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

Digital networks – General aspects

Unified functional architecture of transport networks

ITU-T Recommendation G.800

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ITU-T Recommendation G.800

Unified functional architecture of transport networks

Summary

ITU-T Recommendation G.800 describes a unified functional architecture for transport networks in a technology-independent way.

Source

ITU-T Recommendation G.800 was approved on 6 September 2007 by ITU-T Study Group 15 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). 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 Assembly (WTSA), 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 WTSA 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.

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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, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Unified 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.

This Recommendation provides a set of constructs (definitions and diagrammatic symbols) and the semantics that can be used to describe such a viewpoint.

A transport network transfers user information from a sender at one location to a receiver at another location. 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.

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 specific layer network technologies including those that use circuit switching or packet switching technology, and a corresponding set of Recommendations for management, performance analysis and equipment specifications.

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; 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. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.805] ITU-T Recommendation G.805 (2000), *Generic functional architecture of transport networks.*

[ITU-T G.809] ITU-T Recommendation G.809 (2003), *Functional architecture of connectionless layer networks.*

[ITU-T G.8080] ITU-T Recommendation G.8080/Y.1304 (2006), *Architecture for the automatically switched optical network (ASON).*

[ITU-T X.200] ITU-T Recommendation X.200 (1994), *Information technology – Open Systems Interconnection – Basic Reference Model: The basic model.*

3 Definitions

This Recommendation defines the following term:

3.1 information system: A system that processes only information.

4 Abbreviations

This Recommendation uses the following abbreviations:

AI	Adapted Information
AP	Access Point
BIP	Bit Interleaved Parity
CI	Characteristic Information
CP	Connection Point
FwEP	Forwarding End Point
FwEPt	Forwarding End Port
FwP	Forwarding Point
FwPt	Forwarding Port
LI	Layer Information
LP	Link Point
MP	Maintenance Point
MPt	Maintenance Port
OAM	Operations, Administration and Maintenance
SDH	Synchronous Digital Hierarchy
sFwP	Sublayer Forwarding Point
VPN	Virtual Private Network
WDM	Wavelength Division Multiplexing

5 Conventions

A number of diagrammatic conventions have been developed to support the descriptions that follow and these are illustrated in Figures 1 to 4.

A number of terminological conventions have been developed as follows:

Output port: The port, viewed from inside the boundary of an information system, at which information that has been processed leaves the system.

Input port: The port, viewed from inside the boundary of an information system, at which information to be processed enters the system.

Receiver: The role of an information system that consumes information from another information system.

Sender: The role of an information system that originates information to be processed by another information system.

Sink: The port, viewed from outside the boundary of an information system that accepts information to be processed.

Source: The port, viewed from outside the boundary of an information system, from which information is emitted.

NOTE – Ingress and Egress are synonymous with Input and Output and may be used interchangeably.

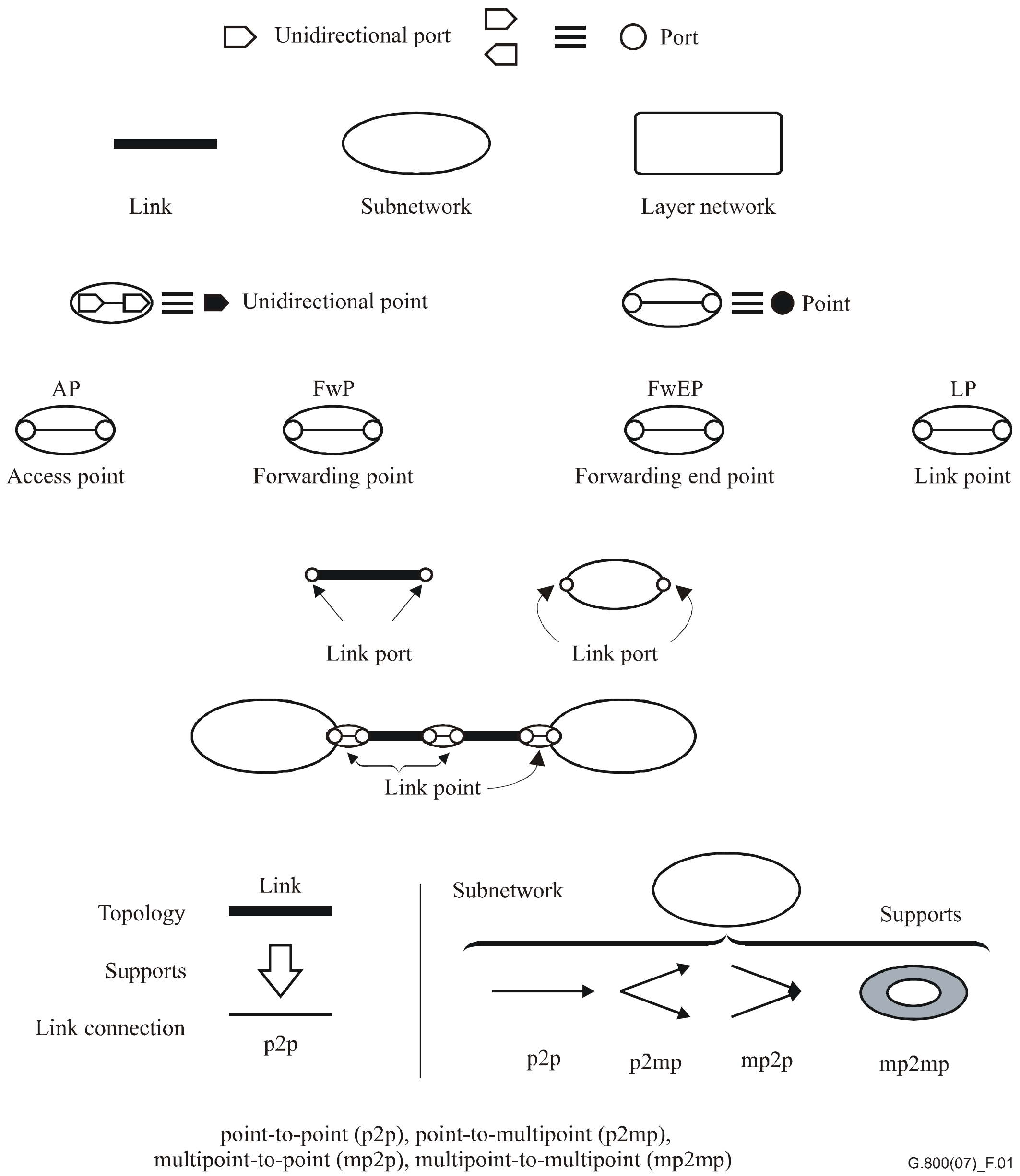


Figure 1 – Diagrammatic conventions

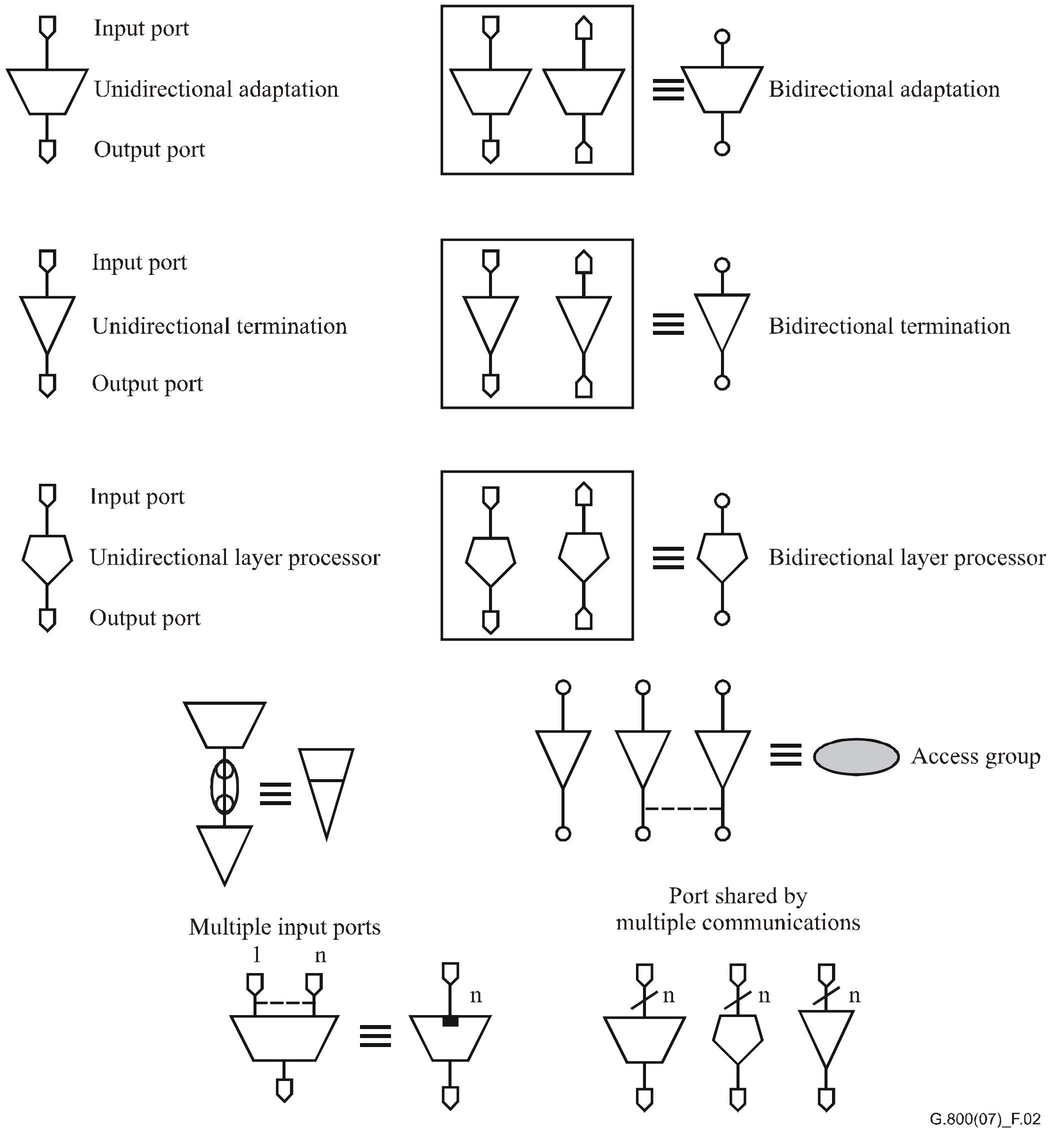


Figure 2 – Further diagrammatic conventions

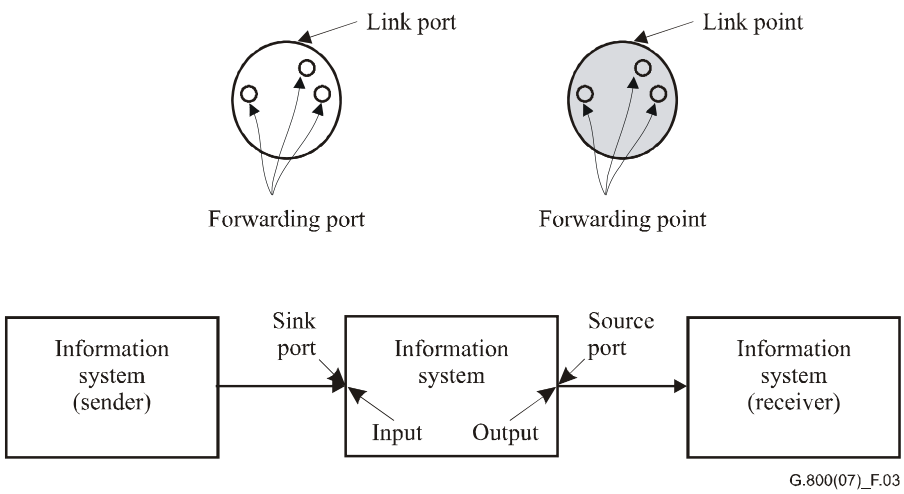


Figure 3 – Further diagrammatic conventions

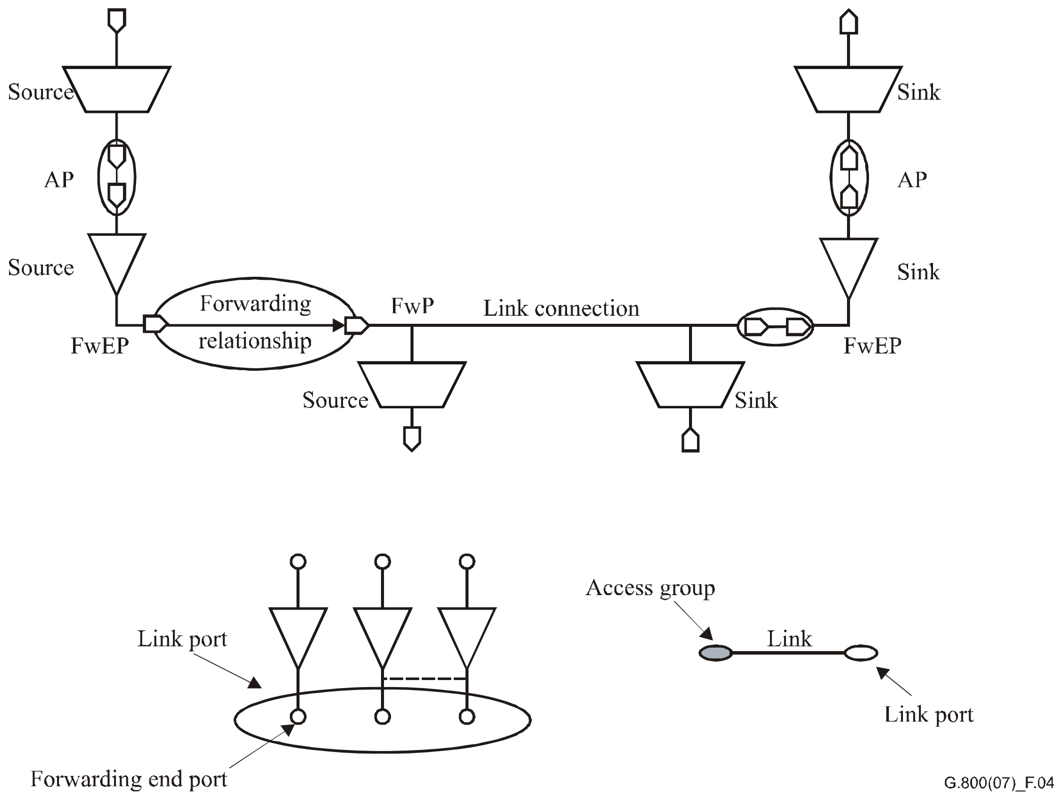


Figure 4 – Further diagrammatic conventions including allowable bindings

6 Functional architecture of transport networks

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) and this forms the transport plane. 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 a sender at one location to a receiver at another location. 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 recursion. 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). It is recommended that this method be used for describing the transport network.

