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**Amendment 2**  
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SERIES G: TRANSMISSION SYSTEMS AND MEDIA,  
DIGITAL SYSTEMS AND NETWORKS

Data over Transport – Generic aspects – Transport  
network control aspects

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Common control aspects

**Amendment 2**

Recommendation ITU-T G.7701 (2016) – Amendment 2

ITU-T



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**TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS**

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# Recommendation ITU-T G.7701

## Common control aspects

### Amendment 2

#### Summary

Recommendation ITU-T G.7701 describes concepts that are common to both software defined networking (SDN) controller and automatically switched optical network (ASON) control approaches, including common aspects of the interaction between the control functions, management functions and transport resources.

#### History

| Edition | Recommendation             | Approval   | Study Group | Unique ID*  |
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#### Keywords

ASON, control components, management-control continuum, transport SDN.

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# Recommendation ITU-T G.7701

## Common control aspects

### Amendment 2

*Editorial note: This is a complete-text publication. Modifications introduced by this amendment are shown in revision marks relative to Recommendation ITU-T G.7701 (2016) plus its Amendment 1.*

#### 1 Scope

This Recommendation describes concepts that are common to both software defined networking (SDN) controller [ITU-T G.7702] and automatically switched optical network (ASON) control [ITU-T G.8080] approaches. This encompasses common aspects of:

- transport resources and their representation;
- control components used to describe architecture for application of SDN and ASON to the control of transport resources;
- control communication aspects;
- common management aspects of common control components;
- identifiers with respect to naming and addressing, which involves separation of identity from location.

#### 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.698.1] Recommendation ITU-T G.698.1 (2009), *Multichannel DWDM applications with single-channel optical interfaces.*
- [ITU-T G.698.2] Recommendation ITU-T G.698.2 (2009), *Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces.*
- [ITU-T G.800] Recommendation ITU-T G.800 (2016), *Unified functional architecture of transport networks.*
- [ITU-T G.805] Recommendation ITU-T G.805 (2000), *Generic functional architecture of transport networks.*
- [ITU-T G.872] Recommendation ITU-T G.872 (~~2017~~2019), *Architecture of optical transport networks.*
- [ITU-T G.7702] Recommendation ITU-T G.7702 (2018), *Architecture for SDN control of transport networks.*
- [ITU-T G.7710] Recommendation ITU-T G.7710 (~~2019~~20), *Common equipment management function requirements.*

- ~~[ITU-T G.7718] Recommendation ITU-T G.7718 (2020), *Framework for the management of MCmanagement-control components and function.*~~
- [ITU-T G.7711] Recommendation ITU-T G.7711/Y.1702 (~~2015~~2018), *Generic protocol-neutral information model for transport resources.*
- [ITU-T G.7712] Recommendation ITU-T G.7712/Y.1703 (2010), *Architecture and specification of data communication network.*
- [ITU-T G.7714.1] Recommendation ITU-T G.7714.1/Y.1705.1 (~~2015~~2017), *Protocol for automatic discovery in transport networks.*
- [ITU-T G.8080] Recommendation ITU-T G.8080/Y.1304 (2012), *Architecture for the automatically switched optical network.*
- [ITU-T M.3100] Recommendation ITU-T M.3100 (2005), *Generic network information model.*
- [ITU-T Q.2982] Recommendation ITU-T Q.2982 (1999), *Broadband integrated services digital network (B-ISDN) – Digital subscriber signalling system No. 2 (DSS2) – Q.2931-based separated call control protocol.*
- [ITU-T X.731] Recommendation ITU-T X.731 (1992), *Information technology – Open Systems Interconnection – Systems management: State management function.*
- [ITU-T Y.3300] Recommendation ITU-T Y.3300 (2014), *Framework of software-defined networking.*
- ~~[ITU-T G.7710] Recommendation ITU-T G.7710 (2019), *Common equipment management function requirements.*~~
- ~~[ITU-T G.7718] Recommendation ITU-T G.7718 (2020), *Framework for the management of MC components and function.*~~

### 3 Definitions

#### 3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

- 3.1.1 access point:** [ITU-T G.800].
- 3.1.2 adaptation:** [ITU-T G.800].
- 3.1.3 characteristic information (CI):** [ITU-T G.800].
- 3.1.4 connection:** [ITU-T G.800].
- 3.1.5 data communications network:** [ITU-T G.7712].
- 3.1.6 forwarding point (FP):** [ITU-T G.800].
- 3.1.7 layer network:** [ITU-T G.805].
- 3.1.8 link:** [ITU-T G.805].
- 3.1.9 link connection:** [ITU-T G.805].
- 3.1.10 logical termination point:** [ITU-T G.7711].
- 3.1.11 software defined networking:** [b-ITU-T Y.3300].
- 3.1.12 subnetwork:** [ITU-T G.805].
- 3.1.13 subnetwork connection:** [ITU-T G.805].
- 3.1.14 trail:** [ITU-T G.805].
- 3.1.15 transitional link:** [ITU-T G.800].

## 3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

**3.2.1 address:** A string of symbols that is valid regardless of the location of the source but changes if the destination moves. An address is used for the purpose of routing. Source and destination addresses must be globally unique.

**3.2.2 administrative domain:** A type of domain that belongs to a single entity such as a network operator, a service provider or an end-user.

**3.2.3 allocated (resource) label range:** The set of labels that can be used by the adaptation function of a particular link to carry user traffic. It is a subset of the potential resource label range. The allocated labels are entities that can be referenced in the transport resource name space. Each allocated label is associated with one or multiple subnetwork point (SNP) IDs that exist in the control component name space (1:n relationship). Termination and adaptation performers (TAPs) hold this binding information.

**3.2.43 boundary resource identifier (BRI):** Used at a domain boundary to identify both the transport resources, and the interface(s) between control components, at that boundary.

**3.2.54 call:** An association between two or more users and one or more domains that support an instance of a service through one or more domains. Within domains, the association is supported by network entities that contain call state. Between a user and a network call control entity and between network call control entities, there are call segments. The call consists of a set of concatenated call segments.

**3.2.65 call admission control:** A policy function invoked by an originating role in a network and may involve cooperation with the terminating role in the network.

**3.2.7 call control:** A signalling association between one or more user applications and the network to control the set-up, release, modification and maintenance of sets of connections.

**3.2.86 call controller:** Calls are controlled by means of call controllers. There are two types of call controller components.

**3.2.97 calling/called party call controller:** The control component associated with an end of a call and may be co-located with end systems or located remotely and acts as a proxy on behalf of end systems. This controller acts in one or both of two roles, one to support the calling party and the other to support the called party.

**3.2.108 call segment:** An association between two call control entities (as per [ITU-T Q.2982]). Each call segment has zero or more associated connections. Call segments between network call control entities have zero or more supporting calls.

**3.2.119 component:** An abstract representation of a functional entity. In this Recommendation, components do not represent instances of implementation code. They are used to construct scenarios to explain the operation of the architecture.

**3.2.120 component interface:** Interfaces that represent the logical relationships between control components and are defined by the information flow between these entities.

NOTE – Such a relationship allows for choice in selection of potentially exposable interfaces in support of different equipment implementations and network architectures.

**3.2.13 configured (resource) label:** A transport resource label that has been configured in support of a connection. For each configured label, a forwarding table entry exists on the receiving end of the link such that packets can be forwarded based on the label value of the received packet.

**3.2.141 connection admission control:** A process that determines if there are sufficient resources to admit a connection (or re-negotiates resources during a call).

**3.2.152 connection controller (CC):** The control component responsible for coordination among the link resource manager, the routing controller and both peer and subordinate connection controller components for the purpose of the management and supervision of connection setups, releases and the modification of connection parameters for existing connections.

**3.2.163 control domain:** A type of domain that represents the scope of control over a collection of resources allocated to that domain as determined by a set of functions from the management-control continuum.

3.2.17 discovery agent (DA): The "federation" of discovery agents operates in the transport resource name space, and provides for separation between that space and the control component name space. The federation has knowledge of forwarding points (FPs) in the network, while a local DA has knowledge of only those FPs assigned to it.

**3.2.1418 domain:** Represents a collection of resources that are grouped for a particular purpose. Domains of the same type do not overlap among themselves, but a hierarchical containment relationship of domains is possible.

NOTE – In general, resources may be considered to encompass compute, networking, and storage.

3.2.19 link resource manager (LRM): A component responsible for the management of a subnetwork point pool (SNPP) link, including the allocation and un-allocation of subnetwork point (SNP) link connections, managing resource reservation, the configuration of policing and shaping functions via the termination and adaptation performer (TAP) (if required), providing topology and status information.

**3.2.1520 network call controller (NCC):** A control component providing three roles, one for support of the calling party, another to support the called party and a third to support calls across domain boundaries.

3.2.21 node: In the context of this Recommendation, the term "node" is used to signify a subnetwork or a routing area.

**3.2.1622 policy:** The set of rules selected from among alternatives and in the light of given conditions to guide and, usually, to determine present and future decisions.

3.2.23 port controller: A class of component that implements the set of rules applied to a system.

3.2.24 potential (resource) label range: Full label range of resource labels in the transport resource name space that an adaptation function supports to distinguish different information flows.

3.2.25 potential subnetwork points (SNPs): Those SNPs that are associated with a (resource) label.

3.2.26 protocol controller (PC): A component, which provides the function of mapping the parameters of the abstract interfaces of the control components into messages that are carried by a protocol to support interconnection via an interface. Protocol controllers are a sub-class of policy ports.

3.2.27 provisioning: The act of specifying the parameters necessary when assigning/deassigning network resources to/from the management and control (MC) component or to invoke/remove services provided by a MC component instance. These parameters are specific to a resource or service request, causing changes to these parameters to only impact a specific resource or service request. Therefore, provisioning is allowed in the initialization and operations phases of the MC component lifecycle.

**3.2.1728 recovery domain:** A type of control domain whose purpose is assuring the reliable transfer of information across the resources allocated to that domain.

NOTE – Approaches to support reliable transfer of information may include, e.g., protection, distributed or centralized restoration, etc. A pre-condition for establishing a recovery domain is that there are sufficient

network resources in the domain to maintain a specified level of reliability for the selected approach(es). In multi-layer transport networks, a recovery domain in a client layer network must fully contain any recovery domains in the server layer networks that it uses.

**3.2.1829 resource database (RDB):** A logical entity that holds (makes available) information that components use for their operations. Related components share the same RDB.

**3.2.1930 route:** A sequence of the artefacts representing the transport resources (i.e., SNPs, SNPPs, and routing areas) that support, or are intended to support, a connection.

**3.2.31 routing:** A control function used to select paths for the establishment of connections through one or more operator networks.

**3.2.2032 routing area (RA):** An instance of a routing domain, and is defined by a set of subnetworks, the SNPP links that interconnect them, and the SNPPs representing the ends of the SNPP links exiting that routing area. A routing area may contain smaller routing areas interconnected by SNPP links. The limit of subdivision results in a routing area that contains a subnetwork.

**3.2.2133 routing controller (RC):** A control component with the roles to:

- respond to requests for path (route) information needed to set up connections. This information can range from end-to-end path details to a next hop. The route can be computed by one or more cooperating RCs;
- respond to requests for topology (SNPs and their abstractions) information for management-control continuum purposes.

**3.2.2234 routing level:** A relationship between a routing area (RA) and a containing RA or contained RAs. The containment hierarchy of routing areas creates routing levels.

**3.2.2335 routing domain:** A type of control domain whose purpose is routing across the collection of resources allocated to that domain.

**3.2.2436 service level agreement:** A contract between two parties such as a service provider and a customer. It defines the services available to the customer, and the grade of service of those services as offered to the customer. It also usually describes the service guarantee and potential penalties in case of service degradation or failure.

**3.2.37 subnetwork point pool (SNPP) alias:** An alternate SNPP name for the same SNPP link that is generated from another SNPP name space.

**NOTE –** If present in a routing area, it is available to the routing controller (RC) that is associated with the routing area (RA).

**3.2.38 Subnetwork point (SNP) identifier:** An instance of an identifier for an SNP.

**NOTE –** A subnetwork point (SNP) identifier is used for link connection assignment and, in some cases, routing. The SNP identifier is derived from the subnetwork point pool (SNPP) identifier concatenated with a locally significant SNP index. When the identifier is routable, it is an SNPP address. When it is not routable, the identifier is an SNP name.

**3.2.39 subnetwork point pool (SNPP) identifier:** An instance of an identifier for an SNPP.

**NOTE –** When the identifier is routable, it is an SNPP address. When it is not routable, the identifier is an SNPP name. The constituents of an SNPP identifier may include routing area (RA) identifiers, a subnetwork identifier and resource context identifiers.

**3.2.4025 subnetwork point (SNP):** A control abstraction that represents an actual or potential underlying forwarding point (FP) or forwarding end point (FwEP) (see [ITU-T G.800]). Several SNPs (in different VNs) may represent the same FP or FwEP.

**3.2.4126 subnetwork point pool (SNPP):** A set of SNPs that are grouped together.

**NOTE –** An SNPP usually represents a link end. An SNPP may be further subdivided (sub-structured) into smaller pools.

**3.2.42 subnetwork point pool link (SNPP link):** An association between [subnetwork point pools \(SNPPs\)](#) on different subnetworks.

**3.2.43 termination and adaptation performer (TAP):** A component [that provides the link resource manager \(LRM\) with a control view \(in the subnetwork point \(SNP\) name space\) of the adaptation and termination functions \(in the forwarding point \(FP\) name space\), and abstracts any hardware and technology-specific details.](#)

**3.2.44 transitional SNPP link:** A [subnetwork point pool \(SNPP\) link with an SNPP in a subnetwork in one layer, and an SNPP in a subnetwork of a different layer. It may also be an SNPP link with an SNPP in a subnetwork in one sublayer and an SNPP in a subnetwork of a different sublayer, where both sublayers are in the same layer.](#)

**3.2.2745 virtual network (VN):** A designated subset of abstracted network resources.

NOTE – The network resources in the VN may be at different levels of abstraction and may correspondingly use identifiers from different name spaces.

## 4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

[AGC](#) — [Access Group Container](#)

ASON Automatically Switched Optical Network

BRI Boundary Resource Identifier

~~CallC~~ — ~~Call Controller~~

CAC Connection Admission Control

CC Connection Controller

CCC Calling/called party Call Controller

CCI Connection Controller Interface

CCN Control Communications Network

CI Characteristic Information

CIR Committed Information Rate

cFP Client Forwarding Point

[CoS](#) — [Class of Service](#)

CTP Connection Termination Point

DA Discovery Agent

DCN Data Communication Network

DM Discovery Message

EMS Element Management System

[E-NNI](#) — [External Network-Network Interface](#)

[FEF](#) — [Fault Event Filtering](#)

[FRM](#) — [Fault Reporting Management](#)

FP Forwarding Point

FwEP Forwarding End Point

[GFP](#) — [Generic Framing Procedure](#)

|                |  |
|----------------|--|
| IM             | Information Model                          |
| <u>I-NNI</u>   | <u>Internal Network-Network Interface</u>  |
| LRM            | Link Resource Manager                      |
| LP             | Layer Protocol                             |
| LTP            | Logical Termination Point                  |
| <u>MC</u>      | <u>Management and control</u>              |
| <del>MCC</del> | <del>Management Control Continuum</del>    |
| MCS            | <u>Management and Control System</u>       |
| MPLS           | Multiprotocol Label Switching              |
| NCC            | Network Call Controller                    |
| NE             | Network Element                            |
| NMS            | Network Management System                  |
| OAM            | Operations, Administration and Maintenance |
| OCN            | Overhead Communications Network            |
| OSS            | Operations Support System                  |
| OTN            | Optical Transport Network                  |
| OTSi           | Optical Tributary Signal                   |
| OTSiA          | Optical Tributary Signal Assembly          |
| PC             | Protocol Controller                        |
| PDP            | Policy Decision Point                      |
| PEP            | Policy Enforcement Point                   |
| PIR            | Peak Information Rate                      |
| RA             | Routing Area                               |
| RC             | Routing Controller                         |
| RDB            | Resource Database                          |
| SDN            | Software Defined Networking                |
| sFP            | Server Forwarding Point                    |
| SNC            | Subnetwork Connection                      |
| SNP            | Subnetwork Point                           |
| SNPP           | Subnetwork Point Pool                      |
| TAP            | Termination and Adaptation Performer       |
| TTP            | Trail Termination Point                    |
| UML            | Unified Modelling Language                 |
| UNI            | User-Network Interface (reference point)   |
| <u>VC</u>      | <u>Virtual Container</u>                   |
| <u>VCAT</u>    | <u>Virtual Concatenation</u>               |
| VN             | Virtual Network                            |

## 5 Conventions

This Recommendation uses the diagrammatic conventions defined in [ITU-T G.800] to describe the transport resources.

## 6 Overview

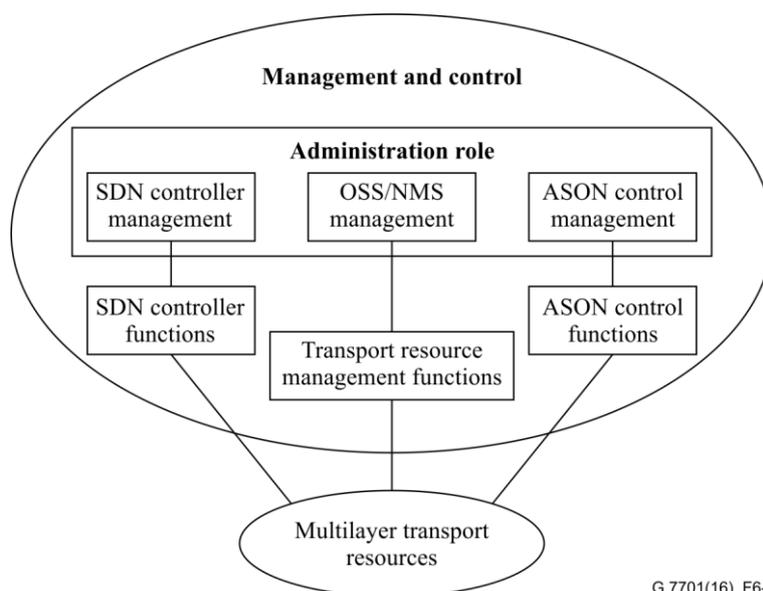
Considering connection management, network management, ASON control, and SDN controllers all perform the same operations on the transport resources. The distinctions among these approaches are based upon variations that may exist in the degree of automation (high human intervention to none), distribution of their implementation (centralized versus fully or partially distributed), and exposure of interfaces (closed versus open). However, the transport resources themselves make no distinctions based upon how the connection management function is performed but simply respond to the functions operating on them and report changes (via notifications).

The concept whereby management and control (MC) functions are considered to be a continuum is known as the management-control continuum (MCC); i.e., it expresses the view that ~~management and control~~ MC functions are essentially the same and, thus, they can be grouped into one set of MCC functions.

In the management-control continuum MCC, interfaces between functions may be exposed when resources are placed into adjacent domains, when an automated interface to users is desired, when a connection management function operates on a multi-vendor set of resources, as well as other factors.

Figure 6-1 illustrates the management-control continuum MCC concept and its relationship with transport resources, whereby ~~management and control~~ MC functions operate on transport resources and receive state information about resources. Transport resource management functional areas are identified in [ITU-T M.3010] as: performance management, fault management, configuration management, accounting management and security management.

The ~~management and control~~ MC functions themselves require management, depicted as the administration role functions in Figure 6-1. SDN controller management provides the ability to configure SDN controllers. ASON control management provides for management of control components such as the routing controller (RC) component. For network management, this role provides the ability for configuration and management of operations support system (OSS)/network management system (NMS)/element management system (EMS).

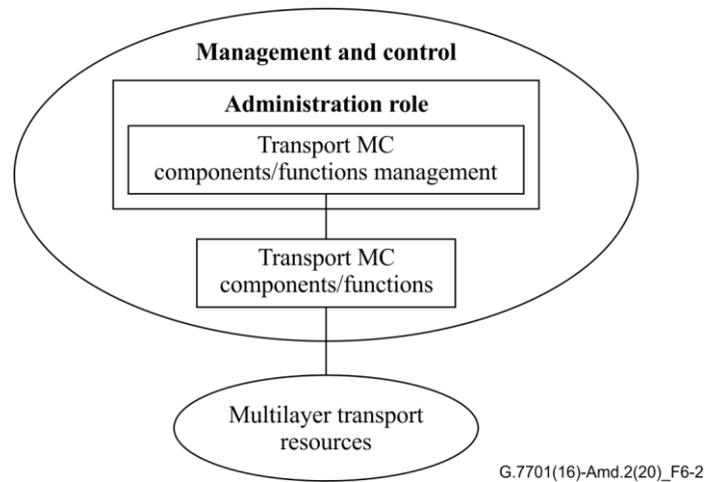


**Figure 6-1 – Management-control continuum**

Not shown is the data communications network (DCN), which provides the communication paths to carry, e.g., ASON control, SDN controller, and management information communications. The details of the DCN, management functions, and transport resources are specified in other Recommendations and are outside the scope of this Recommendation.

Network resources may be partitioned among those under the authority of management systems, those under the authority of the SDN controllers, and those under the authority of the ASON control. Once a subset of the resources is assigned to a particular MCC instance (e.g., ASON control), other MCC instances (e.g., SDN controller) cannot modify these resources.

This includes transport network resources not currently in use, but reserved for future use (e.g., by network planners). As such, transport resource partitioning is performed by the management function and thus, is outside the scope of this Recommendation.



**Figure 6-2 – Transport management and control system (MCS)**

Figure 6-2 shows the transport management-control continuum concept in a general way. In Figure 6-2, transport MC components/functions cover the SDN controller functions, transport resource management functions and ASON control functions. The transport MC components/functions management covers SDN controller management, OSS/NMS management, ASON control management.

## 7 Transport resources and their representation

The transport network is a large, complex network with various components, and an appropriate network model with well-defined, technology agnostic, functional entities is essential for its design, control, and management. The transport network can be described by defining the associations between points in the network. The resultant logical network topology allows the separation between logical connections and the physical routes and resources used.

### 7.1 Transport functional architecture

The functional architecture of the transport network describes the way that the transport resources are used to perform the basic transport functions in a manner that makes no reference to the control and management of those functions. As described in [ITU-T G.805] and [ITU-T G.800], in order to simplify the description, the functional architecture utilizes the concepts of layering and partitioning within each layer network in a manner that allows a high degree of transport network recursion.

- a layer network describes the generation, transport and termination of a particular characteristic information (CI). Layering enables decomposition of a transport network into a number of independent transport layer networks. There is a client/server relationship

between each of these layer networks where the client refers to the signal being carried, and the server refers to the layer network providing its transport. The client/server paradigm is recursive because any particular server layer could itself be a client of another server layer.

- partitioning is the division of a larger subnetwork into disjoint subnetworks that are interconnected by links. Because the model requires partitions to be nested, partitioning is also recursive.

The components of the transport network architectural model can be divided into three groups: topological components, transport processing functions, and transport entities.

