performance monitoring (error performance and failure/alarm conditions);

- tandem connection monitoring independent of incoming server signal fail indication (AIS, FDI);
- tandem connection incoming signal fail indication (signal fail before the tandem connection);
- tandem connection connectivity verification (i.e. trace) (between the ends of the tandem connection);
- tandem connection continuity verification (i.e. loss of signal, unequipped, loss of continuity) (between the ends of the tandem connection);
- tandem connection near end outgoing signal monitoring in order to allow localization of faults and errors in white spot areas between two successive tandem connection domains;
- tandem connection far end outgoing signal monitoring in order to allow localization of faults and errors in white spot areas between two successive tandem connection domains;
- tandem connection idle signal (including idle signal identity).

Three applications of tandem connections can be identified:

- *serving operator administrative domain* (e.g. public network domain, network operator domain, network operator subnetwork domain) [refer to Figure 18 a)]. A tandem connection that measures the quality of the service delivered to the customer. A serving operator administrative domain supporting tandem connection has its source as close as possible behind the NNI/UNI and its sink as close as possible in front of the NNI/UNI;
- *protected domain* (e.g. sublayer monitored SNC protection) [refer to Figure 18 b)]. A tandem connection that measures the defect status of the working and protection connections. A protected domain supporting tandem connection has its source behind the protection switch bridge and its sink in front of the protection switch selector functions;
- *service requesting administrative domain* (e.g. user domain) [refer to Figure 18 c)]. A tandem connection that measures the quality of the service received from the operator. A service requesting administrative domain supporting tandem connection has its source as close as possible in front of the UNI/NNI and its sink as close as possible behind the NNI/UNI.



TC Tandem connection

Figure 17/G.805 – Explanation of tandem connection terms

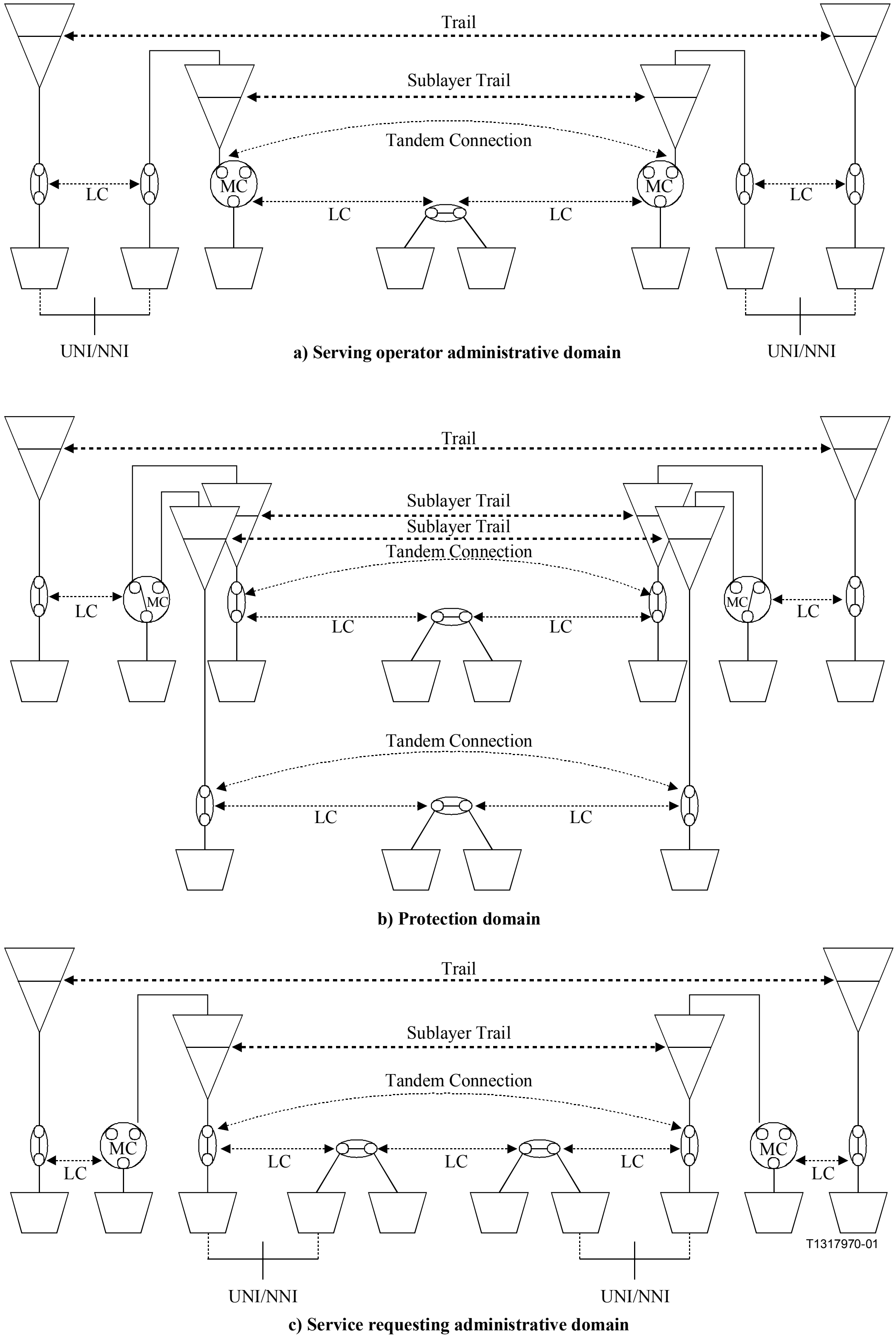


Figure 18/G.805 – Tandem connection applications

5.5 Layer network interworking

The objective of layer network interworking is to provide an end-to-end trail between different types of layer network trail terminations. This requires interworking of characteristic information as different layer networks have per definition different characteristic information. In general the adapted information of different layer networks for the same client layer network is also different, although this is not necessarily the case. Layer networking may therefore require the interworking of adapted information.

The trail overhead of a layer network can be defined in terms of semantics and syntax. Provided that the same semantics exist in two layer networks, the trail overhead can be interworked by passing on the semantics from one layer network to the other in the appropriate syntax, as defined by the characteristic information. In other words layer network interworking shall be transparent for the semantics of the trail overhead. If both layer networks have a different set of semantics, the layer network interworking is restricted to the common set of semantics. The layer network interworking function has to terminate (insert, supervise) the semantics that are not interworked.

Layer network interworking is accomplished through an interworking processing function as depicted in Figure 19. The interworking processing function supports an interworking link connection between two layer network connections. The interworking link connection is special in the sense that it is asymmetric, delimited by different types of ports. It is also special because it is in general, only transparent for a specified set of client layers. An interworking link is a topological component that represents a bridge between two layer networks. The interworking link creates a "super layer network", defined by the complete set of access groups that can be interworked for a specified set of client layer networks.