The transport network has been analysed and generic functionality which is independent of implementation technology has been identified. This provides a means to describe network functionality in an abstract way in terms of a small number of architectural components. These are defined by the functions that they perform, in information processing terms, and by the relationships they describe between other architectural components. In general, these functions act on information presented at one or more inputs and present 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.

This Recommendation describes a transport network as a set of interconnected systems. A full description of the properties of such systems is provided in Annex A.

6.1 Axioms of the unified architecture

The unified architecture of transport networks is derived from the following axioms:

Axiom 1

Telecommunication networks are concerned with the conveyance of information between senders and receivers when the senders and receivers are separated geographically.

NOTE 1 – A body of information produced by a sender and intended, in its entirety, to reach a particular receiver or receivers is called a communication.

Axiom 2

The means by which communications can be conveyed by telecommunications networks (resources) is normally limited and therefore needs to be shared amongst many communications.

Axiom 3

A telecommunications network needs to be able to select (and therefore identify) a sender of a communication and to select (and therefore identify) the intended receivers of that communication.

Axiom 4

The information content of a communication conveyed by the telecommunications network is sometimes subject to loss.

NOTE 2 – Loss of information includes:

- the corruption of symbols;
- loss of symbols;
- insertion of symbols;
- or other impairments whereby the intended receiver does not correctly receive the communication that was sent.

Axiom 5

The resources of a telecommunications network are administered by one or more organizations.

6.2 Information

There are two widely recognized definitions of information: the first, communication information, is relevant to the communication of information as it is defined in terms of the passing of information between entities; whereas the second, algorithmic information, is defined in terms of the complexity of a computation machine. Communication information is defined as a message selected from a possible set of messages, weighted by the probability of that message within the set, passed between a sending entity and one or more receiving entities. This is the definition of information as set out originally by Claude Shannon. Algorithmic information is defined as the smallest programme required for a Universal Turing Machine to construct a required bit sequence of information. This architecture utilizes both forms of information and describes their application, interrelationship and use in specification of functions.

The properties of information as described in this Recommendation are:

Property 1

The measure of information: For both communication information and algorithmic information, the measure of information is the binary "bit". The amount of information is the smallest length sequence of binary bits (with the assumption that for each bit, "1" and "0" are equally probable) needed to encode the information.

Property 2

Copying of information: Information can be arbitrarily copied without loss of information.

Property 3

Merging or combining of communication information: Any merging or combining of communication information will result in a fundamental loss of information unless information is added to distinguish the instances of communication information that have been merged or combined.

There are three basic types of communication information:

a) *Message*

A symbol selected from a finite set of symbols.

NOTE – The set of symbols from which a symbol can be chosen is a lexicon (or dictionary).

b) *Open Sequence (File)*

An open sequence is an open-ended sequence of messages, i.e., each symbol value is selected from a finite set of possible values for the symbol. The order of messages in the open sequence carries (implicit) information. An open sequence communication preserves the order of the messages.

c) *Timed Sequence (Stream)*

A timed sequence is an open-ended sequence of messages where the timing of each message relative to another is significant. The sequence and the relative time of each symbol carries (implicit) information. A timed sequence communication preserves both the order of the messages and the timing between each message.

These forms of communication information are illustrated in Figure 5.

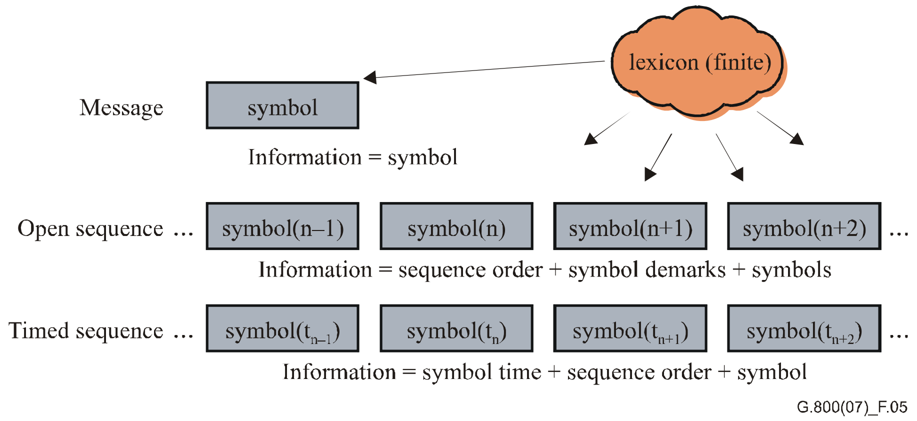


Figure 5 – Types of communication information

A symbol is a recursive construct in that a new symbol can be constructed from a sequence of symbols. Similarly a symbol can be decomposed into a sequence of smaller symbols. The smallest possible symbol is a bit.

A consequence of axiom 3 and property 3 is that the telecommunications network must create and use its own information in order to distinguish communications.

6.3 Topological components

The topological components provide the most abstract description of a network in terms of the topological relationship 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.

6.3.1 Layer network

A layer network is a topological component that represents the finite non-empty set of access groups of the same type which may be associated for the purpose of transferring information. The structures within and between layer networks are described by the components defined below.

6.3.2 Subnetwork

A subnetwork exists within a single layer network. It is defined by the set of link ports which are available for the purpose of transferring characteristic information. It represents a point of flexibility where relationships between the forwarding ports (within the link ports) at the edge of a subnetwork may be created and broken. These relationships allow characteristic information to be transferred across the subnetwork. In general, subnetworks may be partitioned into smaller subnetworks interconnected by links; this is described in clause 6.4.

6.3.3 Link

A link consists of a link port at the edge of one subnetwork or access group which is associated with a corresponding link port 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. Multiple links may exist between any pair of subnetworks.

6.3.4 Access group

An access group is a group of co-located termination functions. It is bounded by a link port that contains the individual FwEPts and the set of individual access ports of each of the termination functions. When the link port is bound to a subnetwork or link, it forms a link point.

6.4 Topology

The network topology of interest is in the plane that transfers the characteristic information (CI), and this is represented by the largest subnetwork. This plane is the transport plane. This is illustrated in Figure 6 below.

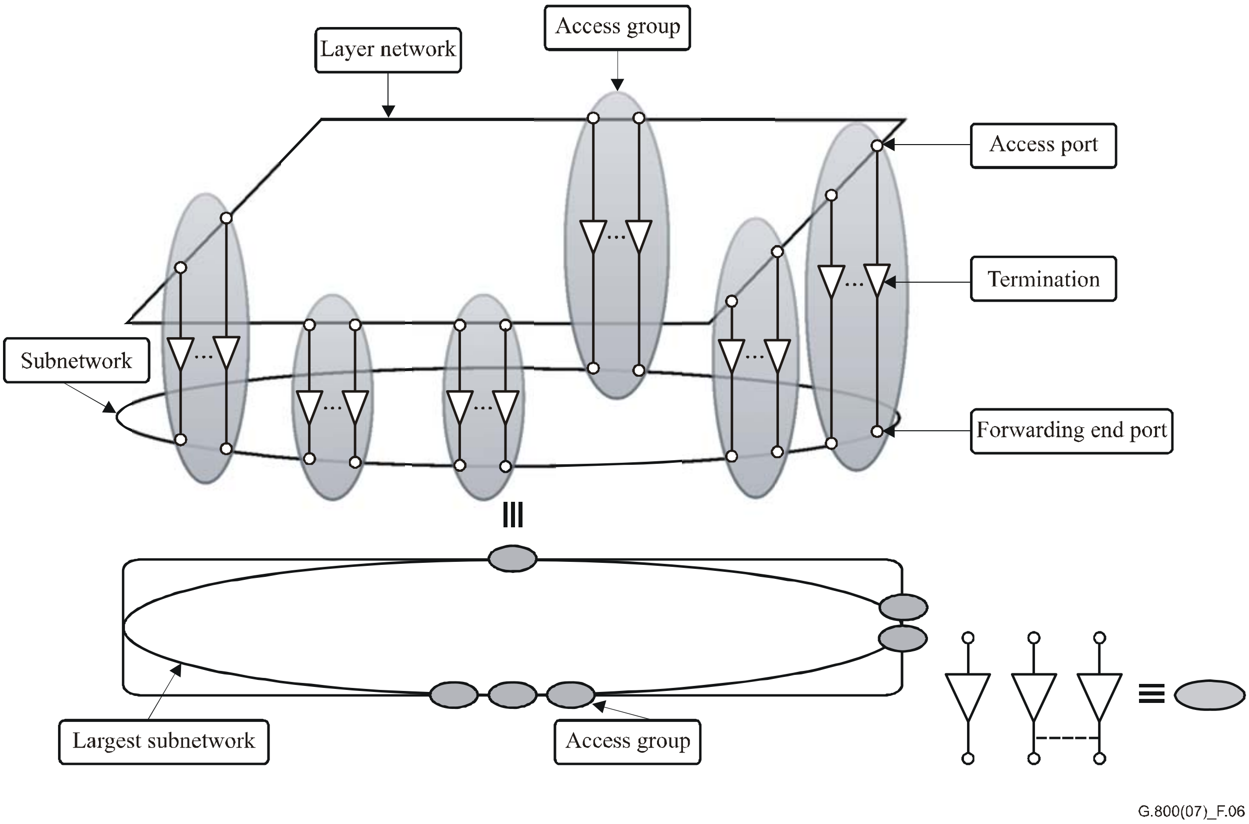


Figure 6 – Layer network

The internal structure of this plane can be further described by partitioning the largest subnetwork into smaller subnetworks (points of flexibility) and the links that interconnect them. The binding between a link and a subnetwork results in a link point.

The representation of a layer network as subnetworks and links is equivalent to a graph theory representation where a subnetwork corresponds to a node (or vertex) on the graph and a link corresponds to an arc (or edge) on the graph.

A subnetwork may be partitioned into smaller subnetworks interconnected by links. In addition, subnetworks and the links that interconnect them can be aggregated into a larger (containing) subnetwork. In this case, the details of the contained links and subnetworks are not visible.

An example of recursive partitioning is provided in Figure 7 below.

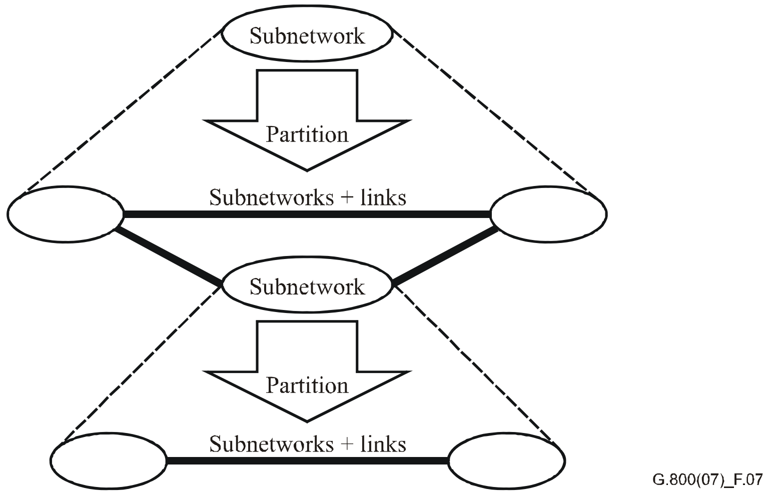


Figure 7 – Example of recursive partitioning

Partitioning of a layer network allows different subnetworks to be administered by different organizations (as required by axiom 5).