- 1) topological components: Provide a description of a transport network in terms of the relationship between sets of forwarding points (FPs) within a layer network. These encompass, for example, layer network, subnetwork, link (including transitional link), access group.
- 2) transport processing functions: Are used to model the processes implemented in equipment that manipulate the information that is being transferred across the transport network. These include, for example, adaptation, (trail) termination, layer processor, forwarding.
- 3) transport entities: Provide the means to transfer information across the transport network between forwarding points. Transport entities are configured within topological components. These encompass, for example, forwarding relationship, subnetwork transport entity, connection, link connection.

The optical transport network (OTN) has both digital layers and a media layer. The control of optical signals and the media layer must take into account the limitations imposed by the accumulation of analogue impairments within the media. Many of these impairments and the magnitude of their effects are associated with particular technological implementations and the network topology. Annex A provides some clarification on the control of the OTN media layer.

## 7.2 Domains

ASON control and SDN controller deployments will occur within the context of network operator business practices and the multi-dimensional heterogeneity of transport networks. These business and operational considerations lead to the need for architectural support of, for example, strong abstraction barriers to protect commercial business operating practices, segmenting transport networks into domains according to managerial and/or policy considerations, and inherent transport network heterogeneity (including control and management).

The domain notion referred to is the generalization [ITU-T G.8080] of the [ITU-T G.805] definition of administrative domain and the Internet administrative regions (e.g., autonomous systems) to express differing administrative and/or managerial responsibilities, trust relationships, addressing schemes, infrastructure capabilities, survivability techniques, distributions of control functionality, etc. Domains are established by operator policies and have a range of membership criteria, as exemplified above.

The scope (or boundary) of a domain is defined for a particular purpose, and domains defined for one purpose need not coincide with domains defined for another purpose. Domains that have been defined for the same purpose are restricted in that they do not overlap; however, they may:

- fully contain other domains that have been defined for the same purpose;
- border each other;
- be isolated from each other.

Examples of domains include administrative domains, control domains, routing domains, and recovery domains. Resources may be shared among domains of the same type; an example of this is the shared resources in a virtual network (VN), as described in clause 7.4.

The current assumption is that a control domain must be contained in an administrative domain. Investigation of a peer relationship between control domains that are in different administrative domains is for further study.

A control domain is comprised of a collection of MC components and functions, and provides an architectural construct that encapsulates and hides the detail of a distributed implementation of a particular group of architectural components of one or more types. It allows for the description of a group of distributed components in such a way that the group can be represented by distribution interfaces on a single entity, the domain, that has identical characteristics to that of the original component distribution interfaces. The nature of the information exchanged between control domains captures the common semantics of the information exchanged between component distribution interfaces, while allowing for different representations inside the domain.

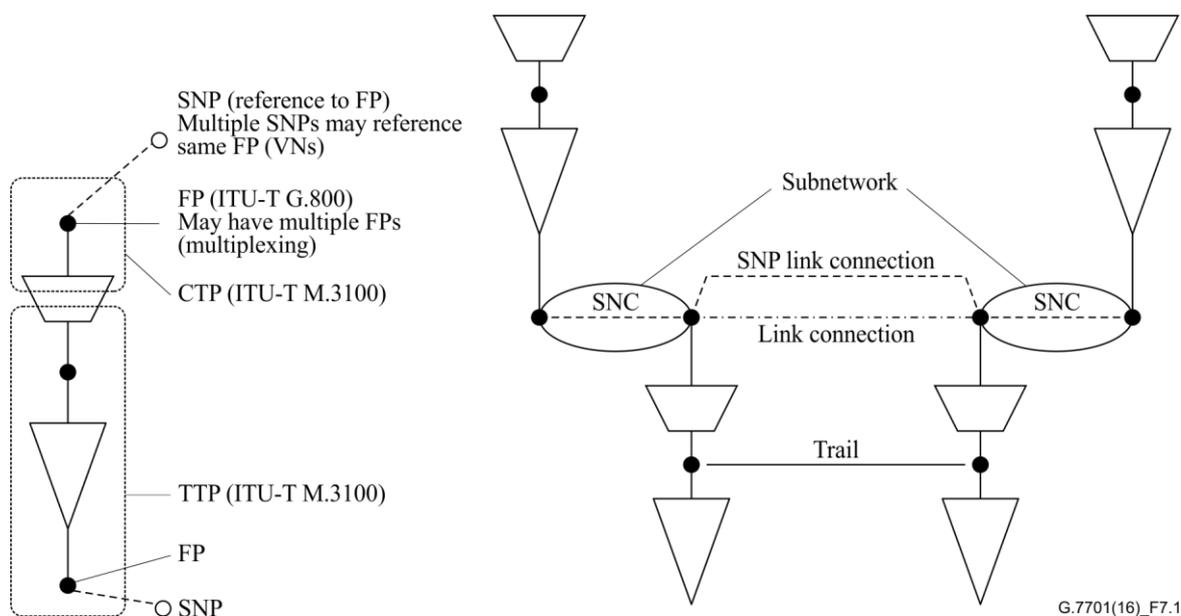
Generally, a control domain is derived from a particular MC component type, or types, that interact for a particular purpose. For example, routing domains are derived from routing controller components whilst a re-routing domain is derived from a set of connection controller and network call controller components that share responsibility for the re-routing/restoration of connections/calls that traverse that domain. In both examples the operation that occurs, routing or re-routing, is contained entirely within the domain. In this Recommendation, control domains are described in relation to MC components associated with a layer network.

Collections of MC components and functions may interact at reference points. These reference points include [ITU-T G.8080] UNIs, I-NNIs and E-NNIs and [ITU-T G.7702] CPIs. Control domains border each other at these reference points.

### **7.3 Control view of transport resources for connection management**

Connectivity is the basic service provided by a transport network. Connection management functions include: path computation, connection creation, connection modification, connection teardown, and configuration and activation of operations, administration and maintenance (OAM) and survivability mechanisms. These connection management functions could be operated under instructions from an SDN controller, management system, or ASON control.

The underlying transport resources used to support aspects of connection management to the SDN controller and ASON control functions are represented by a set of entities, termed subnetwork point (SNP) and subnetwork point pool (SNPP). The SNP and SNPP entities are organized into routing area (RA), subnetwork and link topological constructs which represent the view of the transport resources as seen by the SDN controller and ASON control components from a connection management perspective. Figure 7-1 illustrates the relationship of the SNP to the transport resources described in [ITU-T G.800] and, the entities that represent these resources from the perspective of network management (as described in [ITU-T M.3100]).



**Figure 7-1 – Relationship between architectural entities in the control-management continuum**

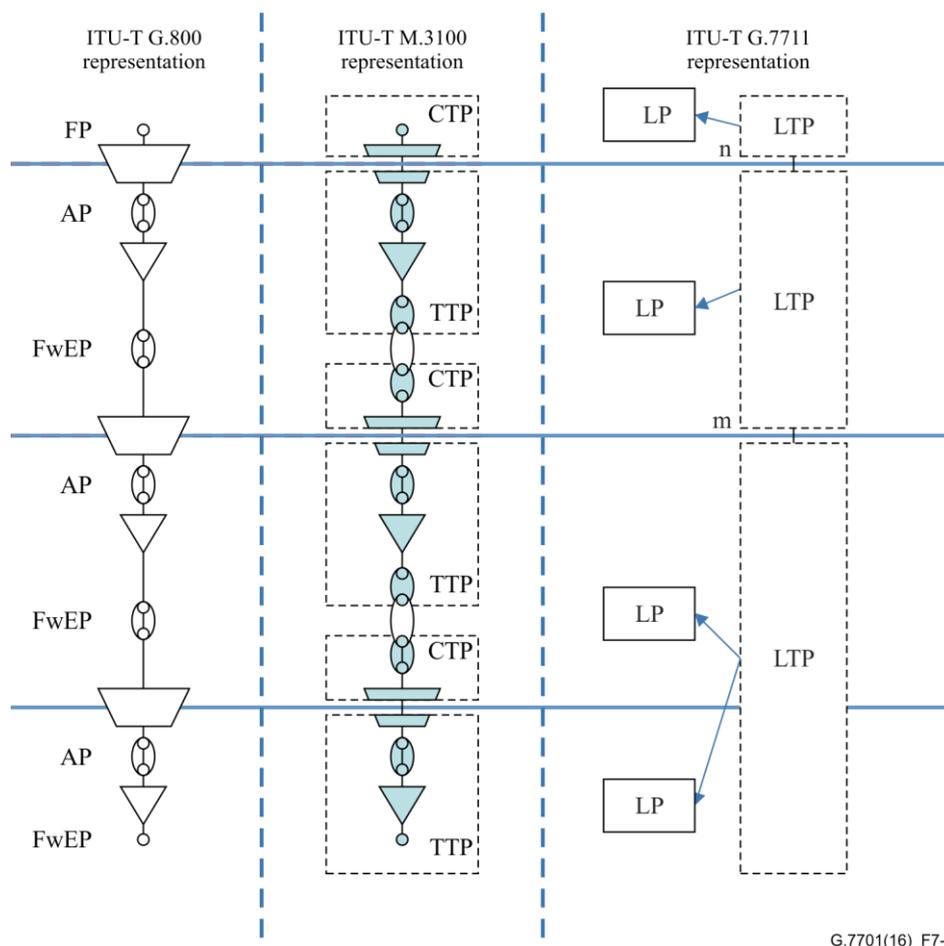
An SNP has a number of relationships with other SNPs:

- a static relationship between two SNPs in different subnetworks. This is referred to as an SNP link connection.
- a dynamic relationship between two (or more in the case of broadcast connections) SNPs at the boundary of the same subnetwork. This is referred to as a subnetwork connection (SNC).

An SNP may also be grouped with other SNPs for the purpose of routing. This is an SNPP and has a strong relationship with link ends; however, this relationship is more flexible than the link end. An SNPP may be further subdivided into smaller pools. One use of this sub-structuring is to describe different degrees of route diversity. For example, all the SNPs in one subnetwork that have a relationship to a similar group on another subnetwork may be grouped into a single SNPP. This SNPP may be further subdivided to represent diverse routes and further subdivided to represent, for example, individual wavelengths.

The association between SNPPs on different subnetworks is an SNPP link. An SNPP link where each subnetwork is in a different layer is known as a transitional SNPP link. It may also be an SNPP link in which the subnetworks are in different sublayers of the same layer. They only occur across boundaries between layers or sublayers where [ITU-T G.800] transitional links can exist.

Figure 7-2 illustrates the relationship between the transport resources described in [ITU-T G.800] and the entities that represent these resources from the perspective of network management as described in [ITU-T M.3100] and [ITU-T G.7711], respectively.



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**Figure 7-2 – Relationship of ITU-T G.800 architectural entities with their representation from a management perspective**

As may be seen from Figure 7-1 and Figure 7-2 (which provides a simplified version of Figure 5-2 of [ITU-T G.7711]), the logical termination point (LTP) is used to represent transport resources and the FP, forwarding end point (FwEP), and SNP reference points.

The implications on the SNP when it inherits properties from the resource is for further study.

#### 7.4 Virtualization

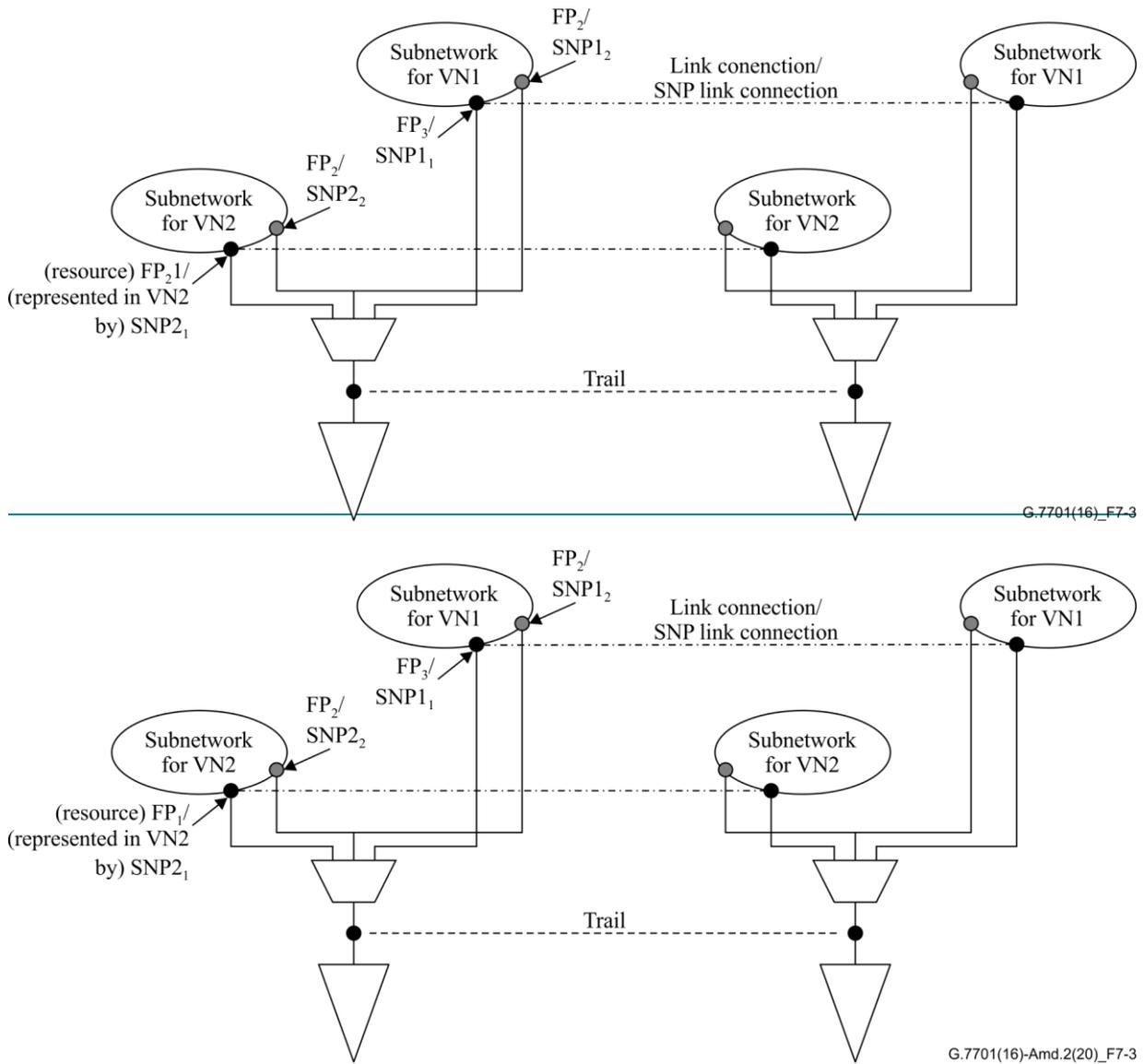
An abstraction is a representation of an entity in terms of selected characteristics, while hiding or summarizing characteristics irrelevant to the selection criteria. An abstraction may also use identifiers from a name space that is different from the name space of the resources that are being represented. A virtualization is an abstraction and subset whose selection criterion is dedication of resources to a particular client or application. A VN is an abstraction of a designated subset of [ITU-T G.800] layer network resources.

Connection routing in a VN can only use the SNPPs associated with that VN.

An FP can be assigned and allocated to only one VN; in this case the FP is represented by a single SNP (in the VN).

An FP can be assigned (but not allocated) to multiple VNs; in this case the FP is represented by multiple SNPs (one in each VN). Connectivity on a link that is shared between VNs is modelled by creating a (potential) SNP for each of the shared FPs in each VN. When an FP is allocated to a particular SNP in one VN, the SNPs referencing the same FP in other VNs become busy. This is illustrated in Figure 7-3 which shows an example of two VNs, each with two SNPs. The resources support three FPs, FP<sub>1</sub> is assigned to VN2 and is represented by SNP<sub>21</sub>, FP<sub>3</sub> is assigned to VN1 and

is represented by SNP1<sub>1</sub>, FP<sub>2</sub> is shared by VN1 and VN2, FP<sub>2</sub> is represented by SNP1<sub>2</sub> in VN1 and SNP2<sub>2</sub> in VN2.



**Figure 7-3 – Allocation of link resources between VNs**

During the operation of the network if FP<sub>2</sub> is allocated to VN1, SNP1<sub>2</sub> becomes available while SNP2<sub>2</sub> (in VN2) becomes busy.

A resource label is the information required to distinguish a communication within the context of other communications [ITU-T G.800] (an example of a resource label is a multiprotocol label switching (MPLS) label). The SNP references an FP that has a resource label. In the case where the resource label does not carry a resource reservation (e.g., packet switching, see clause 8.3.4), the connection request must include an explicit resource reservation.

## 7.5 Multi-layer aspects

For a multi-layer network, the topology and connectivity of the underlying server layer is not explicitly visible to the client layer, rather aspects of the server layer are encapsulated and presented to the client layer network. The server layer may be represented as a client layer SNPP link, or as client layer subnetworks interconnected by SNPP links. If the resources available to the client layer network are insufficient to support a connection request, additional resources may be provided by

activating or creating new connections in one or more server layer networks. Operator policies should govern the availability of underlying server layer resources to the client layer.

### **7.5.1 Representation as SNP link connections**

A planning process may cause a pair of access points in the server layer to be connected, this creates a client layer SNPP link that contains multiple SNP link connections for the supported client layers. The SNP link connections may initially be either active or potential, as the underlying resource may or may not be allocated for the exclusive use of the client layer (see clause 7.4).

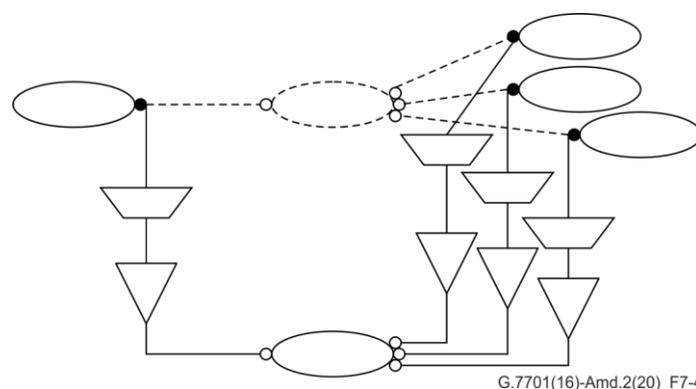
It may be applied recursively in multiple client/server layer networks. Thus, the connection between the pair of access points may be supported by potential link connections. The connection of the access points in the server layer is not activated until a request to use one of the potential client layer SNP link connections is received by the MCC component. At this time, the client layer request is "suspended" while the server layer connections are established. Once the server layer connections are in place, the client layer SNP link connections are made active, allowing the client layer signalling to resume. If a connection in the server layer cannot be established, the client layer SNP link connections cannot be made active, causing the client layer connection attempt to fail due to lack of resources.

When the SNP link connection is removed, the underlying resources that supported the connection are freed, allowing them to return to the potential state if allowed by policy. When all SNP link connections supported by a server trail return to the potential state, the server trail may be changed to potential if allowed by policy.

### **7.5.2 Representation as a set of SNPP links and subnetworks**

A planning process may also allow the client layer MC components more flexibility in the selection of the server layer resources to satisfy a connection request. To accomplish this, some of the server layer resources are represented to the client layer as SNPP links and subnetworks. The server layer flexibility and its corresponding client layer flexibility are shown in Figure 7-4. This enables the routing controller to know that a set of client layer SNPs can be reachable through a common server layer. That is, in Figure 7-4, absence of the server layer representation would not allow paths to be computed between all of the client layer SNPs.

The adaptation and termination functions used to transition from the client layer to the server layer are represented as SNPP links in the client layer. In this figure, the dashed elements are used to distinguish this representation of the server layer resources to the client layer from other client layer resources. Additionally, client and server layer SNPs are represented as small solid-line black and white circles, respectively; however, to the client layer routing controller, there is no distinction between the represented elements and the other client layer elements.



**Figure 7-4 – Relationship between client and server architectural elements**

As in the SNPP link representation, the SNP link connections connecting the client layer subnetwork to the server layer are potential, as the server layer resources have not been allocated for exclusive use to the client layer. When a connection request is received that utilizes a potential resource, a path through the server layer is calculated identifying the specific resources to be used. As a result of identifying these resources, client layer SNP link connections are created, and processing continues as above.

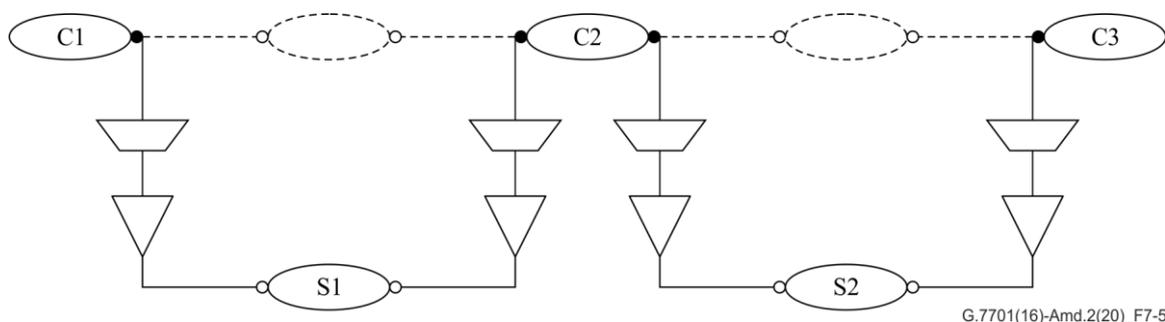
## **7.6 Interlayer client support**

In transport networks, resources from multiple layers may be present. For example, resources at the edge of the network may support the adaptation of service into a lower order virtual container (VC) whilst resources in the core of the network may only provide flexibility at the high order VC layer; or adaption of an Ethernet service into high order VCs at the edge. A general problem faced is how to transfer client characteristic information (CI) when a continuous/connected client layer network is not present between two client access group containers (AGCs).

There are two solutions to this problem. Either client layer topology may be created from server layer connections as described in clause 7.5 or, the client CI could be adapted, possibly multiple times, onto server layer connections. This would not be visible to the client routing controller.

Interfaces between network call controllers (NCCs) (see clause 8.3.1) in different layer networks are used in the second solution. This interlayer interface enables an association between calls in a client/server layer relationship. This association can recur to mirror a set of "stacked" adaptations. That is, the NCCs recur with ITU-T G.800 layers. NCCs at different layers may still be instantiated differently from each other. For example, an NCC could be distributed at a client layer and centralized at a server layer in an ASON architecture. In an SDN architecture, it may be in several controllers with client layer scope and in one controller with server scope, or vice versa. A server layer CC creates the connection(s). The client CI is mapped to the server layer connection and this association is maintained by the client/server NCC relationship. In this situation, a client layer link connection is created as a result of the server layer connection and CI mapping, but the client layer CC is not involved in this. This recurs upward and creates a link connection at each of the affected client layers.

The interlayer NCC relationship may occur at points other than where access group containers are attached to the client layer network. In Figure 7-4, a call traverses a client subnetwork first before being supported by a server layer subnetwork. In Figure 7-5, the call may also be supported by connections in a client layer subnetwork that is not contiguous with client layer subnetworks at the ingress or egress. Here, interlayer NCCs relationships are found between client subnetwork C2 and server subnetworks S1 and S2.