Layer network interworking function unidirectional: A transport processing function which converts characteristic information of one layer network to the characteristic information of another layer network. The integrity of end-to-end performance and maintenance information is maintained. The function may be limited to a set of client layer networks.

Layer network interworking function bidirectional: A transport processing function that consists of a pair of co-located unidirectional service interworking functions, one for the interworking form layer network X to Y and the other for the interworking from layer network Y to X.

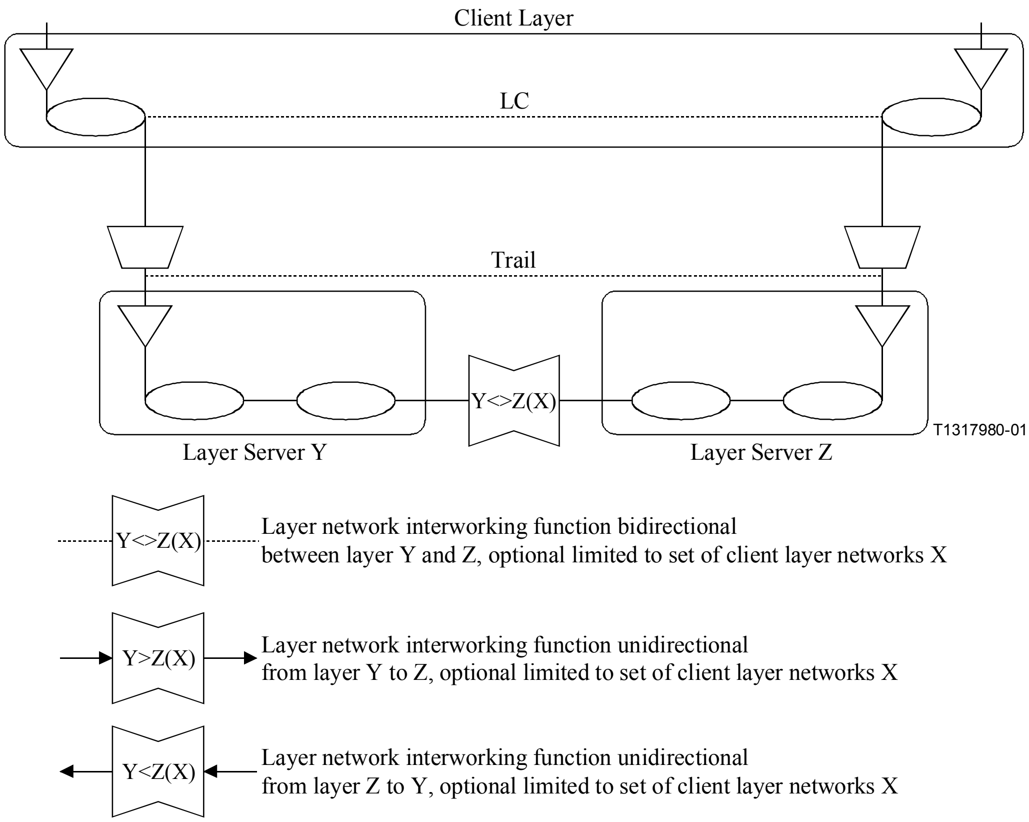


Figure 19/G.805 – Layer network interworking

6 Application of concepts to network topologies and structures

NOTE 1 – The naming schemes used in the examples may not correspond with the naming schemes used in the related equipment specifications.

NOTE 2 – The examples show only the basic network topologies and structures. Additional functionality (e.g. protection, monitoring) is provided in the related equipment specifications.

6.1 PDH supported on SDH layer networks

Figure 20 shows an example of the case where PDH signals are supported on SDH. Six layer networks are shown:

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

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

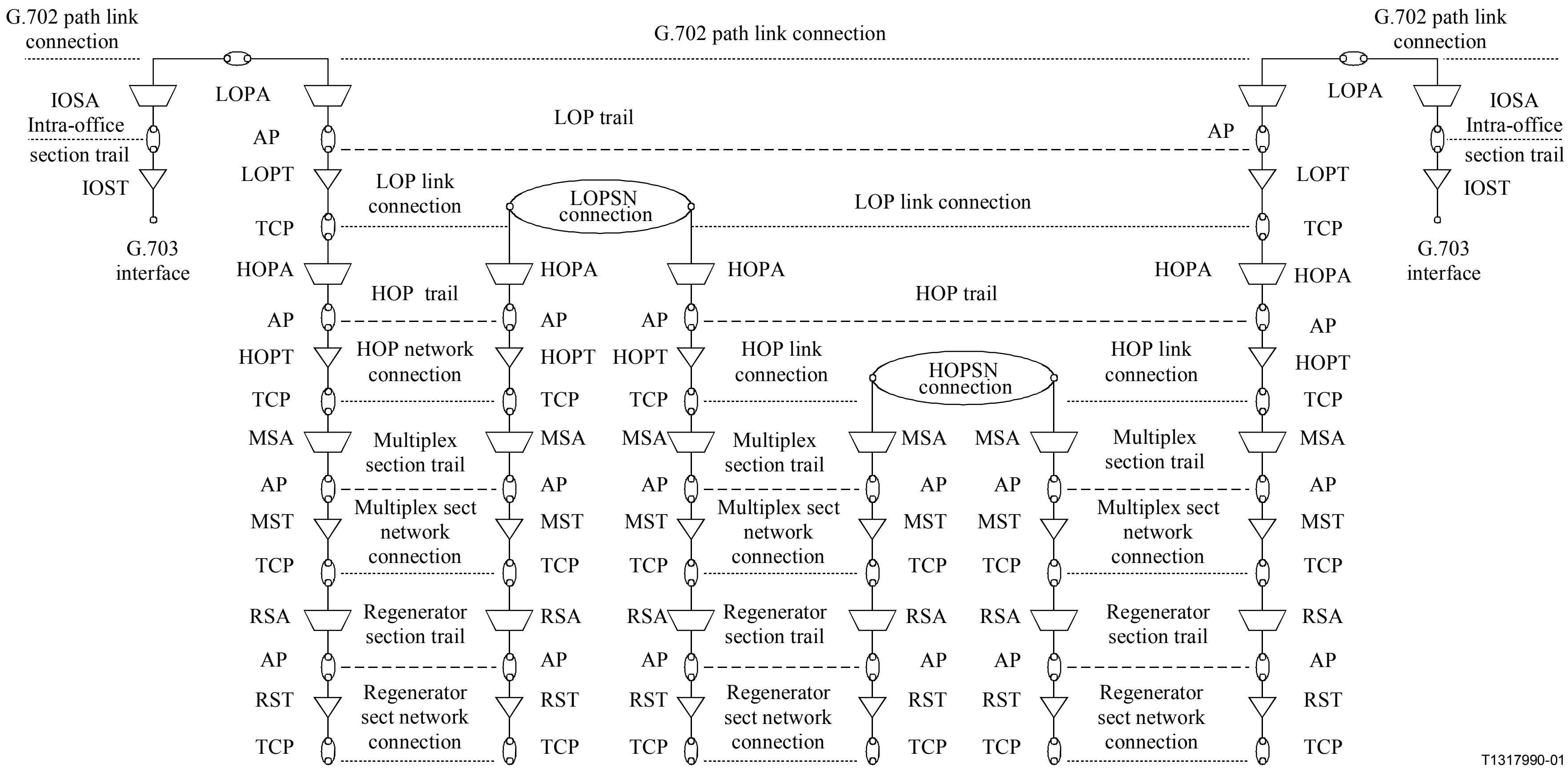
c) SDH G.707 lower-order path (e.g. VC-12) layer network;