The links in a client layer network are supported by trails in a server layer network; this is illustrated in Figure 8 below. The transport entities and the components that support these relationships are described later in this clause.

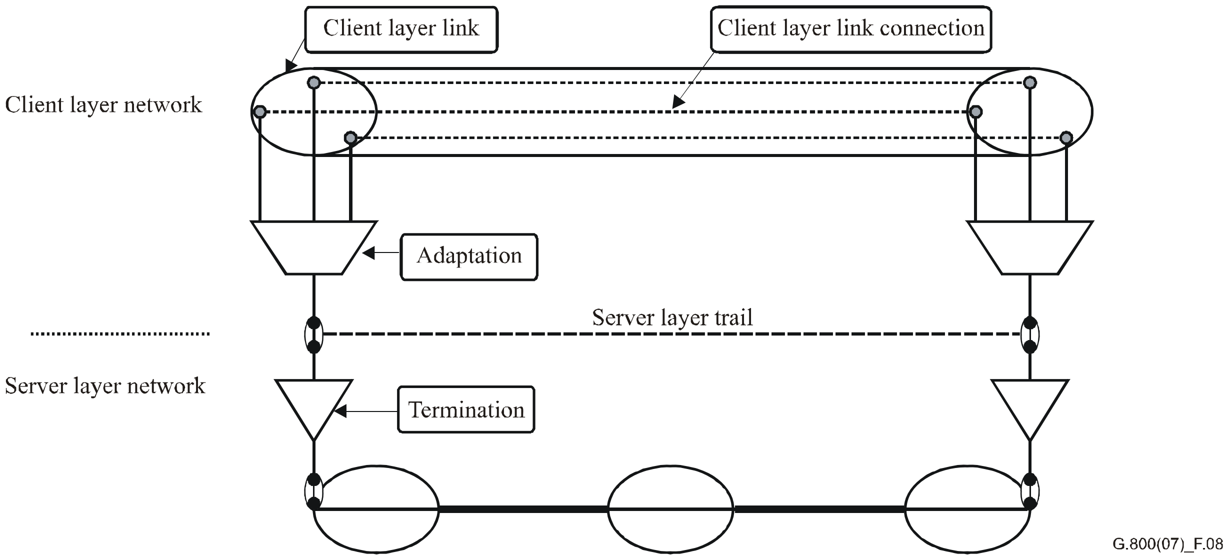


Figure 8 – Client-server relationship

6.4.1 Partitioning of a topological component

When addressing the partitioning of topological components, both the topological and resource aspects of the components must be considered. A subnetwork may be recursively partitioned to a degree such that the resultant subnetwork is considered to be in a single (spatial) location, and therefore further partitioning does not result in the ability to add any more precision to the location information. At this level of partitioning, the subnetwork is considered to be a node. Note that a node is not necessarily the limit of recursive partitioning, of a subnetwork. Further, depending on the network implementation, it may not be possible to partition a subnetwork to the level of a node.

For example, if a subnetwork belongs to a different administration and the policy of that administration is not to allow other administrations to see internal structure, or where the subnetwork is supported by a server layer that uses destination-based forwarding as described in clause 6.5.2.

6.4.2 Resource considerations

When considering the support of communications, it is necessary to examine the resource and connectivity restriction aspects of topological components.

The resource aspects of a link are the capacity, support (or not) of capacity reservation and temporal characteristics (e.g., delay, jitter) and other impairment characteristics (e.g., symbol loss after mitigation). The link inherits the characteristics of the server layer trail (or trails) supporting it. Some of these characteristics may be mitigated as described in clause 8. The inheritance of characteristics applies recursively over all layer networks down to the physical infrastructure.

A subnetwork may have some restrictions on the forwarding capabilities that it supports:

– It may not offer full flexibility because of restrictions imposed on the forwarding that it supports between some or all of its ports.

These flexibility restrictions may be imposed by the supporting hardware, the network configuration or the policy of the network operator. These restrictions can be described as a set of constraints that may be attached to the subnetwork. Partitioning of the subnetwork may yield simpler constraint rules.

The underlying resources that support the subnetwork may have capacity limitations because of either:

– the capacity of the links that interconnect any contained subnetworks; or

– the physical forwarding hardware has capacity limitations.

It is also possible to partition a node into multiple independent subnetworks, each of which is under the control of an independent control functional group (e.g., different routing areas, see [ITU-T G.8080]).

We can define a "matrix" as the limit of recursion of subnetwork partitioning which need not be further partitioned to expose connectivity restrictions or location information (i.e., the subnetwork is a node) and is non-blocking, i.e., it has the resource capacity to:

– accept any request to configure a forwarding relationship; and

– ensure that any symbol offered for transfer is guaranteed resource allocation.

NOTE – It may not always be possible to partition a subnetwork to a matrix.

Most common path computation algorithms expect nodes to be non-blocking and expect blocking or congestion on links. Thus, for the purposes of path computation, the network should be partitioned to the level of matrices and links. This allows a network planning application to observe link utilization and adjust the link capacity to reduce the blocking or congestion to an acceptable level.

6.4.3 Assignment of topology to organizations or communications

Partitioning allows different organizations to administer different links and subnetworks. It is also possible to allow multiple organizations to administer resources within the same subnetwork. An example application is the support of VPNs using a common set of network resources. This is achieved by dividing the subnetwork (including the contained links and subnetworks) into domains and assigning control of a domain to an organization. The representation of the capability to share resources between multiple organizations is outside the scope of this Recommendation (see [ITU-T G.8080]). Domains are also used to model semantically different networks using common underlying resources, thereby allowing for mixed networks using a common hardware platform.

A domain may be further divided into subdomains that support communications for a single user.

A subnetwork domain is formed from a subset of the ports on the containing subnetwork and inherits all of the properties of the containing subnetwork.

A sublink is formed from a subset of the ports on the containing link and inherits all of the properties of the containing link. A specific portion of the capacity of the containing link is assigned to a sublink.

From the perspective of the organization that has control over the resources, a subnetwork domain is a subnetwork and a sublink is a link.

6.5 Transport entities and their properties

Transport entities provide the means to transfer information across the network, between reference points, and are derived from topological components by the addition of a forwarding function which requires configuration. The properties of a topological component are unchanged by the addition or configuration of a forwarding function. The forwarding function can only further restrict any topological or resource constraints that are initially present. The following basic entities are described: forwarding relationship, link connection, connection and transfer association.

6.5.1 Forwarding relationship

A forwarding relationship is the transport entity that is created by a forwarding function that has been configured in a subnetwork. The ingress forwarding points and egress forwarding points of the forwarding relationship are identified together with any policy related to these points. The selection of the ingress and egress points to be used may be based on a policy that considers, for example, the condition of a link connected to the subnetwork for the purpose of protection switching. The creation of the forwarding relationship binds the forwarding ports on the subnetwork to the forwarding ports on the link or termination. This binding creates the forwarding points (FwP). Two types of forwarding are possible:

Destination forwarding: Symbols presented at an ingress forwarding port are selectively forwarded to zero or more egress forwarding ports. The forwarding function requires control information to identify the output port(s) to which a communication is destined. This control information is carried by the symbol being forwarded (commonly in the form of a destination address). The resulting network behaviour is traditionally known as "connectionless".

Channel forwarding: All symbols on all ingress forwarding ports are forwarded to all egress forwarding ports. No additional control information is required with the symbol. When there is a single ingress forwarding port the forwarding relationship is equivalent to a subnetwork connection in [ITU-T G.805].

NOTE – A broadcast medium has a forwarding function associated with it that allows no further configuration of the forwarding relationship and is represented as a broadcast forwarding relationship.

6.5.2 Link connection

A link connection is the transport entity that is created when a forwarding function is configured in a link. The link connection has exactly one ingress forwarding port and one egress forwarding port. Any symbol presented at the ingress is delivered to the egress port. Resources are reserved for that link connection and there is no possibility of further reservation of capacity. This is equivalent to a link connection in [ITU-T G.805]. A bidirectional link connection is a pair of link connections in opposite directions in the same bidirectional link. The link connection can be created in the link either before the FwPt is bound to another FwPt or at the time the binding is created. Changing the binding can only create or delete a link connection; it cannot modify an existing link connection.

6.5.3 Connection

A connection is a channel forwarding relationship with the added constraint that all the link connection resources have been reserved for a specific communication. A connection has only one ingress forwarding port. Further, the user of a connection has complete control over the allocation of the capacity of the connection. The allocation can be controlled by a local synchronous information system and so the local allocation decisions can be instantaneous, deterministic and flexible. A bidirectional connection is a pair of unidirectional connections between the same bidirectional FwPs (in opposite directions). The network connection is a connection that has an FwEP at each end.

6.5.4 Access relationship

An "access relationship" transport entity is created when a forwarding function is configured in a layer network. The ingress access ports and egress access ports of the forwarding relationship are identified together with any policy related to these ports. An access relationship cannot be partitioned. The access relationship may be established either before or after the termination is bound to an adaptation, i.e., it may be bounded by access ports or access points or a combination. Modifications to the bindings do not change the access relationship. The access relationship is supported by a corresponding forwarding relationship in the largest subnetwork.

In a network that uses channel forwarding, the access relationship is supported by a network connection, i.e., it is equivalent to a trail in [ITU-T G.805].

In a network that uses destination-based forwarding, the access relationship is supported by a corresponding destination forwarding relationship in the largest subnetwork.

6.5.5 Partitioning of transport entities

When a subnetwork that contains a channel forwarding relationship is partitioned to reveal the internal structure, the subnetworks contain only channel forwarding relationships and the links contain link connections.

When a subnetwork that contains a destination forwarding relationship is partitioned to reveal the internal structure, the subnetworks contain destination or channel forwarding relationships and the links contain link connections.

6.5.6 Reservation and allocation

In the network, resources are represented by links and matrices and these resources can be reserved for a particular forwarding relationship, or a set of forwarding relationships, for supporting a particular communication (a connection) or set of communications. A resource is allocated to a communication only when the communication is using the resource. Resources are limited by the installed capacity and allocations must be within this capacity.

In networks using packet switching, a resource is only allocated when a symbol is present. Therefore it is possible that the total of the reservations exceeds the capacity of the link. This overbooking may cause link congestion in which case some symbols may suffer increased delay and in extreme cases may be discarded. Note that policing functions are derived from contracts and are not part of resource reservation. However, they may be used to ensure that the resource allocated does not exceed the reservation. Communications transported by destination forwarding may be subjected to policies even when there is no explicit resource reservation in the network.

In networks using circuit switching, the resource allocation takes place at the time the reservation is made, i.e., when the forwarding relationship is provisioned, and the allocated resource is used even in the absence of any meaningful communication.

6.6 Transport information entities

Transport information entities are entities that are constructed by a network to convey a communication between a sender and receivers. They are formed by the combination of client information with appropriate labels and equivocation overhead. They are the information entities of the transport plane.

Transport information entities, being themselves instances of information, exist separately as three forms of information:

a) *Client information*: This is the communication that the client requires to be transported transparently and accurately.

b) *Adapted information*: Adapted information is the information that is transported transparently across a server layer network. Adapted information is the client information encoded in such a manner that it is transportable across the layer network. This encoding can include labelling of the client information in order to distinguish the client information within the context of a single instance of adapted information. Adapted information is the construct that allows independence between client and server.

c) *Characteristic information*: This is the combination of the adapted information with additional information (layer information) that is transported across the network. Some of the layer information can remain unchanged across the network, though it can be read within the network, while other layer information may be altered within the network.

The only information which can be read (and by implication understood) within the layer network is the layer information which is added to the adapted information to form the characteristic information and is added by a termination function. This is irrespective of whether or not the symbols encoding the information are changed within the layer network. For example, if the layer network needs to read a field for its operation, this field is not transparent to the layer network and cannot be part of the adapted information. This field must be treated as belonging to the termination function.

The client may pass information to the server layer network, and vice versa, which must be understood by both. Payload type, destination and QoS marking are examples. These must be passed as parameters between client and the layer network along with the adapted information and may be carried as part of the CI, or, may be carried 'out of band'.

6.7 Transport processing functions

A transport processing function may be considered, without implying an implementation, as a universal algorithmic state machine and "firmware" information as the programme which defines the specific behaviour of the entity. This "firmware" information is pertinent to the design of the entity. The behaviour of the entity is now controlled by the information passing into it through the ports.

This Recommendation is only concerned with configuration information that is material to the external behaviour of the entity as a specific labelling and encoding entity.

Four generic processing functions of adaptation, termination, layer processor and forwarding, together with labelling and encoding are described below.