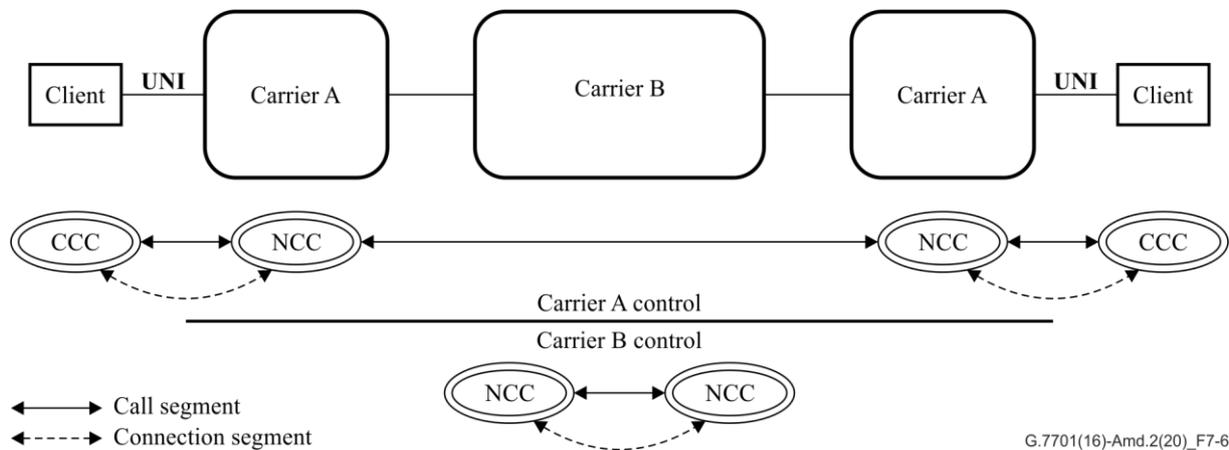
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**Figure 7-5 – Non-contiguous client layer subnetworks**

## **7.7 Calls supported by calls at same layer**

Similar to the arrangement of NCCs in an interlayer relationship, a call segment may be supported by a separate call at the same layer. In this arrangement, an NCC to NCC call segment is supported by a complete call with calling/called party call controllers. Figure 7-6 illustrates this in a carrier's carrier

business scenario. Here, a call between two clients associated with Carrier A is supported in two subnetworks that belong to Carrier A. Between those two subnetworks, the call is supported by a separate connection within Carrier B. The connection returned by the management and control of Carrier B is joined with the connections established in the Carrier A subnetworks.



**Figure 7-6 – Calls supported by calls in the same layer**

NOTE 1 – In an ASON architecture this would not use an E-NNI between carrier MC components in each carrier as there would be no RC-RC interaction. Interlayer NCC calls specify the SNPs to be connected in the server layer. Thus, an RC-RC association is not present with the interlayer NCC pair to make the server SNPs visible in the client NCC, and the boundary between the two subnetworks is not an ENNI reference point.

NOTE 2 – Hierarchical SDN controllers could perform the same result using interaction type 3 in clause 10.3 of [ITU-T G.7702].

## **7.8 Mapped server interlayer relationships**

When a client layer CI is mapped to a server layer as described in clauses 7.5 and 7.6, several types of arrangements can exist. They include client/servers in 1:1 and 1:n relationships. The ratio refers to the number of connection points in each layer.

### **7.8.1 1:1 relationship**

In the 1:1 relationship support for a client communication is supported by the server layer as a single trail. The  $NCC_{client}:NCC_{server}$  relationship is also 1:1.

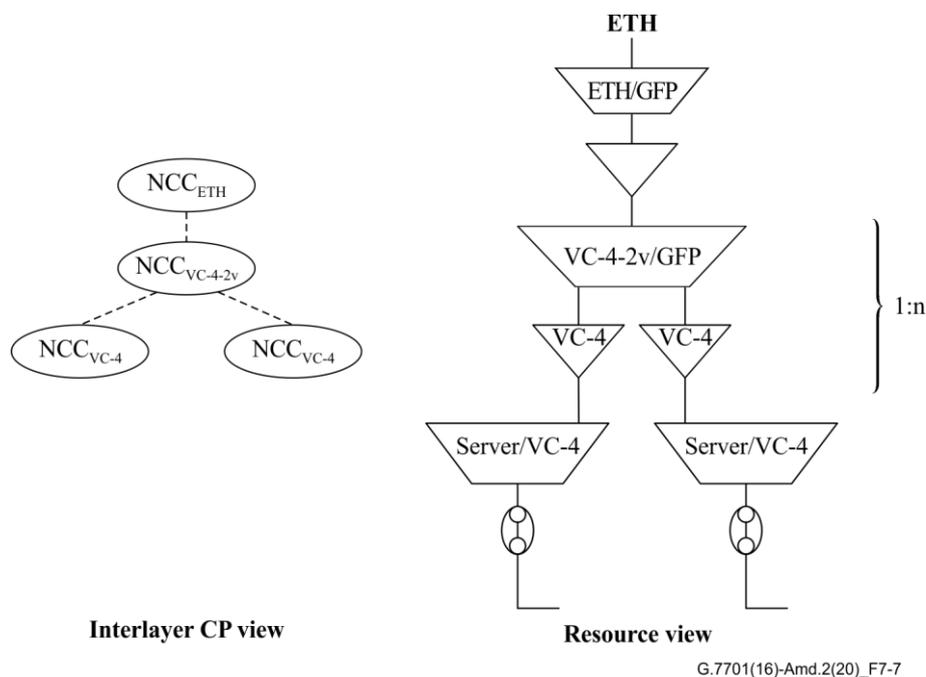
As the  $NCC_{client}$  is trying to use the server layer, it must have knowledge of the relevant call parameters of the  $NCC_{server}$  including whether the client initiated the server layer call (server NCC coordination out interface) or whether the server layer already existed for client layer use (client NCC coordination out interface).

The  $NCC_{server}$  is not required to possess knowledge of the client layer call parameters, but should inform the  $NCC_{client}$  if there are changes in the server layer call.

### **7.8.2 1:n relationship**

In a 1:n relationship, the client communication is supported by multiple connections in the server layer. This is supported either by the server NCC supporting multiple connections or multiple NCCs in the server layer supporting the one client layer NCC.

The example below in Figure 7-7 illustrates the latter case. The Ethernet call is mapped to a VC-4-2v virtual concatenation (VCAT) call. The VCAT call is related to multiple server layer VC-4 calls. The Ethernet/GFP layer to VCAT relationship is 1:1. The relationship of Ethernet/GFP layer NCC to VCAT NCC is 1:1, and the relationship of VCAT layer NCC to VC4 server layer NCC is 1:n.



**Figure 7-7 – Example 1:n mapped server**

It is necessary for the client layer NCC (the VC-4-2v layer) to be aware of the call parameters of the server layer as it must ensure that there are a sufficient number of server layer calls as well as what their aggregate characteristics are. The server layer is not required to possess knowledge of the client layer call parameters, but should inform the client call if there are changes in the server layer call.

## 8 Control component approach

A control component approach is used to express the architectures for ASON and that for application of SDN to transport in a way that facilitates the construction of reasonable scenarios.

Control components are identified in such a way that the most commonly used distributions of functionality are supported. Interfaces are exposed according to when there is a desire to distribute components among platforms, which is implementation specific. Where this is the case, the primitives exchanged between components are combined into streams carried over an external protocol.

It should be noted that the architecture is not solely comprised of control components and their interactions, but also assumes the presence of key conceptual constructs. A resource database (RDB) is a logical entity that holds information used by components and it is assumed to be present as needed to support components. The RDB is used by various distributions of components and may be used to exchange information between components.

### 8.1 Notation

In unified modelling language (UML), a component is defined as "a physical and replaceable part of a system that conforms to and provides the realisation of a set of interfaces" [b-UML]. A component in this sense typically represents the physical packaging of otherwise logical elements including classes and interfaces. In the context of this Recommendation, a component is defined as "an element that is a replaceable part of a system that conforms to and provides the realisation of a set of interfaces". A component here represents an abstract entity rather than a piece of implementation code. Thus, in this context, components represent logical functions rather than physical implementations. With this in mind, UML can be used in describing the component architecture for the ASON and the application of SDN to transport.

This clause considers the component architectural notation based upon some simple building blocks from the vocabulary of the UML.

**Component interface:** A component interface supports a collection of operations that specify a service of a component, and is specified independently from the components that use or provide that service. Operations specify the information passed in or out together with any applicable constraints. Interface definitions are presented in the form of a table, an example of which is presented in Table 8-1. Each interface has an interface name that identifies the role. Input interfaces represent services provided by the component; the basic input parameters are required for the specific role and basic return parameters are a result of the action on the input parameters. Output interfaces represent services used by the component; the basic output parameters define the information provided, the basic return parameters (if identified) are those required in response to the output parameters. Notification interfaces represent unsolicited output actions by the component, and are represented by an output interface with no return parameters. These three interface types are described separately in interface specifications.

**Table 8-1 – Generic component interface descriptions table format**

| <b>Input interface</b> | <b>Basic input parameters</b> | <b>Basic return parameters</b> |
|------------------------|-------------------------------|--------------------------------|
| Interface name         | Input parameters              | Returned parameters            |

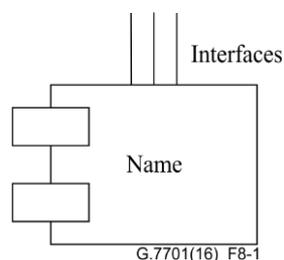
  

| <b>Output interface</b> | <b>Basic output parameters</b> | <b>Basic return parameters</b> |
|-------------------------|--------------------------------|--------------------------------|
| Interface name          | Output parameters              | Returned parameters            |

Transaction semantics associated with a particular transaction are assumed to be handled transparently, and there is no need to explicitly mention separate parameters for this purpose in interface description.

**Role:** A role is the behaviour of an entity when it is participating in a particular context. Roles allow for the possibility that different entities participate at different times, and are denoted by annotating a relationship with the name of an interface.

**Component:** In this Recommendation, components are used to represent abstract entities, rather than instances of implementation code. They are used to construct scenarios to explain the operation of the architecture. This component is represented as a rectangle with tabs. This is illustrated in Figure 8-1.



**Figure 8-1 – Representation of a component**

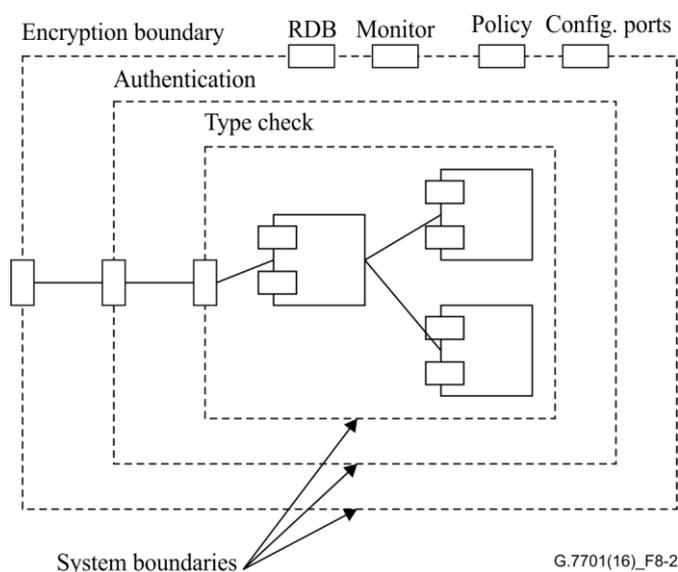
Generically, every component has a set of special interfaces to allow for monitoring of the component operation, dynamically setting policies and affecting internal behaviour, and obtaining resource information. These interfaces are not mandatory, and are provided on specific components only where necessary. Where appropriate, the use of the monitor interface is described in individual component descriptions. Components are not assumed to be statically distributed.

Component interfaces are defined based on the operations that the component is intended to perform and are, therefore, component specific. When interfaces on components are described, only the different interface types are specified. All components have the property of supporting multiple instances of an interface.

As components are used in an abstract way, this specification is extendable by the techniques of component sub-classing and composition.

## 8.2 Policy

For the purposes of this policy model, systems represent collections of components, and a system boundary provides a point where policy may be applied. Policy is defined as the set of rules applied to interfaces at the system boundary, and implemented by port controller components. Policy ports are used to simplify the modelling of policies that are applied to multiple ports. System boundaries are nested to allow for correct modelling of shared policies applied to any scope (full system, any set of components, individual components, etc.). The order of the policy application is that which is specified by the nesting.



**Figure 8-2 – Example of system boundaries related to policy control**

In Figure 8-2, the dashed boxes represent system boundaries, while the closed rectangles on the boundary, called ports, represent port controller components.

The monitor, policy, configuration, and RDB ports may be available on every system (and component) without further architectural specification. The monitor port allows management information to pass through the boundary relating to performance degradations, trouble events, failures, etc., for components, subject to policy constraints. The policy port allows for the exchange of policy information relating to components. The configuration port allows for the exchange of configuration, provisioning and administration information relating to components (subject to policy constraints) that may dynamically adjust the internal behaviour of the system. The RDB port allows for the exchange of resource information that is relevant to the component.

Figure 8-2 shows an example of how encryption, authentication and type checking may be implemented as a set of three nested port controllers, where the policy application order follows the nesting order. The components inside the authentication boundary do not specify encryption or authentication requirements, as these are properties of the component environment. Port controllers are defined for each independent aspect of port policy, and combined policy is achieved by

composition of port controllers. This allows the creation of reusable components, which are distinguished by a descriptive prefix. Policy violations are reported via the monitoring port.

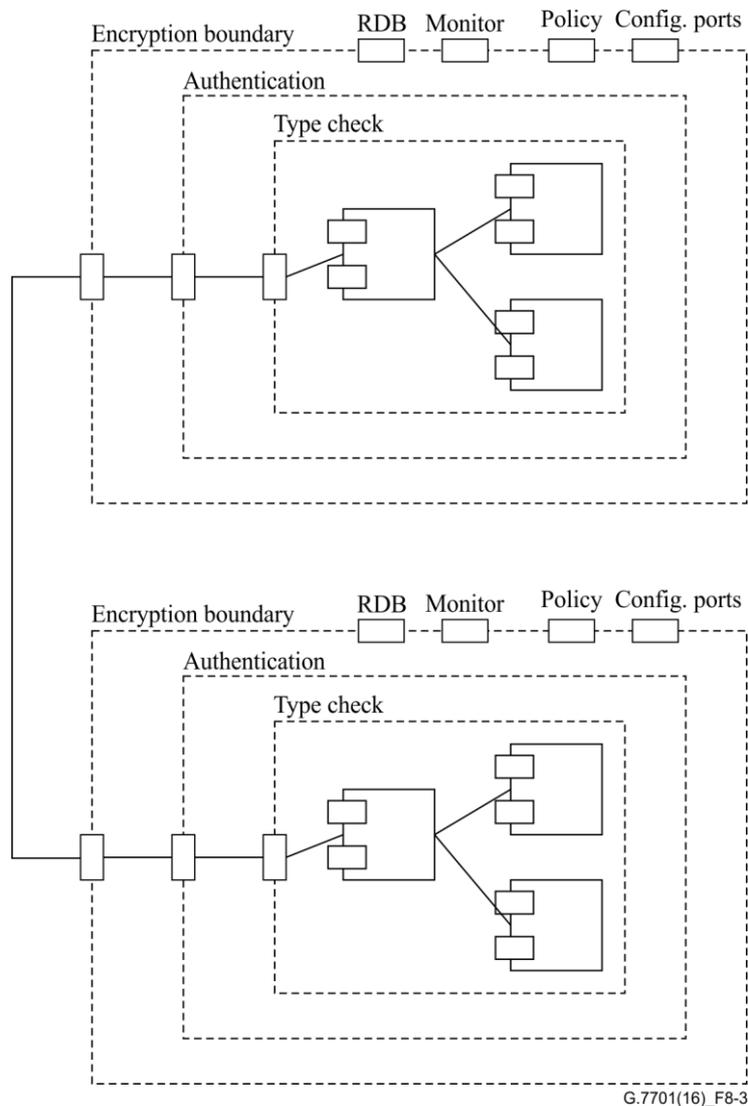
The policy port may be seen as a filter of incoming messages, where messages that are rejected have violated the policy. Policies may be dynamically changed via the system policy port, and in this way, dynamic behavioural changes may be described.

It is common to discuss how policy is applied at a reference point, but policy can only be applied to the individual interfaces crossing the reference point. A method of combining several interfaces into a single implementation interface is described later in clause 8.3, which includes a discussion of protocol controllers (PCs).

Other aspects of policy relate to variable behaviour of the components (such as schedules, access rights, etc.) and these aspects are specified and implemented by the components. Component behaviour may also be dynamically changed, and the ability to do this may be controlled by policy. This allows the determination of which aspects of system behaviour are specified where.

Policy, as other aspects of the system, may be distributed. The policy enforcement point (PEP), the point where the policy decisions are enforced, of that model corresponds to the port in this model. The policy decision point (PDP) is the point where policy decisions are made. This can be done within the port, though it may be distributed to a different system. This distribution decision depends on many factors that in turn depend on the actual policy. As an example, performance reasons may force the PDP to be within the port (encryption), while security reasons may force the PDP to be elsewhere (password lookup).

When the PEP and PDP are not collocated, cooperation is required.



**Figure 8-3 – Example of system boundaries related to policy control**

Figure 8-3 provides an example of interaction between two different subsystems. They communicate with each other through ports which are connected together. The received messages are decrypted first, then pass authentication type check, and finally processed by the correct control component.

### 8.3 Common components

The component architecture for the application of control functions to transport networks is described in this clause. A summary of the primary function of each component is first provided, followed by descriptions of component interfaces and detailed operations, respectively.

The connection controller (CC), hierarchical call controller (~~CallC~~), and RC are all control components. The VN context includes the name space that control components use to operate on VN resources.

Special components are defined in this Recommendation to allow for implementation flexibility. These components are PCs and port controllers. The detail of the interfaces of these and other components are provided in other technology specific Recommendations.

Protocol controllers are provided to take the primitive interface supplied by one or more architectural components, and multiplex those interfaces into a single instance of a protocol. In this way, a PC absorbs variations among various protocol choices, and the component architecture remains invariant. One or more PCs are responsible for managing the information flows across a reference point.

Port controllers are provided to apply rules to system interfaces. Their purpose is to provide a secure environment for the architectural components to execute in, thereby isolating the architectural components from security considerations. In particular, they isolate the architecture from distribution decisions made involving security issues.

### 8.3.1 **Network call controller components**

Calls are controlled by means of call controllers, which are able to recur hierarchically or horizontally.

There are two types of call controller components:

- 1) a calling/called party call controller (CCC): This is associated with an end of a call and may be co-located with end systems or located remotely and acts as a proxy on behalf of end systems. This controller acts in one, or both, of two roles, one to support the calling party and the other to support the called party. [The CCC component is described in \[ITU-T G.8080\].](#)
- 2) a network call controller (NCC): This provides three roles, one for support of the calling party, another to support the called party and a third to support calls across domain boundaries.

A calling party call controller interacts with a called party call controller by means of one or more intermediate NCCs.

Network call controllers are instantiated at policy boundaries (e.g., at reference points or aggregated interfaces).

Call controllers that are adjacent (in the context of a call) form a call segment.

[NCC-NCC relationships may occur in peering and hierarchical relationships. Four cases of these are:](#)

- 1) [Peering. NCC-NCC interactions are in the same layer network and form a chain which is a form of the \[ITU-T G.8080\] cooperative federation model.](#)
- 2) [Hierarchical in the same layer but with different resources in scope. In this case client calls are supported by other calls at the same layer, but the client calls are scoped to a different set of resources as the server calls. This is similar to the mapped server case for multi-layer except that the server layer is an instance of the same layer as the client.](#)
- 3) [Hierarchical in the same layer but with the same resources in scope. NCCs are arranged in a hierarchy with resources in the same layer network. They are scoped to different subsets \(including overlapping\) of those resources. Client NCCs make requests of server NCCs in order to complete calls in their scope.](#)
- 4) [Hierarchical between different layers. NCCs are arranged in a hierarchy with resources in different layer networks. A pair of NCCs in different layers have an association for the purpose of call setup between layers. Typically, this occurs at a transitional link in a multi-layer topology.](#)

The role of ~~this~~ NCC component is:

- processing of incoming call requests;
- generation of outgoing call requests;
- generation of call termination requests;
- processing of call termination requests;
- translation from call source and destination identifiers (which are boundary resource identifiers) to identifiers from the transport resource name space (i.e., SNPs, SNPPs) via directory request;
- call admission control based on validation of call parameters, user rights and access to network resource policy;
- state management of client calls and itself (call state could be held in the RDB);

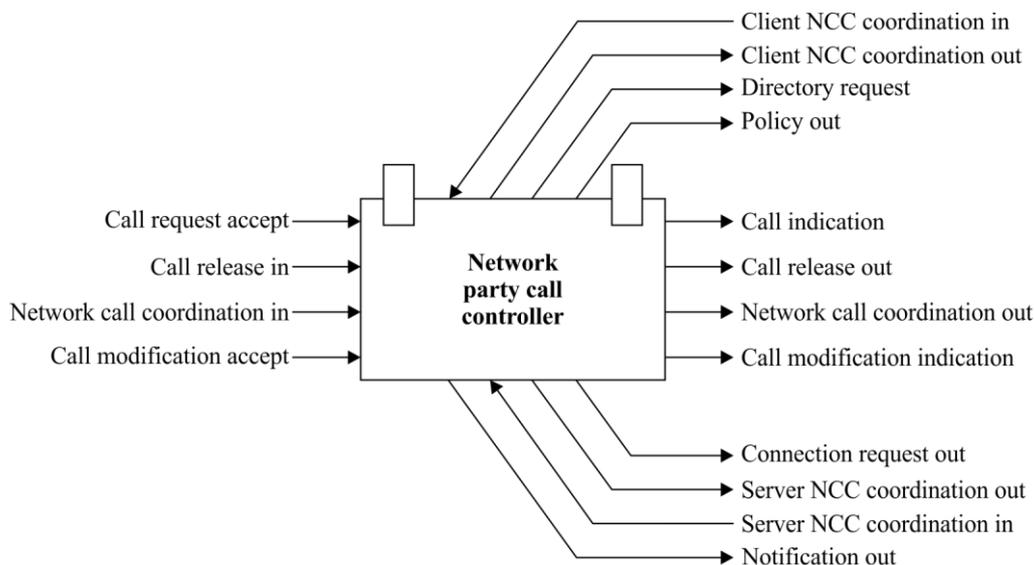
- application of policies such as quality of service (QoS), protection, access control, and security;
- adaptation management of transport resources via the termination and adaptation performer (TAP) component.

This component has the interfaces provided in Table 8-2 and illustrated in Figure 8-4.