d) SDH G.707 higher-order path (e.g. VC-4) layer network;

e) SDH G.707 multiplex section layer network;

f) SDH G.707 regenerator section layer network.

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.



AP	Access Point
CP	Connection Point
HOP	Higher-Order Path (e.g. VC-4)
HOPA	Higher-Order Path Adaptation
HOPSN	Higher-Order Path Subnetwork
HOPT	Higher-Order Path Termination
IOSA	Intra-Office Section Adaptation
IOST	Intra-Office Section Termination
LOP	Lower-Order Path e.g.VC-12
LOPA	Lower-Order Path Adaptation
LOPSN	Lower-Order Path Subnetwork
LOPT	Lower-Order Path Termination
MSA	Multiplex Section Adaptation
MST	Multiplex Section Termination
RSA	Regenerator Section Adaptation
RST	Regenerator Section Termination
TCP	Termination Connection Point

Figure 20/G.805 – Application of the functional architecture to the case of PDH supported on SDH

6.2 ATM supported on SDH layer networks

Figure 21 shows an example of the case where ATM cells are supported on SDH. Five layer networks are shown:

a) ATM I.361 virtual channel layer network;

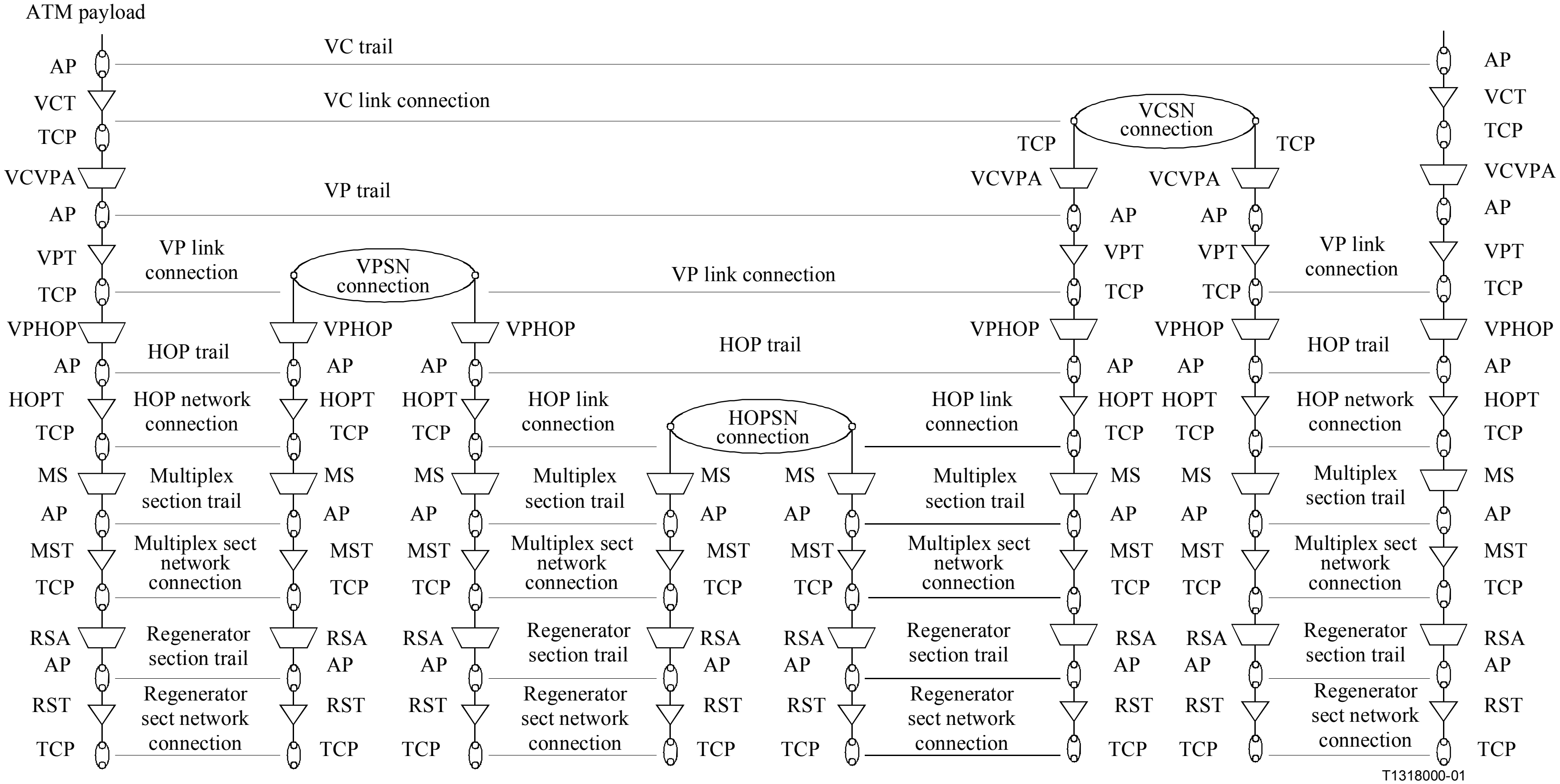
b) ATM I.361 virtual path layer network;

c) SDH G.707 higher-order path (e.g. VC-4) layer network;

d) SDH G.707 multiplex section layer network;

e) SDH G.707 regenerator section layer network.