6.7.1 Encoding and labelling

Labelling and encoding entities are information processing entities and have the following ports:

– a client facing port;

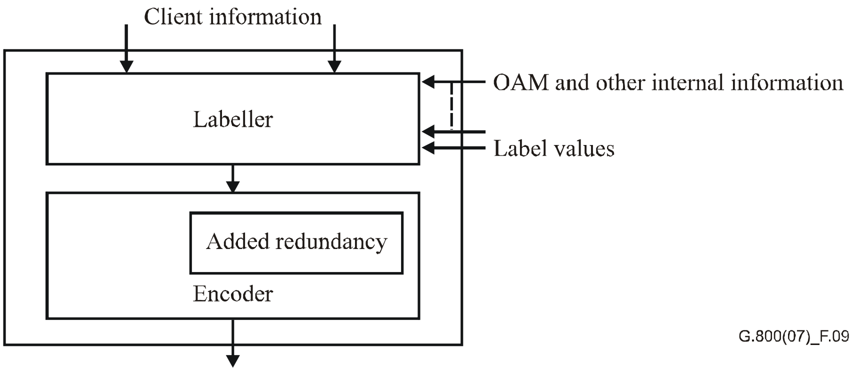
– a server facing port;

– a configuration and control port;
– an OAM message port.

In the case of the labeller, the value in any added fields is independent of the value of client information. A key characteristic of encoding which clearly distinguishes it from labelling is that the values of any added fields by the encoder (resulting from redundancy in the encoding) are dependent on the value of the client information.

The order in which encoding and labelling may take place inside an adaptation function or a termination function is such that either order is possible and that it is essential to the unified model that this flexibility is clear and unfettered. Figure 9 shows a possible configuration to which many existing adaptation and termination functions can be mapped.

For any particular adaptation or termination function, the order does matter and the order is part of the definition of the behaviour of the function which is essential for the interface specification and interoperability. For example, the SDH termination functions specify clearly the bytes over which the BIP is calculated.



NOTE – A transport processing function may contain more than one labeller and encoder. The arrows external to the information system represent information that is presented via ports.

Figure 9 – Labelling and encoding

6.7.1.1 Distinguishing and identifying individual communications on shared resources

A label provides a means of providing added information for the purpose of distinguishing and identifying individual communications within a communication which is formed to convey a combination of communications.

The terms "distinguish" and "identify" have a particular meaning in this Recommendation. To distinguish is essential from information theory in order to separate out communications from each other when they have been combined. To identify is essential to manage a communication.

The following types of label are used in this Recommendation:

Resource label: A resource label is the information required to *distinguish* a communication within a combination of communications.

Source label: A label which is used to identify the access point that a sender of information is attached to.

Destination label: A label which is used to identify the access point that the intended receiver of information is attached to.

Connectivity label: A connectivity label is the information required to identify the sender and intended receivers of an information instance.

Further details on these labels are provided in clause 7.

6.7.1.2 Equivocation overhead

Equivocation overhead is information that is added to ameliorate for the possible loss of information in the process of its transfer from a sender to a receiver. The following forms of equivocation overhead are defined in this Recommendation:

a) *Communication information equivocation overhead*: This is information that is coupled to the communication information. This coupling may be achieved in one of two ways (or in combination):

   – Overhead information that is derived from the communication information itself, in that its value is dependent on the communication information.

     NOTE 1 – Examples include cyclic redundancy check (CRC), bit interleaved parity (BIP), forward error correction (FEC) schemes.

   – Overhead information that is known and deterministic but which is indistinguishable from communication information when transferred and is therefore subject to the same information loss mechanisms.

     NOTE 2 – Examples include connectivity check (CC) flows in packets/cell networks and frame alignment words in circuit networks.

   The purpose of communication information equivocation overhead is to allow a receiver to reliably monitor loss of client information.

b) *Control information equivocation overhead*: This is information that ameliorates for the loss of label information and/or loss of configuration and control information.

   NOTE 3 – Examples include path trace, signal label/protocol identifier (ID), time to live (TTL).

c) *Forwarding equivocation overhead*: This is a communication that can be injected in order to make available a monitor for a transport entity in the transport plane. This overhead communication is independent of any other communications and is also distinguished from any client communications. Normally forwarding equivocation overhead will give a good indication of the performance of other communications also using the forwarding relationship; however, this overhead can be subject to systematic failures where another communication is impaired but the forwarding equivocation overhead will not detect the impairment, even in a statistical way.

   NOTE 4 – Examples include routing protocol "hello" messages.

6.7.2 Adaptation function

6.7.2.1 Adaptation source function

The adaptation source function is a labelling and encoding entity that takes one or more client communications passing through its client facing input port(s), and combines them into instances of adapted information. The adaptation source function also adds sufficient labelling in order to distinguish each client communication from all others within the scope of the access point to which the adaptation source is bound. The instances of adapted information are passed through the server facing port.

6.7.2.2 Adaptation sink function

The adaptation sink function is a labelling and encoding entity that receives adapted information at its server facing port, identifies the labels for client communications that are intended to be received by the adaptation sink function and ignores all others. It then reconstructs the client communications and passes these out through its client facing output port(s).

6.7.2.3 Adaptation and information constructs

The relationship between an adaptation function and information entities is illustrated in Figure 10.

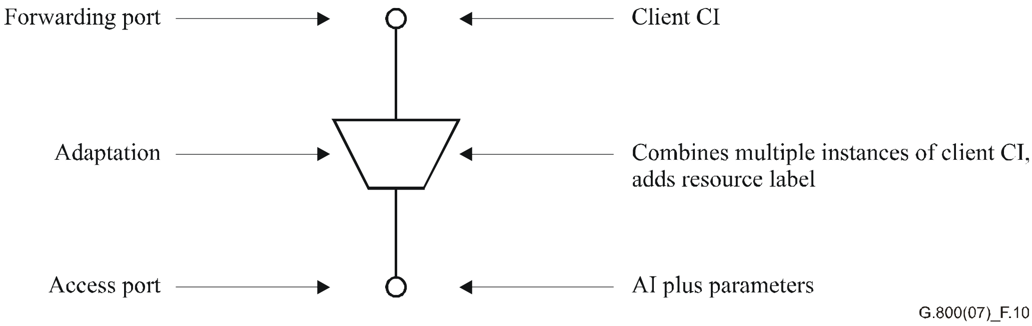


Figure 10 – Relationship between adaptation and information entities

6.7.3 Termination function

6.7.3.1 Termination source function

The termination source function adds layer specific information (e.g., encoding, labelling, fields for sublayer OAM) to create the layer characteristic information. The added information is the layer information (LI), such that characteristic information is equal to the adapted information plus the layer information. The operation of the termination function is independent of the client layer network. In accordance with the ability to offer transparency only, the layer information may be interpreted or modified within a layer network. Further fields cannot be added to the characteristic information symbol unless they have been predefined by the termination function that creates the characteristic information.

6.7.3.2 Termination sink function

The termination sink function extracts layer specific information (e.g., encoding, labelling, fields for sublayer OAM) to create the layer adapted information. The extracted information is the layer information (LI), such that the adapted information is equal to the characteristic information minus the layer information. The operation of the termination function is independent of the client layer network. In accordance with the ability to offer transparency only the layer information may be processed within a layer network. Further fields cannot be extracted from the characteristic information symbol unless they have been predefined by the termination function that outputs the adapted information.

6.7.3.3 Termination and information constructs

The relationship between a termination function and information entities is illustrated in Figure 11.

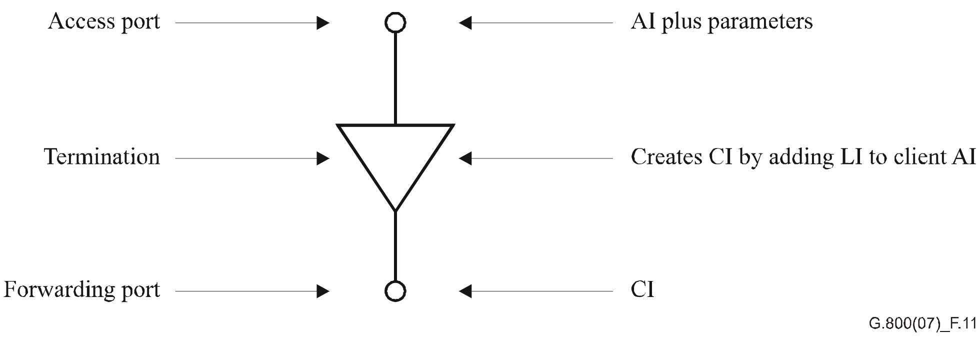
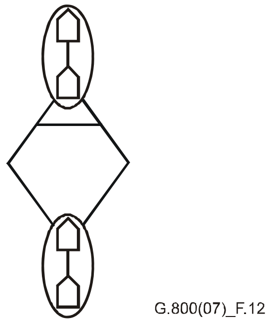


Figure 11 – Relationship between termination and information entities

6.7.4 Layer processor function

A layer processor function is a transport processing function that operates within a single layer network. To preserve the transparency of the AI, this type of function can, by definition, only read and modify LI. An example of a layer processor function is a traffic conditioning function, which can also be denoted as shown in Figure 12. The traffic conditioning function accepts the characteristic information of the layer network at its input, classifies the traffic units according to configured rules, meters each traffic unit within its class to determine its eligibility, polices non-conformant traffic units and presents the remaining traffic units at its output as characteristic information of the layer network.



Note that the diagram illustrates a unidirectional function. It is also possible to have a bidirectional function.

Figure 12 – Traffic conditioning function

The relationship between a layer processor function and information entities is illustrated in Figure 13.

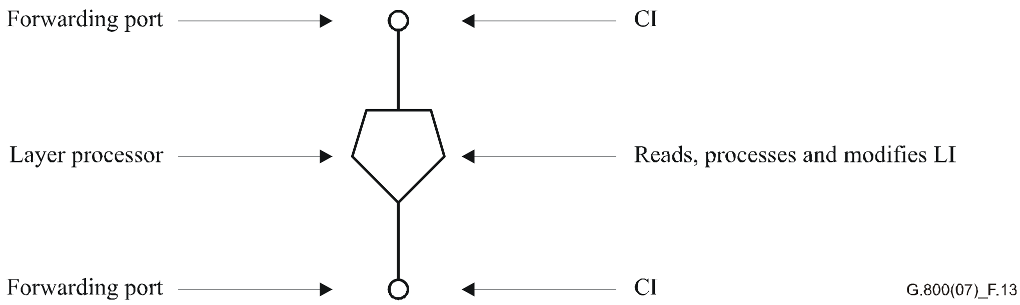


Figure 13 – Relationship between layer processor and information entities

6.7.5 Forwarding function

A forwarding function is a transport processing function that is configured in a subnetwork or link[1] topological component. It is responsible for transferring symbols presented at its ingress ports to its egress ports based on control information and configuration policy. During configuration, the following information must be provided:

– the ingress and egress forwarding ports[2];

– the type of forwarding that is supported (channel or destination);

---

[1] The forwarding function in a link is normally present as a default and does not need to be configured.

[2] In the case of a subnetwork, normally the forwarding port on a link that is bound to the subnetwork is referenced (instead of the forwarding point on the boundary of the subnetwork); this creates a forwarding point directly.

– port selection policy (may be null);
– forwarding policy (may be null).

6.8 Reference points

Reference points are formed by the binding between input ports and output ports 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 – Allowable bindings and resulting reference points

Architectural components				Reference point	
Adaptation	Source output	Termination	Source input	AP	Uni
	Sink input		Sink output		Uni
	Source/sink pair		Source/sink pair		Bi
Termination	Source output	LC	uni input	FwEP	Uni
	Sink input		uni output		Uni
	Source/sink pair		Source/sink pair		Bi
Termination	Source output	Forwarding relationship	uni input	FwEP	Uni
	Sink input		uni output		Uni
	Source/sink pair		Source/sink pair		Bi
LC	uni input	Forwarding relationship	uni output	FwP	Uni
	uni output		uni input		Uni
	Source/sink pair		Source/sink pair		Bi
LC	uni input	LC	uni output	FwP	Uni
	uni output		uni input		Uni
	Source/sink pair		Source/sink pair		Bi
Adaptation	Source input	Adaptation	Sink output	FwP	Uni
	Sink output		Source input		Uni
	Source/sink pair		Source/sink pair		Bi
Layer processor	Source output	Adaptation	Source input	FwP	Uni
	Sink input		Sink output		Uni
	Source/sink pair		Source/sink pair		Bi
Termination	Source output	Layer processor	Source input	FwEP	Uni
	Sink input		Sink output		Uni
	Source/sink pair		Source/sink pair		Bi

AP	Access Point	LC	Link Connection
bi	Bidirectional	FwEP	Forwarding End Point
uni	Unidirectional	FwP	Forwarding Point

6.9 Layer relationships

The interlayer relationship allows us to "build" a client layer topology in terms of links and subnetworks that are supported by transport entities in a server layer. The topology of the server layer network is used to construct transport entities which in turn support the topology of a client layer network. Each instance of a client layer network inherits the mitigated characteristics of the transport entities of its server layer network. The characteristics of this layer network are combined with the inherited mitigated characteristics and are presented as the characteristics of this layer network when it is acting as a server layer network.