**Table 8-2 – Network call controller component interfaces**

| <b>Input interface</b>       | <b>Basic input parameters</b>  | <b>Basic return parameters</b>                                       |
|------------------------------|--|--|
| Call request accept          | Boundary resource identifier   | Confirmation or rejection of call request                            |
| Network call coordination in | Boundary resource identifier   | Confirmation or rejection  |
| Call release in              | Boundary resource identifier   | Confirmation of call release   |
| Client NCC coordination in   | Optional client call parameters, optional client context <a href="#">or client layer</a> identification, boundary resource identifiers | A pair of SNPs in the <a href="#">view of the client NCC context</a> |
| Server NCC coordination in   | A pair of SNPs   | Confirmation or rejection of use                                     |
| Call modification accept     | Call name, parameters to change  | Confirmation or rejection of call modification                       |

| <b>Output interface</b>       | <b>Basic output parameters</b>  | <b>Basic return parameters</b>                 |
|-------------------------------|---|--|
| Call indication               | Boundary resource identifier  | Confirmation or rejection of call request      |
| Connection request out        | Boundary resource identifier  | A pair of SNPs                                 |
| Network call coordination out | Boundary resource identifier  | Confirmation or rejection of call request      |
| Directory request             | Boundary resource identifier  | SNP, SNPP                                      |
| Policy out                    | Call parameters   | Accept or rejection of call                    |
| Call release out              | Boundary resource identifier  | Confirmation of call release                   |
| Client NCC coordination out   | A pair of SNPs in the <a href="#">view of the client NCC context</a>            | Confirmation or rejection of use               |
| Server NCC coordination out   | Optional call parameters, context identification, boundary resource identifiers | A pair of SNPs                                 |
| Call modification request     | Call name, parameters to change   | Confirmation or rejection of call modification |
| Notification out              | notification  |  |



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**Figure 8-4 – Network call controller component**

**Call request accept:** This interface is used to accept a call source and destination identifier pair. This interface also confirms or rejects the incoming call setup request. It is used in the cooperative model for peer call controllers.

**Call indication:** Call requests are forwarded to NCCs as calls are progressed. This interface also confirms or rejects the outgoing call setup request. It is used in the cooperative model for peer call controllers.

**Connection request out:** This interface is used to place a connection setup request to a connection controller as a pair of SNPs.

**Directory request:** This interface is used to translate a boundary resource identifier (BRI) into an SNP/SNPP identifier.

**Network call coordination:** This interface is used for network-level call coordination in the cooperative model between NCCs.

**Call release in/out:** These interfaces are used to place, receive and confirm release requests.

**Policy out:** This interface provides policy checking.

**Client NCC coordination in:** This interface is used in NCC hierarchies to accept a request from ~~another~~ the calling NCC for a pair of SNPs. The called NCC is provided with source and destination identifiers in its context view in order for it to provide a network connection for use by the client calling context NCC. The NCCs can be in the different layers or in the same layer with a hierarchical arrangement. For NCCs in different layers a client context, SNPs in the view of the calling NCC client context that are supported by an adaptation to the network connection in the server layer are returned, such as the case described in clause 7.6. For NCCs in the same layer, SNPs are returned that are used by the CC associated with the calling NCC, which is in a hierarchical arrangement, such as the case described in clause 7.7. This interface is also used to release or modify the use of the SNP pair. The called NCC returns the result of the action.

**Client NCC coordination out:** This interface is used in NCC hierarchies to present a pair of SNPs ~~to a client layer~~ to the calling NCC. The NCCs can be in a different layer or in the same layer with the hierarchical arrangement. The SNPs that are supported by an adaptation to a network connection when the NCCs are in the different layers, or to an NCC in the same layer that is in a hierarchical arrangement. The client calling NCC indicates whether or not it accepts this resource. This interface

is also used to ~~release or~~ present a modified or released SNP pair. The ~~called~~ calling NCC returns the result of the action.

**Server NCC coordination out:** This interface is used in NCC hierarchies to request a pair of SNPs (~~input and output~~) that can be used by the call to transfer CI. The NCCs can in the different layers or NCCs in the same layer with a hierarchical arrangement as described in clause 7.8. For ~~a~~ called NCCs in a different layer, ~~the input SNPs is are~~ identical to the return parameters of the connection request out interface except that a network connection in ~~this the~~ layer of the called NCC is not assumed to be created. For ~~a~~ called NCCs in the same layer, ~~the requested SNPs are is~~ identical to the return parameters of the connection request out interface. ~~When the context is in the same layer, NCCs are in a hierarchical arrangement.~~ This interface is also used to release or request modification of the use of the SNP pair provided by the called NCC. The called NCC returns the result of the action.

**Server NCC coordination in:** This interface is used in NCC hierarchies to ~~accept~~ present a pair of SNPs (~~input and output~~) ~~presented~~ from ~~another the~~ called NCC. The NCCs can be in a different layer or the same layer with a hierarchical arrangement. ~~The SNPs may be accepted or rejected by the calling NCC. For the interlayer case, the other NCC is in a server layer. For the same layer case, it is another NCC providing resources in a hierarchical arrangement.~~ This interface is also used ~~by~~ to ~~release or~~ present a modified or released SNP pair. The calling NCC returns the result of the action.

**Call modification accept:** This interface is used to accept a call modification request. This interface also confirms or rejects the incoming call modification request. It is used in the cooperative model for peer call controllers.

**Call modification indication:** This interface is used to continue a call modification request to another NCC. It also receives confirmation or rejection of the request. It is used in the cooperative model for peer call controllers.

**Notification out:** This interface is used to inform the ~~resource~~ notification component of a call related notification.

The role of call admission control in the calling party NCC is to check that a valid called user name and service parameters have been provided. The service parameters are checked against a service level specification. If necessary, these parameters may need to be renegotiated with the calling party call controller. The scope of this negotiation is determined by policies derived from the original service level specification, which itself is derived from the service level agreement.

The role of call admission control in the called party NCC, if present, is to check that the called party is entitled to accept the call, based on the calling party and called party service contracts. For example, a caller address may be screened, and the call may be rejected.

The directory request interface of the NCC is used to access a directory function that is used to transform identifiers between or within name spaces. An identifier is supplied as input to the directory function which returns one or more identifiers. How the directory is maintained or configured is outside the scope of this Recommendation and will be described in other Recommendations.

Using the Call request accept and Call indication interface, a call is progressed between CCC and NCCs forming call segments. Using the Network call coordination in and Network coordination out interface, a call is progressed between NCCs forming call segments. A chain of NCCs can be formed that result in a horizontal chain of call segments. For the hierarchical NCC case the Client/Server NCC Coordination in/out interfaces are used. These returned pairs of SNPs represent a connection and allow the calling NCC to gather both call and connection segments.

### 8.3.2 Connection controller component

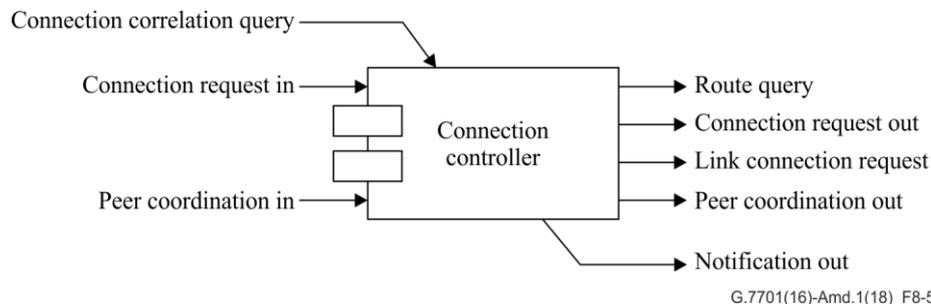
The CC is responsible for coordination among the link resource manager (LRM), RC, and both peer and subordinate connection controllers for the purpose of the management and supervision of connection setups, releases and the modification of connection parameters for existing connections.

This component services a single subnetwork, and provides the abstract interfaces to other control components given in Table 8-3. The connection controller component is illustrated in Figure 8-5. Connection state could be held in the resource database.

**Table 8-3 – Connection controller component interfaces**

| Input interface              | Basic input parameters  | Basic return parameters |
|------------------------------|---|-------------------------|
| Connection request in        | A pair of local SNP identifiers and optionally a route                                  | A subnetwork connection |
| Peer coordination in         | 1) A pair of SNP identifiers; or<br>2) SNP and SNPP; or<br>3) SNPP pair; or<br>4) route | Confirmation signal     |
| Connection correlation query | Original resource identifiers   | Relevant state          |

| Output interface        | Basic output parameters   | Basic return parameters         |
|-------------------------|---|---------------------------------|
| Route query             | Unresolved route fragment   | Route                           |
| Link connection request | –   | A link connection (an SNP pair) |
| Connection request out  | A pair of local SNP identifiers   | A subnetwork connection         |
| Peer coordination out   | 1) A pair of SNP identifiers; or<br>2) SNP and SNPP; or<br>3) SNPP pair; or<br>4) route | Confirmation signal             |
| Notification out        | notification  |                                 |



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**Figure 8-5 – Connection controller component**

**Connection request in:** This interface is used to receive a connection request.

**Connection request out:** This interface is used to initiate a connection request to another connection controller component.

**Peer coordination in:** This interface is used to receive a connection request that is in progress. Specific or general topology identifiers are included to indicate points that the connection should traverse.

**Peer coordination out:** This interface is used to continue a connection request that is in progress. It is sent to a peer connection controller.

**Connection correlation query:** This interface is used to return to the ~~resource~~-notification component, the relationship between the resource that generated the notification and the connections which are supported by that resource.

**Link connection request:** This interface is used to request a link connection from LRM. It is also used at the bottom of hierarchical recursion and in the peer coordination process.

**Route Query:** This interface is used to request a route from the routing controller. Some constituents of the route may be given in the request and the RC completes unresolved parts of the route.

**Notification out:** This interface is used to inform the ~~resource~~-notification component of a connection related notification.

Connection setup is performed in response to either a connection request, from an enclosing scope connection controller, or from a peer connection controller. In the case of hierarchical routing, there could be CCs in adjacent routing levels. The higher level CC divides the responsibility for the network connection across the multiple lower routing levels, where the superior (i.e., parent) A higher level CC selects the source and destination SNPs and requests the network connections from the CCs for the specific lower routing levels, via the connection request in/out interface is used. A parent CC may have multiple subordinate CCs in a hierarchy and in that case, the The parent higher level CC concatenates the connections from lower level CCs together in an end-to-end manner. In all other cases, the peer coordination in/out interfaces are used. Component operation is the same in both cases.

When the CC has two link connections that are in sequence for a route, it creates the subnetwork connection (SNC) between the end of one link connection and the end of the other link connection. If the TAP component for those links is used, then the FP name space will be configured and the SNC will support information transfer. Otherwise, the SNP name space will be configured.

The first unresolved portion of the route is resolved, via the route table query interface, into a set of links to be traversed, and this new set of links adds to the set. The connection controller inspects the new set of links to see which of these links are available for link connection allocation. Link connections are obtained, and their links are removed from the link set. Next, corresponding subnetwork connections are requested from subordinate (i.e., child) connection controllers via the connection request out interface. Any unallocated route components are passed on to the next downstream peer connection controller. The actual sequence of operations depends on many factors, including the amount of routing information available and the access to particular LRMs; however, the operation of the connection controller is invariant. Connection release is an analogous operation to connection setup, except the operations are reversed.

### 8.3.3 Routing controller component

The routing controller component is an abstract entity that provides the routing function. It can be implemented as a single entity, or as a distributed set of entities that make up a cooperative federation.

The role of the RC is to respond to requests for:

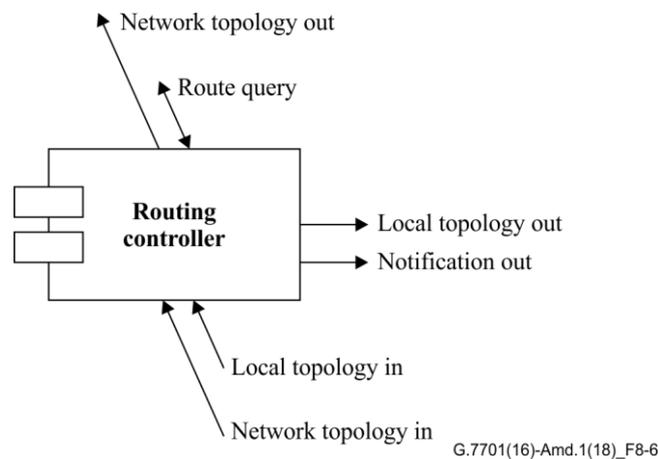
- path (route) information needed to set up connections. This information can range from end-to-end path details to a next hop. The route can be computed by one or more cooperating RCs;
- topology (SNPs and their abstractions) information for control and management purposes.

Information contained in the RC (SNPPs, SNP link connections) enables it to provide routes within the domain of its responsibility. The RC may also receive topology updates from its peers, consisting of identifiers for adjacent nodes/subnetworks and their links, that may also include identifiers of specific peer subnetwork resources. RC information may be contained in the resource database. The resource database may also maintain knowledge of SNP state to enable constraint based routing. Using this view, a possible route can be determined between two or more (sets of) SNPs taking into account some routing constraints. There are varying levels of routing detail that may be provided.

The functional requirements of the RC include:

- topology management for intra-domain and multi-layer transport network;
- topology management for inter-domain and multi-layer transport network;
- path computation of intra-domain, inter-domain or multi-layer for transport network;
- abstraction of topology and resources of transport network.

The component architecture of RC is shown in Figure 8-6.



**Figure 8-6 – Component architecture of routing controller**

The input and output interfaces for RC are described below.

**Table 8-4 – Routing controller component – input interfaces**

| Input interface     | Basic input parameters                    | Basic return parameters |
|---------------------|---|-------------------------|
| Route query         | Unresolved route element,<br>Route policy | Route                   |
| Local topology in   | Local topology update                     | –                       |
| Network topology in | Topology update                           | –                       |

**Table 8-5 – Routing controller component – output interfaces**

| Output interface     | Basic output parameters                   | Basic return parameters |
|----------------------|---|-------------------------|
| Route query          | Unresolved route element,<br>Route policy | Route                   |
| Local topology out   | Local topology update                     | –                       |
| Network topology out | Network topology update                   | –                       |
| Notification out     | notification                              |                         |

**Local topology interface in:** The local topology interface in is used to maintain accurate information on the local topology and its state. This is the topology information that is within the domain of responsibility of the RC.

**Local topology interface out:** The local topology interface out is used to convey information on the local topology and its state.

**Network topology interface in:** The network topology interface in is used to retain accurate information on the network topology and its state. This is the topology information that is outside the domain of responsibility of the RC. Information from other RCs Local topology interface out and Network topology interface out are received on this interface.

**Network topology interface out:** The Network topology interface out is used to convey the information received from the Network topology interface in, or a summarized version thereof (further abstracted), and may also provide a summarized version of the local topology.

**Route query interface:** This interface accepts an unresolved route element and returns a route. Route queries may be either from the connection controller component (CC) or may be from another RC.

**Notification out:** This interface is used to inform the ~~resource~~-notification component of a routing related notification.

Depending upon the context, the RC component can receive local topology information from the LRM component or network topology information from an RC at a lower hierarchical level.

In the routing calculation process, RC can cooperate with other RCs to perform multi-domain and multi-layer route calculation.

#### 8.3.4 Link resource manager component

The LRM component is responsible for the management of an SNPP link; this includes the assignment and unassignment of SNP link connections (to a connection), managing resource reservation, the configuration of policing and shaping functions via the TAP (if required), providing topology and status information. The SNPs and the associated resource (e.g., capacity) that are in the SNPP at each end of the link are provided by the TAP (see clause 8.3.6), the LRM also receives resource status information from the TAP. A LRM may request the TAP to modify the allocated capacity or the list of allocated SNP identifiers (i.e., change capacity or the binding state of the SNPs to allocated from potential or from allocated to potential). The LRM functions are shown in Figure 8-7.

##### *Layer network using circuit switching with a fixed bitrate*

The TAP supplies the LRM with the set of SNPs in the SNPP. When the TAP allocates an SNP, and associates it with a resource label, the FP and link connection are created; the resource label provides an implicit reservation of the link resource. The LRM may assign any of its SNPs to support a connection without further interaction with the TAP. The LRM can track the utilization of the SNPP link by tracking the SNPs that it has assigned. In general, the same SNP identifier and resource label are used for both directions of a bidirectional connection.

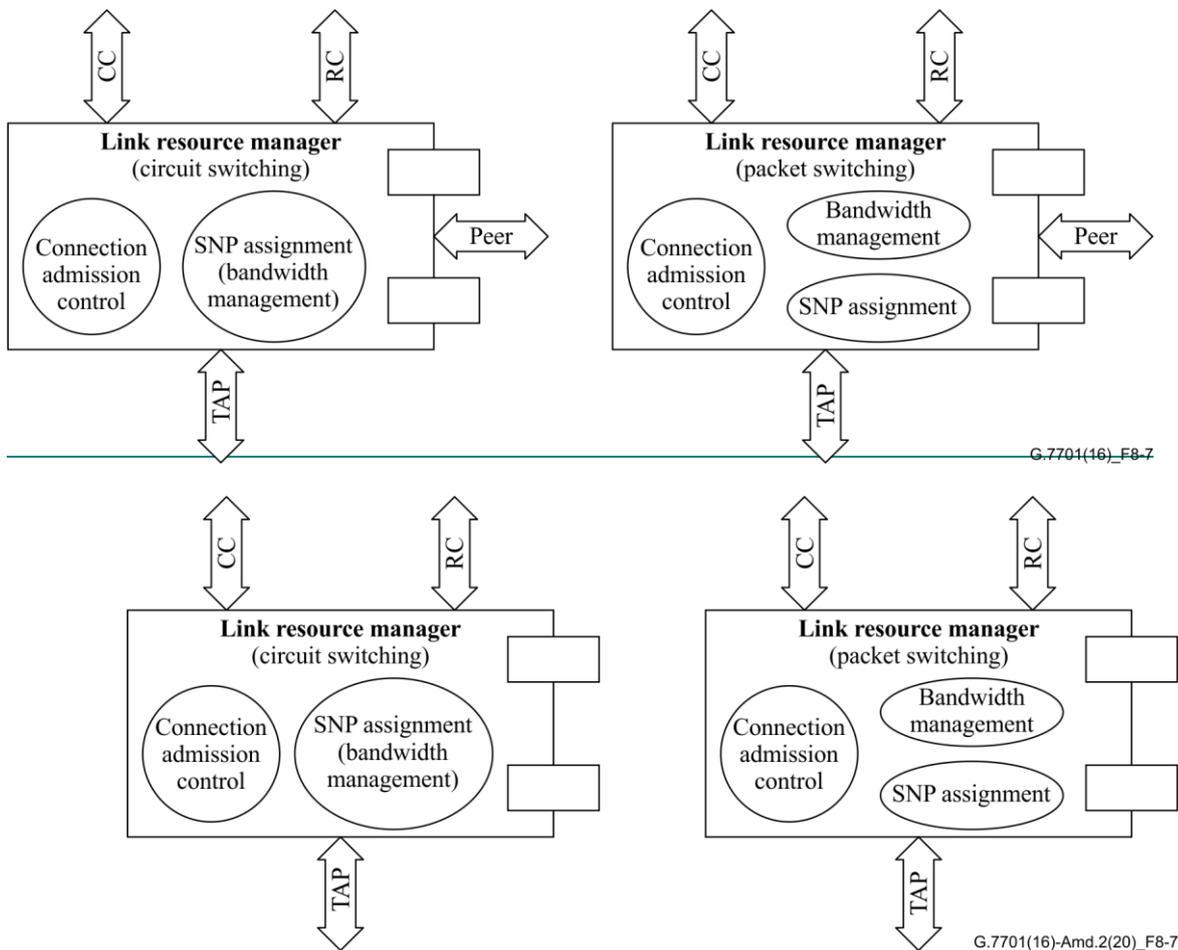
##### *Layer network using circuit switching with a flexible bitrate, (e.g., OTN with ODUflex)*

The TAP supplies the LRM with the set of SNPs in the SNPP, the potential and allocated capacity, together with the capacity assignment policy. The FP and link connections are not created (by the TAP) until the LRM assigns an SNP and capacity to a connection. A LRM may request the TAP to modify (i.e., increase or decrease) the capacity used by the connection. The LRM advises the TAP when an SNP is assigned or unassigned, this allows the TAP to create or delete the FP. The LRM is responsible for the assignment of the allocated capacity within the constraints of the capacity reservation policy provided by the TAP. The LRM can track the utilization of the SNPP link by tracking the SNPs and capacity that it has assigned. In general, the same SNP identifier and resource label are used for both directions of a bidirectional connection.

*Layer network using packet switching*

The SNPP link information held by the LRM must include the admission control policy (e.g., amount of overbooking allowed for the committed information rate (CIR) and peak information rate (PIR)). When the LRM receives a connection create request, or connection modification request, the LRM's connection admission control (CAC) function determines whether the request can be granted or whether it has to be rejected.

The TAP supplies the LRM with the set of SNPs in the SNPP, the potential and allocated capacity (CIR and PIR), together with the capacity assignment policy. The FP and link connections are not created (by the TAP) until the LRM assigns an SNP and capacity (CIR and PIR) to a connection. A LRM may request the TAP to modify (i.e., increase or decrease) the capacity used by the connection. The LRM advises the TAP when an SNP is assigned or unassigned, this allows the TAP to create or delete the FP. The LRM (via the TAP) must also configure the appropriate traffic policing and shaping functions. The LRM is responsible for the assignment of the allocated capacity within the constraints of the capacity reservation policy provided by the TAP. The LRM can track the utilization of the SNPP link by tracking the SNPs and capacity (CIR and PIR) that it has assigned. Different SNP identifiers and resource labels may be used for each direction of a bidirectional connection.