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



AP	Access Point
CP	Connection Point
HOP	Higher-Order Path (e.g. VC-4)
HOPSN	Higher-Order Path Subnetwork
HOPT	Higher-Order Path Termination
MSA	Multiplex Section Adaptation
MST	Multiplex Section Termination
RSA	Regenerator Section Adaptation
RST	Regenerator Section Termination
TCP	Termination Connection Point
VC	Virtual Channel
VCA	Virtual Channel Adaptation
VCSN	Virtual Channel Subnetwork
VCT	Virtual Channel Termination
VCVPA	VC to VP Adaptation
VP	Virtual Path
VPHOPA	VP to Higher-Order Path Adaptation
VPSN	Virtual Path Subnetwork
VPT	Virtual Path Termination

Figure 21/G.805 – Application of the functional architecture to the case of ATM supported on SDH

6.3 ATM supported through ATM inverse multiplexing

Figure 22 shows an example of the case where an aggregate ATM cell stream is supported through ATM inverse multiplexing over a number of parallel G.702 primary rate paths, which in turn are supported over PDH and SDH. Nine layer networks are shown:

a) ATM I.361 virtual path layer network;

b) Composite ATM Inverse Multiplex layer network;

c) Individual ATM Inverse Multiplex layer network;

d) PDH G.702 primate rate layer network;

e) PDH G.703 intra-office section layer network;

f) SDH G.707 lower order path layer network;

g) SDH G.707 higher order path layer network;

h) SDH G.707 multiplex section layer network;

i) SDH G.707 regenerator section layer network.

This example shows two ATM Virtual Path terminations interconnected through ATM inverse multiplexing via a number of parallel primary rate PDH paths. One ATM VP terminating equipment interfaces at the PDH rate to an SDH multiplexer. The other has an integrated SDH interface. In Figure 22 the ATM inverse multiplex trail termination has been decomposed to portray the individual ATM inverse multiplex trails that support the VP network connection.

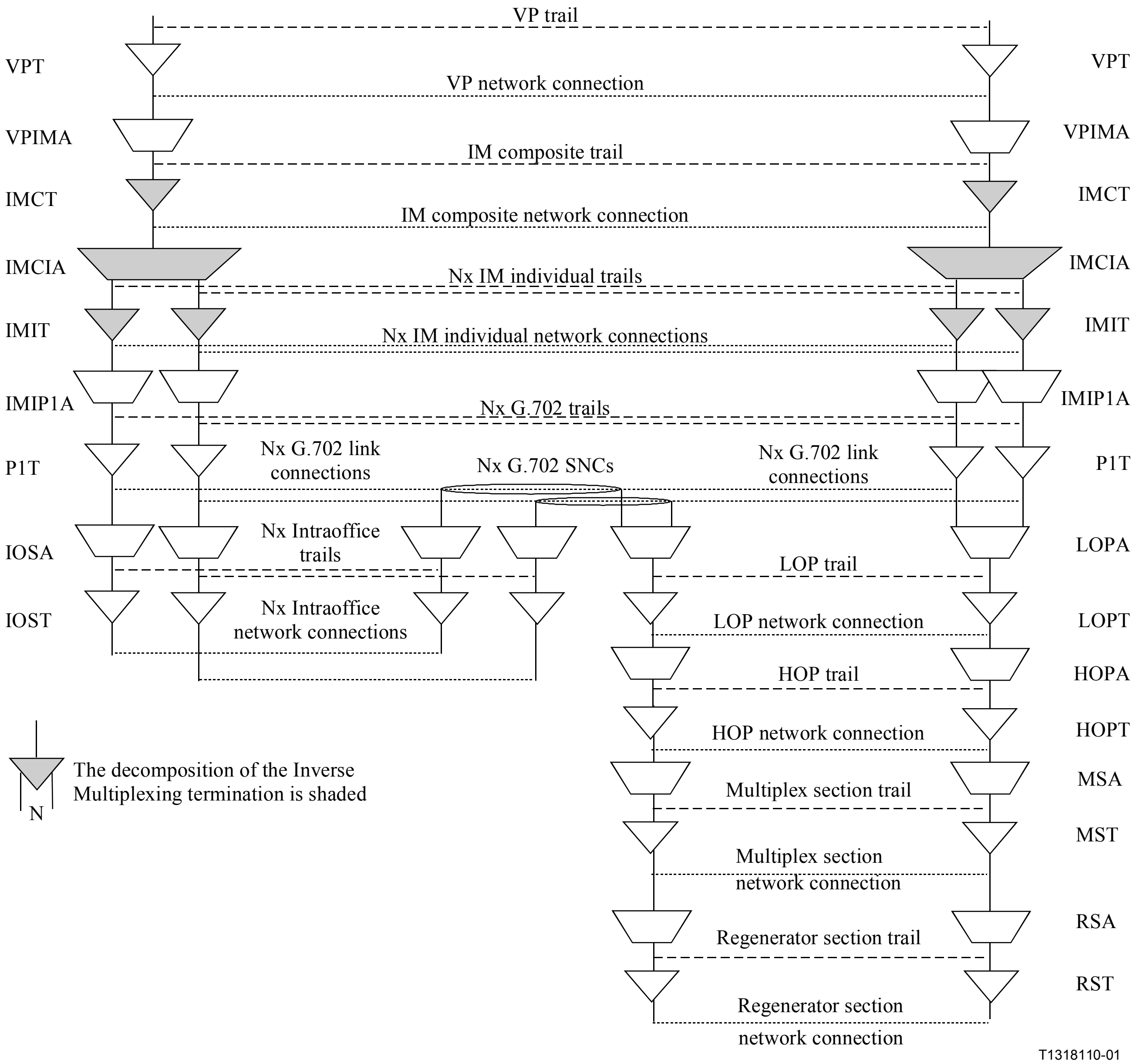


Figure 22/G.805 – Application of the functional architecture to the case of ATM inverse multiplexing

7 Transport network availability enhancement techniques

7.1 Introduction

This 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). Protection switching may be either unidirectional or bidirectional. Bidirectional protection switching takes switching actions for both traffic directions, even when the failure is unidirectional. Unidirectional protection switching takes switching actions only for the affected traffic direction in the case of a unidirectional failure.

Restoration – This makes use of any capacity available between nodes. In general the algorithms used for restoration will involve rerouting. When restoration is used some percentage of the transport network capacity will be reserved for rerouting of working traffic. Further description of restoration is not within the scope of this Recommendation.