To describe the characteristics of a layer network, it must be partitioned to an appropriate degree. In some cases this may not be possible, for example, due to an administrative policy or because of the nature of the server layer network.

If the layer network uses channel forwarding, at its access points, the layer network provides a trail transport entity. This is represented as a link in the client layer network topology.

If the server layer network uses destination forwarding, at its access points, the server layer network offers a multipoint to multipoint access relationship transport entity and expects the client adaptation to provide destination information with each message. At the ingress access point, the interlayer adaptation function must translate the destination information associated with each symbol into a primitive that identifies the intended egress access point. The termination function maps this primitive into the server layer network destination address. We have two cases for the client layer network:

- If the client layer network uses destination forwarding, the server layer transport entity may be represented as a subnetwork in the client layer network topology. The ingress adaptation function maps the destination information carried by each message into the primitive that identifies the intended egress access point. However, this subnetwork cannot be partitioned within the client layer network and in general is not a node since it may have some geographic distribution.
- If the client layer network uses channel forwarding, then the server layer transport entity may be represented as a link in the client layer topology. In this case, the ingress adaptation function must map the intended link end point into the primitive that identifies the intended egress access point. This creates (from the perspective of the client) a persistent point to point forwarding relationship. However, this forwarding relationship cannot be decomposed into a predetermined concatenation of subnetwork connections and link connections.

6.9.1 Inheritance of geographic properties

In order to predict the degree to which a layer network can offer resilience against resource failures (caused for example by the failure of a cable or physical site), the topology must include geographic data, and therefore it can be partitioned to the level of nodes and links. Each link must be supported by a forwarding relationship (in the server layer network) that can also be partitioned into nodes and links. This recursive relationship must be supported down to the physical infrastructure.

6.9.2 Links supported by multiple server layer trails

Three different cases exist, these are described below:

Multiple parallel links between the same subnetworks can be bundled together into a single composite link. Each component of the composite link is independent in the sense that each component link is supported by a separate server layer trail. The composite link conveys communication information using different server layer trails thus the sequence of symbols crossing this link may not be preserved. This is illustrated in Figure 14.

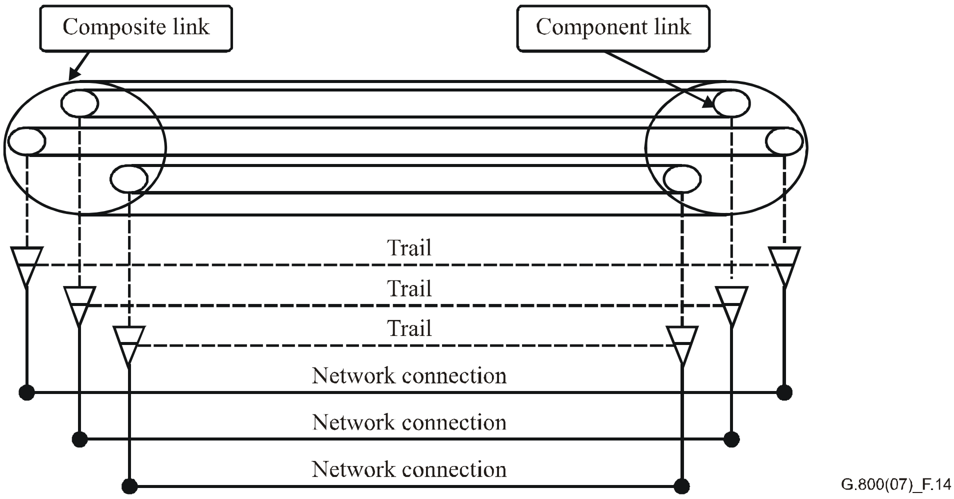


Figure 14 – Composite link supported by multiple independent server layer trails

Multiple server layer trails can be combined using the inverse multiplexing technique described in [ITU-T G.805]. This creates a new composite rate trail with a capacity that is the sum of the capacity of the component trails. The link in the client layer is supported by this composite trail. This link may support a single link connection and it preserves the sequence of any symbols that use this link connection. This is illustrated in Figure 15. Note that the composite trail is not visible in the network.

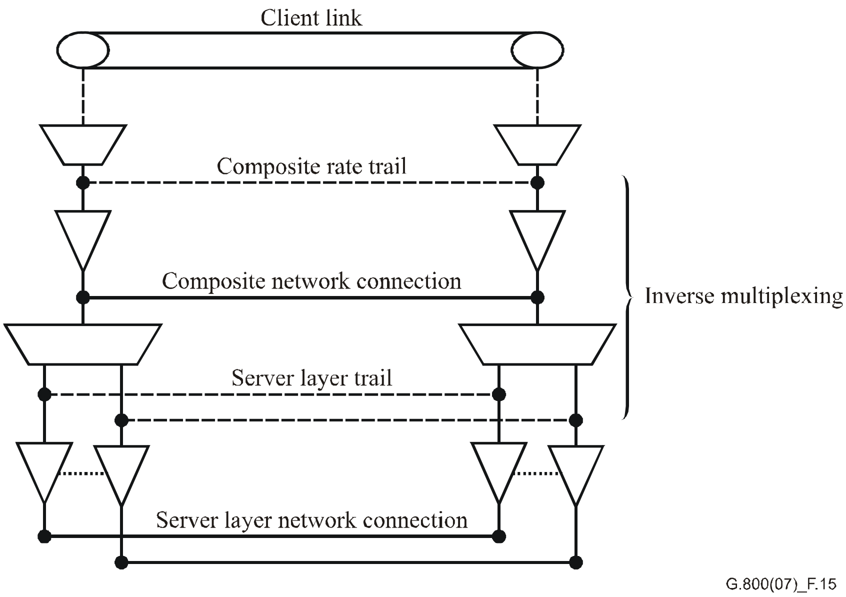


Figure 15 – Client link supported by inverse multiplexing

A link can also be constructed by a concatenation of component links and configured channel forwarding relationships. The forwarding relationships must have a 1:1 correspondence to the link connections that will be provided by the client link. In this case, it is not possible to fully infer the status of the link by observing the server layer trails visible at the ends of the link. This is illustrated in Figure 16.

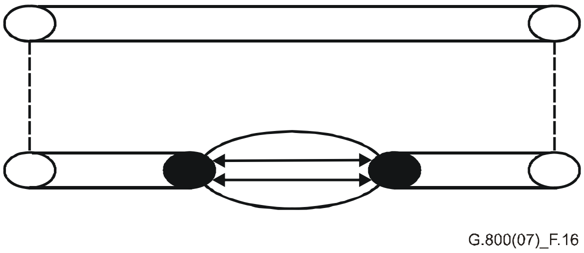


Figure 16 – Serial compound composed of component links and a subnetwork with configures channel forwarding relationships

7 Identity and identifiers

Each entity within a transport network has a unique identity but does not necessarily have a visible globally unique identifier. The various applications that control, use or observe the transport network (including entities within the transport network itself) need the ability to identify some entities (e.g., reference points, communications, functions) within the transport network. Each of these applications requires an identifier for each of the transport network entities that are of interest. These identifiers are from the name space of that application and must be unique within the context of that application. In general, multiple applications may reference the same network entity; in this case, multiple identifiers will exist. Identifiers are an alias to the identity of the entity within the context of the mechanism of identification.

In some cases, an entity may make some implicit characteristic visible, e.g., a timeslot in a SDH frame or a wavelength in a WDM layer. These implicit characteristics are considered to be a label for the resource.

7.1 Identifiers

As defined in Axiom 2, the resources of the layer network are shared by multiple users. To allow the network to be configured to support multiple communications that are delivered to only the intended receiver(s), the configuration application and the layer network must be able to distinguish the topological components, the resources and the individual communications. The identifiers described below are used for this purpose; Figure 17 is an example of layer network with a single connection.

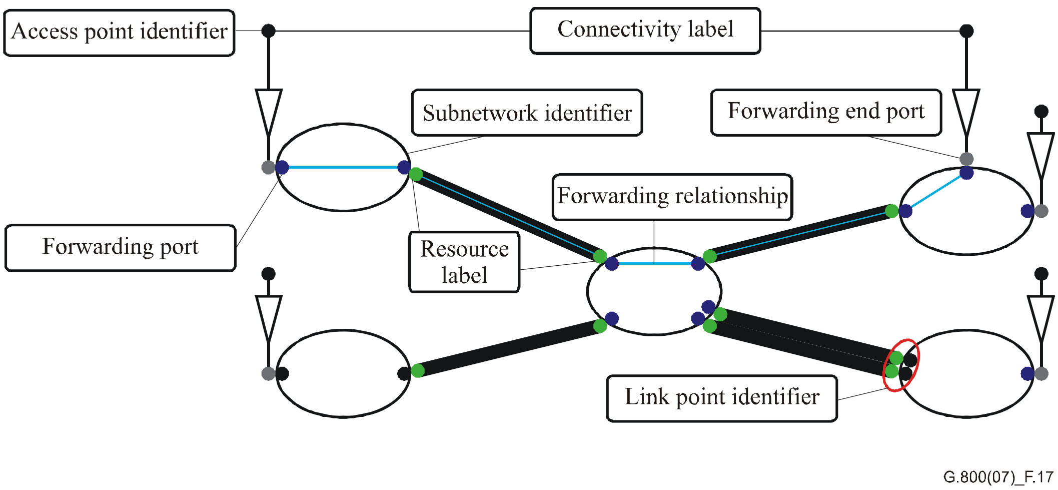


Figure 17 – Identifiers in a layer network

All networks (independent of forwarding topology) require the same set of identifiers, the forwarding topology only impacts the scope and encoding of those identifiers:

Access point identifier: This identifier must be unique within the context of the layer network. This is used as the source or destination label described in clause 6.7.1.1.

Connectivity label: Identifies the access points between which AI symbols are transferred.

Resource label: This identifier allows the symbols belonging to one communication to be distinguished from the symbols that belong to another communication on the same link. This identifier is logically associated with the link not the symbols (or communications) being carried. It must be unique in (at least) the context of the link. This identifier must be encoded with the symbols (since by definition it is not local information). This label is used to identify the forwarding port (FwPt) of a link connection. The resource label is frequently used as the identifier for the forwarding point (FwP) that results from the binding of the link connection to a forwarding relationship.

Forwarding end port identifier: This label identifies the FwEPt on a termination function. This identifier is frequently used for the forwarding end point (FwEP) that results from binding the termination to a forwarding relationship.

Forwarding port identifier: Identifies the forwarding ports (FwPt) on the boundary of a subnetwork. The identifier for a forwarding port must be unique within the context of the subnetwork.

Forwarding identifier: This identifier is used by the forwarding function to deliver a symbol from an ingress forwarding point to the appropriate egress forwarding point(s). The forwarding identifier is logically associated with a set of communications.

Link point identifier: Allows the links that terminate on a subnetwork to be identified. It is unique in the context of a subnetwork.

Subnetwork identifier: Allows the subnetwork within a layer network to be identified. It must be unique in the context of the containing subnetwork.

The use of these identifiers is described in Appendix I.

8 Transparency and impairments

This Recommendation describes the network in terms of recursive layer networks that offer "transparent" information transfer. In general, a layer network is not capable of transferring information without imparting some impairments.

As described in clause 6.6, when the CI of a client layer is transported over a server layer network, the symbols from a client layer CI lexicon are mapped into the AI lexicon of the server layer by an inter layer adaptation function. The inter layer adaptation function may multiplex multiple instances of client CI into a single instance of AI. The client layer CI must be transferred with the required degree of transparency. The mapping between the lexicon of the client layer CI and the server layer AI must include the information required to both demultiplex the individual instances of client CI and mitigate any AI transfer impairments (e.g., loss of order, corruption of timing information) to a degree that is acceptable to the client. The server layer does not have the ability to interpret the meaning (semantics) of the AI symbols. The transparency of the information transferred across a layer network between its access points is defined in terms of:

– The AI lexicon from which the inter layer adaptor can select symbols that are to be transferred.
– The integrity of the symbols that are transferred.
– The inherent information in a sequence of symbols in an open sequence or timed sequence.

Figure 18 below illustrates the transparency that is required to provide layer independence.

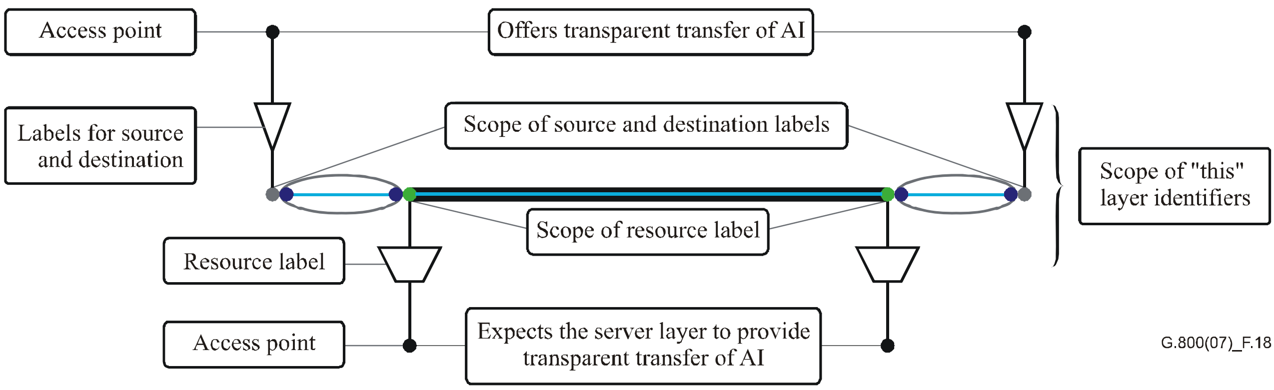


Figure 18 – Scope of identifiers and transparency

The access point provides an abstraction barrier that isolates the client from the server. This allows arbitrary stacking of layer networks.