**Figure 8-7 – Basic LRM functions for circuit switching and packet switching**

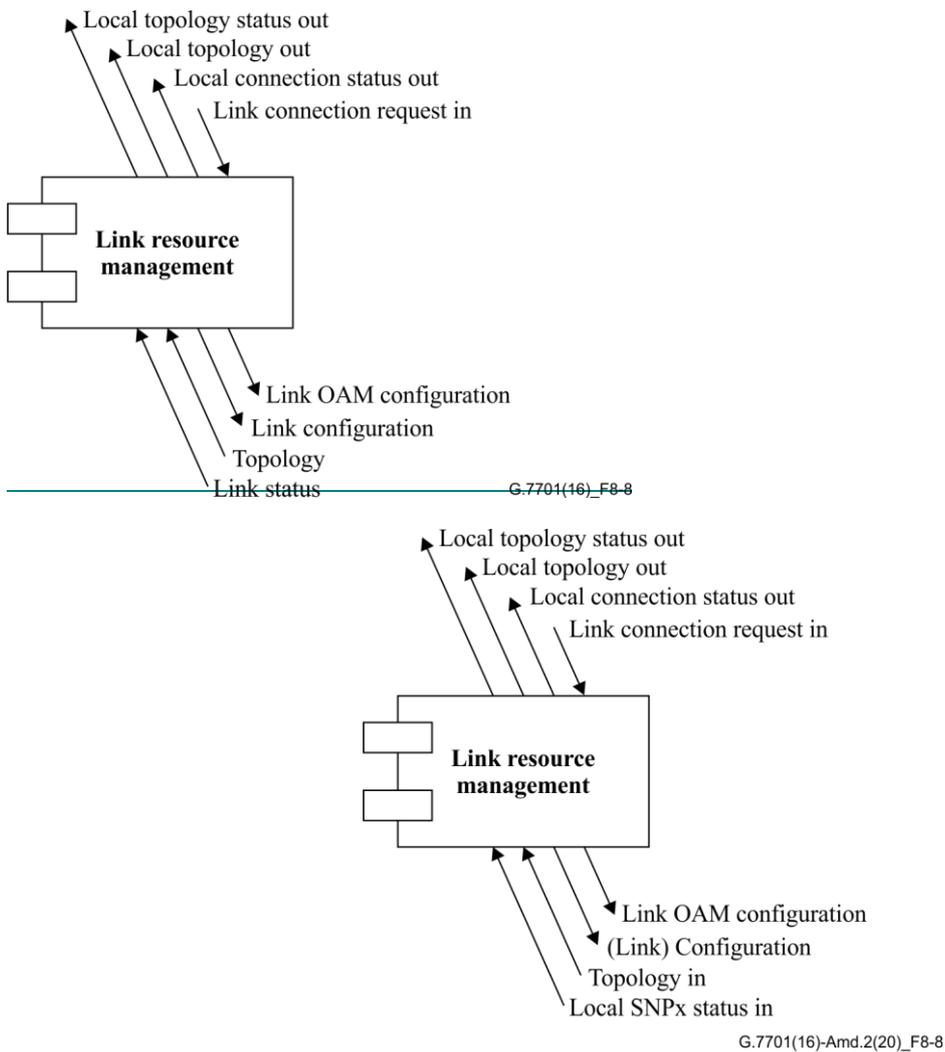
To support controller-based restoration, the LRM must be aware of the fault reporting management (FRM) and fault event filtering (FEF) information [ITU-T G.7710] for each SNP. The call/connection set-up request can indicate to use the FRM and FEF information for restoration. The LRM assigns the SNPs to the call/connection and maintains the indication of using the FRM and FEF information for those assigned SNPs. TAP maintains the operational state of the SNP based on the filtered faults

from the FRM function for the FP that supports that SNP. The LRM further updates and sends the changed link connection state to the CC.

The functional requirements of LRM include:

- the output of local topology (nodes and links), resources and abilities information of transport network;
- the status update of topology (nodes and links), resources and abilities information of transport network;
- link configuration, OAM configuration and maintenance;
- assist RC to update the status of topology of transport network;
- assist CC to update the status of connections of transport network.

The component architecture of LRM is shown in Figure 8-8:



**Figure 8-8 – Component architecture of LRM**

**Table 8-6 – Link resource management component – input interfaces**

| Input interface                   | Basic input parameters             | Basic return parameters   |
|-----------------------------------|------------------------------------|---------------------------|
| Link connection request <u>in</u> | A link connection (an SNP pair)    | Confirmation or rejection |
| Topology in                       | Local topology update              | –                         |
| Local <u>link-SNPx</u> status in  | Link <u>connection-SNPx</u> status |                           |

**Table 8-7 – Link resource management component – output interfaces**

| Output interface            | Basic output parameters  | Basic return parameters  |
|-----------------------------|--|--|
| Local topology out          | Local topology update  | –  |
| Local topology status out   | Network topology update  | –  |
| Link OAM configuration      | OAM parameters   | Confirmation or rejection of OAM parameters                                    |
| (Link) eConfiguration       | Link information, <a href="#">FEF information</a>  | Confirmation or rejection of link information, <a href="#">FEF information</a> |
| Local connection status out | Local connection status <ul style="list-style-type: none"> <li>– operational state</li> <li>– administrative state</li> <li>– performance</li> </ul> |  |

**Link connection request in:** This interface is used to receive the request from CC for a link connection between the associated SNP pair. This interface can be used to receive the indication for using the FEF information from the CC.

**Topology in:** This interface is used to receive the local topology updates from TAP.

**Local SNPx status in:** This interface is used to receive the SNPx status from TAP.

**Local Topology out:** This interface is used to convey information on the local topology to RC.

**Local topology status out:** This interface is used to convey the information on the local topology status to RC.

**Link OAM configuration:** This interface is used to request TAP for the configuration of Link OAM.

**(Link) Configuration:** This interface is used to request TAP for the configuration of Link information. This interface is used to request TAP to configure the FEF information for the associated SNPs.

**Local connection status out:** This interface is used to convey the information on the local connection status to CC, it also reports the state of SNPx.

### 8.3.5 Discovery agent component

The discovery agent (DA) component deals with transport resources that have not yet been assigned to a control function. The federation of discovery agents operates solely in the transport resource name space, and provides for separation between that space and the control name spaces. The federation has knowledge of FPs in the network, while a local DA has knowledge of only those FPs assigned to it.

The transport resource name space provides the native identifiers used by transport resources; this Recommendation assumes that a transport resource name space exists for the ITU-T G.800 FPs in the layer network. SNP name spaces are mapped to those FPs and the mappings are maintained by TAP components. The TAP also maintains the relationship between the client forwarding point (cFP) and server forwarding point (sFP).

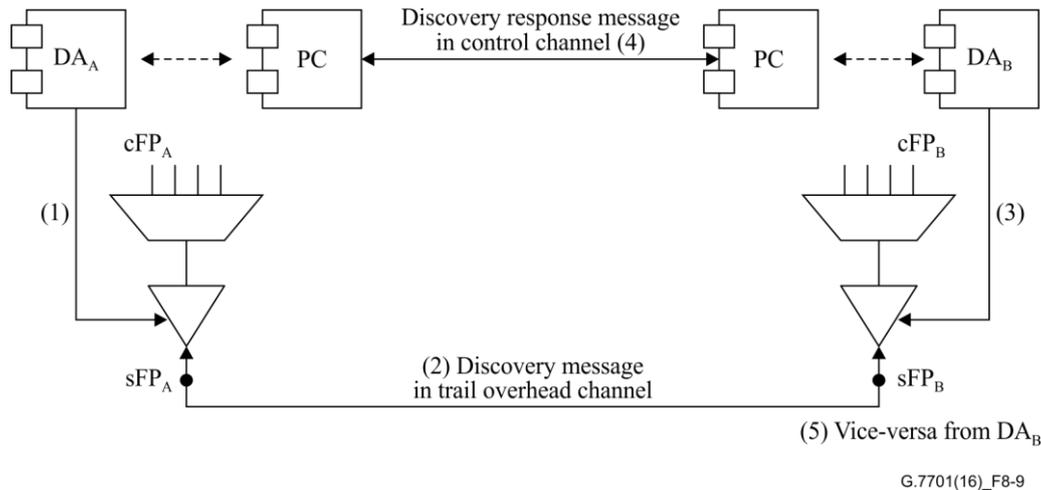
DAs discover the trail FP to FP relationship from which the link relationships from client FP to client FP are inferred [ITU-T G.7714.1]. Generally, multiple client FPs (cFPs) are associated with a trail FP in the server layer (sFP). Client FPs result from adaptation and if the adaptation is flexible, FPs in different layers may result. LRMs hold the corresponding SNP to SNP relationship for links in the SNP name space.

FP identifiers are only used in the context of DA and TAP components and all other control components use SNP identifiers. That is, the DA and TAP have access to the FP name space for the resources in their scope.

The DA uses the coordination in/out interface to communicate with adjacent DAs to obtain the sFP(s)-sFP(s) relationship between the local sFP and the remote sFP. The local cFP(s) and sFP and the remote cFP(s)-sFP binding relationship is provided by the local and remote TAP. With this information, the cFP-cFP relationship can be determined.

A DA can be located on any suitable platform. That is, it can be on a network element (NE), the lowest level controller, or any platform that is independent of NE and controller.

Figure 8-9 depicts actions of the DA used to establish the cFP-cFP relation.



**Figure 8-9 – Discovery agent actions**

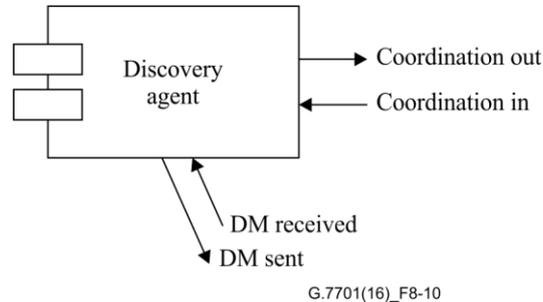
The steps to establishing FP to FP relationships are:

- 1) DA<sub>A</sub> triggers sFP<sub>A</sub> to inject a discovery message (DM) that contains the sFP<sub>A</sub> identifier and the DA<sub>A</sub> identifier.
- 2) The discovery message is carried by the trail from sFP<sub>A</sub> to sFP<sub>B</sub>.
- 3) DA<sub>B</sub> receives the discovery message from sFP<sub>B</sub>, which contains sFP<sub>A</sub>'s identifier and the DA<sub>A</sub> identifier.
- 4) DA<sub>B</sub> sends a discovery response message to DA<sub>A</sub> that provides the pair of server FPs (sFP<sub>A</sub> and sFP<sub>B</sub>) and the DA<sub>B</sub> identifier.
- 5) The same discovery process (steps 1 through 4) is performed by DA<sub>B</sub> in the reverse direction.
- 6) When the discovery processes in the two directions have completed, each DA locally compares the discovered sFP relationships in the forward and reverse directions to determine whether the relationships in the two directions A→B and B→A are consistent and the sFP<sub>A</sub>-sFP<sub>B</sub> relationship has been successfully discovered.

**Table 8-8 – Discovery agent component interface**

| Input interface | Basic input parameters   | Basic return parameters |
|-----------------|--|-------------------------|
| Coordination in | Receives DA response message (responder DA identifier and pair of sFP identifiers) |                         |
| DM received     | Initiator sFP identifier and initiator DA identifier                               |                         |

| Output interface | Basic output parameters   | Basic return parameters |
|------------------|---|-------------------------|
| Coordination out | Sends DA response message (responder DA identifier and pair of sFP identifiers) |                         |
| DM sent          | Initiator sFP identifier and initiator DA identifier                            |                         |



**Figure 8-10 – Discovery agent component**

**Coordination in:** The coordination in interface receives the DA discovery response message that includes the responder DA identifier and the pair of sFP identifiers.

**DM received:** This interface receives the in-band discovery message that was sent by the initiator sFP that includes the initiator sFP identifier and the initiator DA identifier.

**Coordination out:** The coordination out interface sends a discovery response message including the responder DA identifier and pair of sFP identifiers.

**DM sent:** The initiator DA uses this interface to trigger the initiator sFP to inject an in-band discovery message that contains the initiator DA identifier and the initiator sFP identifier.

Specifics of the discovery message are dependent on specific technology but there are no differences in the discovery procedure for circuit-switched networks, connection oriented packet switched networks and connectionless oriented packet switched networks.

### 8.3.6 TAP component

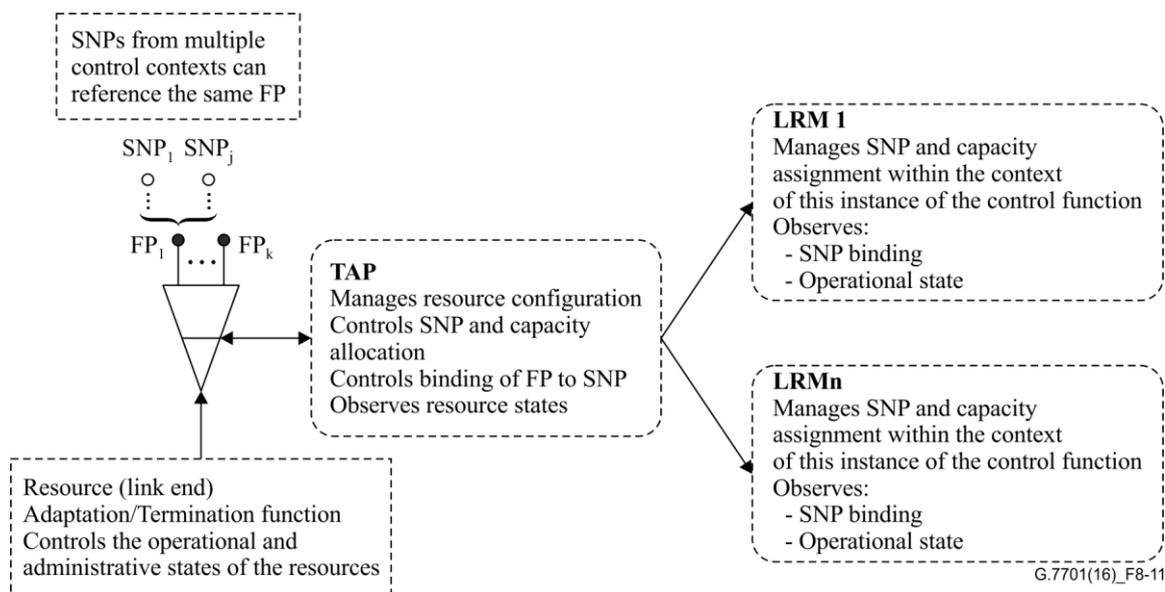
#### 8.3.6.1 Termination and adaptation performers

The TAP is collocated with the resources (i.e., the adaptation and termination functions). It provides the LRM with a view of the resources that support a link end; it abstracts the hardware and technology with specific details of the adaptation and termination functions. When utilized in an SDN control context, the TAP component resides with SDN controllers that can directly configure forwarding in the resources associated with the controller. TAP holds the relationship between SNP and FP name spaces. The identifiers in the FP name space are referred to as "labels" in this clause.

#### 8.3.6.2 TAP resource model

Only those transport resources that are allocated to a control function are made visible to the TAP. When a resource is permanently withdrawn (unallocated) from a control function, the SNP that references that resource should be deleted. The LRM is responsible for the assignment of the allocated capacity within the constraints of the capacity reservation policy provided by the TAP. An LRM may request the TAP to modify the allocated capacity or the list of allocated SNP identifiers (i.e., change capacity or the binding state of the SNPs to allocated from potential or from allocated to potential).

The relationship between the TAP, LRM and the network resources is shown in Figure 8-11.



**Figure 8-11 – Relationship between TAP, LRM, and transport resources**

NOTE – The multiple control contexts may exist because of different VNs or different levels in a controller hierarchy, or both.

The TAP operates at two different times and provides two different functions.

When a resource is assigned to a control function, the TAP is configured with a list of the resource identifiers, the capacity of the link resource, together with the capacity reservation policy. The link resources may be shared between multiple control functions (e.g., different layer networks or different VNs, see clause 7.4). For each LRM that is within the scope of the TAP (i.e., references resources controlled by the TAP), the TAP is configured with the permitted bindings between the resource labels and SNPs. The TAP controls the allocation of SNPs and capacity to each LRM. In a circuit-switched network with a fixed bitrate, only the resource labels are configured since they carry an implicit resource capacity and reservation policy. In the case of a time division multiplexing (TDM) network with flexible bitrate (e.g., OTN with ODUflex) the TAP provides the potential and allocated capacity to each LRM, together with the capacity assignment policy. In the case of packet-switched networks, the TAP provides the potential and allocated capacity (CIR and PIR) to each LRM, together with the capacity assignment policy. The LRM can only assign SNP link connections (to a connection) if the SNPs and resource capacity has been allocated by the TAP.

The TAP makes resources visible to an LRM by associating a resource label to an SNP identifier. The existence of the SNP identifier is independent of the configuration of the resources.

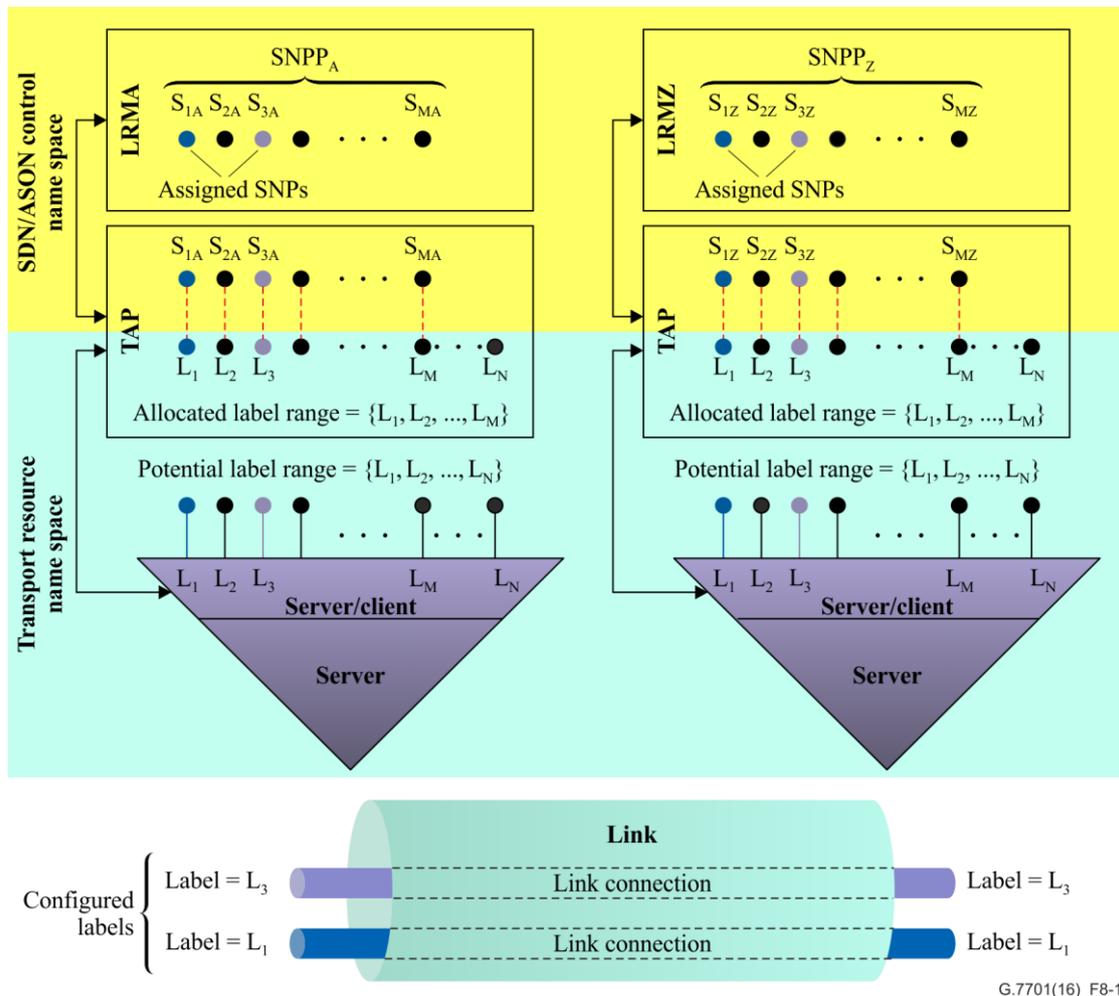
In the case of a circuit-switched network with fixed capacity, when the TAP allocates the resource to an LRM (i.e., sets the SNP state to allocated), it also configures those resources and creates the FP and the link connection is created. This configuration action is independent of the assignment of those resources to a connection.

In the case of a circuit-switched network with flexible capacity, when the TAP allocates capacity and SNPs to a LRM (i.e., sets the SNP state to allocated), it only performs the configuration required to allow those resources to be activated. When the LRM assigns an SNP to a connection, the TAP creates the FP (i.e., it activates the binding between the SNP and the FP), it also configures the resource to support the requested capacity.

In the case of a packet-switched network, when the TAP allocates capacity and SNPs to an LRM (i.e., sets the SNP state to allocated), it only performs configuration required to allow those resources to be activated. When the LRM assigns an SNP to a connection, the TAP creates the FP (i.e., it activates

the binding between the SNP and the resource label), it also configures the traffic conditioning and policing functions, if required.

Figure 8-12 below depicts the relationships between the potential and allocated resource identifiers, or resource labels, and SNPs. Moreover, it shows that the assigned SNPs are associated with labels from the allocated label range that are configured labels, i.e., a link connection exists for those SNPs. For a given label in the transport resource name space, the pair of SNP identifiers allocated for it are the same on both ends of the link. That is,  $S_{nA}=S_{nZ}$ , for  $n=1..m$  in Figure 8-12.



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**Figure 8-12 – Control components and link resource model**

The various types of resource labels are:

- **Potential (resource) label range**

The "potential label range" is the full label range of resource labels in the transport resource name space that an adaptation function supports. In packet switching layers, this range can be much larger than the allocated label range. Example: the 20-bit MPLS label provides  $2^{20} = 1048576$  possible label values including reserved labels (label values 0..15) for specific purposes.

- **Configured (resource) label**

A "configured label" is a transport resource label that has been configured in support of a connection. If a label is configured, a forwarding table entry exists on the receiving end of the link such that packets can be forwarded to an outgoing link if a packet is received with a label value that is equal to the configured label. If a label is configured, a packet flow can be distinguished from other flows and

can be forwarded based on the label value. This is equivalent to the existence of a link connection. This means that a link connection is created whenever a label has been configured consistently on either end of a link. The deletion of the configuration entry also deletes the link connection.

– **Allocated (resource) label range**

The "allocated label range" is the set of labels that can be used by the adaptation function of a particular link to carry user traffic. It is a subset of the potential label range. The allocated label range must not include reserved label values. When a system uses a per platform (system) label space, each interface is typically configured with an (allocated) label range that does not overlap with the label ranges of the other interfaces, and a specific label value is selected from this label range in response to, e.g., a connection request.

The allocated labels are entities that can be referenced in the transport resource name space. Each allocated label is associated with one or multiple SNP identifiers that exist in the control component name space (1:n relationship). In the simplest case, there is exactly one SNP identifier per allocated label (1:1 relationship between allocated label and SNP identifier). TAP holds the binding information between SNPs and an allocated label.