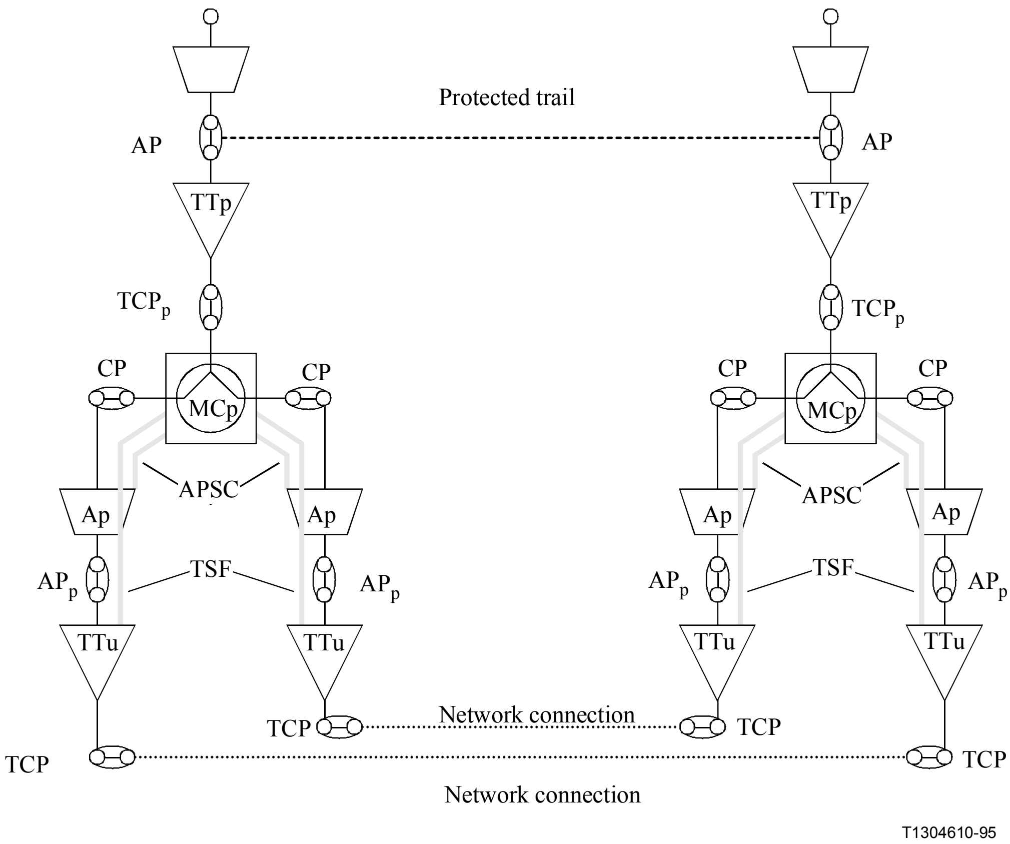
7.2 Protection

Two types of protection architecture have been identified.

7.2.1 Trail protection

A signal selected from a working trail (SNC) is replaced by the signal selected from protecting trail (SNC) if the working trail fails or if the performance falls below the required level. This is modelled by introducing a protection sublayer as shown in Figure 23. The trail termination is expanded, according to the rules given in Figure 13, by introducing the protection adaptation function, unprotected trail termination function and protected trail termination function. A protection matrix is used to model the switching between the protecting and working connections. The status of the trails in the protection sublayer is made available to the protection matrix (trail signal fail in Figure 23) by the unprotected trail termination. If communication between the control functions of the protection matrices is required, the protection adaptation function may provide access to an Automatic Protection Switch (APS) channel. The protected trail termination provides the status of the protected trail.

Trail protection is a protection method applied in a transport layer network when a defect condition is detected in the same layer network (i.e. switching is activated in the same transport layer network).



Ap Protection Adaptation
AP_p Protection Access Point
APSC Automatic Protection Switch Channel
MCp Protection Matrix Connection
TCP_p Protection TCP
TSF Trail Signal Fail
TTp Protected Trail Termination
TTu Unprotected Trail Termination

Figure 23/G.805 – Trail protection

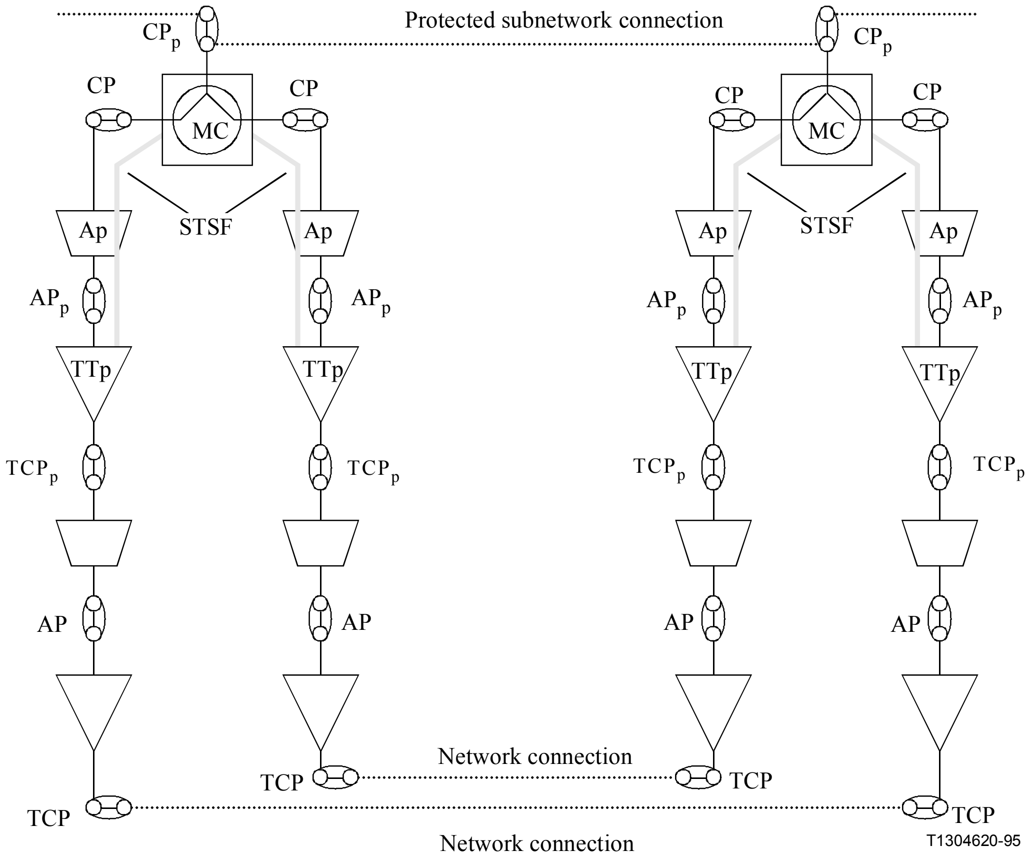
7.2.2 Subnetwork connection protection

The signal selected from a working (sub)network connection is replaced by the signal selected from a protecting (sub)network connection if the working (sub)network connection fails or if the performance falls below the required level. It is a protection switching method applied in the client layer network when a defect condition is detected in a server layer network, sublayer or other transport layer network.