If a server layer relies on some specific information that is encoded by the client layer, then those layer networks are no longer independent and must always be deployed as a pair of layer networks. In a network with recursive layer networks that do not support the transparency property as defined, all possible combinations of layer networks must be defined.

There are several aspects of symbol impairment within a "forwarding relationship":

– symbol value degeneration;
– symbol order degeneration (deviation from original order);
– symbol timing degeneration (deviation from original time position);
– symbol delivery degeneration (deviation from the intended output port or ports or delivery of unintended symbols to the designated ports);
– non delivery of symbols (e.g., caused by resource exhaustion (resulting in the failure to allocate a resource to a symbol), or symbol corruption).

The server layer may encode the AI symbols to allow mitigation of impairments incurred within the layer or its server layer.

Besides degeneration of the symbols, the forwarding relationship may experience unintended modifications:

– ingress port with attached sender is added (unexpected symbols inserted);
– egress port with attached receiver is added (misdelivery of symbols);
– ingress port with attached sender is removed;
– egress port with attached receiver is removed;
– failure or mis-configuration of the resources supporting the forwarding relationship (resulting in a short or long break in the forwarding relationship);
– combinations of the above.

The techniques applied to the detection and mitigation of some or all of these impairments are described in technology-specific Recommendations.

9 Sublayers

It is often useful to identify sublayers within a specific layer network in order to identify additional reference points. To be able to activate a sublayer, the definition of the CI must already include the fields that will be used by the sublayer. A sublayer is activated within the context of an existing forwarding relationship.

A sublayer provides a set of reference points that are unique within the scope of the forwarding relationship. These "sublayer reference points" are typically used for OAM or protection switching. The term maintenance point (MP) or maintenance port (MPt) is used to differentiate the sublayer reference points from the layer network access points (AP). Maintenance points (or ports) are only visible or accessible within the forwarding relationship within which the sublayer has been activated.

Sublayer OAM information may be added or removed by introducing an intra layer processing function and a sublayer OAM termination function at a termination forwarding point or a forwarding point[3] in a forwarding relationship. The type of forwarding (channel or destination) that the layer network uses creates different cases for the sublayer.

9.1 Channel forwarding

The sublayer (OAM) information is added within the channel forwarding relationship used by the client information. The OAM information may either be added to the original message (for example the tandem connection overhead in a SDH network); or, it may be contained in a new message with an identical envelope. The latter method can only be used in a packet-switched network and must be taken into account by the resource reservation/allocation process.

9.1.1 Insertion/removal at a forwarding point

Figure 19 shows the insertion of sublayer processing functions at an FwP.

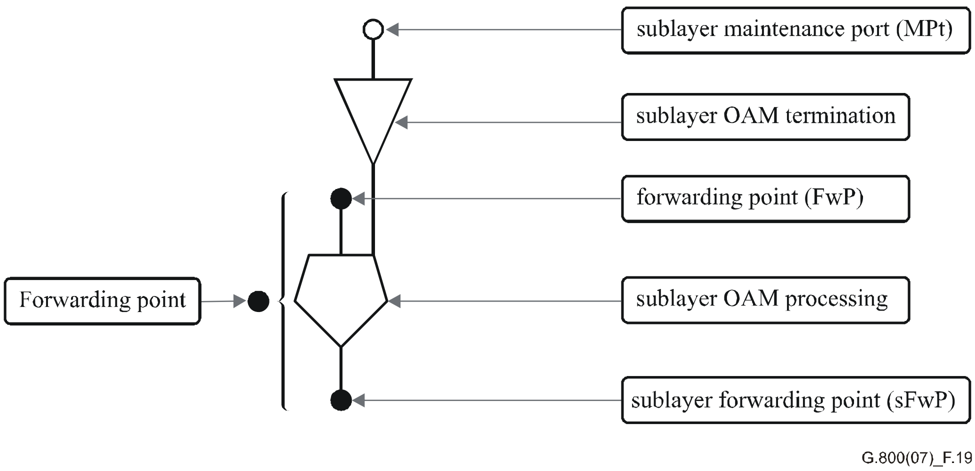


Figure 19 – Insertion at a forwarding point

The sublayer OAM termination source function originates the sublayer OAM information. It must also insert an identifier for the maintenance port. The scope of the maintenance port identifier is limited to that of the original forwarding relationship. The intra layer processing source function monitors the client traffic presented at the FwP, passes the appropriate information to the sublayer OAM termination function. It multiplexes the sublayer OAM information (from the termination) with the CI.

3 [ITU-T G.805] describes this as "decomposing the trail termination function or connection point and describes this by inserting sublayer adaptation and termination functions".

The intra layer processing sink function monitors the traffic at the sublayer FwP, passes the appropriate information to the sublayer OAM termination function. It demultiplexes the sublayer OAM information from the CI. The sublayer OAM information is passed to the termination sink function where it is terminated.

9.1.2 Insertion/removal at a forwarding end point

Figure 20 shows insertion of a sublayer processing function at FwEP.

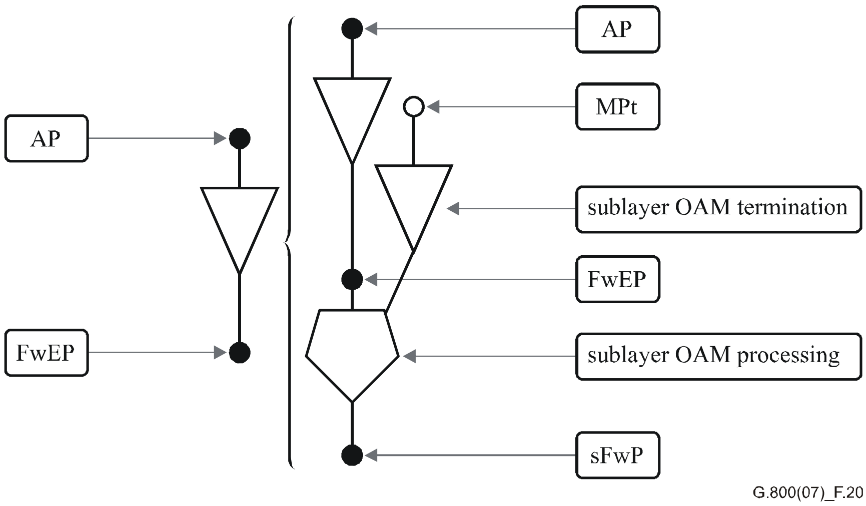


Figure 20 – Insertion at a forwarding end point

The operation of the sublayer termination function and intra layer processing function is identical to that described in the previous clause.

9.1.3 Sublayer trail

The sublayer trail exists between the source and destination maintenance ports. The sublayer trail uses the same forwarding relationships as the client signal. Therefore, the symbols conveying OAM information follow the same path across the network (and are exposed to the same impairments) as the symbols conveying client traffic AI. The lifetime of the sublayer trail is tied to the lifetime of the forwarding relationship. This tight coupling between the sublayer trail and the client communication makes the insertion of OAM indications (such as forward defect indication) relatively simple. A non-intrusive monitor may be used to allow the sublayer OAM information to be observed at intermediate points. In this case, an intra layer processing sink function monitors the traffic at the sublayer FwP, passes the appropriate information including the sublayer OAM information to the sublayer OAM termination function.

The visibility of the maintenance ports is inherently limited to the scope of the forwarding relationship within which it has been activated. The sublayer OAM information may include MP source and destination identifiers. Use of these identifiers may allow multiple sublayer OAM trails to exist in the same channel forwarding relationship.

9.2 Destination forwarding

The sublayer (OAM) information is added within the destination forwarding relationship used by the client information. The OAM information is added in a new message that conforms to the CI of the layer network. Since destination forwarding is used, each message carries a forwarding identifier that identifies the intended destination. The messages carrying OAM information must also contain a forwarding identifier that identifies the intended OAM destination or destinations (within the destination forwarding relationship). This (maintenance) forwarding identifier may be independent of any client communications. Therefore, OAM messages and client messages may be subject to independent forwarding decisions. The exchange of OAM messages allows the functionality of the segment of the forwarding relationship between the source and sink functions to be verified.

9.2.1 Insertion/removal at a forwarding point

When sublayer processing functions are added to allow the insertion of OAM information at a forwarding point, we have two possibilities, either:

– the sublayer OAM information can be inserted in the context of a specific client communication; this is equivalent to insertion at the FwP described above. Given the nature of the communication (i.e., independent messages), monitoring individual client communications is not practical; or

– the sublayer OAM information is carried in the same forwarding relationship by a new message that includes the forwarding identifier for the destination MP. This is illustrated in Figure 21 below.

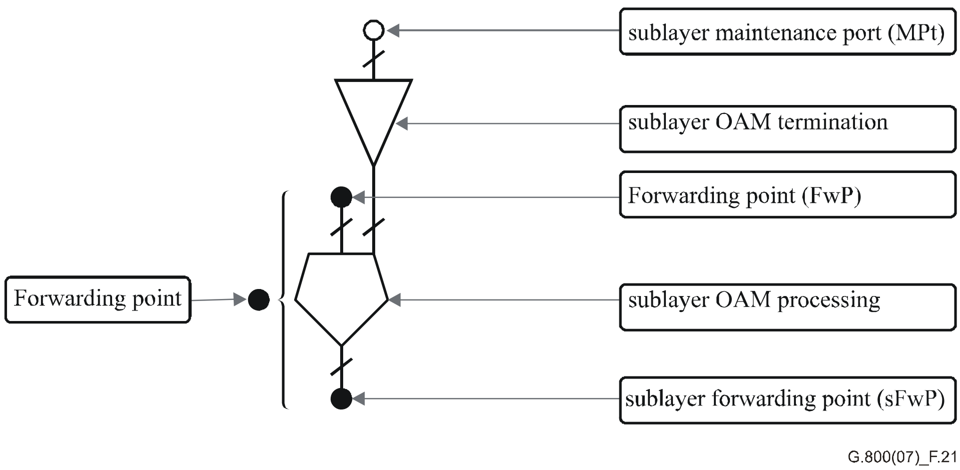


Figure 21 – Insertion at a forwarding point

This results in the generation of new messages, to carry the OAM information, with forwarding identifiers that are independent of the messages conveying client AI.

The sublayer OAM termination source function originates the sublayer OAM information. This must include the target (destination) maintenance port in the form of a forwarding identifier. It must also insert an identifier for the local (source) maintenance port. The scope of the maintenance port identifier is limited to that of the original destination forwarding relationship. The intra layer processing source function monitors the messages presented at the FwP, passes the appropriate information to the sublayer OAM termination function and multiplexes the sublayer OAM messages with the client traffic.

The intra layer processing sink function monitors the messages at the sublayer FwP, passes the appropriate information to the sublayer OAM termination function and demultiplexes the client traffic from the sublayer OAM messages. The sublayer OAM messages are passed to the termination sink function where they are terminated.

9.2.2 Insertion/removal at a FwEP

The FwEP supports messages to/from multiple FwEPs. This is analogous to the case of the forwarding point, i.e., it can be "converted" into a dedicated FwEP (as described in clause 9.2.1) or a new message can be created, including the intended destination, to carry the sublayer OAM information within the same forwarding relationship. This is illustrated in Figure 22 below.

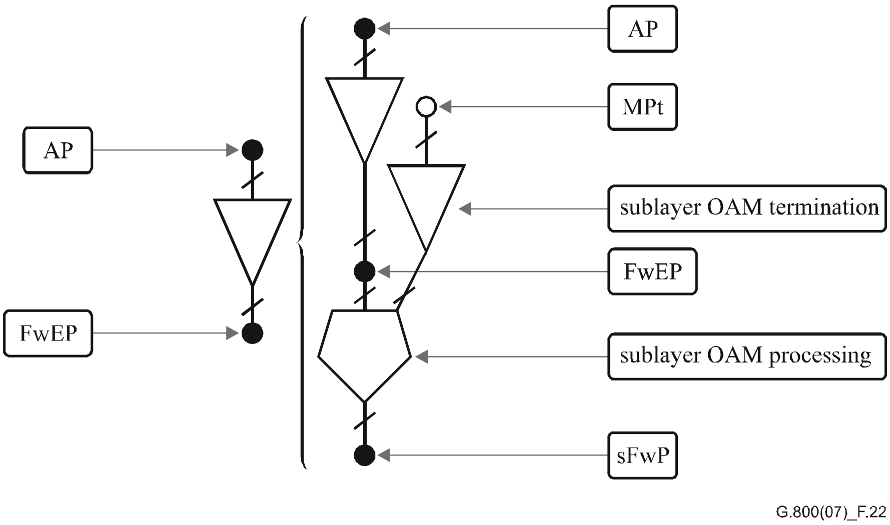


Figure 22 – Insertion at a forwarding end point

The operation of the sublayer termination function and intra layer processing function is identical to that described in the previous clause.