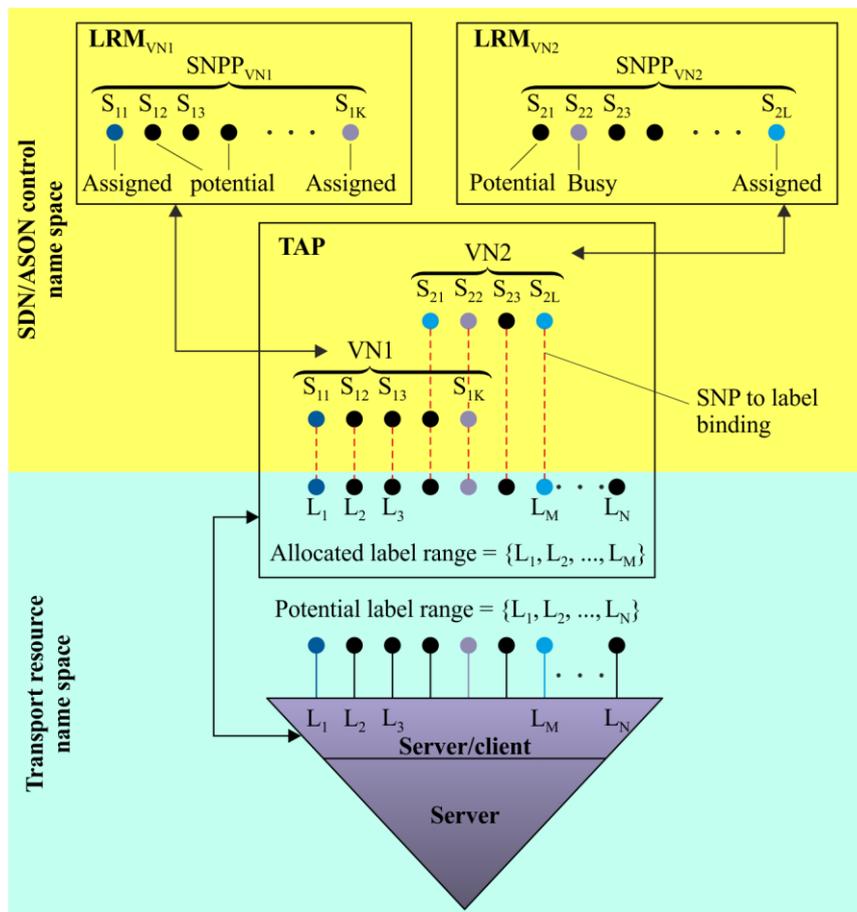
– **Potential SNPs**

Potential SNPs are those SNPs that are associated with a label. In general, multiple SNPs can be associated with a single label.

– **Assigned SNPs**

Assigned SNPs are those SNPs out of the set of potential SNPs that have been assigned to a particular connection. This means that the associated label is a configured label.

Figure 8-13 depicts how VNs can be modelled. In the provided example, the allocated label range is subdivided into three subsets, a subset that can exclusively be used by VN1, a subset that can exclusively be used by VN2, and a subset that is shared between VN1 and VN2. Each label of the subsets for exclusive use has a single SNP associated, whereas each label of the shared subset is associated with two SNPs, one SNP within the scope of  $LRM_{VN1}$  and another one SNP within the scope of  $LRM_{VN2}$ . When an SNP is assigned, e.g., by  $LRM_{VN1}$  that corresponds to a label from the shared label subset, the SNP in  $LRM_{VN2}$  becomes busy.



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Figure 8-13 – Control component organizational model for VNs

### 8.3.6.3 TAP states

The TAP holds the SNP binding states and the capacity allocation to each LRM, and provides a specific (coordinated) view to each LRM. As described in Table 8-9, the SNP binding states that the TAP provides to the LRM are constrained by the administrative state of the resources.

The transport resources are aware, from the [ITU-T X.731] usage state (idle, busy), if the resources have been allocated to the TAP. The resources have no visibility of any allocation that the TAP makes to LRMs. Therefore, the resources should use the shutting down state to withdraw resources from the TAP.

The TAP uses the SNP binding states to allocate resources to LRMs. The TAP has no visibility of the assignment of those resources to connections. Therefore, the TAP should use the SNP binding state of shutting down to remove resources from the LRM.

**Table 8-9 – SNP binding states**

| State         | Description   |
|---------------|---|
| Busy          | Permitted binding, the resource label and capacity being referenced by the SNP is currently allocated to another control function or the management function.   |
| Potential     | Permitted binding, currently the resource label and capacity being referenced by the SNP is not allocated to any control function or the management function.   |
| Allocated     | Permitted binding and the resource label and capacity being referenced by the SNP has been configured for and allocated to this LRM.  |
| Shutting down | TAP notification that the resource label and capacity being referenced by the SNP must be returned within an explicit timeframe e.g., <ul style="list-style-type: none"><li>– immediately (interrupt the current call)</li><li>– quickly (re-route call before dropping)</li><li>– next maintenance window</li><li>– when call is dropped</li></ul> |

When an SNP identifier is in the allocated state, the TAP must correctly configure the resources (e.g., variable adaptation) and set the state of any other SNPs referencing the same resource to busy.

When SNP identifiers are bound to their corresponding FP, the TAP is responsible for holding the SNP-FP binding. A local TAP cooperates with a remote TAP via the LRM to coordinate any variable adaptation or other coordination required when forming the FP link connections.

If an LRM wishes to use capacity or an SNP with a binding state of "potential" to satisfy a connection request then during connection setup, a pair of TAPs cooperate via the LRM to coordinate any adaptation setup, or link resource allocation, required by the link connection.

When the TAP modifies the resource capacity that is allocated to an LRM, it also makes a corresponding adjustment to the potential resource capacity.

The TAP provides SNP state information to the LRM and accepts resource state ~~status~~ from the adaptation and termination functions to ensure that the management function indications are consistent. Management function consistency includes ensuring that the alarm state of the link connection is consistent, so that spurious alarms are neither generated nor reported.

There are three [ITU-T X.731] states for transport resources:

- 1) operational: This state reflects the combined status of the trail supporting the link and adaptation function. It is controlled by the underlying resources and is observed by TAP.
- 2) administrative: This state reflects the permission to use the resource which is managed by a management interface to the TAP.
- 3) usage: This state reflects whether the resource is actively in use. As TAP allocates and unallocates resources to the control function, it adjusts the usage state accordingly.

Permitted combinations of the resource states and the SNP binding state for each SNP are described in Table 8-10 below:

**Table 8-10 – Resource and SNP binding states**

| ITU-T X.731 resource states |                        |       | SNP binding states |                         |
|-----------------------------|------------------------|-------|--------------------|-------------------------|
| Operational                 | Administrative         | Usage | LRM x              | All other LRMs (Note 2) |
| Enabled, disabled (Note 1)  | Unlocked               | Busy  | Potential          | Potential               |
| Enabled, disabled (Note 1)  | Unlocked               | Busy  | Allocated (Note 3) | Busy                    |
| Enabled, disabled (Note 1)  | Shutting down (Note 4) | Busy  | Shutting down      | Busy                    |
| Enabled, disabled           | Locked (Note 5)        | Idle  | Busy (Note 6)      | Busy (Note 6)           |

NOTE 1 – When an LRM observes that the operational state of a link is disabled, it may notify the RC component, it may also notify the connection controllers for the connections that are impacted. The call controller manages the recovery of any connections that are using a failed link.

NOTE 2 – If an LRM does not contain an SNP that references the same resource, then the binding state is not present.

NOTE 3 – The LRM assigns allocated SNPs and resource capacity to a connection. These assignments are not visible to the TAP.

NOTE 4 – If the resource administrative state is changed from unlocked to shutting down, then the TAP must change the binding state of any allocated SNPs that are referencing that resource to shutting down.

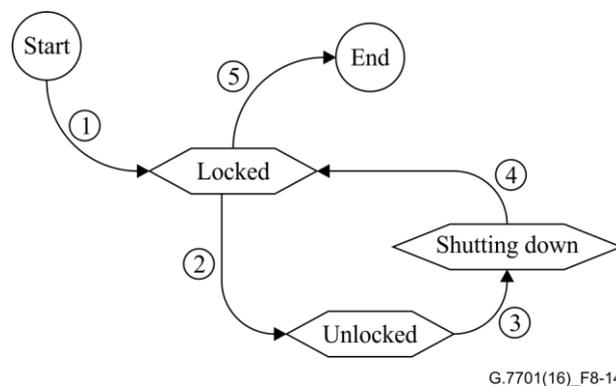
NOTE 5 – If the resource administrative state is set to locked, then the TAP must set the SNP binding state to busy.

NOTE 6 – This combination occurs when the resource is allocated to the management function or when the resource is being withdrawn from the control function. The management function will operate directly on the transport function resources. Changes to the [ITU-T X.731] states will not be visible to the TAP during this time.

### 8.3.6.4 Adding/removing resources from a control function

The resource administrative and usage states may be used to control the addition or withdrawal of a resource from the control function. This is illustrated in the administrative state transition diagram in Figure 8-14.

This is visible to TAP and is the [ITU-T X.731] resource state.



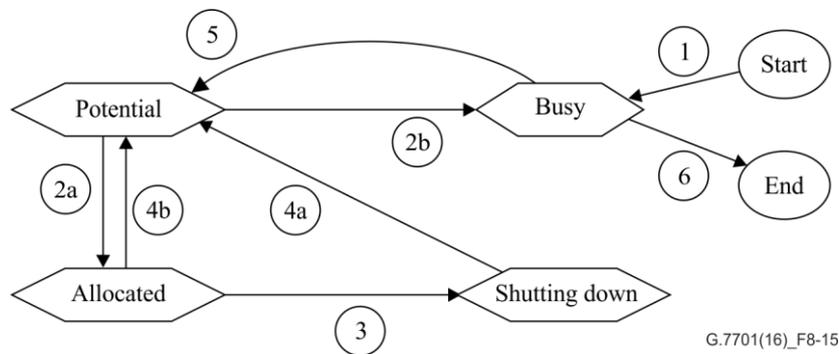
**Figure 8-14 – Resource administrative state**

**Table 8-11 – Transition descriptions**

| Transition | Description  | Interface      |
|------------|--|----------------|
| 1          | Resource is made visible to the TAP  | Usage update   |
| 2          | TAP is permitted to use the resource<br>The usage state is set to busy   | Resource state |
| 3          | The resource is being withdrawn  | Resource state |
| 4          | TAP has set the binding state of all SNPs that reference the resource to busy  | Usage update   |
| 5          | Resource is withdrawn from the control function:<br>If the withdrawal is permanent, then the TAP is instructed to delete all SNPs that referenced the resource | Resource state |

**8.3.6.5 SNPx binding state transitions per LRM**

Figure 8-15 shows the SNP binding state held by an LRM. This is the view that the TAP provides to each LRM based on the [ITU-T X.731] state of the resources. Operations on the TAP affect each LRM's SNP binding state view.



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**Figure 8-15 – SNP binding state in LRM**

**Table 8-12 – Transition descriptions**

| Transition | Description   | Interface                                   |
|------------|---|---|
| 1          | TAP adds SNP in the scope of the LRM  | Add SNP                                     |
| 2a         | TAP allocates resource to an LRM  | SNP binding state;<br>SNP operational state |
| 2b         | TAP sets the SNP binding state to busy when:<br>a) the TAP has allocated the resource to another LRM; or<br>b) the administrative state of the resource has been set to shutting down | SNP binding state                           |
| 3          | TAP requests return of a resource   | SNP binding state                           |
| 4a         | LRM is no longer using the resource<br>TAP modifies states to potential   | Release SNP                                 |
| 4b         | LRM is no longer using the resource<br>TAP modifies states to potential   | Release SNP                                 |
| 5          | TAP moves resource to potential since it is:<br>a) no longer allocated; or;<br>b) the administrative state has been set to unlocked   | SNP binding state                           |
| 6          | SNP is removed from the scope of the LRM  | Withdraw SNP                                |

### 8.3.6.6 TAP component interfaces

**Table 8-13 – TAP component interface**

| Input interface                                   | Basic input parameters   | Basic return parameters                                     |
|---|--|---|
| Operational state                                 | Enabled, disabled  | Confirm   |
| Administrative state                              | Locked, unlocked, shutting down  | Confirm for locked, unlocked<br>User quit for shutting down |
| <a href="#">(Link) Configuration in</a>           | <a href="#">Link configuration information</a><br><a href="#">FEF information;</a> | <a href="#">Confirm</a>                                     |
| SNP id assigned/unassigned (packet switched only) | SNP id (from LRM)<br>CIR and PIR   |   |
| Capacity change request                           | List of SNP ids<br>CIR and PIR (packet switched only)                              | Link configuration  |
| <a href="#">Fault reporting in</a>                | <a href="#">List of FP ids,</a><br><a href="#">Faults (reason, status)</a>         | <a href="#">Hardware specific</a>                           |

| Output interface                         | Basic output parameters   | Basic return parameters                                    |
|--|---|--|
| Control                                  | Hardware specific   | Hardware specific  |
| <a href="#">(Link) Configuration out</a> | List of SNP ids<br>CIR and PIR, capacity assignment policy (packet switched only) | confirm  |
| Capacity change (packet switched only)   | CIR<br>PIR  | Confirm  |
| SNPx binding state                       | Busy, potential, allocated, shutting down   | Resource released (in response to the shutting down state) |
| SNPx operational state                   | Enabled, disabled   | Confirm  |
| Add SNP                                  | List of SNP identifiers   | Confirm  |
| Withdraw SNP                             | List of SNP identifiers   | Confirm  |
| Usage update                             | New user, user quit   | Usage state (idle, busy)                                   |

**Operational state:** This interface accepts resource state information from adaptation and termination functions.

**Administrative state:** This interface accepts administrative state.

**[\(Link\) Configuration in:](#)** This interface receives the request from LRM to configure the link. This interface can be used to receive the FEF information from LRM for the SNP that is indicated to use it.

**SNP id assigned/unassigned:** This interface receives notification of SNP binding actions from LRM.

**Capacity change request:** This interface receives requests from LRM to change the capacity of packet resources associated with its assigned SNPs.

**[Fault reporting in:](#)** This interface is used to accept fault information from transport resource.

**Control:** This hardware specific interface allows the TAP to communicate with the resources that it controls.

**(Link) Configuration out:** This interface allows the TAP to provide the link end configuration information to an LRM.

**Capacity change:** This interface is used by the TAP to advise the LRM if the capacity of the link has been modified. This interface is only used for packet switching.

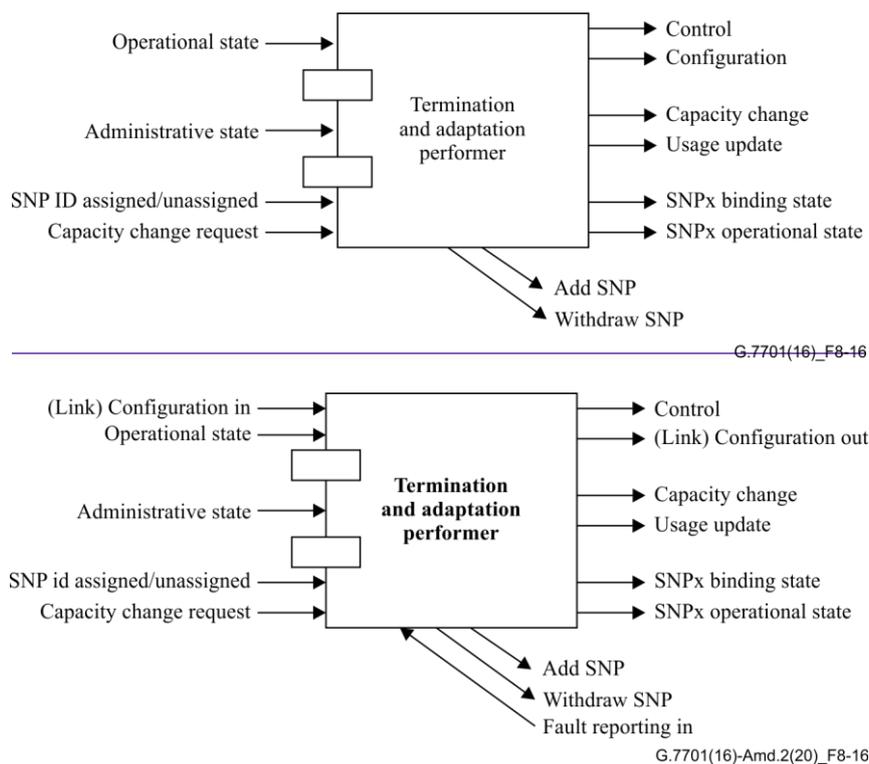
**SNPx binding state:** SNP binding state is sent to an LRM.

**SNPx operational state:** SNP operational state is sent to an LRM.

**Add SNP:** This interface is used to inform an LRM of a new SNP.

**Withdraw SNP:** This interface is used to inform an LRM of the removal of an SNP.

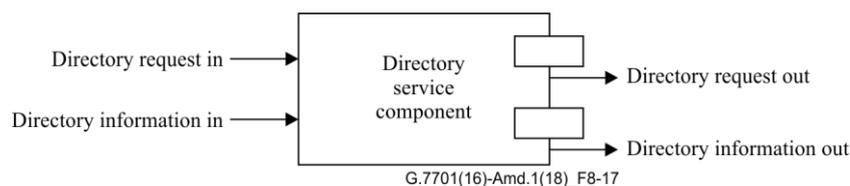
**Usage update:** This interface provides resource state usage information to adaptation and termination functions.



**Figure 8-16 – Termination and adaptation performer component**

### 8.3.7 Directory service component

The directory service component is responsible for identifier resolution and coordination among peer directory service components. The role of this component is to provide mappings between name spaces for other components; for example, mapping between VN name spaces. Figure 8-17 shows the directory service component.



**Figure 8-17 – Directory service component**

The input and output interfaces for the DS are described in Table 8-14:

**Table 8-14 – Directory service (DS) component interface**

| <b>Input interface</b>   | <b>Basic input parameters</b>  | <b>Basic return parameters</b>   |
|--------------------------|--|--|
| Directory request in     | <ol style="list-style-type: none"> <li>1) Boundary resource identifier (BRI); or</li> <li>2) Boundary resource identifier (BRI) alias; or</li> <li>3) SNPP identifier; or</li> <li>4) SNPP alias;</li> </ol>   | <ol style="list-style-type: none"> <li>1) Boundary resource identifier (BRI); or</li> <li>2) Boundary resource identifier (BRI) alias; or</li> <li>3) SNPP identifier; or</li> <li>4) SNPP alias;</li> </ol> |
| Directory information in | <ol style="list-style-type: none"> <li>1) &lt; Boundary resource identifier (BRI), SNPP identifier&gt;</li> <li>2) &lt; Boundary resource identifier (BRI) alias, Boundary resource identifier (BRI)&gt;</li> <li>3) &lt;SNPP identifier, Boundary resource identifier (BRI)&gt;</li> <li>4) &lt;SNPP alias, SNPP identifier&gt;</li> <li>5) &lt;SNPP identifier, SNPP alias&gt;</li> <li>6) list of Boundary resource identifier (BRI)</li> </ol> |  |

| <b>Output interface</b>   | <b>Basic output parameters</b>  | <b>Basic return parameters</b>  |
|---------------------------|---|---|
| Directory request out     | <ol style="list-style-type: none"> <li>1) Boundary resource identifier (BRI); or</li> <li>2) Boundary resource identifier (BRI) alias; or</li> <li>3) SNPP identifier; or</li> <li>4) SNPP alias;</li> </ol>  | <ol style="list-style-type: none"> <li>1) SNPP identifier; or</li> <li>2) Boundary resource identifier (BRI); or</li> <li>3) Boundary resource identifier (BRI); or</li> <li>4) SNPP identifier.</li> </ol> |
| Directory information out | <ol style="list-style-type: none"> <li>1) &lt; Boundary resource identifier (BRI), SNPP identifier&gt;</li> <li>2) &lt; Boundary resource identifier (BRI) alias, Boundary resource identifier (BRI)&gt;</li> <li>3) &lt;SNPP identifier, Boundary resource identifier (BRI)&gt;</li> <li>4) &lt;SNPP alias, SNPP identifier&gt;</li> <li>5) &lt;SNPP identifier, SNPP alias&gt;</li> <li>6) list of Boundary resource identifier (BRI)s</li> </ol> |   |

### 8.3.8 ~~Resource n~~Notification component

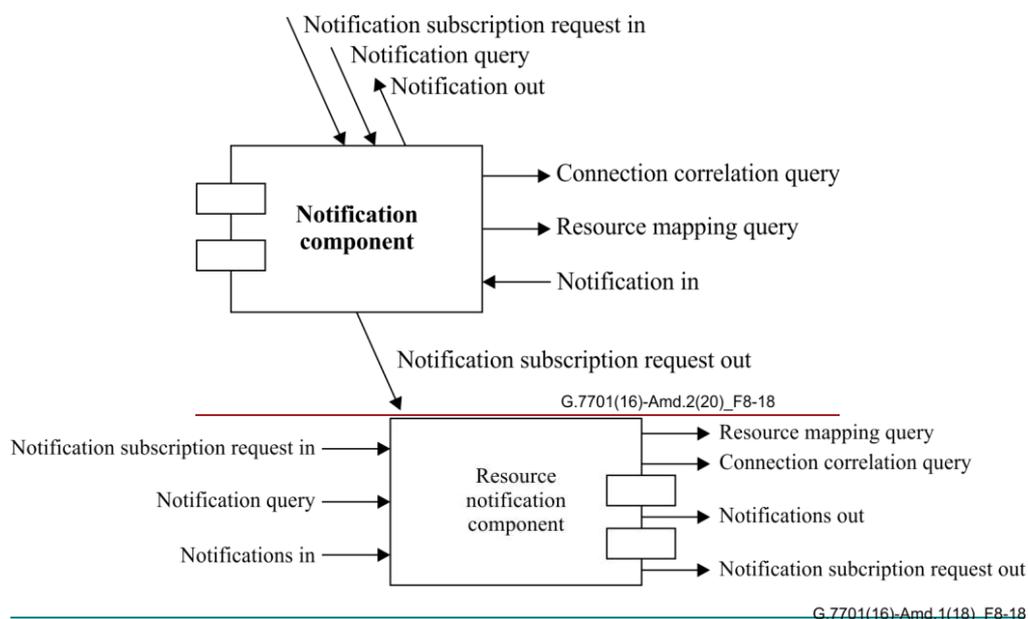
The ~~resource~~-notification ~~control~~ component is responsible for receiving, processing and delivering notifications (including alarms) related to network resources ~~to clients~~. Inside the same MCS, the MC components interact directly using the notification in/out interfaces. The notification component is not involved. For the notifications need to be delivered between the MC components in different MCSs, the notifications are relayed via the notification component using the notification in/out interfaces. The processes would be: The notification component receives the notifications from the other MC components (e.g., NCC, CC, RC) in the same MCS using notification in interface and then after processing, the notification component delivers the notifications to the notification component

in another MCS using notification out interface. Then after receiving the notifications, the notification component in another MCS processes them and then delivers the notifications to the target MC components in the same MCS. It is also responsible for the management of subscriptions for notifications. ~~This~~ The notification component provides the ~~abstract~~ interfaces ~~to other control components~~ given in Table 8-15. The ~~resource~~ notification ~~control~~ component is illustrated in Figure 8-18.

**Table 8-15 – Resource nNotification component interfaces**

| Input interface                      | Basic input parameters | Basic return parameters           |
|--------------------------------------|------------------------|-----------------------------------|
| Notification subscription request in | Subscription filter    | Notification subscription service |
| Notification query                   | Query filter           | Notifications                     |
| Notifications in                     | Notifications          | -                                 |

| Output interface                      | Basic output parameters       | Basic return parameters           |
|---------------------------------------|-------------------------------|-----------------------------------|
| Resource mapping query                | Original resource identifiers | Mapped resources                  |
| Connection correlation query          | Original resource identifiers | Relevance state                   |
| Notifications out                     | Notifications                 | -                                 |
| Notification subscription request out | Subscription filter           | Notification subscription service |



**Figure 8-18 – Resource nNotification component**

**Notification subscription request in:** This interface is used to receive a notification subscription request from the client or another MCS.