Note that (sub)network connection protection may be applied to any layer network; also the (sub)network connection being protected may be made up of a sequence of lower level subnetwork connections and link connections. (Sub)network connection protection schemes can be characterized by the monitoring method used to derive the switching criteria:

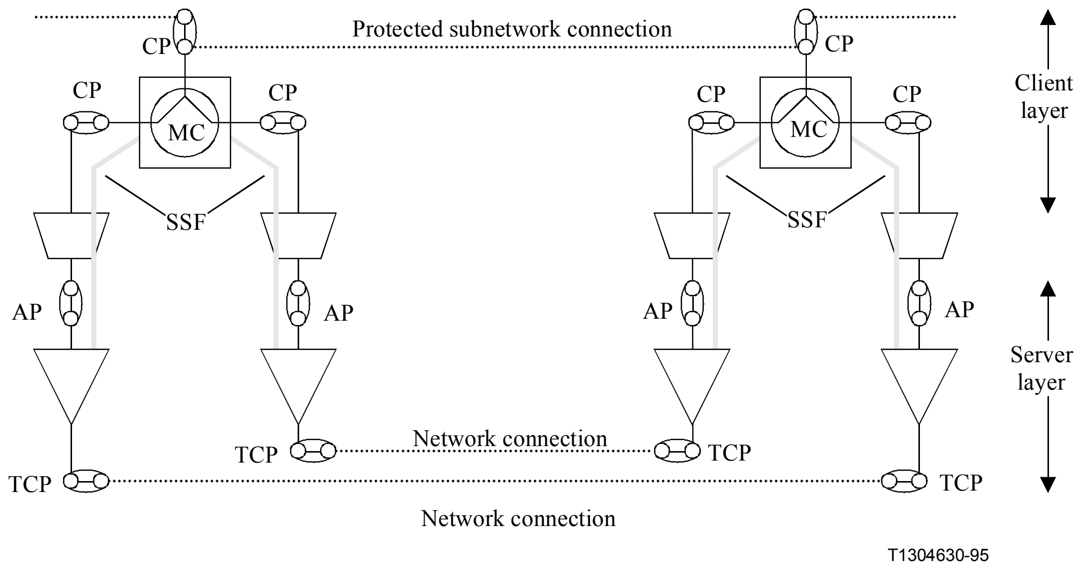
- Sublayer trail monitoring – (Sub)network connection protection can be modelled by a protection sublayer generated by expanding the subnetwork connection points, according to the rules given in Figure 13. The introduction of a sublayer results in a trail protection of the sublayer trail. This is illustrated in Figure 24.

- Inherent monitoring – The information derived by the server layer network as described in 5.4.1.1, is used to initiate protection switching. This is illustrated in Figure 25. The status of the trails in the server layer network are made available to the matrix (server signal fail in Figure 25).
- Non-intrusive monitoring – The (sub)network connection is directly monitored by use of listen-only (non-intrusive) monitoring of the client layer characteristic information as illustrated in Figure 26.
- Intrusive monitoring – Use of this type of monitor is not recommended as part of a protection scheme.



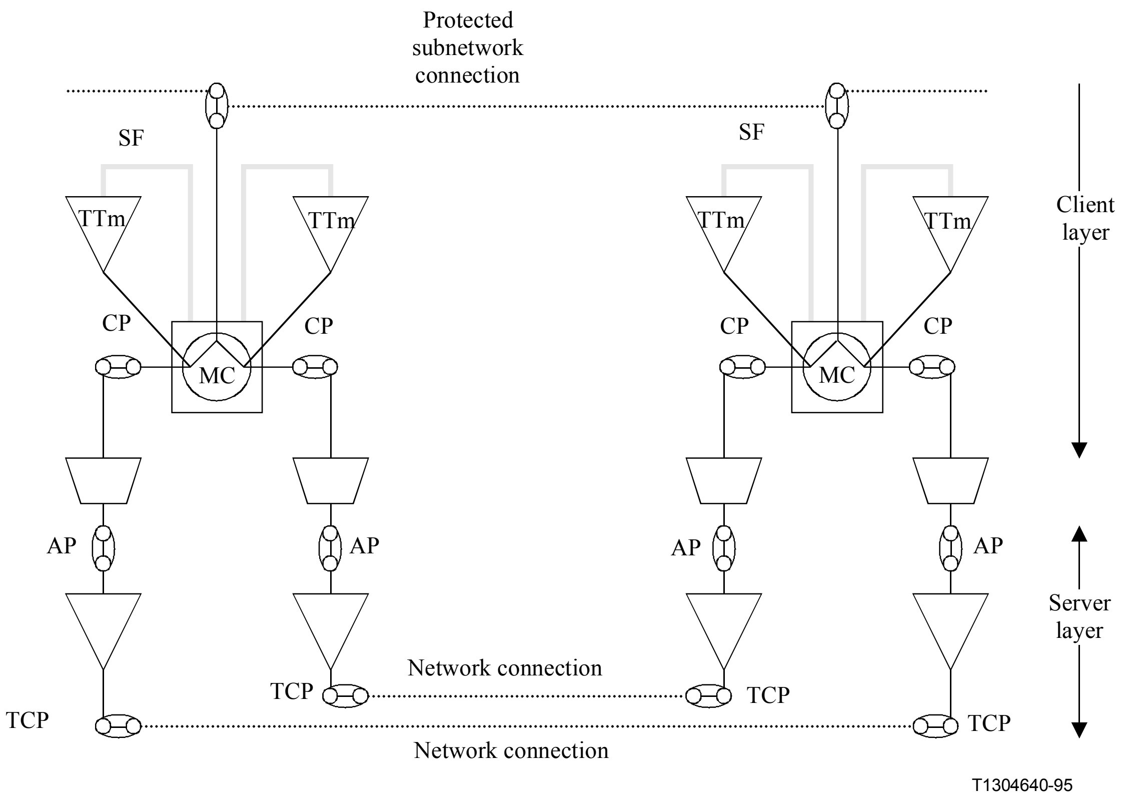
Ap	Protection Adaptation
AP_p	Protection Access Point
CP_p	Protection Connection Point
MC	Matrix Connection
STSF	Sublayer Trail Signal Fail
TCP_p	Protection TCP
TTp	Protection Trail Termination

Figure 24/G.805 – Subnetwork connection protection using sublayering



AP Access Point
CP Connection Point
MC Matrix connection
SSF Server Signal Fail
TCP Termination Connection Point

Figure 25/G.805 – Subnetwork connection protection using inherent monitoring



AP Access Point
CP Connection Point
MC Matrix Connection
SF Signal Fail
TCP Termination Connection Point
TTm Monitor trail termination

Figure 26/G.805 – Subnetwork connection protection using non-intrusive monitoring

APPENDIX I

Formal description of the architecture

I.1 Introduction

This appendix provides a formal definition of the architectural components defined in this Recommendation using the Z notation. A brief overview of Z is provided in Annex I.A of this appendix. Reference material for the Z notation may be found in the bibliography.