9.2.3 Sublayer OAM maintenance relationship

The sublayer OAM maintenance relationship exists between the source and destination maintenance points, within the destination forwarding relationship used by the client information. It is supported by a sublayer OAM forwarding relationship. Note that if a multicast address is used, a single OAM message may be directed to multiple destination maintenance points within the destination forwarding relationship. The sublayer OAM forwarding relationship is independent[4] of the messages conveying client AI since they have independent forwarding identifiers. The sublayer OAM forwarding relationship may be used to monitor the ability to forward client messages that transit the same sequence of forwarding points between the maintenance points. This monitoring is only valid if the implementation of the forwarding relationship forces all of the messages to follow a common path. It may also be used to monitor the integrity of the transfer of the aggregate of the client messages provided that the forwarding relationship does not merge in any other messages along this path, and maintains the order of messages in the aggregate.

It is possible to activate a non-intrusive monitor at an intermediate point on the sublayer OAM forwarding relationship. However, the stability of this point is dependent on the routing system. This is an update in the forwarding tables that may cause the sublayer OAM messages and the messages carrying client AI to transit a different set of FwPs. Further, the means of identifying the OAM forwarding relationship must be provisioned when the non-intrusive monitor is activated.

[4] The OAM messages may contain information about the client messages, but the forwarding of OAM messages is independent of the forwarding of the client messages.

The lifetime of the sublayer OAM forwarding relationship is dependent on the lifetime of the forwarding relationship within which it is created. It is independent of any messages conveying client AI (client communications). This makes the insertion of OAM indications into client communications (e.g., FDI) somewhat complex. A further degree of complexity is that outside the context of the sublayer OAM forwarding relationship there are no inherent constraints on the routing of the messages conveying client AI (client communications). Since each sublayer OAM forwarding relationship is essentially independent of any other communications, it is possible to have multiple sublayer OAM communications within the same forwarding relationship.

Annex A

Definition and properties of a system

(This annex forms an integral part of this Recommendation)

A.1 Introduction

This annex provides a definition of a system and its properties. A telecommunications network is considered to be a system.

A.1.1 Definition of a system

A system delivers outputs by performing a prescribed function based on inputs to the system. It has input ports through which all inputs enter the system and output ports through which all outputs leave the system.

The specification of a system regards the inputs as independent variables and the outputs as dependent variables. In addition, a system may have internal dependent variables called state variables which will have initial values which are independent variables. The system itself is a transfer function where the output variables are an invariant function of the input variables and the state variables. Note that output variables may also be state variables. The state of the system is defined by the value of the state variables.

The value of the inputs can change over time and this will result in a change in the state of the system. The speed at which the change of state propagates through the system is finite and this sets limiting characteristics on the ability of a system to respond to changing inputs. A system is shown in Figure A.1.

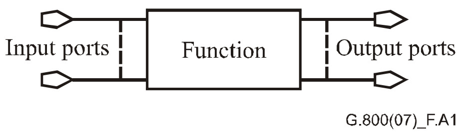


Figure A.1 – System

A.1.2 System binding

Systems can be connected together such that the output of one system feeds the input of another system. This is called a binding. A binding has the property that only one output port from one system is bound to only one input port of another system. A binding is shown in Figure A.2.

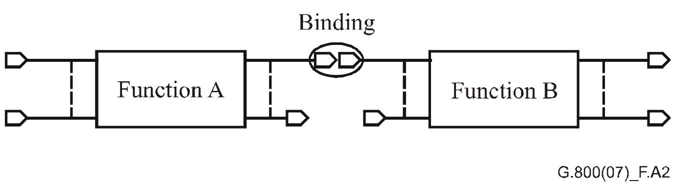


Figure A.2 – System binding

A.1.3 Compound system or aggregation

Binding is used to create more complex systems by combining a number of systems into a single aggregate system. Such a system is called a compound system, or equivalently, an aggregation. The constituent systems within the compound system are called subsystems. The process of binding functions into a compound system is called aggregation while the process of viewing the subsystems and their binding within a compound system is called decomposition.

The compound system is itself a system and has all the properties of a system. Similarly, a subsystem is a system and has all the properties of a system. Aggregation and decomposition are therefore recursive properties of systems.

Figure A.3 shows an example of a compound system.

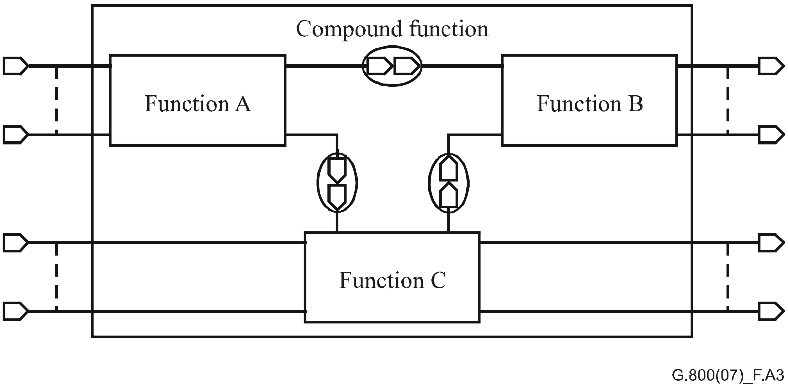


Figure A.3 – An example of a compound system or aggregation

Within a compound system, the bindings are static and become part of the transfer function of the compound system.

A.1.4 Configuration and construction of systems

The formal approach of systems includes the mechanism which we commonly call configuration and construction. Configuration of a system is the ability to take input information that is held in state variables and remains unchanged until such time as it is desired to reconfigure the system. These configuration state variables control the configurable properties of the transfer function. While a particular configuration persists, the state variables are effectively part of the transfer function.

Construction of a system is defined here as the re-interpretation of state variables as a transfer function. In this way inputs may be passed into state variables, thereby defining the transfer function. Formally, configuration and construction is the same thing. The re-interpretation of state variables as a transfer function must always take place in a context of constructing a system. Practically speaking, configuration is re-interpretation of state variables within the context of constructing a system which is already specific to the system which is to be constructed and normally configuration is about the specific purposing of a system. The construction of a system normally describes the re-interpretation of state variables as transfer functions across many subsystems within a compound system. This is illustrated in Figure A.4.

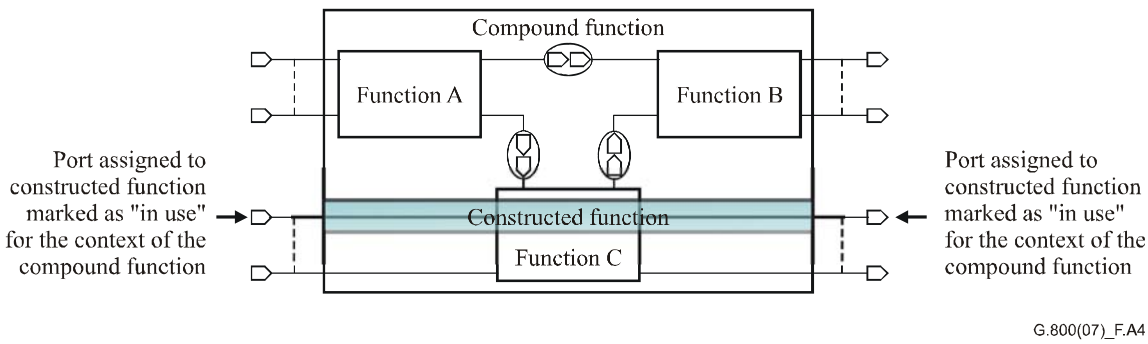


Figure A.4 – Configuration/construction of a system

A.2 Information systems

An information system is a system that processes only information. The inputs and outputs to an information system are information; the state variables of an information system are also information, while the transfer function relates the state information and output information to the input information using an algorithmic state machine which can be described using a logical algebra.

A.2.1 Forms of information

While the variables of an information system and the transfer function of an information system are both information, there is an important difference between the information of the variables and the information of the transfer function. The values of the variables are open, and at the time of the construction of the system are essentially unknown to the system. On the other hand, the value of the information which defines the transfer function is known to the system at the time of its construction/configuration.

The form of information associated with the variables of an information system is information as defined by Shannon. In particular:

– Information is data with a certain semantic where data is a representation of a concept.

– The unit of data is a symbol.

– The enumerable set of symbols is the lexicon.

– Communication can be understood as the passing of information from one location to another.

– A message is an object of communication: It is something that provides information, it can also be information itself.

– A message is a sequence of symbols taken from an enumerable set of possibilities.

Note that it is possible for state variables to hold the previous symbols received on an input port. In this way, it is possible for an information system to operate on a sequence of symbols on an input port and be equivalent to a system which accepted a single larger symbol equivalent to the sequence of smaller symbols.

Information associated with the transfer function of the information system is unique for a particular system. This form of information is called algorithmic information and is in line with the definition set out by Kolmogorov. Note that Kolmogorov information, as normally defined describes only synchronous state information systems; however, the extension to asynchronous state information systems can in principle be made.

A.2.2 State synchronous and state asynchronous information systems

A system where, following a change in input variables, all consequent changes to state variables and output variables have occurred and stabilized within the system before any new change in input variables are accepted is called a state synchronous system. The transfer function of a state synchronous system can be defined using a process calculus such as λ calculus and can be defined with a single thread of execution. It is possible for such systems to have flexible (i.e., input variable driven) and deterministic behaviour. The speed at which output variables are set in response to input variables is determined by the speed with which the system can synchronize the state and output variables.

A system where, following a change in input variables, some consequent changes to state variables or output variables have not occurred and stabilized within the system before any new change in input variables are accepted is called a state asynchronous system. The transfer function of a state asynchronous system can be defined using a process calculus such as π calculus and can only be defined with multiple threads of execution, for example as presented by Petri-Nets. It is possible for such a system to have unavoidable non-deterministic behaviour including "race" and "deadlock" conditions.

As a consequence of the above, when a compound system is made up from subsystems which are spatially dispersed and synchronization of state requires, at a minimum, speed of light delay between the subsystems, such a spatial-distributed compound system can be:

– Flexible in response to input variables, deterministic in its behaviour, but requires a minimum time between changes to inputs;

– Flexible in response to input variables, accept effectively instantaneous changes in input, state, and/or output variables, but have non-deterministic behaviour;

– Flexible in response to input variables, accept effectively instantaneous changes in input, state, and/or output variables, but cannot accept changes in input variables.

Any telecommunications network, by its very definition, is a system to carry information between spatial-separated end points, subjected to the constraints above.

A.3 Basic transfer function and telecommunications network

A.3.1 General

A telecommunications network is a system. The basic transfer function of the telecommunications network relays the sequence of symbols on a selected input port, and transfers them as the same sequence of symbols on selected output port(s).

In the following clauses the information instance corresponds to a communication.

A.3.2 Transparency and labelling

An information system accepts a sequence of symbols through an input port. The behaviour of the system can depend on the sequence of the symbols – the sequence is part of the input information passed through the port.

However, an information system may have more than one input port. The behaviour of the system can depend on which port the sequence of symbols passes to the system – the selection of input port is therefore also part of the input information passed to the system.

Therefore, where the information system has more than one port, the selection of the input port must be included as part of the overall information. For an information system with one input port to be equivalent to an information system with many input ports, the input information must include labelling of the symbols which tells the information system the equivalent of which port each symbol enters the system. This is shown in Figure A.5.

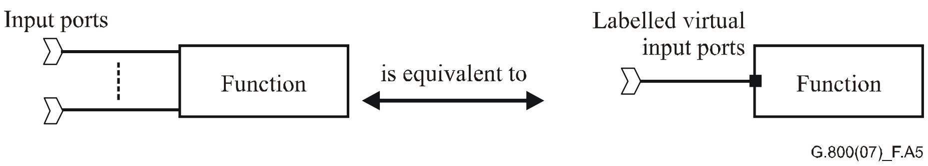


Figure A.5 – Multiple input ports as equivalent to labelling of input symbols

The purpose of a telecommunications network is to transfer information from an input port to an output port. Since the user is transferring information, we may assume that the user is sending information from one information subsystem to another information subsystem. Ideally, to the user of the service, the input port to the network should appear to behave as if it were the input of the user's subsystem at the far end of the network. This means that the sequence of symbols at an input port is to be replicated at an output port. The service is transparent when, given an agreement on the symbol size and the method of inter-symbol demarcation between the user and the network:

– the same sequence of symbols is output through the output port as sent through the input port;

NOTE – Adding or deleting symbols will change the sequence of symbols.