**Notification query:** This interface is used to query the history notifications that have been subscribed.

**Notifications in:** This interface is used to receive notifications from other control components in the same MCS or the notification component from another MCS.

**Resource mapping query:** This interface is used to query to the RDB to get the relationship between the network resources in the server context and the corresponding virtual network resources in the client contexts.

**Connection correlation query:** This interface is used to query to the CC to get the relationship between the resource that generated the notification and the connections which are supported by that resource.

**Notifications out:** This interface is used to deliver notifications to other components in the same MCS or the notification component in another MCS~~other management systems~~.

**Notification subscription request out:** This interface is used to request a notification subscription to ~~other RNs~~another MCS.

### 8.3.8.1 Alarm notification

Alarms are a type of ~~resource~~-notification (clause 8.3.8). One of the primary capabilities of alarm management is alarm correlation. When a notification component ~~an RN~~ receives alarms ~~from~~for network resources, it should be able to do the alarm correlation and process the alarms according to the results of this analysis.

Alarm correlation refers to the analysis of the relationship between the resource that generates alarms and the (virtual) resources occupied by connections handled by the ~~controller~~MCS, to determine whether the alarm has an impact on the connections managed by the ~~controller~~MCS. The information for alarm correlation is provided by the resource mapping query and connection correlation query invoked by the ~~RN~~notification component to RC/CC/NCC components.

For processing alarms, ~~resource~~-notification component should be able to: Suppress the alarms that do not impact the connections managed by the MCS; controller; Derive and report new alarms based on alarm correlation and mapping from the network resources to the connections supported by the network resources. ~~If to the virtual network resources and~~ the connections are supported by ~~those~~ virtual network resources, the mapping would be from the network resources to the virtual network resources, and then to the connections supported by the virtual network resources.

The recommended alarm processing rules are listed in Table 8-16.

**Table 8-16 – Alarm ~~resource~~-notification processing rules**

| Alarm analysis result  | Alarm processing  |
|--|---|
| The alarm resource is supporting a connection <del>in the client context</del> .   | Report the alarm against the <u>(virtualized)</u> resource. |
| The alarm resource is not supporting a connection <del>in the client context</del> . Then the alarm is determined to have no influence on the connections <del>in the client context</del> . | Suppress the alarm.   |

### 8.3.8.2 Notification subscription

Subscription is a mechanism that allows the client to track specific parameters in the network provided by the server. The client and the server need to achieve agreement on the establishment, maintenance, modification, and the closing of any subscription. During the subscription, a report will be sent to the client at specific time or once there is a certain event, depending on the pre-agreement between the client and the server.

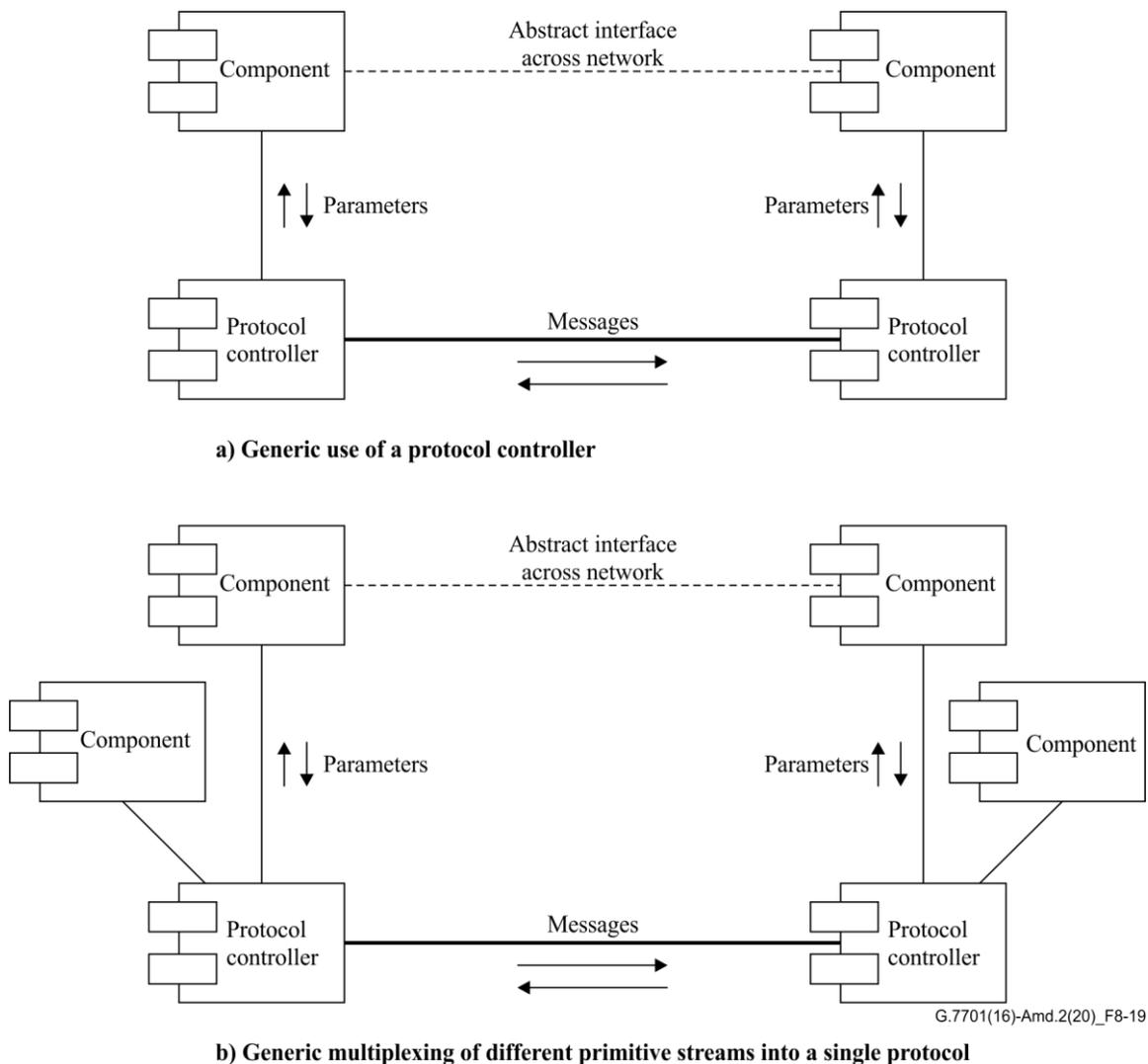
The notification subscription is proceeded by the notification component, the notification subscription request in/out interface is used to receive/send the request to establish, modify or close the notification subscription, and the feedback would be the notification subscription service.

### 8.3.9 Protocol controller (PC) component

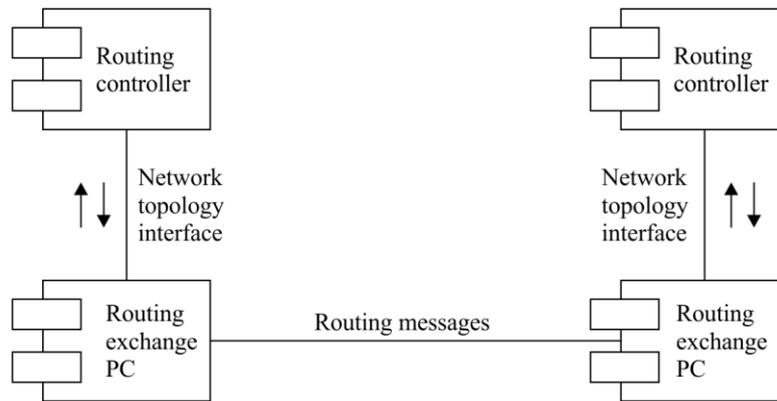
The protocol controller provides the function of mapping the parameters of the abstract interfaces of the control components into messages that are carried by a protocol to support interconnection via an interface. Protocol controllers are a subclass of port controllers and provide all the functions associated with those components. In particular, they report protocol violations to their monitoring ports. They may also perform the role of multiplexing several abstract interfaces into a single protocol instance as shown in Figure 8-19. The details of an individual protocol controller are in the realm of protocol design, though some examples are given in this Recommendation.

The role of a transport protocol controller is to provide authenticated, secure, and reliable transfer of control primitives across the network by means of a defined interface. This permits transactions to be tracked and to ensure expected responses are received, or that an exception is reported to the originator. When security functions are present, the protocol controller will report security violations via its monitoring port.

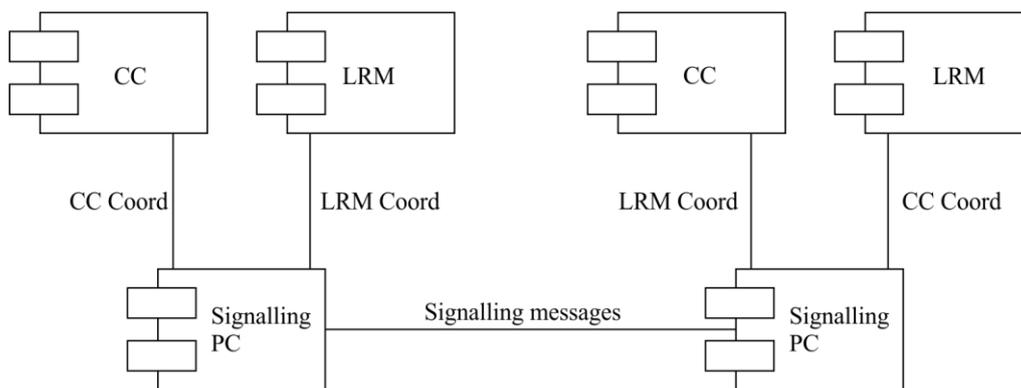
Control primitives are passed between the connection controller and the protocol controller, which is semantically transparent to the messaging primitives as this results in external protocol messages and vice versa. Control messages are passed between the two protocol controllers. This is illustrated in Figure 8-20.



**Figure 8-19 – Protocol controller**



a) Routing table exchange using routing exchange PC



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b) Multiplexing of LRM and CC coordination using signalling PC

### Figure 8-20 – Examples of protocol controller use

Examples of protocol controller use are the transfer of the following information:

- Route table update messages via a routing exchange protocol controller (shown in Figure 8-20-a).
- Link resource manager coordination messages (where appropriate as in available bit rate connections) via a link resource manager protocol controller.
- Connection control coordination messages via a connection controller protocol controller, (shown in Figure 8-20-b). Note that the LRM and CC coordination interfaces may be multiplexed over the same protocol controller.

For the route query interface between the connection controller and routing controller, authenticated and secure information is transferred with the appropriate domain scope policy.

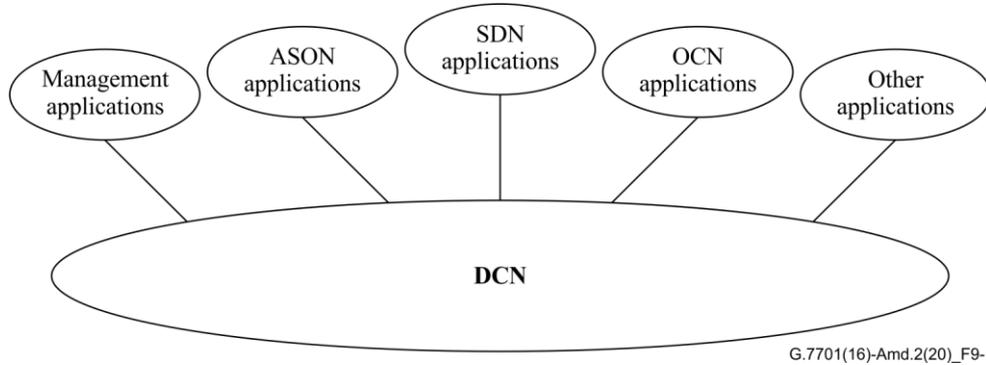
#### 8.3.10 Traffic policing (TP) component

The role of this component is to check that the incoming user connection is sending traffic according to the parameters agreed upon. Where a connection violates the agreed parameters, then the TP may instigate measures to correct the situation. The TP policies may be requested in the call/connection set-up process.

NOTE – This is not needed for a continuous bit rate transport layer network and is not further expanded in this Recommendation.

## 9 Common control communications

Various applications (management, SDN, ASON, overhead communications network (OCN), etc.) require a communications network to transport information between a variety of components, as illustrated in Figure 9-1. [ITU-T G.7712] specifies DCN functions that can be used to support one or more application's communication network (e.g., communications among management components, communications among control components, and other operations communications).



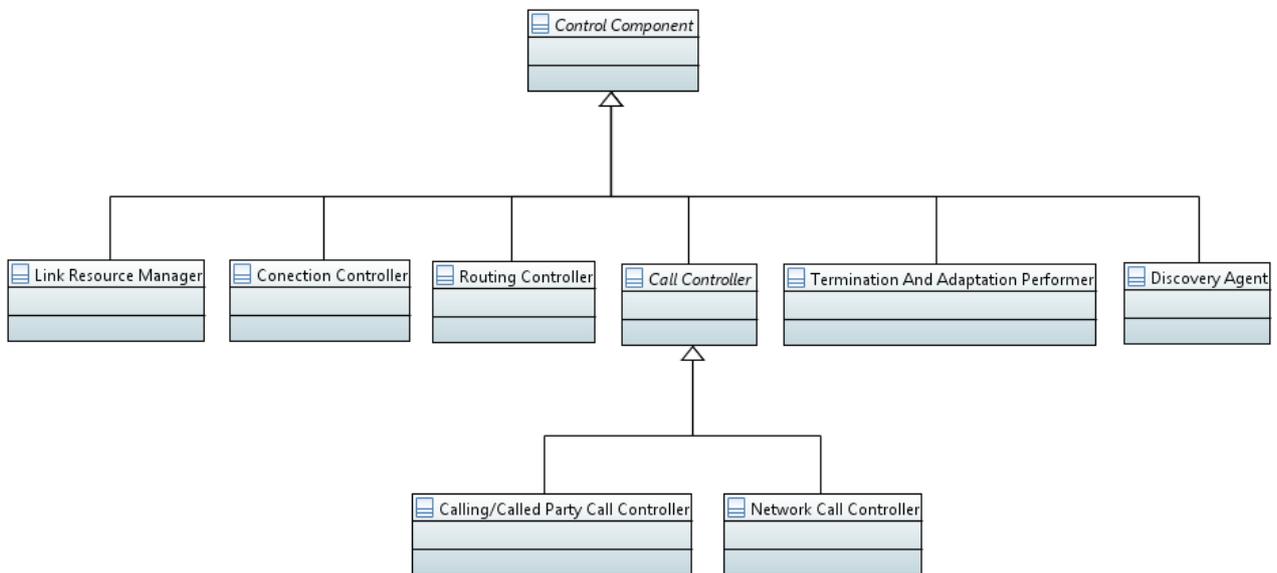
**Figure 9-1 – Example applications supported by a DCN**

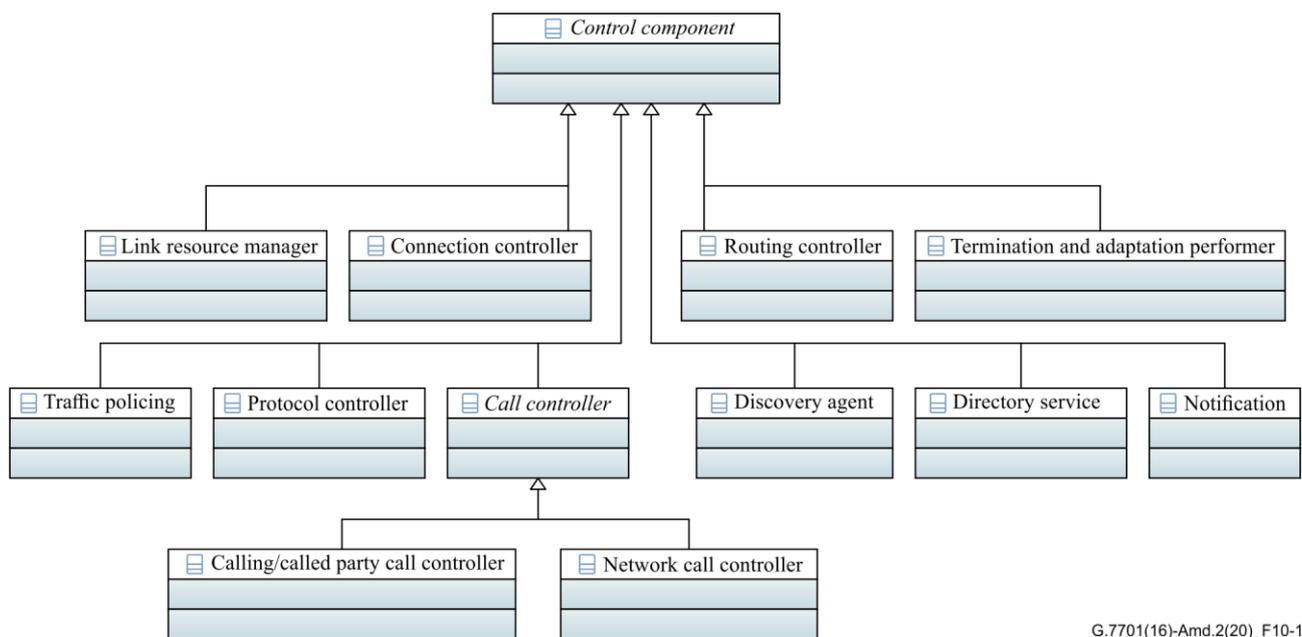
## 10 Common management aspects of common control components

This clause introduces constructs relevant to the management of control components.

### 10.1 Control component relationships

Figure 10-1 illustrates the relevant control components as defined within previous clauses of this Recommendation.





**Figure 10-1 – Control component relationships**

The following management functions apply to the control components shown in Figure 10-1. Accounting management and security management requirements are for further study.

- TAPs require ~~fault management~~, configuration management, ~~and performance management~~.
- DAs require fault management, configuration management, ~~and performance management~~.
- LRMs require ~~fault management~~, configuration management, and performance management.
- NCCs require performance management including call statistics, e.g., number of call completed, number rejected, etc. NCCs also require ~~fault management and~~ configuration management.
- RCs require ~~fault management~~, configuration management, ~~and performance management~~.
- CCs require ~~fault management~~, configuration management, and performance management.
- DSs require configuration management.
- Notification components require configuration management.
- PCs require fault management and configuration management.

## 10.2 Control function management requirements

The fundamental requirements for control function management ~~refer to [ITU-T G.7718]are for further study.~~

## 11 Identifiers

Distinct and independent sets of name spaces exist, from which identifiers are drawn, for:

- resources in the transport network;
- control view of transport resources;
- control components;
- control artefacts;
- reference points;
- control communications network.

## 11.1 Resources in the transport network

The architecture of transport resources is described in [ITU-T G.800] and summarized in clause 7.1. The identifiers used by transport resources to allow it to deliver communications from a source to a defined set of destinations are described in [ITU-T G.800] (clause 7, Annex A.4 and Appendix I). [ITU-T G.800] describes topological components that are relationships between reference points, for example, the subnetwork and link. Transport processing functions in the architecture manipulate information at points, and include functions such as adaptation and termination. Transport entities provide the means to transfer information and include connections.

A topological component may have zero or more identifiers associated with it. Similarly, transport processing functions and transport entities may have zero or more identifiers associated with it. A common use of multiple identifiers for the same component is when multiple applications refer to the same component.

This Recommendation assumes that there is a singular [ITU-T G.800] FP name space for a set of resources in a layer network. The identifiers drawn from this name space are used by the transport resources to allow the delivery of communications from a source to a sink. Examples of these resource identifiers are; MPLS label; Ethernet SA and DA; wavelength; the TS of an ODU server. The only SDN components that use identifiers from the FP name space are the DA and TAP.

## 11.2 Control view of transport resources

Name spaces need to be understood by an MCS. The translation function is used to convert the name space from one MCS to another. Such translation between systems may occur from any component in one MCS to another component in the MCS. It is also possible to have such name space translation between components within an MCS.

The DS component provides the name space translation function for the different MC components within a MCS, for example, as described in clause 8.3.1, the NCC can request DS to translate a boundary resource identifier (BRI) into an SNP/SNPP identifier.

The control components use three different name spaces to reference the transport resources:

- Routing area name space and subnetwork name space provide identifiers for [ITU-T G.800] topological entities (subnetworks and links).
- Link context name space that provides the identifiers (SNPs) for the ends of transport entities ([ITU-T G.800] FPs).
- FP name space used by the TAP and DA to directly configure forwarding in transport entities. The TAP and DA provide a mapping between the SNP identifier and the forwarding resource identifier<sup>1</sup>.

Independent identifiers (drawn from these name spaces) may be used for each layer network, client context and server context. Normally the routing area identifiers and link identifiers (SNPPs) are structured in a way that simplifies the implementation of routing and connection management. For example, in the case of hierarchically arranged routing areas it may be convenient to use recursive (hierarchical) identifiers for the contained SNPP links or routing areas.

### 11.2.1 Name spaces for routing and connection control

Components that perform routing control operate on a particular set of transport resources within the scope of their designated routing domain/routing area. As defined in clause 3.2, a routing area is defined by a set of subnetworks, the SNPP links that interconnect them, and the SNPPs representing

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<sup>1</sup> In some cases, in an implementation it may be convenient to reuse the value of the forwarding resource identifier as the SNP identifier at higher levels in the controller hierarchy. However, in this context the resource semantics are absent, and the value is treated as an opaque SNP identifier.

the ends of the SNPP links exiting that routing area. Thus, components collectively use three separate name spaces in order to reference routing area and SNP/SNPP abstractions. These are the routing area name space, subnetwork name space, and link context name space.

The link context name space specifies within the SNPP where the SNP is. At some (low) level in a hierarchy of controllers the SNP identifier must be mapped to a resource label and the TAP component can maintain this mapping. The TAP makes resources visible to an LRM by binding a transport resource label to an SNP identifier.

An SNPP identifier is a concatenation of:

- one or more nested routing area identifiers;
- an optional subnetwork identifier within the lowest routing area level; this can only exist if the containing RA identifiers are present;
- one or more nested resource context identifiers.

This Recommendation does not specify formats or values for identifiers in instances of the aforementioned name spaces. It is possible for implementations to assign the same value to identifiers in different name spaces (e.g., SNPP identifier and BRI) in order to simplify configuration.

### **11.2.2 Name space recursion**

An SNPP identifier can recur with routing areas as the routing area name space is typically hierarchical. As recursion is a property of [ITU-T G.800] subnetworks it would be natural, though not mandatory, for the naming associated with subnetworks to also be hierarchical.

[ITU-T G.800] also describes recursion between layers using adaptation and termination functions. While name spaces are independent between layers, if an operator owns and manages a client layer supported by a server layer, it is a common operational requirement to understand how a server layer trail can support a client layer connection and in this case a common name space may be used.

Some relationship between recursive name spaces thus needs to be maintained and one mechanism for managing such name space interactions is through the use of the directory service component.