The fuZZ tool (also from Spivey) enables syntax and type checking of a Z specification.

I.2 General definitions

Format, Location and Point are considered to be atomic types.

Direction is defined here by enumeration of its permitted values, as well as BindingDone.

Architectural Component is a general type which is only defined by the characteristic information of the architectural component. It will be redefined later.

Transport networks are defined by:

- layerNetworks: the finite set of layer networks that compose it;
- chInfo: the association between all its layer networks and their proper characteristic information;
- internal: the association between its layer networks and their set of architectural components;
- clientsServers: the association (n to m relationship) between its layer networks.

Both transport entities (TransportEntity), topological components (TopologicalComponent), transport processing functions (TransportProcessingFunction) and reference points (ReferencePoint) are special kinds of architectural components (ArchitecturalComponent). As such, they have all the characteristics of architectural components (declaration part) and they verify all the predicates of architectural components (predicate part). In addition, a transport entity has a direction; a transport processing function has a location name (locationName); a reference point has a location name, a direction, and its two composing points may be bound or not. The predicate part of ReferencePoint indicates that, inside a reference point, a point is either bound to another one or not, but cannot be bound to more than one point.

[Format, Location, Point]

Direction ::= source | sink | bid

BindingDone ::= yes | no

CharacteristicInformation

format: Format

ArchitecturalComponent

characInfo: CharacteristicInformation

TransportNetwork

layerNetworks: F LayerNetwork

chInfo: LayerNetwork >--->> CharacteristicInformation

internal: LayerNetwork >-++-> F_1 ArchitecturalComponent

clientsServers: LayerNetwork <----> LayerNetwork

TransportEntity

ArchitecturalComponent

direction: Direction

TopologicalComponent

ArchitecturalComponent

TransportProcessingFunction

ArchitecturalComponent

locationName: Location

ReferencePoint

ArchitecturalComponent

locationName: Location

binding: Point >-++--> Point

boundReferencePoint: BindingDone

direction: Direction

#binding ≤ 1

#binding = 0 ⇔ boundReferencePoint = no

#binding = 1 ⇔ boundReferencePoint = yes

Some useful classifications:

sourceReferencePoint __, sinkReferencePoint __, bidirReferencePoint __ : ReferencePoint

∀ p: ReferencePoint •

sourceReferencePoint p ⇔ p.direction = source

∧

sinkReferencePoint p ⇔ p.direction = sink

∧

bidirReferencePoint p ⇔ p.direction = bid

I.3 Reference points

Access points (AccessPoint) and connection points (ConnectionPoint) are special kinds of reference points (ReferencePoint).

An access group (AccessGroup) is a set named setOfTtfs of trail termination functions (TrailTerminationFunction) which are all co-located, i.e. for any pair of trail termination functions of this set, their location name attribute value is similar.

AccessPoint

ReferencePoint

ConnectionPoint

ReferencePoint

I.4 Others

AccessGroup

setOfTtfs: P TrailTermination[2]
$\forall$ {ttf11,ttf2} $\subseteq$ setOfTtfs •
ttf1.locationName = ttf2.locationName

I.5 Topological components

A link may be terminated either by a subnetwork or an access group.

The definition of Acyclic is generic in order to be applied to any relation. For any relation R, Acyclic R is true if, x being related to y, y is never related to x through transitive closure of the relation.

AnyNetwork is a general definition of networks for both layer networks and subnetworks. It is defined by:

- the finite set of inner subnetworks (subnetworks);
- the non-empty finite set of inner links (links);
- its topology, i.e. the whole set of associations between link ends (topology);
- its partitioning (partitioning);
- the finite set of connections in the network (connections).

Moreover, the predicate part indicates that:

- the partitioning is acyclic, i.e. a subnetwork cannot be inside itself;
- subnetworks contain the whole set of inner subnetworks, including all levels of partitioning.

A layer network (LayerNetwork) is a special case of network (AnyNetwork). Additionally, it is defined by a non-empty finite set of access groups (accessGroup) that delimit the layer network and the finite set of trails (trails) that cross it.

LayerNetworkInit states that, in its initial state, i.e. just after commissioning, the set of trails that cross a layer network as well as the set of connections are empty.

---

[2] P power set.

A subnetwork (Subnetwork) is a special kind of network which is also defined by the finite set of connection points (setOfCPs) that delimit it.

SubnetworkInit indicates that, in its initial state, any given subnetwork is delimited by connection points in which the binding between points is not realized.

A matrix (Matrix) is a special kind of subnetwork (SubNetwork) in which delimiting connection points are all co-located.

A LinkEnd is either a SubNetwork or an AccessGroup.

LinkEnd::= subNetworkLE << SubNetwork >>

| accessGroupLE << AccessGroup >>

[X]

Acyclic _: P (X <----> X)

∀ R: X <----> X •

Acyclic R $\Leftrightarrow R^{+} \cap$ id X = ∅

AnyNetwork

subNetworks: F SubNetwork

links: F_1 Link

topology: LinkEnd <----> LinkEnd

__ partitions __: SubNetwork --++-> SubNetwork

connections: F Connection

Acyclic partitions

∀ sn: SubNetwork / sn ∈ subNetworks •

sn.subNetworks ⊆ subNetworks

LayerNetwork

AnyNetwork

accessGroups: F_1 AccessGroup

trails: F Trail

LayerNetworkInit

LayerNetwork

---

trails = ∅

connections = ∅

SubNetwork

AnyNetwork

setOfCPs: F ConnectionPoint

SubNetworkInit

SubNetwork

$\forall$ snp $\not\subseteq$ setOfCPs •

snp.boundReferencePoint = no

Matrix

SubNetwork

$\forall$ {snp1,snp2} $\subseteq$ setOfCPs •

snp1.locationName = snp2.locationName

Link

TopologicalComponent

I.6 Transport entities

A connection (Connection) is a special kind of transport entity. Moreover, we define uni- and bidirectional connections by stating explicitly that their direction attribute value is equal to bidir or not.

A link connection (LinkConnection) is a relationship between two connection points.