– the user has complete freedom over the choice of symbols he/she sends and has also complete freedom in the meaning he/she attaches to each symbol in the set.

This implies that the network, for it to be transparent, must not add, subtract or alter symbols, nor must the network take any functional actions based on the value of any symbol other than those that are derived purely from the shared knowledge of the symbol set and inter-symbol demarcation.

Some subsystems may themselves not be transparent and lose information, for example by merging symbols from multiple inputs. An example is shown in Figure A.6.

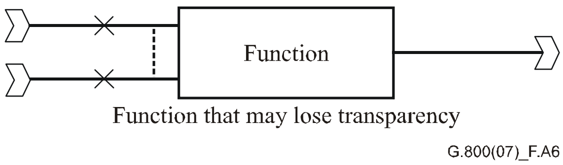


Figure A.6 – A system which loses information, for example by merging symbols from multiple input ports

A.3.3 Passing information to control an information system

As well as passing user information, information systems need to receive input information to construct, configure, and control its operation as well as issue output information for the construction, configuration and control of other information systems.

The distinction between input ports intended only to input user information from ports carrying construction, configuration and control information is shown in Figure A.7.

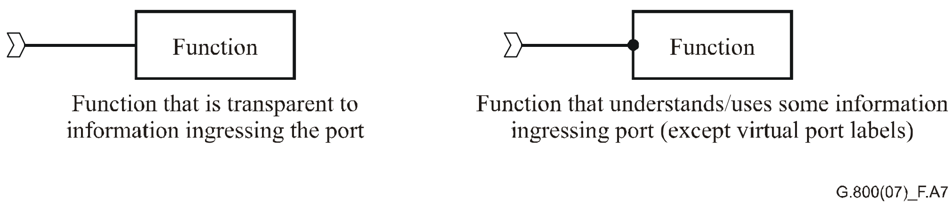


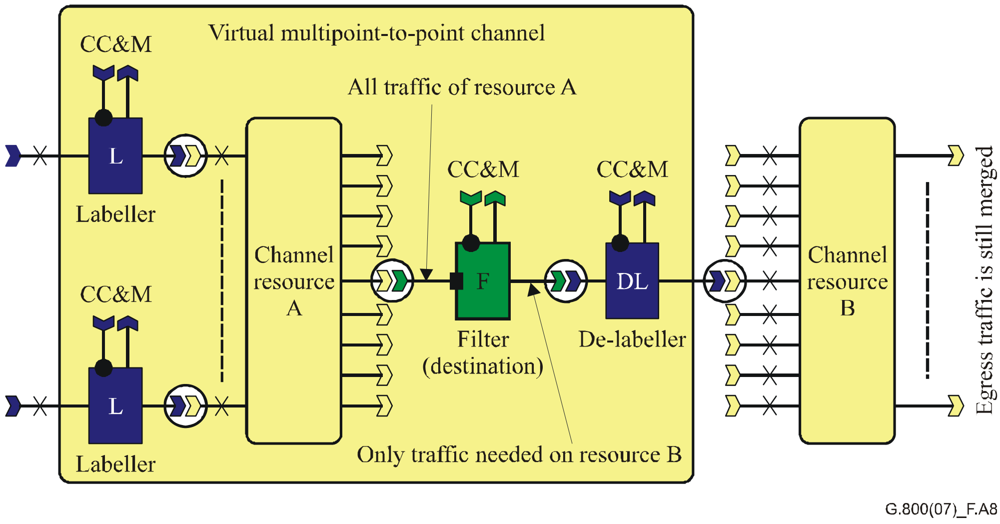
Figure A.7 – Inputs carrying user information and input ports carrying construction configuration and control information

A.3.4 Examples of forwarding and demerging

We can illustrate the use of the formal systems approach to two of the basic processes of the unified model – forwarding and demerging (i.e., demultiplexing).

A.3.4.1 Forwarding

The need for forwarding arises from the second axiom. As resources do not scale, it is necessary to filter only traffic which needs to use a resource onto the resource. Figure A.8 shows the basic operation of labelling and filtering which achieves this forwarding process when based on a multipoint-to-multipoint broadcasting channel.



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NOTE – It is possible to the scope of labelling to extend over more than one channel resource.

Figure A.8 – Forwarding using a multipoint-to-multipoint channel resource

A.3.4.2 Demerging

The demerging process is required to recover individual sequences of symbols after they have been merged with other sequences of symbols. The individual sequences must be labelled in order to overcome the loss of information inherent in the merging.

In the case where the information instance is an open sequence of symbols, the demerging process results in the construction of a point-to-point connection.

This is illustrated in Figure A.9 below.

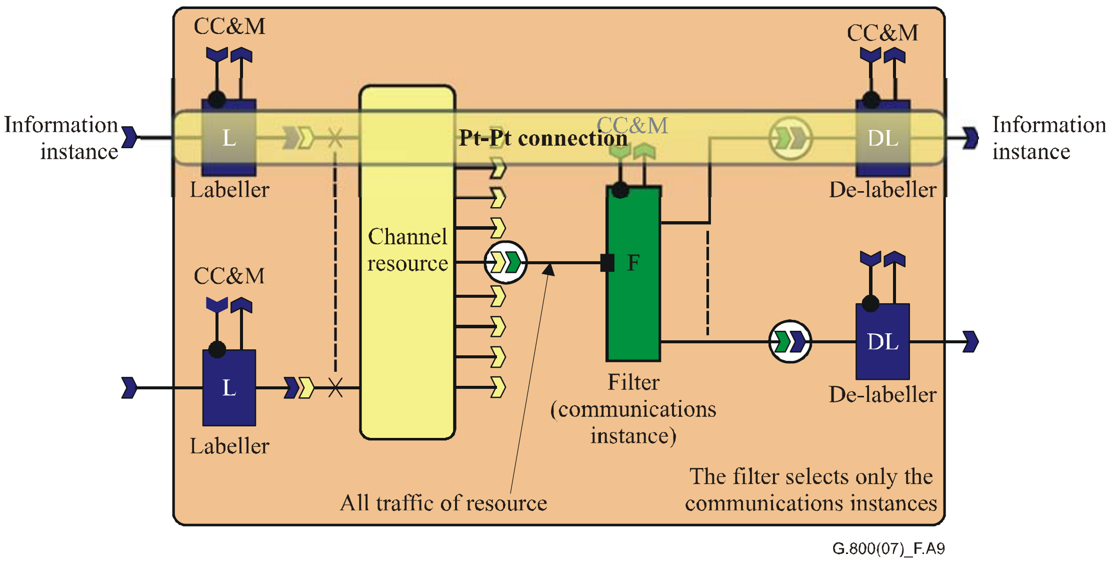

Figure A.9 – Demerging and the construction of a point-to-point connection

A.3.4.3 Connection oriented and connectionless examples

In the above examples, a new channel function has been constructed by the configuration of labelling and filtering. In connection-oriented networks, the multipoint-to-point channels and the point-to-point connections are formed by the above construction processes as enduring constructions. In the case of connectionless networks, some of the channels are transient and only last for the duration of the connectionless packet. However, in both cases, symbols ultimately are transferred using channel forwarding within channels that are constructed by the configuration of labelling and filtering.

Appendix I

Use of identifiers

(This appendix does not form an integral part of this Recommendation)

I.1 Use of identifiers

At the boundary of the layer network, the termination function adds the required fields to the AI symbol presented at the access point to allow this layer network to insert the identifiers that it requires. Note that in some cases, the encoding of the resource label is provided by the characteristics of the server layer network, e.g., a timeslot in a SDH frame.

The text below describes the insertion, removal and use of each identifier with the assumption that each identifier is encoded into an independent field in the layer network LI. In most practical layer networks, the same label field within the LI is reused for several purposes. In general, any identifier with a scope that is equal to or greater than the scope required for the purpose may be reused. When an existing identifier is reused, the insertion process is null and the removal process is implemented as a read.

Resource label: This is used to deliver symbols between the ingress and egress forwarding points in the context of a link. It is injected by the client to server adaptation function[5] at the ingress link point and removed by the server to client adaptation at the egress link point. It allows the symbols to be delivered to the correct egress forwarding point. The scope of this identifier must be (at least) the link point on the subnetwork and must be large enough to distinguish all of the link connections that appear within that link point.

NOTE 1 – Examples of a resource label are: a timeslot in SDH, an ATM VPI or VCI.

Forwarding point identifier: This identifier is used by the forwarding function in a subnetwork to deliver a symbol from the ingress point to the egress point (or points) of the forwarding relationship. Note that the resource label of the link connection is commonly used for this identifier.

Forwarding identifier: This identifier is inspected at the ingress of a forwarding relationship. It provides an index to an entry in the forwarding table (within the forwarding function) that identifies the target egress FwP (or FwPs). Typically a forwarding identifier that targets a specific access point (or set of access points) is used. The message could be broadcast to all of the access points in the layer network and discarded if the destination does not match the target. However, this is an inefficient use of the layer network resources. The path that a specific message (communication) will take across the network is not pre-provisioned for each (potential) communication. The commonly used forwarding identifier is an address (with network wide scope). However, it is also possible to use a sequence of next hops (e.g., egress link point). These semantics impart different network properties. For example, if an address is used, even under fault conditions, delivery may still be possible and misdelivery is impossible. A sequence of next hops does not have these properties.

The forwarding identifier may also include other information that is encoded in the LI, e.g., type of application, QoS/Priority.

Address: This has a network wide scope and identifies the destination access point. This identifier is carried within the LI and is inserted by the termination at the ingress to the layer network.

NOTE 2 – In general, the address is a subset of the information contained in the connectivity label.

NOTE 3 – This may be via a gateway if address translation is used along the path.

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5 In some cases, the value of the resource label value may be modified by an intra layer transport processing function.

NOTE 4 – A multicast address is an alias to a set of destinations. A destination may appear in more than one multicast address group, also the composition of a multicast address group may change.

Sequence of next hops: Each entry (i.e., link point and forwarding point) in the list has limited scope (target subnetwork) and is carried by the LI. It is inserted by the termination at the ingress to the layer network as an explicit route, i.e., a sequence of the subnetworks that the message will transit.

– The next hop may only define the egress link point, this allows the selection of a specific forwarding point to be determined locally.

– In hybrid cases, the LI may contain both the destination address and the "next hop" or "sequence of hops" to allow intermediate nodes to compute the path.

Communication instance identifier: The instantiation of this identifier can be split into two cases depending on the topology:

– Point-to-point: The topology of the forwarding relationship provides a 1:1 relationship between the source and destination. Therefore, communication instance can be identified by the relationship between the access points in the control/management plane. The communication instance identifier need not be present in the LI.

– Multipoint-to-point or multipoint-to-multipoint: The connectivity of the forwarding relationship provides an n:1 relationship between the source and destination access points. This arrangement does not allow a specific source to be identified. Therefore, the transport plane must carry a connectivity label. Typically the transport plane identifier for the source and destination access points are used for this purpose. However, an explicit route (to the destination) and a source access point identifier may also be used.

NOTE 5 – In the case of MPLS, since communications from multiple sources may share the same mp2p forwarding relationship and a link scope resource label is used, the connectivity label is not supported.

Access point identifier: This identifier is used by both the client layer and the server layer. The client layer uses the access point identifier to indicate to the server layer the intended destination for the communication.

Use of the access point identifier within a layer network can be split into two cases depending on the type of forwarding used:

– Channel forwarding: The access point identifier is only used by the routing process in the control/management plane to configure the channel forwarding relationship. It need not be represented as a label in the LI.

– Destination forwarding: The transport plane identifier for the destination access point is used in different ways: As (part of) the connectivity label and either, (part of) the forwarding identifier; or to compute a route from the source. This identifier must be passed to the server layer as a parameter across the access point along with the AI symbol.

Appendix II

Relationships between architectural entities

(This appendix does not form an integral part of this Recommendation)

This appendix describes the relationships between architectural entities described in this Recommendation, in [ITU-T G.805] and [ITU-T G.809]. These are described in Table II.1.

Table II.1 – Relationships between architectural entities in G.800, G.805 and G.809

Unified architecture (G.800)	**G.809**	**G.805**
Topological Components:		
Layer Network	Layer Network	Layer Network
Subnetwork	Flow Domain	Subnetwork
Link	Flow Point Pool Link	Link
Access Group	Access Group	Access Group
Transport Entities:		
Access Relationship	Connectionless Trail	Trail
Channel Forwarding Relationship (single source)	Flow Domain Flow	Subnetwork Connection
Channel Forwarding Relationship (multiple sources)	Flow Domain Flow	Not Applicable
Destination Forwarding Relationship	Flow Domain Flow	Not Applicable
Link Connection	Link Flow	Link Connection
Transport Processing Functions:		
Adaptation	Adaptation	Adaptation
Termination	Flow Termination	Trail Termination
Layer Processor	Not described	Not described
Forwarding	Not described	Not described
Reference Points:		
Access point	Access Point	Access Point
Forwarding Point	Flow Point	Connection Point
Forwarding End Point	Termination Flow Point	Termination Connection Point

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