### **11.3 Control components**

Control components also require separate name spaces, as they may be instantiated differently from each other for a given control function instance. For example, an implementation may have a centralized NCC with distributed CCs. Thus, separate identifiers are needed for RCs, NCCs, and CCs.

Additionally, the PCs that are used for protocol specific communication also require a separate name space and this is referred to as the CCN name space (see clause 11.6). The separate name spaces ensure that there is no dependency on the identifiers of the resources that the control component have in scope (e.g., routing area), the identifier of the control component itself, or the CCN address that is used to deliver messages to that control component. This independence allows, for example, the location or scope of a control component to be changed without modifying its identifier.

The control component name space is also used for configuration and fault reporting of the control components.

### **11.4 Control artefacts**

Control functions create and use artefacts including, for example, connections, routes, calls, and directories. Normally the control component that creates a control artefact assigns an identifier. These artefacts have identifiers associated with them and are drawn from an independent name space.

## 11.5 Reference points

A reference point represents a collection of services, provided via interfaces on one or more pairs of MC components. The MC component interface is independent of the reference point; hence, the same interface may be involved with more than one reference point. From the viewpoint of the reference point the MC components supporting the interface are not visible, hence the interface specification can be treated independently of the MC components.

Various logic reference points are defined, for example the UNI, I-NNI and E-NNI reference points in [ITU-T G.8080] and the CPIs in [ITU-T G.7702].

At the boundary of administrative domains, the BRI is used to identify both the transport resources and the interface between ~~control~~-MC components that are exposed at the domain boundary. ~~The ITU-T G.8080 user network interface (UNI) is an example of a reference point.~~ The BRI is drawn from an independent name space. The use of an independent name space avoids exposing the identifiers that the ~~control~~-MC components use within the domain.

## 11.6 Control communications network

To enable control components to communicate with each other, a control communications network (CCN) is used as specified in [ITU-T G.7712]. CCN addresses identify the points of attachment for the PCs that instantiate control communication functions (generating and processing messages in protocol specific formats). Each PC has a distinct CCN point of attachment (CCN attachment).

Control components access the CCN via a PC, a PC may support one or more control components. A directory may be used to relate the control component identifier with the CCN address of its (current) PC. The independence between the control component identifier and the CCN address allows, for example, the location of a control component to be changed, or for the CCN to be reconfigured, without modifying the identifier of the control component.

## 12 Resilience

Resilience refers to the ability of the MC components to continue operating under failure conditions. Operation of the MC components depends upon elements of the control communication network (CCN), the transport network, and the internal components of the MCS itself.

### 12.1 Principles of MC component and transport network interactions

The following principles are used for MC component and transport network interactions when communications become available between them.

- 1) The MC component relies on the transport network for information about transport resources.
- 2) Consistency between the control view and the corresponding transport resources is established first.
- 3) MC components synchronize with their adjacent components. This is used to re-establish a consistent view of routing, call, and connection state.

Another principle of MC component and transport network interaction is that:

- 4) existing connections in the transport network are not altered if the MC component fails and/or recovers. MC components are therefore dependent on SNC state.

For resiliency, the transport network resource and SNC state information should be maintained in non-volatile store. Further, some information about the MC component use of the SNC should be stored. This includes whether the SNC was created by CC and how it was used. For example, which end of the SNC is towards the head end of the whole connection. The MC components must ensure it has resource and SNC state information that is consistent with the resource and SNC state information maintained by the transport network. If not, the MC components must:

- ensure that there will be no network requests to route a new connection through that node;
- not perform any connection changes (e.g., releases).

SNC state is important information to recover first because it is the basis of connections that provide service to end users. This follows the principle above. During recovery, the MC components reconstruct the call and connection state corresponding to existing connections. For example, RC will need to disseminate correct SNP information after it is synchronized with LRM.

The MC components re-establishment of information consistency with the transport node should occur in the following sequence:

- the LRM synchronizes with TAP the transport resource state information;
- the CC then synchronizes with the LRM;
- the NCC then synchronizes with the CC.

Following the re-establishment of state consistency, the MC components must then ensure SNC state information consistency with adjacent components, as discussed in principle 3 above, prior to participating in connection set-up or release requests.

## **12.2 Principles of protocol controller communication**

When communication between protocol controllers is disrupted, existing calls and their connections are not altered. The network operator may be notified if the failure persists and requires operator intervention (for example, to release a call).

A failure of the CCN may affect one or more protocol controller to protocol controller communication sessions. The protocol controller associated with each control channel must detect and alarm a control channel failure.

When a protocol controller to protocol controller communication session recovers, state re-synchronization between the protocol controllers should be performed.

Failure of a protocol controller is handled similarly to a failure of a protocol controller to protocol controller session.

## **13 Connection availability enhancement techniques**

This clause describes the strategies that can be used to maintain the integrity of an existing call in the event of failures within the transport network.

[ITU-T G.805] describes transport network availability enhancement techniques. The terms "Protection" (replacement of a failed resource with a pre-assigned standby) and "Restoration" (replacement of a failed resource by re-routing using spare capacity) are used to classify these techniques. In general, protection actions complete in the tens of millisecond range, while restoration actions normally complete in times ranging from hundreds of milliseconds to up to a few seconds.

The MC components provide a network operator with the ability to offer a user calls with a selectable class of service (CoS) (e.g., availability, duration of interruptions, errored seconds, etc.). Protection and restoration are mechanisms (used by the network) to support the CoS requested by the user. The selection of the survivability mechanism (none, protection, restoration or both) for a particular connection that supports a call will be based on: the policy of the network operator, the topology of the network and the capability of the equipment deployed. Different survivability mechanisms may be used on the connections that are concatenated to provide a call. If a call transits multiple domains (e.g., control or recovery domains), each domain applies its availability enhancement techniques to the segment(s) of the call/connection(s) it supports.

The protection or restoration of a connection may be invoked or temporarily disabled by a command from network operator. These commands may be used to allow scheduled maintenance activities to

be performed. They may also be used to override the automatic operations under some exceptional failure conditions.

The protection or restoration mechanism should:

- be independent of, and support any, client type (e.g., IP, ATM, SDH, Ethernet).
- provide scalability to accommodate a catastrophic failure in a server layer, such as a fibre cable cut, which impacts a large number of client layer connections that need to be restored simultaneously and rapidly.
- utilize a robust control communication mechanism, which remains functional even after a failure in the transport network or CCN.
- not rely on functions which are non-time critical to initiate protection or restoration actions. Therefore, consideration should be given to protection or restoration schemes that do not depend on fault localization.

### **13.1 Protection**

Protection is a mechanism for enhancing the availability of a connection through the use of additional, assigned capacity. Once capacity is assigned for protection purposes there is no re-routing and the SNPs allocated at intermediate points to support the protection capacity do not change as a result of a protection event. The main difference between protection and restoration is that in the event of a failure, protection does not involve re-routing or additional connection set-up.

The CC component is responsible for the creation of the connections. This includes creating both a working connection and a protection connection including the configuration information for the selected protection scheme.

The selection of the working or protection connection can be performed by either: The transport resources, or; the CC responsible for the connection in the associated protection domain.

### **13.2 Restoration**

The restoration of a call is the replacement of a failed connection by re-routing the call using spare capacity. In contrast to protection, some, or all, of the SNPs used to support the connection may be changed during a restoration event. Restoration occurs in relation to re-routing domains (see clause 7.2) or recovery domains. A re-routing domain is a group of call and connection controllers that share control of domain-based re-routing. MC components in the re-routing domains coordinate domain-based re-routing operations for all calls/connections that traverse the re-routing domain. A re-routing domain must be entirely contained within a routing domain or area. A routing domain may fully contain several re-routing domains. The network resources associated with a re-routing domain must therefore be contained entirely within a routing area. Where a call/connection is re-routed inside a re-routing domain, the domain-based re-routing operation takes place entirely within it.

The activation of a re-routing service is negotiated as part of the initial call establishment phase. For a single domain, an intra-domain re-routing service is by connection and call controller components within the re-routing domain. Requests for an intra-domain re-routing service do not cross the domain boundary.

Where multiple re-routing domains are involved, components of each re-routing domain determine the activation of the re-routing services across the re-routing domain for each call. Once the call has been established, each of the re-routing domains in the path of the call have knowledge as to which re-routing services are activated for the call. As for the case of a single re-routing domain, once the call has been established the re-routing services are not changed. Requests for inter-domain re-routing service are passed across re-routing domain boundaries. Although a re-routing service can be requested on an end-to-end basis, the service is performed on a per re-routing domain basis.

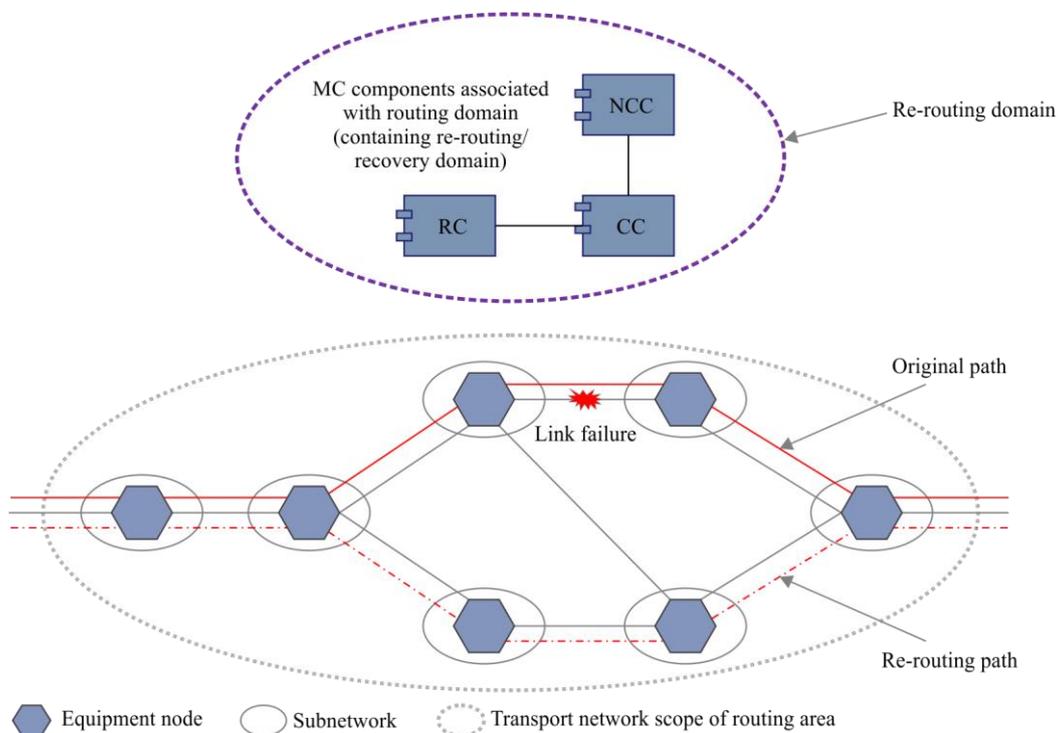
During the negotiation of the re-routing services, components of a re-routing domain exchange their re-routing capabilities and the request for a re-routing service can only be supported if the service is available in all re-routing domains involved.

A hard re-routing service offers a failure recovery mechanism for calls and is always in response to a failure event. When a link or a network element fails in a re-routing domain, the call is cleared to the edges of the re-routing domain. For a hard re-routing service that has been activated for that call, an alternative connection segment is created between the edges of the re-routing domain. This alternative connection is the re-routing connection. In hard re-routing, the original connection segment is released prior to the creation of an alternative connection segment. This is known as break-before-make. An example of hard re-routing is provided in Figure 13-1. In this example, the routing domain is associated with a single routing area and a single re-routing domain. The call is re-routed by the associated MC components within the re-routing domain.

Soft re-routing service is a mechanism for the re-routing of a connection for administrative purposes (e.g., path optimization, network maintenance, and planned engineering works). When a re-routing operation is triggered by the network operator, the components establish a re-routing connection. Once the re-routing connection is created, the CC components use the re-routing connection and delete the initial connection. This is known as make-before-break.

During a soft re-routing procedure, a failure may occur on the initial connection. In this case, the hard re-routing operation pre-empts the soft re-routing operation and the RC components within the re-routing domain proceed according to the hard re-routing process.

If revertive behaviour is required (i.e., the call must be restored to the original connections when the failure has been repaired), NCCs must not release the original (failed) connections. The NCCs must continue monitoring the original connections, and when the failure is repaired, the call is restored to the original connections.



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**Figure 13-1 – Example of hard re-routing**

## 13.2.1 Re-routing in response to failure

### 13.2.1.1 Intra-domain failures

Any failures within a re-routing domain should result in a re-routing (restoration) action within that domain such that any downstream domains only observe a momentary incoming signal failure (or previous section fail). The connections supporting the call must continue to use the same source (ingress) and destination (egress) gateway nodes in the re-routing domain.

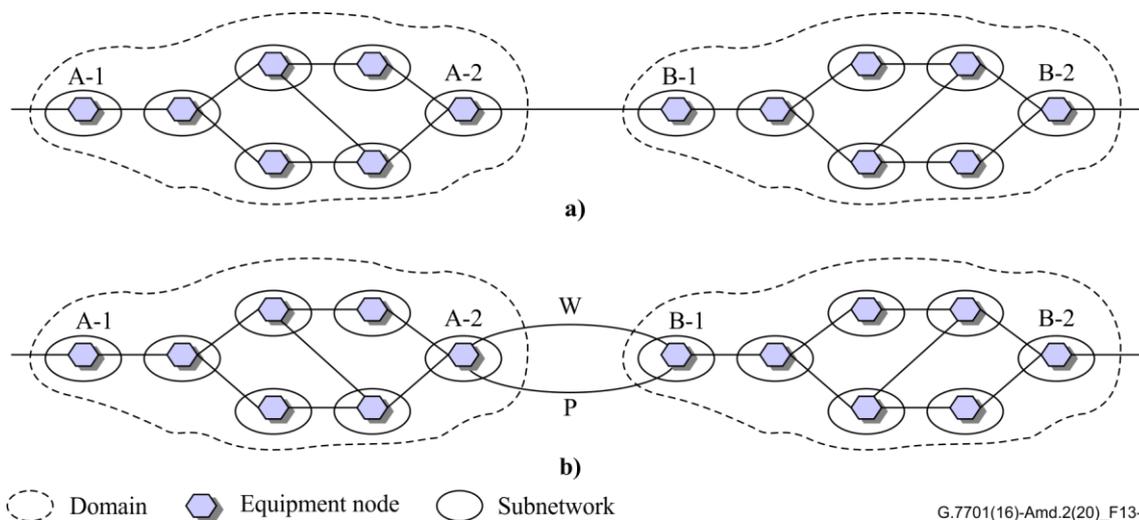
### 13.2.1.2 Inter-domain failures

Two failure cases must be considered, failure of a link between two gateway network elements in different re-routing domains and failure of inter-domain gateway network elements.

#### 13.2.1.2.1 Link failure between adjacent gateway network elements

When a failure occurs outside of the re-routing domains (e.g., the link between gateway network elements in different re-routing domains A and B in Figure 13-2-a) no re-routing operation can be performed. In this case, alternative protection mechanisms may be employed between the domains.

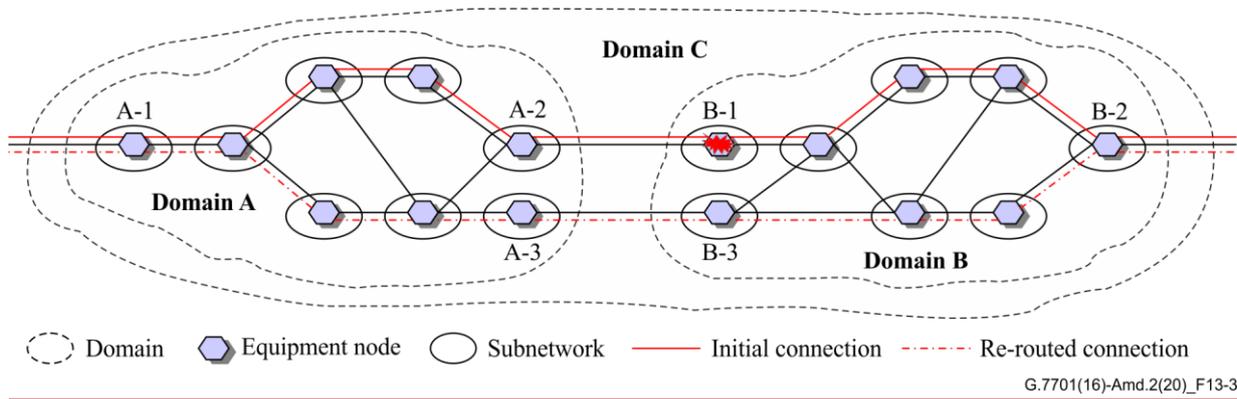
Figure 13-2-b shows the example with two links between domain A and domain B. A link between domains with the appropriate level of protection must be selected by RC component. The simplest method of providing protection in this scenario is via a protection mechanism that is pre-established (e.g., in a server layer network. Such a scheme is transparent to the connections that run over the top of it). If the protected link fails, the link protection scheme will initiate the protection operation. In this case, the call is still routed over the same ingress and egress gateway network elements of the adjacent domains and the failure recovery is confined to the inter-domain link.



**Figure 13-2 – Link failure scenarios**

#### 13.2.1.2.2 Gateway network element failure

This case is shown in Figure 13-3. To recover a call when B-1 fails, a different gateway node, B-3, must be used for domain B. In general, this will also require the use of a different gateway in domain A, in this case A-3. In response to the failure of gateway NE B-1 (detected by gateway NE A2) a new connection should be created to support the call. This can be considered as re-routing in a larger domain, C, which occurs only if re-routing in A or B cannot recover the connection.



**Figure 13-3 – Re-routing in event of a gateway network element failure**

### 13.3 Nested routing domains

Protection, re-routing and recovery domains are types of routing domains. As such, they inherit the containment property of control domains. Coordination between the actions taken by two domains in a containment relationship to a resource failure is a matter of policy.

## Annex A

### Configuration of OTN digital and media layers

(This annex forms an integral part of this Recommendation.)

[ITU-T G.872] describes the OTN digital layer networks and the media layer. The abstractions used to represent the digital layer networks and the media are similar. However, configuration of the media and the association of media channels to optical signals requires some special consideration.

The configuration of a digital layer network may be simplified since the hypothetical reference model used to allocate impairments has sufficient scope (and implementations have sufficient operating margins) that impairments do not need to be considered. Further, layer independence allows a client (digital) layer network to be configured in a way that is largely independent of the server (digital) layer network.

This simplification cannot be applied to all cases of configuring the media and optical tributary signal (OTSi). As a result, further requirements are imposed ~~when on a media control function<sup>2</sup> that is intended to configure~~ the media layer and the signals that cross that media layer.

- The media can be configured in advance of the assignment of the media channel to one or more OTSi
  - The configuration of a media channel is independent of the presence (or absence) of any optical signal.
- The width of the media channels may be different from the width required to carry a single OTSi. (e.g., a "wide" media channel may be used to provide what is commonly called an "express" channel in a ROADM)
- A single client digital stream (optical transport unit (OTU)) may be carried by more than one OTSi
  - Hence the configuration of the media to carry an OTU may require the configuration of one or more network media channels. Further, some of the optical tributary signal assembly (OTSiA) OAM functions are supported by non-associated overhead (OTSiG-O) and this must be configured when an OTSi is assigned to a network media channel.
- Determining the compatibility between an OTSi and a network media channel is a complex process. There is currently no standardized method defined for confirming compatibility in the case where the media is divided across dense wavelength division multiplexing (DWDM) line segments from more than one vendor as described in [ITU-T G.680] scenario 2. Three single domain cases must be considered:
  - 1) the black link approach as described in [ITU-T G.698.1] and [ITU-T G.698.2]. In this case, compatibility can be checked by considering the application codes defined in [ITU-T G.698.1] and [ITU-T G.698.2].
    - The optical domain is normally configured by vendor specific media control, which would not need to manage the optical signal terminations.
  - 2) pre-computed optical paths: In this case paths through the media network are pre-computed and only those that are compatible with the candidate OTSi are provided in response to request for a network media channel. In general, the determination of compatibility is vendor specific.

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<sup>2</sup>~~The media control function may be implemented by, for example, an EMS/OSS, an SDN controller or an ASON/GMPLS control plane.~~

- 3) compatibility check at the time of request: In general, the determination of compatibility is vendor specific. In this case paths through the media are computed, and after path computation is complete these paths are checked for compatibility with the OTSi. Compatibility checking is a complex process that must take into account the interaction of the "new signal" with all existing or planned<sup>3</sup> signals that share the same fibre and the impact of these existing (or planned) signals on the candidate "new signal". The actual transfer characteristics of the media elements in the path (e.g., filters, amplifiers) also needs to be considered.

A media<sup>4</sup> control function must, in addition to the capabilities required to manage digital layer networks, provide the additional capabilities described below. Two scenarios should be considered.

- 1) In the first scenario the client requests a network media channel, where all network media channels, the optical source and sink are compliant with the black link approach as specified in [ITU-T G.698.1] and [ITU-T G.698.2]. The request must include the end points of the network media channel being requested and the application code. Specific details on the network media channel center-frequency and spectral width may or may not be included in the request, depending on the control architecture of the implementation. The media controller must configure the non-associated overhead that is conveyed via the overhead communications channel (OCC) (defined in [ITU-T G.7712]), to support control/management of the network media channel. The client controller is responsible for ensuring that the OTSi provided across the interface is compliant with the network media channel requested and that the digital content of the optical signals passed across the network media channel can be successfully received at the far end. The media control function must also:
  - Support the configuration of the requested media channel and the non-associated overhead.
  - Support the configuration and monitoring of the optical multiplex section (OMS) and optical transmission section (OTS) maintenance entities.

Where network media channels are not compliant with in [ITU-T G.698.1] or [ITU-T G.698.2], joint engineering is required to ensure proper interoperability between the client and media providers and their associated control functions (if separate). In this case, a connection request must include the end points of the network media channel being requested and a mutually agreed application identifier. Beyond that, the request contents are dependent on the decisions reached in the joint engineering of the network and control/management scheme employed.

- 2) In the second scenario the client network requests an OTU network connection. In this case the media control function must:
  - Accept requests for an OTU connection that is translated into an OTSiA connection.
    - This requires the capability to configure the media channels, the non-associated overhead and the optical termination source and sink. Some of the OTSiA OAM functions are supported by non-associated overhead and this must be configured when an OTSi is assigned to a network media channel.
    - As described above, ensure that the OTSi and network media channel are compatible.
    - Ensure that the OTU supported by the OTSi/OTSiA passed across the network media channel is delivered successfully to the destination interface.

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<sup>3</sup> For example, a fibre may only be carrying one other signal currently, but it is intended to support up to a total of 80 signals

<sup>4</sup> The implementation of a media control function is vendor specific; it may be offered as a stand-alone application or integrated with the control function for digital layer networks.

- Support the configuration of media channels to support the OTSiA.
- Support configuration and monitoring of the OMS and OTS maintenance entities.

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