A network connection (NetworkConnection) is a relationship between two connection points. This relationship can be obtained by a non-null number of iterations of (0 or more point-to-point subnetwork connections followed by 0 or more link connections).

A trail (Trail) is a relationship between two access points. Moreover, the predicate part indicates that, if two given access points ap1 and ap2 are related by a trail, ap1 is related to a trail termination then to a network connection then to the reverse of a trail termination and finally to ap2.

Connection

TransportEntity

UniDirectionalConnection

Connection

---

direction $\neq$ bidir

BiDirectionalConnection

Connection

---

direction = bidir

__LinkConnection__: ConnectionPoint >-++-> ConnectionPoint

__NetworkConnection__: ConnectionPoint >-++-> ConnectionPoint

$\forall$ (cp1, cp2) $\in$ (__ NetworkConnection __) •

cp1 (PointToPointSubNetworkConnection*; LinkConnection*)$^{+}$ cp2

__ PointToPointMatrixConnection __:

ConnectionPoint >-++-> ConnectionPoint

__ Trail __: AccessPoint >-++-> AccessPoint

ap1 Trail ap2

$\Leftrightarrow$

ap1 Ttf; NetworkConnection; Ttf$^{\sim}$ ap2

__ MonitoredPointToPointTandemConnection __:

ConnectionPoint >-++-> ConnectionPoint

$\forall$ (cp1, cp2) $\in$ (__ MonitoredPointToPointTandemConnection __) •

cp1 (PointToPointSubNetworkConnection*; LinkConnection*)$^{+}$ cp2

I.7 Transport processing functions

__ Tff __ : AccessPoint >----> ConnectionPoint

__ Adaptation __ : F1 ConnectionPoint >----> AccessPoint

I.8 Bibliography

– SPIVEY (J.M.): The Z notation – A reference manual (2nd ed.), *Prentice Hall International Series in computer science*, ISBN 0-13-978529-9.

ANNEX I.A

A short introduction to Z

(to Appendix I of Recommendation G.805)

I.A.1 Introduction

Z is a formal notation based on set theory and first order predicate logic. The basic modelling concept in Z is the set. As in mathematics, a set may be defined either by extension (by enumerating its elements) or by comprehension (by providing a predicate that all potential elements should verify). In this latter case, it is equivalent to defining a type. A convenient means to define a type by comprehension in Z is through the definition of a schema. A schema can be named or not. A named schema may be used to define a type or an operation. It has the following form:

Schema-name

Declaration
Predicate

where:

- Declaration is composed of a list of characteristics of the schema; and
- Predicate is a (possibly empty) list of predicates specifying either invariants or pre-conditions or post-conditions.

The reader of a Z specification should keep in mind that, though notational conventions render specifications quite complex, the basic modelling concepts are simple. For the sake of readability, the following specification will not make use of all the tricks that exist in Z to make a specification shorter but, on the contrary, will only use simple Z constructs in order to remain understandable to non-experts.

I.A.2 Example #1

The definition of the set of points, namely Point, defined both by their x and y coordinates, by means of a named schema could be:

Point

x : Integer y : Integer

Moreover, it states that both x and y are characteristics of a point and are of type Integer (which is assumed to be pre-defined).

An example of the specification of an operation by means of a schema is:

MoveToCenter

Δ Point
x' = 0 y' = 0

This schema MoveToCenter defines an operation that modifies the point on which the operation is applied (the symbol Δ indicates that the state of Point is changed by the operation) and states that the values of x and y after the completion of the operation (respectively x' and y') are both 0.

I.A.3 Example #2

A schema can also contain global definitions, e.g. relationships between other sets. For example, square is a function in which both source and target sets are N (set of natural numbers). The _ character placed after the function name indicates that the postfix notation is required. Moreover, the predicate part specifies that, for all natural number n, square(n) is obtained by multiplying n by itself:

```
Square __ : N >----> N
------------------------------------------
∀ n: N •
        square(n) = n ∗ n
```

Moreover, the following symbols are used in this specification (it should be noted that all kinds of binary relationships can be modelled):

1) <---->: a binary relation. If X and Y are sets, then X <----> Y is the set of binary relations between X and Y. Each such relation is a subset of X x Y (cartesian product).
2) --++-->: a partial function. If X and Y are sets, X --++--> Y is the set of partial functions from X to Y. These are relations which relate each member x of X to at most one member of Y.
3) ----->: a total function (or application). If X and Y are sets, X --++--> Y is the set of total functions from X to Y. These are partial functions with domain X; they relate each member x of X to exactly one member of Y.
4) >-+-->: a partial injection. If X and Y are sets, X >-+--> Y is the set of partial injections from X to Y. These are partial functions. The inverse of a partial injection relates to each member of Y at most one member of X.
5) >---->: a total injection, i.e. a partial injection which is also a total function.
6) -+-->>: a partial surjection. If X and Y are sets, X -+-->> Y is the set of partial surjections from X to Y. These are partial functions from X to Y which have the whole of Y as their range.
7) ---->>: a total surjection, i.e. a function which has the whole of X as its domain and the whole of Y as its range.
8) >--->>: a bijection, i.e. both a surjection and an injection. It maps the elements of X onto the elements of Y in a one-to-one correspondence.
9) _: inequality.
10) ∈: membership.
11) _: empty set.
12) ∪: set union.
13) ∩: set intersection.
14) \: set difference.

15) dom, ran: domain and range of a relation. If R is a binary relation between X and Y, the domain of R (dom R) is the set of all members of X which are related to at least one member of Y by R. The range of R (ran R) is the set of all members of Y to which at least one member of X is related by R.

16) ;: relational composition. The composition R; S of two relations R: X <----> Y and S: Y <----> Z relates a member x of X to a member z of Z if, and only if, there is at least one member y of Y to which x is related by R and which itself is related to z by S.

17) ~: relational inversion. An object y is related to an object x by the relational inversion R~ if, and only if, x is related to y by R.

18) *: reflexive-transitive closure. If R is a relation from a set X to itself, R* is the strongest relation containing R which is both reflexive and transitive.

19) #: number of members of a set.

20) partition: a family S partitions a set T if, and only if:
- each pair of sets S(i) and S(j) for i _ j have empty intersection; and
- the union of all the sets S(i) is T.

21) /: disjunction.

22) $\wedge$: conjunction.

23) $\Leftrightarrow$: equivalence.

24) $\forall$: universal quantifier.

25) $\exists$: existential quantifier.

26) $\exists$1: unique quantifier.

27) : power set. If S is a set, S is the set of all the subsets of S.

28) X: cartesian product. If S1, ... , Sn are sets, then S1 X ... X Sn is the set of all n-tuples (x1, ... , xn) where xi $\in$ Si for each i with $1 \leq i \leq n$.

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